iccopt 2013

International Conference on Continuous Optimization

July 27 - August 1, 2013

Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa

FCT FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA

Mathematical Optimization Society

The Fourth International Conference
on Continuous Optimization
of the Mathematical Optimization Society

Sponsors

Mathematical Optimization Society

ICCOPT 2013
International Conference on Continuous Optimization

Dear Participants,

On behalf of the organizers, it is a pleasure to welcome you to ICCOPT 2013, The Fourth International Conference on Continuous Optimization of the Mathematical Optimization Society. The meeting is being held July 27 – August 1, 2013, in the Department of Mathematics of the Faculty of Science and Technology of the New University of Lisbon, Caparica, Portugal.

The activities start during the weekend (July 27-28) with Summer courses on PDE-Constrained Optimization and Sparse Optimization. The conference itself starts on Monday, July 29 and lasts until Thursday, August 1, and is structured around 4 plenary and 8 semi-plenary talks. We take this opportunity to thank all of our excellent course instructors and featured speakers.

The conference program includes over 425 talks grouped in 13 clusters, representing an increase of more than 20% compared to the 2007 edition. The role of the cluster co-chairs and session organizers was crucial to the success of the conference — and we owe them a lot of gratitude. As it is becoming a tradition, we will also have a session of poster presentations and a session for the Best Paper Prize finalists. ICCOPT 2013 will be a great opportunity to learn about the latest developments in all major areas of Continuous Optimization.

The conference could not have happened without the dedicated work of many other people. We would like to thank very deeply Paula Amaral who first convinced us to launch on this adventure and then helped us in coordinating the Lisbon efforts. Our thanks are gratefully extended to the scientific program team (Ana Luísa Custódio, João Gouveia, Zaikun Zhang), the webpage team (Nelson Chibeles-Martins, Ismael Vaz), the Summer school team (Ana L.C., Manuel Vieira), and the registration and financial support team (Carmo Brás, Isabel Correia, Isabel Gomes, Nelson C.).

Finally, we hope that you will also enjoy our specially designed Social Program, in particular the excellence of the Portuguese cuisine and wine and the distinct features of Fado singing and national guitars. The MOS Welcome Reception, the Conference Banquet, the Student Social, the Conference Tour, and so many other events await you.

We wish you a pleasant and productive meeting.

LUIS NUNES VICENTE
University of Coimbra
Co-chair of the Organizing Committee

KATYA SCHEINBERG
Lehigh University
Chair of the Program Committee

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA
Direcção

Dear Participants in the ICCOPT 2013

Faculty of Science and Technology of Universidade Nova de Lisboa is very proud to host ICCOPT 2013 edition and truly rejoices with such concentration of highly distinguished researchers.

Continuous optimization is not the best tool to improve world performance. Indeed it is the tool! Everybody, feeling it or not, owes a lot of its well-being to the outcomes of mathematical optimization.

When our planet faces ultimate challenges from resources vanishing, climate change or unpredictable effects or needs of globalization, optimization of existing processes and systems becomes crucial to increase the lapse of time required to implement improving results of innovation.

On behalf of the Faculty of Science and Technology allow me to welcome all of you to our *campus* and I do hope you will find this country optimized enough to fulfill your expectations for a very pleasant stay.

A word of gratitude to my Colleagues of the Department of Mathematics (Local Organizing Committee) for their efforts to put up this important event which entirely fit in our policy of internationalization as part of our aim to become a research school.

Have a nice and fruitful Conference!

Professor Fernando Santana
Dean

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CÂMARA MUNICIPAL DE ALMADA
Serviços Municipais de Desenvolvimento Social, Informação e Relações Públicas
GABINETE DO VEREADOR

It was with great pride that the Municipality of Almada welcomed and supported the 4th edition of the International Conference on Continuous Optimization ICCOPT 2013, co-organized by the Department of Mathematics of the Faculty of Science and Technology – University Nova de Lisboa – and the Mathematical Optimization Society.

Holding this event in Almada confirms all the work we have done so far. The creation and maintenance of good structural conditions for attracting and hosting meetings, conferences and conventions, allows us to state that Almada has a territory with the full capacity to host events of worldwide importance.

These initiatives, promoted by the academic world, allow researchers and professionals to deepen and share knowledge and expertise. On the other hand, the Municipality and the economic agents, such as hotels, restaurants, transports, etc., work in a concerted manner towards the local economic development, to generate capital gains to the community.

To all who participate in this conference, keep up the good work, in the expectation that you will all return soon and enjoy more time with our gastronomy, our beaches, our cultural offer.

I challenge you to: "Experience more Almada"

António José de Sousa Matos
The City Councilor for Tourism

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Cluster Co-Chairs

Applications of continuous optimization in science and engineering
Mihai Anitescu (Argonne National Laboratory)
Eligius M. T. Hendrix (Wageningen Univ. and Univ. Málaga)

Complementarity and variational inequalities
Francisco Facchinei (Univ. Roma "La Sapienza")
Todd S. Munson (Argonne National Laboratory)

Conic and polynomial optimization
Miguel F. Anjos (École Polytech. Montréal)
Jiawang Nie (Univ. California, San Diego)

Convex and nonsmooth optimization
François Glineur (CORE and Univ. Catholique Louvain)
Peter Richtarik (Univ. Edinburgh)

Derivative-free and simulation-based optimization
Warren Hare (Univ. British Columbia, Okanagan)
Giampaolo Liuzzi (IASI, Consiglio Naz. Ricerche)

Global optimization and mixed-integer programming
Pierre Bonami (LIFM/CNRS)
Leo Liberti (LIX, École Polytechnique)

Nonlinear optimization
Frank E. Curtis (Lehigh Univ.)
Andreas Waechter (Northwestern Univ.)

Optimization software: Modeling tools and engines
Jacek Gondzio (Univ. Edinburgh)
Dominique Orban (École Polytech. Montréal)

PDE-constrained optimization
Georg Stadler (Univ. Texas, Austin)
Stefan Ulbrich (Tech. Univ. Darmstadt)

Robust optimization and optimization in finance
Melvyn Sim (National Univ. Singapore)
Luis F. Zuluaga (Lehigh Univ.)

Sparse optimization and information processing
Michael P. Friedlander (Univ. British Columbia)
Wotao Yin (Rice Univ.)

Stochastic optimization
Shabbir Ahmed (Georgia Inst. Tech.)
Darinka Dentcheva (Stevens Inst. Tech.)

Variational analysis, set-valued and vector optimization
Joerg Fliege (Univ. Southampton)
Alejandro Jofré (Univ. Chile)

Venue

ICCOPT 2013 consists of a Conference and a Summer School and takes place on the campus of the Faculty of Science and Technology of the New University of Lisbon, Caparica, Portugal.

The Summer School (July 27-28) is directed at PhD students and young researchers in the field of continuous optimization, and will take place at the Department of Mathematics (see the campus map on page 111).

The Conference (July 29 - August 1) includes a series of plenary and semi-plenary talks, organized sessions of invited talks and sessions of contributed talks, as well as sessions for prize and poster presentations, and will take place at the Auditorium A and at the Department of Mathematics (see the campus map on page 111).

Practical Information

Front Desk

The front desk will be located at the Entrance Hall of the Department of Mathematics and will be opened during:

Saturday, July 27	from 09:00 to 18:00
Sunday, July 28	from 09:00 to 20:00
Monday, July 29	from 08:00 to 20:00
Tuesday, July 30	from 08:30 to 18:30
Wednesday, July 31	from 08:30 to 20:00
Thursday, August 1	from 08:30 to 16:30

Internet Connection

Free wireless access is available inside the buildings (Auditorium A and Department of Mathematics) by connecting to FCTUNL, an unsecured wireless network.
Internet access is also available in two computer rooms (2.6 e 2.7), located on the second floor of the Department of Mathematics (see the plan of this floor of the Math. Department on page 112) and opened during the opening hours of the Front Desk (see above).

Bus Transportation

Bus transportation between the conference campus and the hotels

- "Costa da Caparica" (H1),
- "Meliá Aldeia dos Capuchos" (H2),

will be provided in the morning and at the end of the afternoon/evening of each day of both the Summer School and the Conference.

Bus transportation will also be provided for the Summer School Dinner, the Conference Banquet, and the Conference Tour, according to the following schedule.

Note that "Lisboa Almada Hotel" (H3) and the train and ferry stations (resp. "Pragal" and "Cacilhas") are served by bus only after the Summer School Dinner, the Conference Banquet, and the Conference Tour.

Day	Time	Departure	Destination
Saturday, July 27	08:30	Hotels H1, H2	Campus
	17:45	Campus	Hotels H1, H2
	18:30	Campus	Summer School Dinner
	22:00	Summer School Dinner	Campus
	22:00	Summer School Dinner	Hotels H1, H2, H3
	22:00	Summer School Dinner	Train and Ferry Stations
Sunday, July 28	08:30	Hotels H1, H2	Campus
	17:45	Campus	Hotels H1, H2
	18:00	Hotels H1, H2	Campus
	20:45	Campus	Hotels H1, H2
Monday, July 29	08:15	Hotels H1, H2	Campus
	18:15	Campus	Hotels H1, H2
	20:45	Campus	Hotels H1, H2
Tuesday, July 30	08:30	Hotels H1, H2	Campus
	18:15	Campus	Hotels H1, H2
	18:15	Campus	Conference Banquet
	22:45	Conference Banquet	Campus
	22:45	Conference Banquet	Hotels H1, H2, H3
	22:45	Conference Banquet	Train and Ferry Stations
Wednesday, July 31	08:30	Hotels H1, H2	Campus
	19:45	Campus	Hotels H1, H2
Thursday, August 1	08:30	Hotels H1, H2	Campus
	16:30	Campus	Hotels H1, H2
	16:30	Campus	Conference Tour
	19:00	Conference Tour	Campus
	19:00	Conference Tour	Hotels H1, H2, H3
	19:00	Conference Tour	Train and Ferry Stations

Remember that the campus is served by a tram line that connects “Universidade” (the campus stop) to

- “Pragal” (the stop for the train station to Lisbon),
- “Almada” (the stop for Lisboa Almada Hotel), and
- “Cacilhas” (the stop for the ferry station to Lisbon),

as shown on the map of page 113.

The layout of this book of abstracts is based on the one created by Imre Pólik for ICCOPT 2007. We thank him for kindly providing the source code and authorizing us to use it.

Summer School

Saturday, July 27

09:00 School and Conference Registration
09:50 Opening Remarks 1
10:00 School Lectures (30 min. break included)
13:00 Lunch
14:30 School Lectures (30 min. break included, end at **17:30**)
19:00 Summer School Dinner (ends at **22:00**)

Sunday, July 28

09:00 School and Conference Registration
09:50 Opening Remarks 2
10:00 School Lectures (30 min. break included)
13:00 Lunch
14:30 School Lectures (30 min. break included, end at **17:30**)

The School and Conference Registration is carried out at the Front Desk, located on the Entrance Hall of the Department of Mathematics (see the campus map on page 111).

The Summer School lectures will take place in Auditorium B (Department of Mathematics).

The Opening, Plenary Talks, Best Paper Prize Session, and Closing will be held in Auditorium A (in a building different from the Math. Department; see the campus map on page 111).

The Session of the Poster Presentations will be in the Entrance Hall of the Department of Mathematics.

Semi-plenary talks will be either in Auditorium A or B (AA for Auditorium A and AB for Auditorium B).

All the Parallel Sessions (either organized or of contributed talks) will be in the Department of Mathematics: See the session code explanation in page 47 and the maps of the two floors of the Math. Department on page 112.

Conference

Sunday, July 28

16:00 Conference Registration (closes at **19:00**)
18:30 MOS Welcome Reception (ends at **20:30**)

Monday, July 29

08:45 Opening (Auditorium A)
09:00 Plenary Session Mon.P.AA
10:00 Coffee Break
10:30 Semi-plenary Sessions Mon.S.xx
11:30 Parallel Sessions Mon.A.xx
13:00 Lunch
14:30 Parallel Sessions Mon.B.xx
16:00 Coffee Break
16:30 Parallel Sessions Mon.C.xx
18:30 Session of Poster Presentations and Reception (end at **20:30**)

Tuesday, July 30

09:00 Plenary Session Tue.P.AA
10:00 Coffee Break
10:30 Semi-plenary Sessions Tue.S.xx
11:30 Parallel Sessions Tue.A.xx
13:00 Lunch
14:30 Best Paper Prize Session Tue.B.AA
16:00 Coffee Break
16:30 Parallel Sessions Tue.C.xx
18:15 Conference Banquet (ends at **22:45**)

Wednesday, July 31

09:00 Plenary Session Wed.P.AA
10:00 Coffee Break
10:30 Semi-plenary Sessions Wed.S.xx
11:30 Parallel Sessions Wed.A.xx
13:00 Lunch
14:30 Parallel Sessions Wed.B.xx
16:00 Coffee Break
16:30 Parallel Sessions Wed.C.xx
18:00 Parallel Sessions Wed.D.xx
20:00 Student Social (ends at **22:00**)

Thursday, August 1

09:00 Parallel Sessions Thu.A.xx
10:30 Coffee Break
11:00 Parallel Sessions Thu.B.xx
12:30 Lunch
14:00 Semi-plenary Sessions Thu.S.xx
15:00 Plenary Session Thu.P.AA
16:00 Closing (Auditorium A)
16:30 Conference Tour (ends at **19:30**)

Michael C. Ferris

University of Wisconsin, Madison, USA, ferris@cs.wisc.edu

Multiple optimization problems with equilibrium constraints

Monday, 09:00-10:00, Mon.P.AA, Auditorium A

Chair: Joaquim João Júdice

We present a mechanism for describing and solving collections of optimization problems that are linked by equilibrium conditions. The general framework of MOPEC (multiple optimization problems with equilibrium constraints) captures many example applications that involve independent decisions coupled by shared resources. Included in this class are classical models such as the PIES model, general equilibria with incomplete market models, and agent based formulations arising from Nash Games. We describe this mechanism in the context of energy planning, environmental and land-use problems, for example for capacity expansion, hydro operation, and water rights pricing. We show how to incorporate stochastic information into these systems and give examples of their use and their possible extensions to hierarchical modeling. We outline several algorithms and investigate their computational efficiency. We demonstrate how stochastic MOPECs can be implemented in modeling systems such as GAMS or AMPL.

Michael C. Ferris is Professor of Computer Sciences and leads the Optimization Group within the Wisconsin Institutes for Discovery at the University of Wisconsin, Madison, USA. He received his PhD from the University of Cambridge, England in 1989. Dr. Ferris' research is concerned with algorithmic and interface development for large scale problems in mathematical programming, including links to the GAMS and AMPL modeling languages, and general purpose software such as PATH, NLPEC and EMP. He has worked on several applications of both optimization and complementarity, including cancer treatment plan development, radiation therapy, video-on-demand data delivery, economic and traffic equilibria, structural and mechanical engineering. Ferris is a SIAM fellow, an INFORMS fellow, received the Beale-Orchard-Hays prize from the Mathematical Programming Society and is a past recipient of a NSF Presidential Young Investigator Award, and a Guggenheim Fellowship. He serves on the editorial boards of Mathematical Programming, SIAM Journal on Optimization, Transactions of Mathematical Software, and Optimization Methods and Software.

Yurii Nesterov

CORE, UCL, Belgium, Yurii.Nesterov@uclouvain.be

Subgradient methods for huge-scale optimization problems

Tuesday, 09:00-10:00, Tue.P.AA, Auditorium A

Chair: Katya Scheinberg

We consider a new class of huge-scale problems, the problems with sparse subgradients. The most important functions of this type are piece-wise linear. For optimization problems with uniform sparsity of corresponding linear operators, we suggest a very efficient implementation of subgradient iterations, which total cost depends logarithmically in the dimension. This technique is based on a recursive update of the results of matrix/vector products and the values of symmetric functions. It works well, for example, for matrices with few nonzero diagonals and for max-type functions. We show that the updating technique can be efficiently coupled with the simplest subgradient methods, the unconstrained minimization method by Polyak, and the constrained minimization scheme by Shor. Similar results can be obtained for a new non-smooth random variant of a coordinate descent scheme. We present also the promising results of preliminary computational experiments and discuss an extension of this technique onto the conic optimization problems.

Yurii Nesterov is a professor at the Catholic University of Louvain, Belgium, where he is a member of the Center for Operations Research and Econometrics (CORE). He is the author of 4 monographs and more than 80 refereed papers in leading optimization journals. He was awarded with the Dantzig Prize 2000 given by SIAM and the Mathematical Programming Society (for research having a major impact on the field of mathematical programming), the John von Neumann Theory Prize 2009 given by INFORMS, the Charles Broyden prize 2010 (for the best paper in Optimization Methods and Software journal), and the Honorable Francqui Chair (University of Liège, 2011-2012). The main direction of his research is the development of efficient numerical methods for convex and nonconvex optimization problems supported by a global complexity analysis. The most important results are obtained for general interior-point methods (theory of self-concordant functions), fast gradient methods (smoothing technique), and global complexity analysis of the second-order schemes (cubic regularization of the Newton's method).

Paul I. Barton

Process Systems Engineering Laboratory, Massachusetts Institute of Technology, USA, pib@mit.edu

Relax anything

Wednesday, 09:00-10:00, Wed.P.AA, Auditorium A
Chair: Mihai Anitescu

The ability to construct and evaluate convex and concave relaxations of nonconvex functions plays a crucial role in modern deterministic global optimization algorithms. One of the best methods for this is the recursive relaxation of factorable functions proposed by McCormick. We show how the basic ideas of McCormick can be extended to construct and evaluate convex and concave relaxations of many different classes of functions, such as parametric solutions of algebraic equations and differential equations. We also discuss the implications of this capability for novel global optimization approaches. Finally, we also discuss current limitations and targets for the development for improved relaxation procedures.

Paul Barton is the Lammot du Pont Professor of Chemical Engineering and Director of the Process Systems Engineering Laboratory at MIT, where he has been since 1992. He received his Ph.D. from the Centre for Process Systems Engineering at Imperial College, London University in 1992. Barton's research interests include hybrid discrete/continuous dynamic systems; numerical analysis of ordinary differential, differential-algebraic and partial differential-algebraic equations; sensitivity analysis and automatic differentiation; global, mixed-integer and dynamic optimization theory and algorithms; and open process modeling software. Some of the applications his group is currently focusing on include energy systems engineering, continuous pharmaceutical manufacturing and nano-scale systems engineering. He has received a number of awards, including the Outstanding Young Researcher Award in 2004 and the Computing in Chemical Engineering Award in 2011, both from AIChE's CAST Division. He served as Director for AIChE's CAST Division from 2001-2004 and is currently a subject editor for Optimal Control Applications and Methods and associate editor for Journal of Global Optimization and Journal of Optimization Theory and Applications.

Yinyu Ye

Department of Management Science and Engineering and Institute for Computational and Mathematical Engineering, Stanford University, USA, yinyu-ye@stanford.edu

Complexity analysis beyond convex optimization

Thursday, 15:00-16:00, Thu.P.AA, Auditorium A
Chair: Tamás Terlaky

A powerful approach to solving difficult optimization problems is convex relaxation. In a typical application, the problem is first formulated as a cardinality-constrained linear program (LP) or rank-constrained semidefinite program (SDP), where the cardinality or rank corresponds to the target support size or dimension. Then, the non-convex cardinality or rank constraint is either dropped or replaced by a convex surrogate, thus resulting in a convex optimization problem. In this talk, we explore the use of a non-convex surrogate of the cardinality or rank function, namely the so-called Schatten quasi-norm. Although the resulting optimization problem is non-convex, we show, for many cases, that a first and second order critical point can be approximated to arbitrary accuracy in polynomial time by an interior-point algorithm. Moreover, we show that such a critical point is already sufficient for recovering the solution of the original problem in the target cardinality or dimension, if the input instance satisfies certain established uniqueness properties in the literature. Finally, our simulation results show that the proposed algorithm could achieve more accurate results than the standard LP or SDP relaxations of the problem. We also generalize and summarize our complexity analysis to more general nonconvex optimization.

Yinyu Ye is currently the K.T. Li Professor of Engineering at Department of Management Science and Engineering and Institute of Computational and Mathematical Engineering, Stanford University. He is also the Director of the MS&E Industrial Affiliates Program. He received the B.S. degree in System Engineering from the Huazhong University of Science and Technology, China, and the M.S. and Ph.D. degrees in Engineering-Economic Systems and Operations Research from Stanford University. His current research interests include Continuous and Discrete Optimization, Algorithm Design and Analysis, Computational Game/Market Equilibrium, Metric Distance Geometry, Dynamic Resource Allocation, and Stochastic and Robust Decision Making, etc. He is an INFORMS (The Institute for Operations Research and The Management Science) Fellow, and has received several academic awards including the inaugural 2012 ISMP Tseng Lectureship Prize for outstanding contribution to continuous optimization, the 2009 John von Neumann Theory Prize for fundamental sustained contributions to theory in Operations Research and the Management Sciences, the inaugural 2006 Farkas Prize on Optimization, the 2009 IBM Faculty Award, etc.. He has supervised numerous doctoral students at Stanford who received the 2008 Nicholson Prize and the 2006 and 2010 INFORMS Optimization Prizes for Young Researchers.

Monday, 10:30-11:15

Sam Burer
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Copositive optimization

Mon.S.AA, Auditorium A
Chair: Miguel F. Anjos

In this talk, we survey the active area of copositive optimization, focusing on two key features: (i) its ability to model difficult problems as equivalent convex problems, for example, broad classes of quadratic programs and also integer programs with uncertain data; (ii) its approximability by linear and semidefinite optimization. We discuss specific applications, recent generalizations, and important obstacles. If time permits, we will also vote on standardizing notation in the area. Come let your voice be heard!

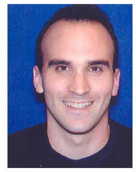
Regina Burachik
School of Information Technology and Mathematical Sciences, University of South Australia, Australia, regina.burachik@unisa.edu.au

The exact penalty map for nonsmooth and nonconvex optimization

Mon.S.AB, Auditorium B
Chair: Alejandro Jofré

Augmented Lagrangian duality provides zero duality gap and saddle point properties for nonconvex optimization. On the basis of this duality, subgradient-like methods can be applied to the (convex) dual of the original problem. These methods usually recover the optimal value of the problem, but may fail to provide a primal solution. We prove that the recovery of a primal solution by such methods can be characterized in terms of (i) the differentiability properties of the dual function, and (ii) the exact penalty properties of the primal-dual pair. We also connect the property of finite termination with exact penalty properties of the dual pair. In order to establish these facts, we associate the primal-dual pair to a penalty map. This map, which we introduce here, is a convex and globally Lipschitz function, and its epigraph encapsulates information on both primal and dual solution sets.

Tuesday, 10:30-11:15



Amir Beck
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Gradient-based methods for convex optimization and applications

Tue.S.AA, Auditorium A
Chair: François Glineur

Many fundamental scientific and engineering problems of recent interest arising in signal recovery, image processing, compressive sensing, machine learning and other fields can be formulated as well structured optimization problems, but which are typically very large scale, and often nonsmooth. This leads to challenging difficulties for their solutions, precluding the use of second-order algorithms such as interior point methods. Elementary first order methods then often remain our best alternative to tackle such problems. This talk surveys classical as well as recent results on the design and analysis of gradient-based algorithms for some generic optimization models arising in a wide variety of applications, highlighting the ways in which problem structures can be beneficially exploited to devise simple and efficient algorithms.

Victor DeMiguel
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Practical portfolio optimization

Tue.S.AB, Auditorium B
Chair: Mustafa C. Pinar

The Nobel laureate Harry Markowitz showed that an investor who cares only about the mean and variance of portfolio returns should hold a portfolio on the efficient frontier. To compute these portfolios, one needs to solve a quadratic program whose coefficients depend on the mean and the covariance matrix of asset returns. In practice, one needs to replace these quantities by their sample estimates, but due to estimation error the mean-variance portfolios that rely on sample estimates typically perform poorly out of sample; a difficulty that has been referred to in the literature as the "error-maximization" property of the portfolio optimization problem.

In this talk, we first illustrate the difficulties inherent to estimating optimal portfolios by comparing the out-of-sample performance of the mean-variance portfolio and its various extensions relative to the naive benchmark strategy of investing a fraction 1/N of wealth in each of the N assets available. The results show that none of the optimal portfolios is consistently better than the 1/N rule in terms of Sharpe ratio across seven empirical datasets. We then discuss several approaches proposed in the recent literature to overcome these difficulties in practice, including robust optimization and estimation, shrinkage estimation, Bayesian estimation, and norm constraints. Finally, we highlight open issues that offer opportunities for researchers in optimization to contribute to this area.

Wednesday, 10:30-11:15

Michael Hintermüller
Humboldt-Universität zu Berlin, Germany, hint@math.hu-berlin.de

Nonsmooth structures in PDE-constrained optimization

Wed.S.AA, Auditorium A

Chair: Stefan Ulbrich

Motivated by several real-world applications in continuum mechanics, mathematical finance or life sciences, the talk highlights recent advances in the analysis and, in particular, the development of robust numerical solution schemes for mathematical programs with equilibrium or complementarity constraints (MPECs or MPCCs), generalized Nash equilibrium problems (GNEPs) and (other) quasi-variational inequalities (QVIs) involving partial differential operators, respectively. For MPECs and MPCCs the derivation of suitable stationarity conditions (such as appropriate variants of C-, M- and strong stationarity) is briefly addressed, and for GNEPs as well as for QVIs the existence of solutions and associated characterizations, which are suitable for numerical realization, are discussed. In particular, for GNEPs novel constraint qualifications are presented, and for QVIs a rather general approach to existence is introduced. For all problems addressed in the talk efficient numerical solution schemes relying on relaxation concepts, the Moreau-Yosida-regularization or semismooth Newton techniques are presented. Also, multilevel approaches relying on adaptive discretization are briefly mentioned, and the practical behavior of the presented solvers is highlighted.

Ya-xiang Yuan
Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, China, yyx@lsec.cc.ac.cn

Subspace techniques for optimization

Wed.S.AB, Auditorium B

Chair: Xiaojun Chen

In this talk, we review various subspace techniques that are used in constructing numerical methods for optimization. The subspace techniques are getting more and more important as the optimization problems we have to solve are getting larger and larger in scale. The essential part of a subspace method is how to choose the subspace in which the trial step or the trust region should belong. Model subspace algorithms for unconstrained optimization, constrained optimization, nonlinear equations and matrix optimization problems are given respectively, and different proposals are made on how to choose the subspaces.

Thursday, 14:00-14:45

Michel De Lara,
École des Ponts ParisTech / Université Paris-Est, France, delara@cermics.enpc.fr

Smart power systems, renewable energies and markets: The optimization challenge

Thu.S.AA, Auditorium A

Chair: Eligius M. T. Hendrix

Electrical power systems are undergoing a deep and fast transformation, fueled by renewable energies penetration, telecommunication technologies and markets expansion. We discuss to what extent optimization is challenged. We shed light on the two main new issues in stochastic control in comparison with deterministic control: risk attitudes and online information. We cast a glow on two snapshots highlighting ongoing research in the field of stochastic control applied to energy:

- Decomposition-coordination optimization methods under uncertainty, with an illustration on multiple dams management,
- Risk constraints in optimization, with the example of a dam management under a tourist chance constraint.

Coralia Cartis
School of Mathematics, University of Edinburgh, UK, Coralia.Cartis@ed.ac.uk

Optimal Newton-type algorithms for nonconvex smooth optimization

Thu.S.AB, Auditorium B

Chair: Andreas Waechter

Establishing the global rate of convergence of standard algorithms or their global evaluation complexity for nonconvex smooth optimization problems is a natural but challenging aspect of algorithm analysis. Until recently, this question has been entirely open for Newton-type methods in the nonconvex setting. We illustrate that, even when convergent, Newton's method can be — surprisingly — as slow as steepest descent. In fact, all commonly encountered linesearch or trust-region variants turn out to be essentially as inefficient as steepest descent in the worst-case. There is, however, good news: cubic regularization (Griewank, Nesterov-Polyak) and its large-scale variants (Cartis, Gould and Toint) are better than both steepest-descent and Newton's in the worst-case; they are in fact, optimal from a worst-case point of view within a wide class of methods and problems. We also present bounds on the evaluation complexity of nonconvexly constrained problems, and argue that, for certain carefully devised methods, these can be of the same order as in the unconstrained case, a surprising but reassuring result.
This is joint work with Nick Gould (Rutherford Appleton Laboratory, UK) and Philippe Toint (University of Namur, Belgium).

The ICCOPT 2013 Best Paper Prize for Young Researchers in Continuous Optimization called for submissions of published or nearly published papers from graduate students and recent Ph.D recipients. The selection committee (Sam Burer and Jean-Baptiste Hiriart-Urruty, chaired by Stefan Ulbrich) invited the following contestants to present their work in a dedicated session of the conference. The session will be chaired by Jean-Baptiste Hiriart-Urruty.

Venkat Chandrasekaran
California Institute of Technology, USA, venkatc@caltech.edu

Rank-sparsity uncertainty principles and matrix decomposition

Suppose we are given a matrix that is formed by adding an unknown sparse matrix and an unknown low-rank matrix. The objective is to decompose the given matrix into its sparse and low-rank components. Such a problem is intractable to solve in general, and it arises in a number of applications including model selection in statistics and system identification in control. We consider a convex optimization formulation based on semidefinite programming to splitting the specified matrix into its components; the approach proceeds by minimizing a linear combination of the L1 norm and the nuclear norm of the components. We develop a notion of rank-sparsity incoherence, expressed as an uncertainty principle between the sparsity pattern of a matrix and its row and column spaces, and we use it to characterize both fundamental identifiability as well as sufficient conditions for exact recovery via the proposed convex program. In this talk, we will emphasize a geometric viewpoint to the matrix decomposition problem, highlighting the prominent role played by the tangent spaces to the algebraic varieties of sparse and low-rank matrices.

Finalist selected based on the paper: V. Chandrasekaran, S. Sanghavi, P. A. Parrilo, and A. S. Willsky, Rank-sparsity incoherence for matrix decomposition, SIAM Journal on Optimization, 21 (2011) 572-596.

Boris Houska
Shanghai Jiao Tong University, China, bhouska@sjtu.edu.cn

Nonlinear robust optimization via sequential convex bilevel programming

This talk is about an algorithm for worst-case robust optimization, a class of min-max optimization problems, which arise frequently in engineering applications, where unknown parameters or unpredictable external influences are present. The first part of the talk focuses on the structural properties of semi-infinite optimization problems discussing first order optimality conditions as well as conservative approximation strategies replacing the original min-max problem with a mathematical programming problem with complementarity constraints (MPCC). In the second part of the talk we introduce a novel algorithm, named sequential convex bilevel programming, which exploits the particular structure of this MPCC. The algorithm proceeds by solving a sequence of convex quadratically constrained quadratic programs (QCQPs). We discuss the surprisingly strong global and locally quadratic convergence properties of this method, which can in this form neither be obtained with existing SQP methods nor with interior point relaxation techniques for general MPCCs. We discuss the application fields of the new method and illustrate its performance with a numerical example.

Finalist selected based on the paper: B. Houska and M. Diehl, Nonlinear robust optimization via sequential convex bilevel programming, to appear in Mathematical Programming.

Meisam Razaviyayn
Department of Electrical and Computer Engineering, University of Minnesota, USA, razav002@umn.edu

A unified convergence analysis of block successive minimization methods for nonsmooth optimization

The block coordinate descent (BCD) method is widely used for minimizing a continuous function f of several block variables. At each iteration of this method, a single block of variables is optimized, while the remaining variables are held fixed. To ensure the convergence of the BCD method, the subproblem of each block variable needs to be solved to its unique global optimal. Unfortunately, this requirement is often too restrictive for many practical scenarios. In this paper, we study an alternative inexact BCD approach which updates the variable blocks by successively minimizing a sequence of approximations of f which are either locally tight upper bounds of f or strictly convex local approximations of f. The main contributions of this work include the characterizations of the convergence conditions for a fairly wide class of such methods, especially for the cases where the objective functions are either non-differentiable or nonconvex. Our results unify and extend the existing convergence results for many classical algorithms such as the BCD method, the difference of convex functions (DC) method, the expectation maximization (EM) algorithm, as well as the block forward-backward splitting algorithm, all of which are popular for large scale optimization problems involving big data.

Finalist selected based on the paper: M. Razaviyayn, M. Hong, and Z.-Q. Luo, A unified convergence analysis of block successive minimization methods for nonmooth optimization, SIAM Journal on Optimization, 23 (2013) 1126-1153.

Please join us on Tuesday, July 30, from 14:30 to 16:00 (Session Tue.B.AA, Auditorium A) as the finalists present their papers. The winner will be announced by Stefan Ulbrich at the conference banquet.

The conference is preceded by a two-day summer school. All lectures will be held at the Auditorium B, Department of Mathematics.

Saturday, July 27, 2013

PDE-CONSTRAINED OPTIMIZATION

MICHAEL ULBRICH
Tech. Univ. Munich, Germany, mulbrich@ma.tum.de
CHRISTIAN MEYER
TU Dortmund, Germany, cmeyer@math.tu-dortmund.de

09:00-09:50	School and Conference Registration
09:50-10:00	Opening Remarks 1
10:00-13:00	School Lectures (30 min. break included)
13:00-14:30	Lunch
14:30-17:30	School Lectures (30 min. break included)
19:00-22:00	Summer School Dinner

Models of complex processes in natural sciences, engineering, and economics often canonically result in systems of partial differential equations (PDEs). Although simulation already provides valuable insights, the efficient optimization and control of the underlying system opens up a whole new dimension of fascinating possibilities. Exploring this high potential poses many challenges in both the analysis and numerical solution of PDE-constrained optimization problems. Achieving tractable approaches requires a unique interplay between the theory and methods of mathematical optimization, partial differential equations, numerical analysis, and scientific computing.
This summer school provides an introduction to the field of PDE-constrained optimization. The presentation follows an accessible, unifying functional analytic framework to develop the main concepts, and illustrates them by suitable model problems. Existence of solutions, optimality conditions, and efficient optimization methods will be discussed, along with some introductory material on PDEs and FE discretization. The course concludes with ongoing and future research directions and with several examples of more advanced applications.

Sunday, July 28, 2013

SPARSE OPTIMIZATION AND APPLICATIONS TO INFORMATION PROCESSING

MÁRIO A. T. FIGUEIREDO
Tech. Univ. Lisbon and IT, Portugal, mario.a.t.figueiredo@gmail.com
STEPHEN J. WRIGHT
University of Wisconsin, Madison, USA, swright@cs.wisc.edu

09:00-09:50	School and Conference Registration
09:50-10:00	Opening Remarks 2
10:00-13:00	School Lectures (30 min. break included)
13:00-14:30	Lunch
14:30-17:30	School Lectures (30 min. break included)

Much of modern data processing requires identification of low-dimensional structures from high-dimensional spaces, using observations that are incomplete or erroneous. This general paradigm applies to denoising and debluring of images (where natural images form a low-dimensional subset of the space of all possible images), compressed sensing (where the signal can be represented in terms of just a few elements of an appropriate basis), regularized regression (where we seek to explain observations in terms of just a few predictive variables), manifold learning (where we wish to identify a manifold from partially observed vectors from that manifold), matrix completion (where we seek a low-rank matrix that fits partial information about the matrix), and so on.
Sparse optimization provides valuable tools for formulating and solving problems of this type. A key concept is regularization, whereby we introduce functions into the optimization formulation that induce the required type of structure in the solutions. In the simplest case, the 1-norm of a vector x is used to derive solutions in which x is sparse, that is, it contains relatively few nonzero components. Often (not always) the regularized formulations are convex but nonsmooth. Customized optimization algorithms are required to handle the large data size and dimension.
This tutorial will survey the scope of applications of sparse optimization in data processing, and then describe the formulation techniques and algorithms that are being used to solve these problems.

MOS WELCOME RECEPTION
SUNDAY, JULY 28, 18:30-20:30
Entrance Hall of the Department of Mathematics

The MOS Welcome Reception will take place at the Entrance Hall of the Department of Mathematics. Typical Portuguese tapas will be served to all participants, accompanied by the sound of a live performance of a Portuguese guitar. Not to be missed as the food will be great!

POSTER PRESENTATIONS AND RECEPTION
MONDAY, JULY 29, 18:30-20:30
Entrance Hall of the Department of Mathematics

During the Poster Presentations Session, dinner will be served to all participants. Here we will combine the excellence of Continuous Optimization with Portuguese cuisine. The event takes place at the Entrance Hall of the Department of Mathematics.

CONFERENCE BANQUET
TUESDAY, JULY 30, 18:15-22:45
60 € per person, not included in the registration fees.

The Conference Banquet will hopefully be a memorable one. It will take place in a beautiful eighteen century palace (Solar dos Zagallos), relatively close to the campus. The food will be excellent for the price, as an entrée (or first course), two main courses, and desert will be served. Dinner will be followed by (i) the announcement of the winner of the Best Paper Prize and (ii) a live Fado singing performance.

Transportation from the campus to the banquet site and back to the three hotels in Caparica and Almada and to the train and ferry stations will be provided (see the bus schedule on page 12).

CONFERENCE TOUR
THURSDAY, JULY 1, 16:30-19:30
15 € per person, not included in the registration fees.

The tour consists of visits to the natural park of Arrábida and to the wine cellars of José Maria da Fonseca. Besides visiting the impressive Manor House Museum, there will be a tour to the cellars and a tasting of the high quality wines locally produced.

Buses will leave from campus and at the end will take participants back to the three hotels in Caparica and Almada and to the train and ferry stations (see the bus schedule on page 12).

LUNCHES DURING THE CONFERENCE

Participants will be offered lunch Monday July 29 through Thursday August 1. The food will be served in the Department of Mathematics, and hopefully if the weather is on our side, outside in the interior courtyard.

MONDAY

09:00-10:00

Mon.P.AA Plenary Session (Michael C. Ferris)

10:30-11:15

Mon.S.AA Semi-plenary Session (Sam Burer)

Mon.S.AB Semi-plenary Session (Regina Burachik)

11:30-13:00

Mon.A.11 Semidefinite optimization: Geometry and applications I

Mon.A.12 Recent advances in first and second order methods for some structured sparse optimization problems

Mon.A.13 Large scale nonlinear optimization

Mon.A.14 Equilibrium problems and variational inequalities: Computation and uncertainty

Mon.A.15 Advances in derivative free optimization I

Mon.A.16 Global optimization of problems with special structure

Mon.A.17 Optimization of dynamic systems I

Mon.A.18 Stochastic optimization in sequential detection and optimal execution

Mon.A.21 Algebraic algorithms and applications

Mon.A.22 Stochastic methods and applications

Mon.A.24 Multilevel and adaptive methods for PDE-constrained optimization

Mon.A.25 Variational analysis and its applications to finance and engineering

Mon.A.AB Nonlinear optimization I

14:30-16:00

Mon.B.11 Semidefinite optimization: Geometry and applications II

Mon.B.12 Algorithms for eigenvalue optimization

Mon.B.13 Sequential and pivoting approaches

Mon.B.14 Numerics and theory of dynamic MPECs

Mon.B.15 Advances in derivative free optimization II

Mon.B.17 Stochastic optimization of complex systems

Mon.B.21 Bilevel programming and MPECs

Mon.B.22 Recent advances in coordinate descent methods

Mon.B.23 Game theory and stochastic control

Mon.B.24 Model reduction and discretization

Mon.B.25 Variational analysis and optimal control

Mon.B.AB Nonlinear optimization II

16:30-18:00

Mon.C.11 Algebraic geometry and semidefinite programming I

Mon.C.13 Augmented Lagrangian methods for nonlinear optimization

Mon.C.14 Numerical aspects of dynamic MPECs

Mon.C.15 Model based methods for derivative-free optimization

Mon.C.16 Integer and mixed-integer nonlinear optimization

Mon.C.17 Optimization of dynamic systems II

Mon.C.18 Modeling and algorithmic developments in stochastic programming

Mon.C.21 Dual and coordinate descent methods

Mon.C.22 First order methods

Mon.C.24 Computational methods for inverse problems II

Mon.C.25 Variational and convex analysis

Mon.C.AB Nonlinear optimization III

Tuesday

09:00-10:00

Tue.P.AA Plenary Session (Yurii Nesterov)

10:30-11:15

Tue.S.AA Semi-plenary Session (Amir Beck)
Tue.S.AB Semi-plenary Session (Victor DeMiguel)

11:30-13:00

Tue.A.11 Algebraic geometry and semidefinite programming II
Tue.A.12 Regularization with polyhedral norms
Tue.A.13 Nonlinear optimization: Optimality conditions
Tue.A.14 Algorithms and applications of dynamic MPECs
Tue.A.15 New derivative-free nonlinear optimization algorithms
Tue.A.16 Global optimization with differential equations embedded
Tue.A.17 Optimization for data analysis and assimilation
Tue.A.18 Recent advances in stochastic programming
Tue.A.21 Structural aspects in nonsmooth optimization
Tue.A.22 Distributed algorithms for constrained convex problems over networks
Tue.A.24 Computational methods for inverse problems I
Tue.A.25 Variational analysis and variational inequalities
Tue.A.AB Nonlinear optimization IV

14:30-16:00

Tue.B.AA Best Paper Prize Session

16:30-18:00

Tue.C.11 Algebraic geometry and semidefinite programming III
Tue.C.12 Recent advances in conic programming
Tue.C.13 Parallelism and optimality conditions
Tue.C.14 Topics in variational inequalities and Nash games
Tue.C.15 Model-based trust-region methods
Tue.C.16 Branch-and-bound algorithms and global optimization
Tue.C.17 Applications for practical planning problems
Tue.C.18 Robust optimization I
Tue.C.21 Structural aspects of nonsmooth optimization II
Tue.C.22 Coordinate descent and incremental gradient methods for nonsmooth optimization
Tue.C.23 Optimal control
Tue.C.24 Preconditioning in PDE-constrained optimization
Tue.C.25 Variational analysis and its applications
Tue.C.AB Algorithms I

Wednesday

09:00-10:00

Wed.P.AA Plenary Session (Paul I. Barton)

10:30-11:15

Wed.S.AA Semi-plenary Session (Michael Hintermüller)
Wed.S.AB Semi-plenary Session (Ya-xiang Yuan)

11:30-13:00

Wed.A.11 Conic programming and related problems II
Wed.A.12 Recent advances in first order optimization methods
Wed.A.13 Nonlinear optimization and linear algebra
Wed.A.14 Variational inequalities and equilibrium problems I
Wed.A.15 Probabilistic derivative free optimization
Wed.A.16 Aircraft conflict detection and resolution
Wed.A.17 Applications in design problems
Wed.A.18 Robust optimization II
Wed.A.21 Geometry in nonsmooth optimization
Wed.A.22 Structured convex and nonconvex optimization
Wed.A.24 Error estimates for optimal control of PDEs
Wed.A.25 Set valued mapping and sensitivity analysis
Wed.A.AB Sparse and low-rank optimization

14:30-16:00

Wed.B.11 Conic programming and related problems I
Wed.B.12 Exploiting structure in machine learning applications
Wed.B.13 Complexity of convex/nonsmooth/nonlinear optimization methods
Wed.B.14 Variational inequalities and equilibrium problems II
Wed.B.15 Advances in derivative free optimization III
Wed.B.16 Algorithms for MINLP: Theory and practice
Wed.B.17 Applications in location problems
Wed.B.18 Robust optimization III
Wed.B.21 Convex programming: Theoretical results
Wed.B.22 Recent developments on first-order methods for large-scale convex optimization
Wed.B.23 Derivatives calculation
Wed.B.24 Optimality conditions in optimal control of PDEs
Wed.B.25 Optimization on manifolds and functional spaces
Wed.B.AB Linear algebra and optimization

16:30-18:00

Wed.C.11 Extended formulations and matrix factorizations
Wed.C.13 Optimality conditions and algorithms
Wed.C.14 MPEC and applications
Wed.C.15 Derivative free methods for nonsmooth and noisy problems
Wed.C.16 Copositive and quadratic optimization

Wed.C.17 Applications in geometry design

Wed.C.18 Robust optimization

Wed.C.21 First-order methods, boosting and related issues

Wed.C.22 Sparse optimization and its applications

Wed.C.23 Continuous optimization solvers within mixed-integer frameworks

Wed.C.24 Optimization of free boundary problems I

Wed.C.25 Variational analysis in nonlinear optimization

Wed.C.AB Nonlinear optimization and applications I

18:00-19:30

Wed.D.11 Optimization of polynomials in commutative and non-commutative variables

Wed.D.12 Semi-continuous sparse reconstruction

Wed.D.13 Algorithm advances for convex quadratic programming

Wed.D.14 Decomposition and cone geometry

Wed.D.15 Constrained derivative free optimization

Wed.D.16 Global optimization with applications to machine learning

Wed.D.17 Optimization in practice I

Wed.D.18 Optimization in finance I

Wed.D.21 Methods for tensor optimization

Wed.D.22 Stochastic and randomized gradient methods for convex optimization

Wed.D.23 Interior point methods for conic optimization

Wed.D.24 Optimization of free boundary problems II

Wed.D.25 Variational analysis in differential and mean field games

Wed.D.AB Nonlinear optimization and applications II

THURSDAY

09:00-10:30

Thu.A.11 New bounds for combinatorial problems using copositive and semidefinite optimization

Thu.A.12 Robust formulations and algorithms for large scale sparse programs

Thu.A.13 Algorithms II

Thu.A.14 Complementarity problems: Algorithms and applications

Thu.A.15 Derivative-free optimization: Algorithms and applications I

Thu.A.16 Recent advances in global optimization

Thu.A.17 Optimization in practice II

Thu.A.18 Optimization in finance II

Thu.A.21 Semidefinite and conic optimization: Models and methods

Thu.A.22 Efficient first-order methods for convex optimization

Thu.A.23 Extending the power and expressiveness of optimization modeling languages

Thu.A.24 Optimization with partial differential equations

Thu.A.25 Variational analysis techniques

Thu.A.AB Nonlinear optimization and applications III

11:00-12:30

Thu.B.11 Modeling and computation in copositive programming

Thu.B.12 High performance linear optimization

Thu.B.13 Analysis of local convergence

Thu.B.14 Advances in algorithms

Thu.B.15 Derivative-free optimization: Algorithms and applications II

Thu.B.16 Distance geometry and applications

Thu.B.18 Optimization in finance III

Thu.B.21 Extending the scope of convexity: From finite to infinite dimensional, ordinary to extraordinary, and from convex to nonconvex

Thu.B.22 Convex optimization in machine learning

Thu.B.23 Convex optimization and related problems

Thu.B.24 Bang-bang-type control of PDEs

Thu.B.25 Advances in multiobjective optimization

Thu.B.AB Advances in nonlinear optimization

14:00-14:45

Thu.S.AA Semi-plenary Session (Michel De Lara)

Thu.S.AB Semi-plenary Session (Coralia Cartis)

15:00-16:00

Thu.P.AA Plenary Session (Yinyu Ye)

Monday, 11:30-13:00

Cluster: Conic and polynomial optimization

Semidefinite optimization: Geometry and applications I *organized by João Gouveia, Rekha Thomas.* Mon.A.11

Frank Vallentin: Spectral bounds for the independence ratio and the chromatic number of an operator

James Saunderson: Polynomial-sized semidefinite representations of derivative relaxations of spectrahedral cones

Tor Myklebust: Hyperbolic cone programming: Structure and interior-point algorithms

Cluster: Sparse optimization and information processing

Recent advances in first and second order methods for some structured sparse optimization problems *organized by Kim-Chuan Toh.* Mon.A.12

Defeng Sun: An adaptive semi-nuclear norm approach for rank optimization problems with hard constraints

Xiaoming Yuan: A strictly contractive Peaceman-Rachford splitting method for convex programming

Kim-Chuan Toh: A proximal point algorithm for log-determinant optimization with group lasso regularization

Cluster: Nonlinear optimization

Large scale nonlinear optimization Mon.A.13

Behzad Azmi: A novel limited memory method for bound-constrained optimization

A. Ismael F. Vaz: Globally convergent DC trust-region methods

Cluster: Complementarity and variational inequalities

Equilibrium problems and variational inequalities: Computation and uncertainty *organized by Shu Lu.* Mon.A.14

Jong-Shi Pang: On the solution of affine generalized Nash equilibrium problems by Lemke's method

Daniel Ralph: Stochastic equilibrium in investment models: Capacity expansion in the power sector

Shu Lu: Stochastic variational inequalities: Confidence regions and intervals

Cluster: Derivative-free and simulation-based optimization

Advances in derivative free optimization I *organized by Jeffrey Larson.* Mon.A.15

Jeffrey Larson: Stochastic derivative-free optimization using a trust region framework

Zaikun Zhang: A derivative-free optimization algorithm with low-dimensional subspace techniques for large-scale problems

Ruobing Chen: Regularized regression models for derivative free methods under controllable noise setting

Cluster: Global optimization and mixed-integer programming

Global optimization of problems with special structure *organized by Alexander Mitsos.* Mon.A.16

Martina Wittmann-Hohlbein: On the approximate solution of mp-MILP problems using piecewise affine relaxation of bilinear terms

Ruth Misener: ANTIGONE: A general mixed-integer nonlinear global optimisation framework

Vladimir Shikhman: On intrinsic complexity of bilevel optimization

Cluster: Applications of continuous optimization in science and engineering

Optimization of dynamic systems I *organized by Victor M. Zavala.* — Mon.A.17

Janick Frasch: A structure exploiting parallel strategy for the efficient solution of sparse quadratic programs arising in SQP-based nonlinear optimal control

Mihai Anitescu: Scalable dynamic optimization

Mattia Vallerio: Multi-objective optimal control using fast gradient-based optimisation techniques

Cluster: Stochastic optimization

Stochastic optimization in sequential detection and optimal execution *organized by Olympia Hadjiliadis.* — Mon.A.18

Michael Carlisle: Sequential decision rules and times for two-dimensional hypothesis testing

Gerardo Hernandez-del-Valle: Optimal execution with jumps (or known structural break points)

Neofytos Rodosthenous: Quickest detection in a system with correlated noise

Cluster: Convex and nonsmooth optimization

Algebraic algorithms and applications *organized by Amir Ali Ahmadi.* — Mon.A.21

David Monniaux: On the generation of positivstellensatz witnesses in degenerate cases

Caroline Uhler: Ellipsoid packing with applications to chromosome organization

Antonios Varvitsiotis: Positive semidefinite matrix completion, universal rigidity and the strong Arnold property

Cluster: Convex and nonsmooth optimization

Stochastic methods and applications *organized by Stephen J. Wright.* — Mon.A.22

Stephen J. Wright: Convergence of a stochastic algorithm for subspace identification

Peter Richtarik: Mini-batch primal and dual methods for support vector machines

Cluster: PDE-constrained optimization

Multilevel and adaptive methods for PDE-constrained optimization *organized by Drew Kouri, Sven Leyffer.* — Mon.A.24

Drew Kouri: An approach for the adaptive solution of optimization problems governed by PDEs with uncertain coefficients

Anton Schiela: An affine covariant composite step method for nonlinear optimization in function space

Stefanie Bott: Adaptive multilevel SQP method for state constrained optimization with Navier-Stokes equations

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis and its applications to finance and engineering *organized by Samir Adly.* — Mon.A.25

Radek Cibulka: Newton's method for solving generalized equations using set-valued approximations

Francisco J. Silva: Some sensitivity results for optimal control problems

CANCELLED

Cluster: Nonlinear optimization

Nonlinear optimization I *organized by Daniel P. Robinson, Philip E. Gill, Nick Gould.* — Mon.A.AB

Nick Gould: A practical dual gradient-projection method for large-scale, strictly-convex quadratic programming

Jorge Nocedal: Stochastic quasi-Newton methods

Daniel P. Robinson: A restoration free filter method with unified step computation for nonlinear programming

Monday, 14:30-16:00

Cluster: Conic and polynomial optimization

Semidefinite optimization: Geometry and applications II *organized by João Gouveia, Rekha Thomas.* Mon.B.11

Zhao Sun: Handelman's hierarchy for the maximum stable set problem

Daniel Plaumann: Hyperbolic polynomials and sums of squares

Gabor Pataki: Bad semidefinite programs: they all look the same

Cluster: Sparse optimization and information processing

Algorithms for eigenvalue optimization *organized by Zaiwen Wen.* Mon.B.12

Xin Liu: Trace-penalty minimization for large-scale eigenspace computation

Chao Yang: A preconditioner for accelerating a fixed point iteration in electronic structure calculations

Zaiwen Wen: Adaptive regularized self-consistent field iteration with exact Hessian

Cluster: Nonlinear optimization

Sequential and pivoting approaches Mon.B.13

Adrienn Nagy: A new proof for the fineness of the quadratic simplex method

Le Hong Trang: A sequential convex programming algorithm for minimizing a sum of Euclidean norms with non-convex constraints

Cluster: Complementarity and variational inequalities

Numerics and theory of dynamic MPECs *organized by Kathrin Hatz, Sven Leyffer.* Mon.B.14

Sebastian Albrecht: Inverse optimal control problems for the analysis of human motions

Christian Kirches: A parametric active-set method for linear programs with complementarity and vanishing constraints

Cluster: Derivative-free and simulation-based optimization

Advances in derivative free optimization II *organized by Margaret H. Wright.* Mon.B.15

Genetha Gray: Using surrogates to calculate sensitivities and improve optimization-based calibration routines

Juan C. Meza: Derivative-free optimization methods for the surface structure determination problem

Dmitri Kvasov: Diagonal methods in Lipschitz global optimization

Cluster: Applications of continuous optimization in science and engineering

Stochastic optimization of complex systems *organized by Mihai Anitescu.* Mon.B.17

Arvind U. Raghunathan: Global optimization of optimal power flow (OPF) problems

Vincent Leclere: On the convergence of decomposition methods for multistage stochastic convex program

Andreas Grothey: Contingency generation by interior point methods for optimal power flow

Cluster: Convex and nonsmooth optimization

Bilevel programming and MPECs *organized by Stephan Dempe, Alain B. Zemkoho.* Mon.B.21

Alain B. Zemkoho: Stationarity concepts for strong and weak Stackelberg problems

Alexandra Schwartz: The price of inexactness: Convergence properties of relaxation methods for mathematical programs with equilibrium constraints revisited

Stephan Dempe: Bilevel programming – formulation and optimality conditions

Cluster: Convex and nonsmooth optimization

Recent advances in coordinate descent methods *organized by Martin Takac.* Mon.B.22

Amir Beck: On the rate of convergence of block coordinate descent type methods	**CANCELLED**	**Pradeep Ravikumar**: Convex reparameterization of a large class of biconvex functions

Cluster: Robust optimization and optimization in finance

Game theory and stochastic control Mon.B.23

Mohamed Assellaou: Probabilistic safety reachability analysis	**Alexander S. Belenky**: Application of continuous optimization techniques for calculating equilibriums in large-scale three-person public procurement games	

Cluster: PDE-constrained optimization

Model reduction and discretization Mon.B.24

Aygul Manapova: Approximations of semilinear elliptic optimal control problems in a convex domain with controls in the coefficients multiplying the highest derivatives	**Daniela Koller**: Reduced order models for the optimal control of contact problems	**Ekkehard Sachs**: Model Reduction in the Calibration of Nonlinear PDEs

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis and optimal control *organized by Térence Bayen.* Mon.B.25

Xavier Dupuis: Leukemia and optimal control	**Laurent Pfeiffer**: Sensitivity analysis for relaxed optimal control problem with final-state constraints	**Athena Picarelli**: New approach for stochastic target problems with state-constraints

Cluster: Nonlinear optimization

Nonlinear optimization II *organized by Daniel P. Robinson, Philip E. Gill, Nick Gould.* Mon.B.AB

Philip E. Gill: Stabilized SQP methods for nonlinear optimization	**Elizabeth Wong**: Regularized methods for large-scale quadratic programming	**Jacek Gondzio**: Inexact search directions in very large-scale optimization

Monday, 16:30-18:00

Cluster: Conic and polynomial optimization

Algebraic geometry and semidefinite programming I *organized by Lek-Heng Lim, Cordian Riener.* Mon.C.11

Rekha Thomas: Positive semidefinite rank of polytopes and matrices	**Hamza Fawzi**: New lower bounds on nonnegative rank using conic programming	**Cordian Riener**: Symmetric mean inequalities and sums of squares

Cluster: Nonlinear optimization

Augmented Lagrangian methods for nonlinear optimization Mon.C.13

Sven Leyffer: New augmented Lagrangian filter methods

Vyacheslav Kungurtsev: Local convergence of a primal-dual augmented Lagrangian algorithm with a stabilized SQP subproblem

Riadh Omheni: A primal-dual augmented Lagrangian and log-barrier penalty algorithm for nonlinear optimization

Cluster: Complementarity and variational inequalities

Numerical aspects of dynamic MPECs *organized by Kathrin Hatz, Sven Leyffer.* Mon.C.14

Sou-Cheng (Terrya) Choi: AMPL/PATH tutorial introduction to solving regularized complementarity problems with a case study from CIM-EARTH

Vincent Acary: Ordinary differential equations with discontinuous right-hand sides as complementarity systems. Application to gene regulatory networks.

Jacqueline Morgan: Bilevel problems with Nash equilibrium constraints under perturbations

Cluster: Derivative-free and simulation-based optimization

Model based methods for derivative-free optimization *organized by Sébastien Le Digabel.* Mon.C.15

M. J. D. Powell: Trust region calculations with linear constraints

Yves Lucet: Derivative-free optimization via proximal point methods

Stefan M. Wild: Model-based optimization methods with many simultaneous function evaluations

Cluster: Global optimization and mixed-integer programming

Integer and mixed-integer nonlinear optimization *organized by Christoph Buchheim.* Mon.C.16

Claire Lizon: A direct search algorithm for determining the well location and on/off status for reservoir engineering

Andreas Schmutzer: Exploiting facets of the cut polytope for sparse betweenness problems

Ruth Hübner: The rounding property for nonlinear mixed integer optimization problems

Cluster: Applications of continuous optimization in science and engineering

Optimization of dynamic systems II *organized by Victor M. Zavala.* Mon.C.17

Juan L. Jerez: Embedded optimization in fixed-point arithmetic

Lorenz T. Biegler: Sensitivity-based decomposition for moving finite elements with direct transcription formulations

Sebastian Sager: Decoding complex cardiac arrhythmia using mathematical optimization

Cluster: Stochastic optimization

Modeling and algorithmic developments in stochastic programming *organized by Miguel Lejeune.* Mon.C.18

Victor M. Zavala: Clustering-based interior point strategies for stochastic programs

Miguel Lejeune: Boolean reformulation method for probabilistically constrained stochastic programming problems

Cluster: Convex and nonsmooth optimization

Dual and coordinate descent methods *organized by Martin Takac.* Mon.C.21

Yurii Nesterov: Universal gradient methods

Martin Takac: Parallel block coordinate descent methods for huge-scale partially separable problems

Ion Necoara: A random coordinate descent method on large optimization problems with linear constraints

Cluster: Convex and nonsmooth optimization

First order methods Mon.C.22

Masaru Ito: A unified framework of subgradient algorithms for convex optimization problems

Yoel Drori: A novel approach for analyzing the performance of first-order methods

Natalia Ruiz: Regularized interior proximal alternating directions method

Cluster: PDE-constrained optimization

Computational methods for inverse problems II *organized by Noemi Petra, Antoine Laurain .* Mon.C.24

Carolin Homann: A generalized Chambolle and Pock algorithm for Tikhonov regularization in Banach spaces and application to phase-retrieval problems

Noemi Petra: Computational methods for Bayesian inverse problems governed by PDEs

Carsten Schäfer: Optimal actuator and sensor placement for dynamical systems

Cluster: Variational analysis, set-valued and vector optimization

Variational and convex analysis *organized by Alejandro Jofré.* Mon.C.25

Stephen Simons: The Hahn-Banach Lagrange theorem

Regina Burachik: Conditions for zero duality gap in convex programming

Abderrahim Hantoute: On the calmness property in linear semi-infinite optimization

Cluster: Nonlinear optimization

Nonlinear optimization III *organized by Daniel P. Robinson, Philip E. Gill, Nick Gould.* Mon.C.AB

Frank E. Curtis: Sequential quadratic optimization with inexact subproblem solves

Andreas Waechter: Complementarity formulations for l0-norm optimization problems

Tim Mitchell: A BFGS-based SQP method for constrained nonsmooth, nonconvex optimization

Tuesday, 11:30-13:00

Cluster: Conic and polynomial optimization

Algebraic geometry and semidefinite programming II *organized by Lek-Heng Lim, Cordian Riener.* Tue.A.11

João Gouveia: From approximate factorizations to approximate lifts

Alexander Kova£ec: Positive semidefinite diagonal minus tail forms are sums of squares

Bolor Jargalsaikhan: Conic programming: Genericity results and order of solution

Cluster: Sparse optimization and information processing

Regularization with polyhedral norms *organized by Dirk Lorenz.* Tue.A.12

Frank Schöpfer: Exact regularization of polyhedral norms

Michael Möller: Multiscale methods for polyhedral regularizations

Dirk Lorenz: The linearized Bregman method and its generalizations as an algorithm for split feasibility problems

Cluster: Nonlinear optimization

Nonlinear optimization: Optimality conditions		Tue.A.13
Refail Kasimbeyli: Optimality conditions in nonconvex nonsmooth optimization	**Pál Burai**: Generalized convexity and local-global minimum property of nonlinear optimization problems	**Olga Brezhneva**: Short and elementary proofs of the Karush-Kuhn-Tucker, Lagrange multiplier, and implicit function theorems

Cluster: Complementarity and variational inequalities

Algorithms and applications of dynamic MPECs *organized by Kathrin Hatz, Sven Leyffer.*		Tue.A.14
Stefan Ulbrich: Optimization of deep drawing processes	**Angelia Nedich**: Distributed aggregative Nash-games on graphs	**Kathrin Hatz**: Numerical methods and computational results for solving hierarchical optimal control problems

Cluster: Derivative-free and simulation-based optimization

New derivative-free nonlinear optimization algorithms *organized by José Mario Martínez.*		Tue.A.15
CANCELLED	**Maria A. Diniz-Ehrhardt**: A method for nonlinear least-squares problems based on simplex derivatives	**Lucas Garcia Pedroso**: A derivative-free trust-region method for nonlinear programming

Cluster: Global optimization and mixed-integer programming

Global optimization with differential equations embedded *organized by Paul I. Barton.*		Tue.A.16
Joseph K. Scott: Relaxing dynamic optimization problems: Convergence, clustering, and the effect of time	**Benoit Chachuat**: Branch-and-lift algorithm for deterministic global optimization in nonlinear optimal control	**Holger Diedam**: Global optimal control using direct multiple shooting

Cluster: Applications of continuous optimization in science and engineering

Optimization for data analysis and assimilation *organized by Mihai Anitescu.*		Tue.A.17
Kimon Fountoulakis: Second order methods for sparse signal reconstruction	**Daniel P. Word**: Parallel solution of large-scale nonlinear parameter estimation problems	**Selime Gurol**: Preconditioning of linear systems with multiple right hand sides

Cluster: Stochastic optimization

Recent advances in stochastic programming *organized by Nilay Noyan.*		Tue.A.18
Ruediger Schultz: OR inspirations for stochastic shape optimisation	**Francesca Maggioni**: Bounds in mulstistage stochastic programming	**Nilay Noyan**: Optimization with multivariate conditional value-at-risk constraints

Cluster: Convex and nonsmooth optimization

Structural aspects in nonsmooth optimization *organized by Vladimir Shikhman.*		Tue.A.21
Oliver Stein: Smoothness properties of a regularized gap function for quasi-variational inequalities	**Alexander Mitsos**: Global optimization of generalized semi-infinite programs via restriction of the right hand side	

Cluster: Convex and nonsmooth optimization

Distributed algorithms for constrained convex problems over networks *organized by Ion Necoara.* Tue.A.22

Soomin Lee: Random projection algorithms for distributed optimization

Quoc Tran Dinh: Fast decomposition algorithms for large-scale separable convex optimization

Dusan Jakovetic: Linear convergence rate of a class of distributed augmented Lagrangian algorithms

Cluster: PDE-constrained optimization

Computational methods for inverse problems I *organized by Noemi Petra, Antoine Laurain .* Tue.A.24

Ville Kolehmainen: Sparse tomography

Georg Stadler: Borrowing methods from optimization for the solution of large-scale statistical inverse problems

Antoine Laurain: A shape optimization method for magnetic induction tomography

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis and variational inequalities *organized by Jiri Outrata.* Tue.A.25

Michal Cervinka: Sensitivity analysis of MPECs

Lukas Adam: Optimal control of a rate-independent variational inequality

Cluster: Nonlinear optimization

Nonlinear optimization IV *organized by Daniel P. Robinson, Philip E. Gill, Nick Gould.* Tue.A.AB

Jennifer B. Erway: A new L-BFGS trust-region subproblem solver

William Hager: A primal-dual active set algorithm for nonlinear optimization with polyhedral constraints

Dominique Orban: Fast local convergence of interior-point methods in the absence of strict complementarity

Tuesday, 16:30-18:00

Cluster: Conic and polynomial optimization

Algebraic geometry and semidefinite programming III *organized by Lek-Heng Lim, Cordian Riener.* Tue.C.11

Pablo Parrilo: Approximation quality of SOS relaxations

Luuk Gijben: Scaling relationships between the copositive cone and the cone of sum of squares polynomials

Gabriele Eichfelder: On the set-semidefinite representation of non-convex quadratic programs

Cluster: Conic and polynomial optimization

Recent advances in conic programming *organized by Imre Pólik.* Tue.C.12

Imre Pólik: Rounding solutions in second-order cone programming

CANCELLED

Tamás Terlaky: On the identification of the optimal partition of second order cone optimization problems

Cluster: Nonlinear optimization

Parallelism and optimality conditions *organized by Jonathan Eckstein, Paulo J. S. Silva.* Tue.C.13

Jonathan Eckstein: Object-parallel implementation of a bound-constrained conjugate gradient solver

Paulo J. S. Silva: The role of constant rank in second order constraint qualifications

Ellen H. Fukuda: Slack variables in nonlinear second-order cone programming

Cluster: Complementarity and variational inequalities

Topics in variational inequalities and Nash games *organized by Jong-Shi Pang.* Tue.C.14

Todd S. Munson: Lemke's method for strictly positive linear complementarity problems

Francisco Facchinei: Complex variational inequalities and applications

Alberth Alvarado: On the maximum attainable system sum-rate in distributed Gaussian interference channels with unbounded budgets

Cluster: Derivative-free and simulation-based optimization

Model-based trust-region methods *organized by Afonso S. Bandeira.* Tue.C.15

Katya Scheinberg: Probabilistic model based derivative free methods

Afonso S. Bandeira: On sparse Hessian recovery and trust-region methods based on probabilistic models

Luis Nunes Vicente: A subspace decomposition framework for nonlinear optimization: Global convergence and global rates

Cluster: Global optimization and mixed-integer programming

Branch-and-bound algorithms and global optimization Tue.C.16

Christoph Buchheim: A fast branch-and-bound algorithm for box-constrained integer polynomial optimization

Peter Kirst: An enhanced spatial branch-and-bound method in global optimization with nonconvex constraints

Cluster: Applications of continuous optimization in science and engineering

Applications for practical planning problems *organized by Frédéric Messine.* Tue.C.17

Dag Haugland: New lower and upper bounding techniques for the pooling problem

Frédéric Messine: Combining direct and indirect methods to solve aircraft conflict avoidance problems

M. Montaz Ali: A differential equation-based method for solving nonlinearly constrained nonlinear programming problems

Cluster: Robust optimization and optimization in finance

Robust optimization I *organized by Daniel Kuhn.* Tue.C.18

Bart Paul Gerard Van Parys: Distributionally robust control of linear dynamical systems

Simone Garatti: The risk of empirical costs in min-max sample-based optimization

Daniel Kuhn: Distributionally robust convex optimization

Cluster: Convex and nonsmooth optimization

Structural aspects of nonsmooth optimization II *organized by Vladimir Shikhman.* Tue.C.21

Dominik Dorsch: Generic first-order necessary optimality conditions for a general class of optimization problems

Thomas Surowiec: On a class of generalized Nash equilibrium problems in Banach space with applications to multiobjective PDE-constrained optimization

Dominikus Noll: Convergence of nonsmooth descent methods using the Kudyka-Lojasiewicz inequality

Cluster: Convex and nonsmooth optimization

Coordinate descent and incremental gradient methods for nonsmooth optimization *organized by Olivier Fercoq.* Tue.C.22

Federico Pierucci: Conditional gradient algorithm for machine learning with non-smooth loss and decomposable regularization

Sangwoon Yun: Incrementally updated gradient methods for nonsmooth minimization

Olivier Fercoq: Smoothed parallel coordinate descent method for huge-scale optimization problems

Cluster: PDE-constrained optimization

Optimal control Tue.C.23

Sebastian Pfaff: Optimal control of nonlinear hyperbolic conservation laws at a junction

Hannes Meinlschmidt: Optimal control of PDAEs

Cristopher Hermosilla: Infinite horizon problems on stratifiable state constraints sets

Cluster: PDE-constrained optimization

Preconditioning in PDE-constrained optimization *organized by Martin Stoll, Andreas Potschka.* Tue.C.24

Andreas Potschka: Newton-Picard preconditioning for time-periodic PDE constrained optimization

John Pearson: Preconditioned iterative methods for time-dependent optimal control problems

CANCELLED

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis and its applications *organized by Alejandro Jofré.* Tue.C.25

Alejandro Jofré: Variational analysis and financial equilibrium

Luis M. Briceño Arias: Forward-partial inverse method for solving monotone inclusions: Application to land-use planning

Ari-Pekka Perkkiö: Stochastic programs without duality gaps

Cluster: Nonlinear optimization

Algorithms I *organized by Ernesto G. Birgin.* Tue.C.AB

Luís Felipe Bueno: An inexact restoration method with Lagrange multipliers and applications in multiobjective optimization

Sandra A. Santos: An inexact and nonmonotone proximal method combining trust region and line search for unconstrained minimization

CANCELLED

Wednesday, 11:30-13:00

Cluster: Conic and polynomial optimization

Conic programming and related problems II *organized by Masakazu Muramatsu.* Wed.A.11

Masakazu Muramatsu: Adaptive SDP relaxation for polynomial optimization

Akihiro Tanaka: An LP-based algorithm to test copositivity

Miguel F. Anjos: Towards efficient higher-order semidefinite relaxations for max-cut

Cluster: Sparse optimization and information processing

Recent advances in first order optimization methods *organized by Marc Teboulle.* Wed.A.12

Shoham Sabach: A first order method for finding minimal norm-like solutions of convex optimization problems

Ron Shefi: Rate of convergence analysis for proximal-Lagrangian methods

Marc Teboulle: A first order algorithm for a class of nonconvex-nonsmooth minimization

Cluster: Nonlinear optimization

Nonlinear optimization and linear algebra Wed.A.13

Annick Sartenaer: Using spectral information to precondition saddle-point systems

Sheng Fang: Singular value decomposition computations in matrix optimisation problems

Tove Odland: On the connection between the conjugate gradient method and quasi-Newton methods on quadratic problems

Cluster: Complementarity and variational inequalities

Variational inequalities and equilibrium problems I *organized by Patrizia Daniele.* Wed.A.14

Patrizia Daniele: Recent advances in variational inequalities

Rossana Riccardi: Environmental regulations and competitiveness in the steel industry

Samir Adly: A new method for solving eigenvalue complementarity problems

Cluster: Derivative-free and simulation-based optimization

Probabilistic derivative free optimization *organized by Anne Auger.* Wed.A.15

Nikolaus Hansen: A principled, stochastic approach to continuous black-box Optimization

Youhei Akimoto: Information-geometric optimization: Introduction and theoretical foundations

Dirk Arnold: The dynamical systems approach applied to the analysis of evolutionary strategies for constrained optimisation

Cluster: Global optimization and mixed-integer programming

Aircraft conflict detection and resolution *organized by Laureano F. Escudero.* Wed.A.16

Laureano F. Escudero: Aircraft conflict detection and resolution: A mixed-integer nonlinear optimization model by turn change maneuvers

F. Javier Martin-Campo: Aircraft conflict detection and resolution by mixed-integer nonlinear optimization models by turn change maneuvers using a variable neigborhood search approach

Sonia Cafieri: Aircraft conflict avoidance by mixed-integer nonlinear optimization models combining turn and velocity change maneuvers

Cluster: Applications of continuous optimization in science and engineering

Applications in design problems *organized by Jordi Castro.* Wed.A.17

Juan F. R. Herrera: Improvements of sequential and parallel bi-blending algorithms

Jordi Castro: Protecting three-dimensional tables of data: An application of interior-point methods to statistical disclosure control

Ana Maria A. C. Rocha: A global optimization method to solve engineering design problems

Cluster: Robust optimization and optimization in finance

Robust optimization II *organized by Huan Xu.* — Wed.A.18

Chiranjib Bhattacharyya: Efficient design of robust SVMs

John Wright: Robust optimization and robust estimation in provable object instance verification

Jia Yuan Yu: Data-driven distributionally robust polynomial optimization

Cluster: Convex and nonsmooth optimization

Geometry in nonsmooth optimization *organized by Dmitriy Drusvyatskiy.* — Wed.A.21

Dmitriy Drusvyatskiy: Optimization and intrinsic geometry

Robert Hesse: Non-convex feasibility problems: Qualitative and quantitative characterizations of set intersections

C. H. Jeffrey Pang: The convex set intersection problem: Supporting hyperplanes and quadratic programming

Cluster: Convex and nonsmooth optimization

Structured convex and nonconvex optimization *organized by Zhaosong Lu, Guanghui Lan.* — Wed.A.22

Fatma Kilinc-Karzan: On minimal valid inequalities for mixed integer conic programs

Guanghui (George) Lan: Complexity of large-scale convex optimization under linear minimization oracle

Cluster: PDE-constrained optimization

Error estimates for optimal control of PDEs *organized by Christian Clason, Eduardo Casas .* — Wed.A.24

Ira Neitzel: Numerical analysis of nonconvex elliptic optimal control problems with state constraints

Winnifried Wollner: Pointwise convergence of the feasibility violation for Moreau-Yosida regularized optimal control problems and applications to the finite element error of problems with gradient state constraints

Christian Meyer: Finite element error analysis for optimal control of the obstacle problem

Cluster: Variational analysis, set-valued and vector optimization

Set valued mapping and sensitivity analysis — Wed.A.25

Fernando García Castaño: Paratingent derivative applied to the measure of the sensitivity in multiobjective differential programming

Livia-Mihaela Berchesan: Existence results for variational inequalities with surjectivity consequences related to generalized monotone operators

Gabor Kassay: An inverse map result and some applications to sensitivity of generalized equations

Cluster: Nonlinear optimization

Sparse and low-rank optimization *organized by Coralia Cartis.* — Wed.A.AB

Xiaojun Chen: Worst case complexity of nonconvex non-Lipschiz minimization

Jared Tanner: Matrix completion at the edge of optimal

Martin Lotz: The geometry of phase transitions in convex optimization

Wednesday, 14:30-16:00

Cluster: Conic and polynomial optimization

Conic programming and related problems I *organized by Akiko Yoshise.* Wed.B.11

- **Yu Xia**: A gradient method for the sparse least squares problem
- **Mirai Tanaka**: On the positive definite matrix approximation with condition number constraint
- **Chek Beng Chua**: A barrier-based smoothing proximal point algorithm for nonlinear complementarity problems over closed convex cones

Cluster: Sparse optimization and information processing

Exploiting structure in machine learning applications *organized by Mark Schmidt.* Wed.B.12

- **Simon Lacoste-Julien**: Block-coordinate Frank-Wolfe optimization for machine learning
- **Yuekai Sun**: Proximal Newton-type methods for minimizing composite functions
- **Cristobal Guzman**: Lower bounds on the oracle complexity of convex optimization using information theory

Cluster: Convex and nonsmooth optimization

Complexity of convex/nonsmooth/nonlinear optimization methods Wed.B.13

- **Rohollah Garmanjani**: Worst-case complexity of adaptive cubic with regularization algorithm for nonsmooth objective functions using smoothing approach
- **Masoud Ahookhosh**: Optimal subgradient-based algorithms for large-scale convex optimization
- **Clovis Gonzaga**: On the complexity of steepest descent algorithms for minimizing quadratic functions

Cluster: Complementarity and variational inequalities

Variational inequalities and equilibrium problems II *organized by Patrizia Daniele.* Wed.B.14

- **Monica Gabriela Cojocaru**: Solving generalized Nash games with shared constraints through evolutionary variational inequalities
- **Giovanni Paolo Crespi**: Variational inequalities in set-optimization
- **Sofia Giuffrè**: Variational problems with gradient constraints

Cluster: Derivative-free and simulation-based optimization

Advances in derivative free optimization III *organized by Anke Tröltzsch.* Wed.B.15

- **Ana Luísa Custódio**: GLODS: Global and local optimization using direct search
- **Phillipe R. Sampaio**: Equality-constrained derivative-free optimization
- **Youssef Diouane**: Globally convergent evolution strategies and CMA-ES

Cluster: Global optimization and mixed-integer programming

Algorithms for MINLP: Theory and practice *organized by Giacomo Nannicini.* Wed.B.16

- **Michel Baes**: Mirror-descent methods in mixed-integer convex optimization
- **Emiliano Traversi**: Hybrid SDP bounding procedure
- **Selin Damla Ahipasaoglu**: Algorithms for the minimum volume ellipsoid estimator

Cluster: Applications of continuous optimization in science and engineering

Applications in location problems *organized by Pilar M. Ortigosa.* Wed.B.17

- **Eligius M. T. Hendrix**: On bi-level thinking in continuous competitive location
- **Pilar M. Ortigosa**: A multiobjective optimization algorithm for locating a semi-obnoxious facility in the plane
- **Aránzazu G. Arrondo**: A parallel algorithm for solving a bi-objective location problem

Cluster: Robust optimization and optimization in finance

Robust optimization III *organized by Xuan Vinh Doan.* Wed.B.18

Huan Xu: Optimization under probabilistic envelope constraints

Ihsan Yanikoglu: Adjustable robust parameter design with unknown distributions

Xuan Vinh Doan: Distributionally robust optimization with a general Fréchet class of distributions

Cluster: Convex and nonsmooth optimization

Convex programming: Theoretical results *organized by Roland Hildebrand.* Wed.B.21

Zaid Harchaoui: Conditional gradient algorithms for norm-regularized smooth convex optimization

Telma J. Santos: Some versions of a strong maximum principle for an elliptic functional with the generalized symmetry assumption

Roland Hildebrand: Convex projective programming

Cluster: Convex and nonsmooth optimization

Recent developments on first-order methods for large-scale convex optimization *organized by Renato D. C. Monteiro, Camilo Ortiz.* Wed.B.22

Shiqian Ma: Low-rank tensor optimization problems

Renato D. C. Monteiro: A first-order block-decomposition method for solving two-easy-block structured semidefinite programs

Cluster: Optimization software: Modeling tools and engines

Derivatives calculation Wed.B.23

Robert Gower: Third-order methods and third-order derivatives with AD

Zsolt Csizmadia: Analytic derivatives: Symbolic versus automatic

Joaquim R. R. A. Martins: A matrix-free approach to large-scale nonlinear constrained optimization

Cluster: PDE-constrained optimization

Optimality conditions in optimal control of PDEs *organized by Francisco J. Silva.* Wed.B.24

Juan Carlos De los Reyes: Optimality conditions for VI constrained optimization

Térence Bayen: Strong minima for optimal control problems governed by semi linear parabolic equations

Jameson Graber: Optimal control of viscosity solutions to first-order Hamilton-Jacobi equations

Cluster: Variational analysis, set-valued and vector optimization

Optimization on manifolds and functional spaces Wed.B.25

Saverio Salzo: Convergence analysis of a proximal Gauss-Newton method

Orizon P. Ferreira: A robust Kantorovich's theorem on the inexact Newton method with relative residual error tolerance

Paulo Roberto Oliveira: Proximal point method on Finslerian manifolds

Cluster: Nonlinear optimization

Linear algebra and optimization *organized by Coralia Cartis.* Wed.B.AB

Benedetta Morini: Updating techniques for sequences of KKT systems in quadratic programming

Philippe Toint: Dual space techniques for nonlinear least-squares in data assimilation

Jaroslav M. Fowkes: Branching and bounding improvements for Lipschitz global optimization

Wednesday, 16:30-18:00

Cluster: Conic and polynomial optimization

Extended formulations and matrix factorizations *organized by João Gouveia, Rekha Thomas.* Wed.C.11

Dirk Oliver Theis: Support-based lower bounds for the positive semidefinite rank of a nonnegative matrix

Nicolas Gillis: Robust near-separable nonnegative matrix factorization using linear optimization

Sebastian Pokutta: Common information and unique disjointness

Cluster: Nonlinear optimization

Optimality conditions and algorithms *organized by Ernesto G. Birgin.* Wed.C.13

Gabriel Haeser: Applications of the approximate-KKT optimality condition

Roberto Andreani: Constant rank of subspace component: A new constraint qualification

Leandro F. Prudente: On convergence to infeasible points in augmented Lagrangian methods

Cluster: Complementarity and variational inequalities

MPEC and applications Wed.C.14

Carmo P. Brás: Inverse eigenvalue complementarity problem

Adrian Sichau: Robust nonlinear programming with discretized PDE constraint using quadratic approximations

Matthieu Marechal: Solving a MPEC problem with a partial penalization

Cluster: Derivative-free and simulation-based optimization

Derivative free methods for nonsmooth and noisy problems *organized by Giampaolo Liuzzi.* Wed.C.15

Francesco Rinaldi: A class of derivative-free nonmonotone algorithms for unconstrained nonlinear optimization

Giampaolo Liuzzi: Derivative-free methods for multiobjective Lipschitz problems

Julie Nutini: A derivative-free approximate gradient sampling algorithm for finite minimax problems

Cluster: Global optimization and mixed-integer programming

Copositive and quadratic optimization *organized by Immanuel Bomze.* Wed.C.16

Hongbo Dong: Relaxations for convex quadratic programming with binary indicator variables

E. Alper Yildirim: Copositive optimization based bounds on standard quadratic optimization

Immanuel Bomze: Narrowing the difficulty gap for the Celis-Dennis-Tapia problem

Cluster: Applications of continuous optimization in science and engineering

Applications in geometry design *organized by Phan Thanh An.* Wed.C.17

Phan Thanh An: Optimization methods for computational geometry

Dinh T. Giang: Exact solutions for minimizing a sum of Euclidean norms

Leocadio G. Casado: On simplex longest edge bisection for solving blending problems

Cluster: Robust optimization and optimization in finance

Robust optimization Wed.C.18

Amirhossein Sadoghi: Measuring systemic risk: Robust ranking techniques approach

Jorge R. Vera: Robust approaches for intertemporal consistency in production planning

Mustafa C. Pinar: Mean semi-deviation from a target and robust portfolio choice under distribution and mean return ambiguity

Cluster: Convex and nonsmooth optimization

First-order methods, boosting and related issues *organized by Robert M. Freund.* Wed.C.21

Paul Grigas: New results and analysis for the Frank-Wolfe method	**Oren Anava**: Online learning for loss functions with memory and applications to statistical arbitrage	**Robert M. Freund**: The first-order view of boosting methods: Computational complexity and connections to regularization

Cluster: Convex and nonsmooth optimization

Sparse optimization and its applications *organized by Necdet Serhat Aybat.* Wed.C.22

Michael P. Friedlander: A dual approach to sparse optimization	**Ewout van den Berg**: A hybrid quasi-Newton projected-gradient method with application to Lasso and basis-pursuit denoise	**Ronny Luss**: Sparse rank-one matrix approximations: Convex relaxations, direct approaches, and applications to text data

Cluster: Optimization software: Modeling tools and engines

Continuous optimization solvers within mixed-integer frameworks *organized by Hande Y. Benson.* Wed.C.23

Mehdi Towhidi: Customizing COIN-OR's LP and MIP solvers with Python	**Pablo González-Brevis**: Recent developments in column generation and interior point methods	**Hande Y. Benson**: MILANO: Mixed-integer linear and nonlinear optimizer

Cluster: PDE-constrained optimization

Optimization of free boundary problems I *organized by Juan Carlos de los Reyes, Christian Meyer.* Wed.C.24

Benjamin Tews: Optimal control of incompressible two-phase flows	**Thomas Betz**: Second-order sufficient conditions for optimal control of elastoplasticity	**M. Hassan Farshbaf-Shaker**: Relating phase field and sharp interface approaches to structural topology optimization

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis in nonlinear optimization *organized by Héctor Ramirez.* Wed.C.25

Julio López: Proximal decomposition method for convex symmetric cone programming	**Miguel Carrasco**: Design of robust truss structures for minimum weight using the sequential convex approximation method	**Héctor Ramirez**: Second-order analysis in conic programming with applications

Cluster: Nonlinear optimization

Nonlinear optimization and applications I *organized by Ya-xiang Yuan.* Wed.C.AB

Spartak Zikrin: Limited-memory methods with shape changing trust region	**Hongchao Zhang**: The limited memory conjugate gradient method	**Roummel F. Marcia**: On solving L-BFGS trust-region subproblems

Wednesday, 18:00-19:30

Cluster: Conic and polynomial optimization

Optimization of polynomials in commutative and non-commutative variables *organized by Janez Povh.* Wed.D.11

Igor Klep: Positive polynomials in matrix unknowns which are dimension-free and NCSOStools

Sabine Burgdorf: Polynomial optimization over the NC unit ball

Janez Povh: A new convex reformulation and approximation hierarchy for polynomial optimization

Cluster: Sparse optimization and information processing

Semi-continuous sparse reconstruction *organized by Dirk Lorenz.* Wed.D.12

Yohan de Castro: A result on the spike localization from inaccurate samplings

Carlos Fernandez-Granda: Robust super-resolution via convex programming

Konstantin Pieper: Finite element error analysis for an optimal control problem with sparse solutions

Cluster: Nonlinear optimization

Algorithm advances for convex quadratic programming *organized by Coralia Cartis.* Wed.D.13

Anders Forsgren: A primal-dual active-set method for convex quadratic programming

Stefan Solntsev: An algorithmic framework for convex ℓ_1-regularized optimization

Yiming Yan: Optimal active-set prediction for interior point methods

Cluster: Convex and nonsmooth optimization

Decomposition and cone geometry *organized by François Glineur, Peter Richtarik .* Wed.D.14

Rachael Tappenden: Separable approximations to the augmented Lagrangian

Dennis Amelunxen: Intrinsic volumes of convex cones and applications in convex programming

Takashi Tsuchiya: Information geometry of symmetric cone programs

Cluster: Derivative-free and simulation-based optimization

Constrained derivative free optimization *organized by Warren Hare.* Wed.D.15

Sébastien Le Digabel: Some applications solved with the MADS algorithm

Warren Hare: Derivative free methods for approximating normal cones

Anke Tröltzsch: A new algorithm for solving equality- and bound-constrained optimization problems without derivatives

Cluster: Global optimization and mixed-integer programming

Global optimization with applications to machine learning *organized by Panos Parpas.* Wed.D.16

Dietmar Maringer: Estimating time series models with heuristic methods: The case of economic parity conditions

Vanesa Guerrero: Sparse principal component analysis: A mixed integer nonlinear approach

Panos Parpas: Global optimisation using gentlest ascent dynamics

Cluster: Applications of continuous optimization in science and engineering

Optimization in practice I Wed.D.17

Carmen-Ana Domínguez-Bravo: Optimal location and size of heliostats in solar power tower systems

Anne Philipp: Mixed integer nonlinear models in wireless networks

Anna von Heusinger: Linear matrix inequality formulation of stabilizability of networks of identical linear systems

Cluster: Robust optimization and optimization in finance

Optimization in finance I *organized by Pedro Júdice.* Wed.D.18

Gautam Mitra: Enhanced indexation based on second-order stochastic dominance

John Birge: Extensions of abridged nested decomposition for serially dependent structures

Pedro Júdice: Long-term bank balance sheet management: Estimation and simulation of risk-factors

Cluster: Convex and nonsmooth optimization

Methods for tensor optimization *organized by Zhening Li, Yanqin Bai.* Wed.D.21

Bilian Chen: Applications of maximum block improvement method

Andre Uschmajew: Convergence of first-order techniques in tensor optimization

Zhening Li: Eigenvalues of complex tensors and their approximation methods

Cluster: Convex and nonsmooth optimization

Stochastic and randomized gradient methods for convex optimization *organized by Simon Lacoste-Julien.* Wed.D.22

Leon Bottou: Large-scale learning revisited

Mark Schmidt: Minimizing finite sums with the stochastic average gradient

Dan Garber: A linearly convergent conditional gradient algorithm with applications to online and stochastic optimization

Cluster: Optimization software: Modeling tools and engines

Interior point methods for conic optimization *organized by Joachim Dahl, Erling D. Andersen.* Wed.D.23

Joachim Dahl: Modeling and solving conic optimization problems using MOSEK

Lieven Vandenberghe: Decomposition and partial separability in conic optimization

Martin S. Andersen: A custom interior-point method for matrix-fractional minimization

Cluster: PDE-constrained optimization

Optimization of free boundary problems II *organized by Juan Carlos de los Reyes, Christian Meyer.* Wed.D.24

Christoph Rupprecht: Multi-material structured topology optimization based on a phase field ansatz: H^1-gradient projection and SQP method

Claudia Hecht: A phase-field approach for shape optimization in fluid mechanics

Irwin Yousept: Optimal control of quasilinear H(curl)-elliptic PDEs

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis in differential and mean field games *organized by Francisco J. Silva.* Wed.D.25

Alpár Richárd Mészáros: First order mean field games with density constraints

Elisabetta Carlini: Semi-Lagrangian schemes for mean field game models

Dante Kalise: Accelerated schemes for optimal control and pursuit-evasion games

Cluster: Nonlinear optimization

Nonlinear optimization and applications II *organized by Ya-xiang Yuan.* Wed.D.AB

Yanfei Wang: Gridded tomographic velocity analysis using nonsmooth regularization

Zhenli Sheng: A buildup-based error minimization method with application to protein structure determination

Ya-Feng Liu: An efficient truncated Newton-CG algorithm for the smallest enclosing ball problem of huge dimensions

Thursday, 09:00-10:30

Cluster: Conic and polynomial optimization

New bounds for combinatorial problems using copositive and semidefinite optimization *organized by Juan C. Vera.* Thu.A.11

- **Uwe Truetsch**: Old vs new SDP bounds for the quadratic assignment problem
- **Cristian Dobre**: Copositive formulation for the stability number of infinite graph
- **Juan C. Vera**: Exploiting symmetry in copositive programs

Cluster: Sparse optimization and information processing

Robust formulations and algorithms for large scale sparse programs *organized by Aleksandr Y. Aravkin.* Thu.A.12

- **Hao Wang**: Matrix-free solvers for systems of inclusions
- **Hassan Mansour**: A fast randomized Kaczmarz algorithm for sparse solutions of consistent linear systems
- **Aleksandr Y. Aravkin**: Sparse/robust estimation with nonsmooth log-concave densities

Cluster: Nonlinear optimization

Algorithms II *organized by Ernesto G. Birgin.* Thu.A.13

- **Natasa Krejic**: Inexact restoration for unconstrained optimization
- **Ernesto G. Birgin**: Recent developments in Algencan
- **José Mario Martínez**: Some optimization in electronic structure calculations

Cluster: Complementarity and variational inequalities

Complementarity problems: Algorithms and applications *organized by Francisco Facchinei.* Thu.A.14

- **Andreas Fischer**: Solving nonsmooth equations with nonisolated solutions
- **Rafał Zalas**: Approximately shrinking operators and their applications to variational inequalities
- **Veronica Piccialli**: Non-cooperative computation offloading in mobile cloud computing

Cluster: Derivative-free and simulation-based optimization

Derivative-free optimization: Algorithms and applications I Thu.A.15

- **Per-Magnus Olsson**: Parallel extensions of algorithms for derivate-free optimization
- **Clément W. Royer**: Direct search based on probabilistic descent
- **Delphine Sinoquet**: SQA: A generic trust region derivative free optimization method for black box industrial applications

Cluster: Global optimization and mixed-integer programming

Recent advances in global optimization *organized by Evrim Dalkiran.* Thu.A.16

- **Luís Merca Fernandes**: Eigenvalue complementarity problem: Applications and algorithms
- **Amir Ali Ahmadi**: Continuous dynamical systems for global optimization
- **Evrim Dalkiran**: RLT-POS: Reformulation-linearization technique-based optimization software for solving polynomial programming problems

Cluster: Applications of continuous optimization in science and engineering

Optimization in practice II Thu.A.17

- **Satafa Sanogo**: Topology optimization for the design of electromagnetic devices
- **Thea Göllner**: Optimizing the geometry of branched sheet metal structures using cubic regularization
- **Jan Kleinert**: On using a conical interior point method in large scale soil simulations including friction

Cluster: Robust optimization and optimization in finance

Optimization in finance II *organized by Javier Nogales.* Thu.A.18

Xiaoling Mei: Multiperiod portfolio selection with transaction and market impact costs

Gah-Yi Vahn: Performance-based regularization in mean-CVaR portfolio optimization

Alberto Martin-Utrera: Optimal multiperiod portfolio selection with trading costs and parameter uncertainty

Cluster: Convex and nonsmooth optimization

Semidefinite and conic optimization: Models and methods *organized by Yu Xia.* Thu.A.21

Farid Alizadeh: Applications of algebraic sum-of-squares cones in optimal geometric design

CANCELLED

François Glineur: Second-order cone representations of positive semidefinite cones

Cluster: Convex and nonsmooth optimization

Efficient first-order methods for convex optimization *organized by Shiqian Ma.* Thu.A.22

Wotao Yin: Very large-scale parallel sparse optimization

Necdet Serhat Aybat: An augmented Lagrangian method for conic convex programming

QingNa Li: Matrix recovery with special structures

Cluster: Optimization software: Modeling tools and engines

Extending the power and expressiveness of optimization modeling languages *organized by Robert Fourer.* Thu.A.23

Robert Fourer: Convex quadratic programming in AMPL

Michael C. Ferris: Stochastic programming in GAMS

Feng Qiang: PSMG: A parallel problem generator for a structure conveying modelling language for mathematical programming

Cluster: PDE-constrained optimization

Optimization with partial differential equations *organized by Ronald Hoppe.* Thu.A.24

Harbir Antil: A Stokes free boundary problem with surface tension effects

Michael Hintermüller: Multilevel methods based on adaptive finite elements for elliptic mathematical programs with complementarity constraints

Martin Stoll: Fast solution of Cahn-Hilliard variational inequalities

Cluster: Variational analysis, set-valued and vector optimization

Variational analysis techniques *organized by Dariusz Zagrodny.* Thu.A.25

Dariusz Zagrodny: Regularity and Lipschitz-like properties of subdifferential : Part I (of parts I and II)

Pedro Gajardo: Existence of minimizers on drops

Abderrahim Jourani: Regularity and Lipschitz-like properties of subdifferential : Part II (of parts I and II)

Cluster: Nonlinear optimization

Nonlinear optimization and applications III *organized by Ya-xiang Yuan.* Thu.A.AB

Yu-Hong Dai: A sequential subspace projection method for extreme Z-eigenvalues of supersymmetric tensors

Jinyan Fan: Improvement on the Shamanskii-like Levenberg-Marquardt method

Xiao Wang: An augmented Lagrangian affine scaling method for general nonlinear programming

Thursday, 11:00-12:30

Cluster: Conic and polynomial optimization

Modeling and computation in copositive programming *organized by Sam Burer.* Thu.B.11

Naohiko Arima: A quadratic optimization model for completely positive programming and its application to 0-1 mixed integer linearly constrained quadratic optimization problems

Sunyoung Kim: Extension of completely positive cone relaxation to polynomial optimization

Felix Lieder: Computing a nonnegative decomposition of a matrix

Cluster: Optimization software: Modeling tools and engines

High performance linear optimization *organized by Julian Hall.* Thu.B.12

Julian Hall: Parallelizing the revised simplex method: Is it time to give up?

Matthias Miltenberger: Challenges in linear programming and how SoPlex deals with them

Cluster: Nonlinear optimization

Analysis of local convergence Thu.B.13

Alexey S. Kurennoy: Local convergence of augmented Lagrangian methods under the sole noncriticality assumption

Evgeny I. Uskov: Attraction of Newton method to critical Lagrange multipliers

CANCELLED

Cluster: Complementarity and variational inequalities

Advances in algorithms *organized by Andreas Fischer.* Thu.B.14

Ana Friedlander: Inexact restoration method for derivative-free optimization with smooth constraints

Axel Dreves: A new error bound result for generalized Nash equilibrium problems and its algorithmic application

Roger Behling: A Levenberg-Marquardt method with approximate projections

Cluster: Derivative-free and simulation-based optimization

Derivative-free optimization: Algorithms and applications II Thu.B.15

Frédéric Delbos: Global optimization based on sparse grid surrogate models for black-box expensive functions

MOVED TO Mon.B.15

Emanuele Frandi: Optimization by derivative-free multilevel methods

Cluster: Global optimization and mixed-integer programming

Distance geometry and applications *organized by Carlile Lavor, Antonio Mucherino.* Thu.B.16

Agostinho Agra: Discrete approaches to the molecular distance geometry problem

Antonio Mucherino: Discretizing vertex orders for distance geometry

Cluster: Robust optimization and optimization in finance

Optimization in finance III *organized by Gah-Yi Vahn.* Thu.B.18

Rui Pedro Brito: Efficient cardinality/mean-variance portfolios

Jun-Ya Gotoh: Financial risk minimization-based SVMs and its application to credit rating

Luis F. Zuluaga: Mean-semivariance model for large-scale project selection

Cluster: Convex and nonsmooth optimization

Extending the scope of convexity: From finite to infinite dimensional, ordinary to extraordinary, and from convex to nonconvex *organized by Tim Hoheisel.* Thu.B.21

James V. Burke: Making flippy floppy

Christopher Jordan-Squire: Convex optimization on probability measures

Tim Hoheisel: Epi-convergent smoothing with applications to convex composite functions

Cluster: Convex and nonsmooth optimization

Convex optimization in machine learning *organized by Quoc Tran Dinh.* Thu.B.22

Stephen Becker: Randomized singular value projection

Marco Signoretto: Proximal problems and splitting techniques for learning with composite penalties

Andrei Patrascu: A random coordinate descent algorithm for optimization problems with composite objective function: Application to SVM problems

Cluster: Convex and nonsmooth optimization

Convex optimization and related problems Thu.B.23

Zizhuo Wang: On solving convex optimization problems with linear ascending constraints

Salvador Flores: A new error correction technique with strong theoretical properties

Cluster: PDE-constrained optimization

Bang-bang-type control of PDEs *organized by Christian Clason, Eduardo Casas .* Thu.B.24

Christian Clason: Multi-bang control of elliptic systems

Axel Kroener: A minimum effort optimal control problem for the wave equation

Daniel Wachsmuth: Regularization and discretization error estimates for control problems with bang-bang solutions

Cluster: Variational analysis, set-valued and vector optimization

Advances in multiobjective optimization *organized by Henri Bonnel.* Thu.B.25

Henri Bonnel: Optimization over the Pareto set of a multiobjective parabolic control system

C. Yalcin Kaya: Numerical methods for multi-objective optimal control

Joerg Fliege: Robust multiobjective portfolio optimization

Cluster: Nonlinear optimization

Advances in nonlinear optimization *organized by Francesco Rinaldi.* Thu.B.AB

Silvia Villa: Convergence rates for inexact and accelerated proximal methods

Martin Jaggi: A fresh look at the Frank-Wolfe algorithm, with applications to sparse convex optimization

James Hungerford: Edge concave quadratic programs

How to find your session?

The session code includes all the information you need to identify your parallel session, either organized or of contributed talks (take Mon.C.15 as an example):

Mon **The day of the week:**

Mon	Monday
Tue	Tuesday
Wed	Wednesday
Thu	Thursday

C **The time of the day:**

A	1st slot:	11:30-13:00 (Mon-Wed)
		09:00-10:30 (Thu)
B	2nd slot:	14:30-16:00 (Mon-Wed)
		11:00-12:30 (Thu)
C	3rd slot:	16:30-18:00 (Mon-Wed)
D	4th slot:	18:00-19:30 (Wed)

15 **The room code:**

AB	Auditorium B
1x	Room 1.x
2x	Room 2.x

All the rooms for the Parallel Sessions (either organized or of contributed talks) will be in the Department of Mathematics (see the maps of the two floors of the Math. Department on page 112).

■ Mon.A.11

Monday, 11:30-13:00, Room 1.1, Organized Session

Semidefinite optimization: Geometry and applications I

Cluster: Conic and polynomial optimization
Session organized by: *João Gouveia, Rekha Thomas*

1. **Spectral bounds for the independence ratio and the chromatic number of an operator**

Frank Vallentin (frank.vallentin@gmail.com) University of Cologne, Germany, *Christine Bachoc*, *Evan DeCorte*, *Fernando Mario de Oliveira Filho*

We define the independence ratio and the chromatic number for bounded, self-adjoint operators on an L^2-space by extending the definitions for the adjacency matrix of finite graphs. In analogy to the Hoffman bounds for finite graphs, we give bounds for these parameters in terms of the numerical range of the operator. This provides a theoretical framework in which many packing and coloring problems for finite and infinite graphs can be conveniently studied with the help of harmonic analysis and convex optimization. The theory is applied to infinite geometric graphs on Euclidean space and on the unit sphere.

2. **Polynomial-sized semidefinite representations of derivative relaxations of spectrahedral cones**

James Saunderson (jamess@mit.edu) Massachusetts Institute of Technology, USA, *Pablo Parrilo*

The hyperbolicity cones associated with the elementary symmetric polynomials provide an intriguing family of non-polyhedral relaxations of the non-negative orthant which preserve its low-dimensional faces and successively discard higher dimensional facial structure. We show by an explicit construction that this family of convex cones (as well as their analogues for symmetric matrices) have polynomial-sized representations as projections of slices of the PSD cone. This, for example, allows us to solve the associated linear cone program using semidefinite programming.

3. **Hyperbolic cone programming: Structure and interior-point algorithms**

Tor Myklebust (tmyklebu@csclub.uwaterloo.ca) University of Waterloo, Canada, *Levent Tuncel*

I will first discuss some structural and geometric properties of convex cones which are hyperbolicity cones of some hyperbolic polynomial. Then, I will present some interior-point algorithms and their theoretical features on the hyperbolic cone programming problems.

■ Mon.A.12

Monday, 11:30-13:00, Room 1.2, Organized Session

Recent advances in first and second order methods for some structured sparse optimization problems

Cluster: Sparse optimization and information processing
Session organized by: *Kim-Chuan Toh*

1. **An adaptive semi-nuclear norm approach for rank optimization problems with hard constraints**

Defeng Sun (matsundf@nus.edu.sg) National University of Singapore, Singapore, *Weimin Miao*, *Shaohua Pan*

Rank optimization problems with hard constraints arise in a variety of fields such as engineering, statistics, finance and quantum information. The nuclear norm technique has been widely-used to encourage a low-rank solution in the literature but its efficiency is limited. In this talk, we propose an adaptive semi-nuclear norm approach for rank optimization problems beyond the nuclear norm technique. This approach iteratively solves a sequence of convex optimization problems penalized by a semi-nuclear norm. For an instance of high-dimensional inference in which the goal is to estimate a matrix on the basis of some noisy observations, we show under mild conditions that a two-step semi-nuclear norm penalized least squares estimator possesses a much reduced non-asymptotic recovery error bound, compared with the nuclear norm penalized least squares estimator, and then characterize the corresponding sample size for several specific observation models, including the matrix completion and the low-rank multivariate regression. Numerical results are also reported to show that the proposed approach has advantages in both achieving a low-rank solution and reducing the relative error.

2. **A strictly contractive Peaceman-Rachford splitting method for convex programming**

Xiaoming Yuan (xmyuan@hkbu.edu.hk) Hong Kong Baptist University, Hong Kong, *Bingsheng He*, *Han Liu*, *Zhaoran Wang*

In this paper, we focus on the application of the Peaceman-Rachford splitting method (PRSM) to a convex minimization model with linear constraints and a separable objective function. Compared to the Douglas-Rachford splitting method (DRSM), another splitting method from which the alternating direction method of multipliers originates, PRSM requires more restrictive assumptions to ensure its convergence while it is always faster whenever it is convergent. We first illustrate that the reason of this difference can be explained as the iterative sequence generated by DRSM is strictly contractive, while that by PRSM is only contractive with respect to the solution set of the model. With only the convexity assumption on the objective function of the model under consideration, the convergence of PRSM is not guaranteed. But for this case, we show that the first t iterations of PRSM still enable us to find an approximate solution with an accuracy of $O(1/t)$. A worst-case $O(1/t)$ convergence rate of PRSM in ergodic sense is thus established under mild assumptions. After that, we suggest to attach a underdetermined relaxation factor with PRSM to guarantee the strict contraction of its iterative sequence and thus propose a strictly contractive PRSM. A worst-case $O(1/t)$ convergence rate of this strictly contractive PRSM in nonergodic sense is established. We show the numerical efficiency of the strictly contractive PRSM by some applications in statistical learning and image processing.

3. **A proximal point algorithm for log-determinant optimization with group lasso regularization**

Kim-Chuan Toh (mattohkc@nus.edu.sg) National University of Singapore, Singapore, *Junfeng Yang*, *Defeng Sun*

We consider the covariance selection problem where variables are clustered into groups and the inverse covariance matrix is expected to have a blockwise sparse structure. This problem is realized via penalizing the maximum likelihood estimation of the inverse covariance matrix by group Lasso regularization. We solve the resulting log-determinant optimization problem by the classical proximal point algorithm (PPA). At each iteration, as it is difficult to update the primal variables directly, we first solve the dual subproblem by an inexact semismooth Newton-CG method and then update the primal variables by explicit formulas based on the computed dual variables. We also accelerate the PPA by an inexact generalized Newton's method when the iterate is close to optimality. Theoretically we prove that the nonsingularity of the generalized Hessian matrices (at optimality) of the dual subproblem is equivalent to the constraint nondegeneracy condition for the primal problem. Global and local convergence results are also presented for our PPA. Moreover, based on the augmented Lagrangian function of the dual problem, we derive an easily implementable alternating direction method (ADM) which is efficient for random problems. Numerical results, including comparisons with the ADM on both synthetic and real data, are presented to demonstrate that the proposed Newton-CG based PPA is stable, efficient and, in particular, outperforms the ADM when high accuracy is required.

■ Mon.A.13

Monday, 11:30-13:00, Room 1.3

Large scale nonlinear optimization

Cluster: Nonlinear optimization
Session chair: *A. Ismael F. Vaz*

1. **A novel limited memory method for bound-constrained optimization**

   Behzad Azmi (behzad.azmi@univie.ac.at) Faculty of Mathematics, University of Vienna, Austria, *Arnold Neumaier*

A novel limited memory method for solving large-scale bound constrained optimization problems is introduced. The new algorithm uses a combination of the steepest decent directions and quasi Newton directions in a new schema to identify the optimal active bound constraints. The quasi Newton directions are computed using limited memory SR1 matrices. As it is known, the SR1 matrices are not necessarily positive definite, consequently, the quasi-Newton direction need not be a descent direction. In such a case, we regularize this direction so that it will become a descent direction. After the set of optimal active variables are identified, the algorithm uses a combination of limited memory quasi Newton method and conjugate gradient method to explore the subspace of free variables. The convergence theory of the algorithm is also provided. At the end, numerical results of the algorithm applied to a list of bound constrained problems from the CUTEr library and comparisons with two state-of-the-art bound constrained solvers (L-BFGS-B, ASA-CG) are demonstrated.

2. **Globally convergent DC trust-region methods**

   A. Ismael F. Vaz (aivaz@dps.uminho.pt) University of Minho, Portugal, *Le Thi Hoai An*, *Huynh Van Ngai*, *Pham Dinh Tao*, *Luis Nunes Vicente*

In this talk, we investigate the use of DC (difference of convex) models and algorithms in the solution of Nonlinear optimization problems by trust-region methods. We consider DC local models for the quadratic model of the objective function used to compute the trust-region step, and apply a primal-dual subgradient method to the solution of the corresponding trust-region subproblems. One is able to prove that the resulting scheme is globally convergent for first-order stationary points. The theory requires the use of exact second-order derivatives but, in turn, requires a minimum from the solution of the trust-region subproblems for problems where projecting onto the feasible region is computationally affordable. The numerical efficiency and robustness of the proposed new scheme when applied to bound-constrained problems is measured by comparing its performance against some of the current state-of-the-art nonlinear programming solvers on a vast collection of test problems.

■ Mon.A.14

Monday, 11:30-13:00, Room 1.4, Organized Session

Equilibrium problems and variational inequalities: Computation and uncertainty

Cluster: Complementarity and variational inequalities
Session organized by: *Shu Lu*

1. **On the solution of affine generalized Nash equilibrium problems by Lemke's method**

   Jong-Shi Pang (jspang@illinois.edu) University of Illinois at Urbana-Champaign, USA, *Dane Schiro*, *Uday Shanbhag*

Affine generalized Nash equilibrium problems (AGNEPs) represent a class of non-cooperative games in which players solve convex quadratic programs with a set of (linear) constraints that couple the players' variables. The generalized Nash equilibria (GNE) associated with such games are given by solutions to a linear complementarity problem (LCP). This paper treats a large subclass of AGNEPs wherein the coupled constraints are shared by, i.e., common to, the players. It is first shown that the well-known Lemke method will compute, if successful, only one kind of equilibria characterized by a very special feature of the constraint multipliers. Based on a modification of this method, we present several avenues for computing structurally different GNE based on varying consistency requirements on the Lagrange multipliers associated with the shared constraints.

2. **Stochastic equilibrium in investment models: Capacity expansion in the power sector**

   Daniel Ralph (d.ralph@jbs.cam.ac.uk) University of Cambridge, Judge Business School, UK, *Andreas Ehrenmann*, *Gauthier de Maere d'Aertrycke*, *Yves Smeers*

An investor in power generation assets faces unprecedented uncertainty in the evolution of the sector. The market equilibrium is, hence, one under uncertainty. Agents can be risk neutral or risk averse. We therefore insert risk functions in order to account for idiosyncratic risk (risk that is not priced by the CAPM) in investments. Incorporating a risk function on the cost in a standard (stochastic) capacity expansion planning model can be done while retaining convexity, but this poses questions on the interpretation. We structure the discussion on the interpretation around market completeness: In a world of perfect risk trading we can derive a price vector for all instruments from a system risk function. The complete market can be represented in terms of stochastic programming. The assumption of perfect risk trading is however rather heroic for investments that last 20 to 30 years. We hence relax the assumption of perfect risk trading and allow for different stochastic discount factors. The interpretation becomes more difficult since the incomplete market is no longer amenable to a Stochastic optimization approach.

3. **Stochastic variational inequalities: Confidence regions and intervals**

   Shu Lu (shulu@email.unc.edu) University of North Carolina at Chapel Hill, USA

This talk discusses several methods to compute confidence regions and confidence intervals for the true solution of a stochastic variational inequality, given the solution to a sample average approximation (SAA) problem. We justify these methods by establishing precise limit theorems, and present numerical results in applications including a statistical learning problem called the Lasso.

■ Mon.A.15

Monday, 11:30-13:00, Room 1.5, Organized Session

Advances in derivative free optimization I

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Jeffrey Larson*

1. **Stochastic derivative-free optimization using a trust region framework**

   Jeffrey Larson (jeffreyl@kth.se) KTH - Royal Institute of Technology, Sweden, *Stephen Billups*, *Alexandre Proutiere*

When minimizing stochastic functions without reliable derivatives, many algorithms 1) repeatedly sample the function at a point of interest to more accurately determine the function value, 2) define a fixed pattern of points where the function will be evaluated within regions of interest or, 3) require the user to define a decaying sequence of step sizes to be used by the algorithm. In this talk, we will explain why we consider these three properties to be undesirable in a practical algorithm. We develop a trust region method which does not repeatedly sample points, does not require a predefined pattern of points, and adjusts the trust region radius as the algorithm progresses. After analyzing our method's stochastic convergence properties, we show it to be competitive with existing algorithms on a range of problems.

2. **A derivative-free optimization algorithm with low-dimensional subspace techniques for large-scale problems**

   Zaikun Zhang (zhang@mat.uc.pt) Department of Mathematics, University of Coimbra, Portugal

We will talk about optimization algorithms that do not use derivatives, and discuss how to incorporate subspace techniques into this type of algorithms. We present a new derivative-free algorithm with low-dimensional subspace techniques for large-scale problems. For the new algorithm, we establish global convergence and R-linear convergence rate; we propose a preconditioning technique, which improves the performance of the algorithm on ill-conditioned problems. Our algorithm worked evidently better than NEWUOA for the problems tested, regarding the number of function evaluations and CPU time. Moreover, the new algorithm is capable of solving many 2000-dimensional test problems to high precision within several minutes, using not more than 50000 function evaluations (equivalent to less than 25 simplex gradients). This work is based on Chapter 5 of the author's PhD thesis, which was supervised by Professor Ya-xiang Yuan (Chinese Academy of Sciences, China).

3. **Regularized regression models for derivative free methods under controllable noise setting**

Ruobing Chen (ruc310@lehigh.edu) Lehigh University, USA, *Katya Scheinberg*

Problems with numerical noise form the key domain of Derivative-Free Optimization (DFO) algorithms and response surface methodology. We propose a general DFO algorithm for noisy problems. This algorithm utilizes regularized regression models that leverage between the model complexity and the level of noise in a function. For problems with controllable noise, an accuracy adjustment procedure is employed to dynamically reduce the noise level. Numerical studies on a protein alignment problem and a series of test problems illustrate the effectiveness of the proposed techniques.

■ Mon.A.16

Monday, 11:30-13:00, Room 1.6, Organized Session

Global optimization of problems with special structure

Cluster: Global optimization and mixed-integer programming
Session organized by: *Alexander Mitsos*

1. **On the approximate solution of mp-MILP problems using piecewise affine relaxation of bilinear terms**

Martina Wittmann-Hohlbein (m.wittmann-hohlbein09@imperial.ac.uk) Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College, London, UK, *Efstratios N. Pistikopoulos*

Mixed-integer linear programming has widespread application in process engineering. When confronted with data that has not yet revealed their true value, the introduction of uncertainty into the mathematical model poses an additional challenge on its solution. A particular difficulty arises when uncertainty is simultaneously present in the coefficients of the objective function and the constraints, yielding a general multi-parametric (mp)-MILP problem. To overcome the computational burden to derive a globally optimal solution, we propose novel approximate solution strategies. We present a two-stage method and its extension towards a dynamic decomposition algorithm for mp-MILP problems. Both approaches employ surrogate mp-MILP models that are derived from overestimating bilinear terms in the constraints via McCormick relaxations over an ab initio partition of the feasible set. We incorporate piecewise affine relaxation based models using a linearly scaling scheme and a logarithmically scaling scheme, respectively. The models are tuned by the number of partitions chosen. Problem sizes and computational requirements for the different alternatives are compared. Furthermore, the conservatism of the suboptimal solution of the mp-MILP problem for the proposed approaches is discussed.

2. **ANTIGONE: A general mixed-integer nonlinear global optimisation framework**

Ruth Misener (r.misener@imperial.ac.uk) Imperial College, UK, *Christodoulos A. Floudas*

ANTIGONE (Algorithms for coNTinuous / Integer Global Optimisation of Nonlinear Equations), is a computational framework for the deterministic global optimisation of mixed-integer nonlinear programs (nonconvex MINLP). The approach: reformulates user input; detects special mathematical structure; globally optimises the transformed problem. ANTIGONE is an evolution of the Global Mixed-Integer Quadratic Optimizer (GloMIQO) from quadratic to general nonconvex terms. This presentation highlights the ANTIGONE cutting plane strategies, which expand the GloMIQO branch-and-cut framework from aggregated quadratic terms to aggregated general nonlinear terms. We discuss the hierarchy of cutting planes integrated into ANTIGONE including: convex/concave outer approximation; high-dimensional edge-concave/edge-convex cuts; alphaBB relaxations; the reformulation-linearization technique. Data is presented for globally optimising a range of MINLP test cases using ANTIGONE; these examples include problems from standard libraries and more recent examples from the open literature.

3. **On intrinsic complexity of bilevel optimization**

Vladimir Shikhman (vladimir.shikhman@uclouvain.be) Catholic University of Louvain, Belgium, *Hubertus Th. Jongen*, *Dominik Dorsch*

We examine bilevel optimization from the parametric perspective. Observing the intrinsic complexity of bilevel optimization, we emphasize that it originates from unavoidable degeneracies occurring in parametric optimization. Under intrinsic complexity we understand the involved geometrical complexity of bilevel feasible sets, such as the appearance of kinks and boundary points, non-closedness, discontinuity and bifurcation effects. By taking the study of singularities in parametric optimization into account, the structural analysis of bilevel feasible sets is performed. We describe the global structure of the bilevel feasible set in case of a one-dimensional leader's variable. We point out that the typical discontinuities of the leader's objective function will be caused by follower's singularities. The latter phenomenon occurs independently from the viewpoint of the optimistic or pessimistic approach. In case of higher dimensions, optimistic and pessimistic approaches are discussed with respect to possible bifurcation of the follower's solutions.

■ Mon.A.17

Monday, 11:30-13:00, Room 1.7, Organized Session

Optimization of dynamic systems I

Cluster: Applications of continuous optimization in science and engineering
Session organized by: *Victor M. Zavala*

1. **A structure exploiting parallel strategy for the efficient solution of sparse quadratic programs arising in SQP-based nonlinear optimal control**

Janick Frasch (janick.frasch@iwr.uni-heidelberg.de) Center for Scientific Computing, Heidelberg University, Germany, *Sebastian Sager*, *Moritz Diehl*

A large class of offline and online optimal control algorithms requires the solution of a sparse structured quadratic programming problems at each iteration. A variety of approaches has been proposed for this problem class, including first-order methods, interior-point algorithms, and condensing-based active-set algorithms. We propose a novel algorithm based on a hybrid active-set/Newton-type strategy that aims at combining sparsity exploitation features of an interior point method with warm-starting capabilities of an active-set method. Moreover, the proposed algorithm is parallelizable to a large extend. We address algorithmic details of this strategy and present the open-source implementation qpDUNES. The performance of the solver is evaluated on basis of several problems from the area of linear and nonlinear model-predictive control, showing significant performance improvements over existing software packages for this class of structured quadratic programming problems.

2. **Scalable dynamic optimization**

Mihai Anitescu (anitescu@mcs.anl.gov) Argonne National Laboratory, USA, *Victor M. Zavala*

Motivated by model predictive control of energy systems, we present a scalable nonlinear programming algorithm for dynamic optimization. The algorithm is based on a smooth exact penalty approach, coupled with a trust-region approach, and exhibits global convergence and local superlinear convergence while having excellent warm-starting properties so desirable in an online application. Moreover, the fact that it can achieve convergence entirely matrix-free recommends it for large scale approaches needing scalability. This builds on recent work of the authors where we proved using a generalized equations framework that such methods stabilize model predictive control formulation even when they have explicit inequality constraints. In particular, we present alternatives to enable fast active-set detection and matrix-free implementations.

3. **Multi-objective optimal control using fast gradient-based optimisation techniques**

Mattia Vallerio (Mattia.Vallerio@cit.kuleuven.be) KU Leuven - Chemical Engineering Dept - BioTeC & OPTEC Research Team, Belgium, *Filip Logist*, *Dries Telen*, *Dominique Vercammen*, *Ioanna Stamati*, *Jan Van Impe*

Many processes are described by differential equations and their optimisation involves the determination of optimal time-varying control policies. Moreover, in view of sustainable development multiple and often conflicting objectives arise. For instance, not only more profitable (economically sustainable) but also cleaner (environmentally sustainable) and safer (socially sustainable) processes are aimed at. To enhance decision making in practice (and even allow real-time decision making), it is important to enable (i) fast and accurate generation of optimal alternatives (Pareto optimal solutions) and (ii) evaluation of the trade-offs between them. To achieve this aim a tight integration is needed between efficient multi-objective scalarisation strategies (e.g., Normal Boundary Intersection and (Enhanced) Normalised Normal Constraint) and fast deterministic gradient-based dynamic optimisation approaches (e.g., Single/Multiple Shooting or Collocation). Some recent developments exploiting this integration include (i) robust multi-objective optimal control, (ii) multi-objective mixed-integer optimal control, (iii) multi-objective dynamic optimal experiment design, (iv) multi-objective optimisation of periodic distributed parameter systems and (v) multi-objective tuning of NMPC controllers. For each of the cases an illustration is available. Acknowledgements KUL: OT/10/035, PFV/10/002, KP/09/005; FWO: G.0930.13, 1.5.189.13N; BelSPO: IAP PVII/19, IWT-SB: 101048, 101643, 101080.

■ Mon.A.18

Monday, 11:30-13:00, Room 1.8, Organized Session

Stochastic optimization in sequential detection and optimal execution

Cluster: Stochastic optimization

Session organized by: *Olympia Hadjiliadis*

1. **Sequential decision rules and times for two-dimensional hypothesis testing**

Michael Carlisle (michael.carlisle@baruch.cuny.edu) Baruch College, City University of New York, USA, *Olympia Hadjiliadis*

We consider the problem of sequential decision making on the state of a two-sensor system with correlated noise. Each of the sensors is either receiving or not receiving a signal obstructed by noise, which gives rise to four possibilities: (noise, noise), (signal, noise), (noise, signal), (signal, signal). We set up the problem as a min-max optimization in which we devise a decision rule that minimizes the length of continuous observation time required to make a decision about the state of the system subject to error probabilities. We first assume that the noise in the two sources of observations is uncorrelated, and propose running in parallel two sequential probability ratio tests, each involving two thresholds. We compute these thresholds in terms of the error probabilities of the system. We demonstrate asymptotic optimality of the proposed rule as the error probabilities decrease without bound. We then analyze the performance of the proposed rule in the presence of correlation and discuss the degenerate cases of perfect positive or negative correlation. Finally, we purport the benefits of our proposed rule in a decentralized sensor system versus one in constant communication with a fusion center.

2. **Optimal execution with jumps (or known structural break points)**

Gerardo Hernandez-del-Valle (gerardo@math.cinvestav.mx) CINVESTAV Mathematics Department, Mexico

In this work we derive the Markowitz optimal trading schedule for a trader who wishes to execute, by time T, a large position X of asset S, given that he has prior knowledge of its future structural break points at deterministic times $0 \leq t_1 \leq \cdots \leq t_n \leq T$. A possible application of the result described in this work, and main motivation of this paper, is in the case in which the position X is scheduled to be traded during several days. In this scenario, empirical evidence suggests that between trading days there is a stochastic price jump.

3. **Quickest detection in a system with correlated noise**

Neofytos Rodosthenous (n.rodosthenous@lse.ac.uk) London School of Economics, UK, *Hongzhong Zhang*, *Olympia Hadjiliadis*

This work considers the problem of quickest detection of signals in a system of 2 sensors coupled by a negatively correlated noise, which receive continuous sequential observations from the environment. It is assumed that the signals are time invariant with different strength and their onset times may differ from sensor to sensor. The objective is the optimal detection of the first time at which any sensor in the system receives a signal. The problem is formulated as a Stochastic optimization problem in which an extended Lorden's criterion is used as a measure of detection delay, with a constraint on the mean time to the first false alarm. The case in which the sensors employ their own cumulative sum (CUSUM) strategies is considered, and it is proved that the minimum of 2 CUSUMs is asymptotically optimal as the mean time to the first false alarm increases without bound.

■ Mon.A.21

Monday, 11:30-13:00, Room 2.1, Organized Session

Algebraic algorithms and applications

Cluster: Convex and nonsmooth optimization

Session organized by: *Amir Ali Ahmadi*

1. **On the generation of positivstellensatz witnesses in degenerate cases**

David Monniaux (David.Monniaux@imag.fr) CNRS / VERIMAG, France, *Pierre Corbineau*

Many problems, including the correctness of software, or the truth of mathematical theorems (e.g. Kepler's conjecture) reduce to proving that a real function satisfies some bound on a domain. A numerical global optimization tool, however, might not provide the assurance needed: it may itself contain bugs, or suffer from floating-point round-off errors. We would like the tool to provide a proof witness, independently verifiable by a simple checker (such as the type checker at the core of the Coq proof assistant). We thus seek to obtain witnesses checkable by a Coq script for the following problem: assuming $P_1 \geq 0 \ldots P_n \geq 0$ prove $Q \geq 0$ (and variants with equalities and/or strict inequalities). This problem reduces to finding sums of squares (SOS) of polynomials that satisfy some linear equality (Positivstellensatz). Finding SOS reduces to feasibility in semidefinite programming, for which there exist numerical solvers. Unfortunately, the solution set can have empty interior, in which case numerical solvers (based on interior points) fail. Previously published methods thus assumed strict feasibility; we propose a workaround for this difficulty. The trick is to use approximate numerical solutions to find a parametrization of the linear affine variety generated by the solution set: we obtain one (assuming one exists with small integer coefficients) by repeat search of short vectors in lattices, using the algorithm of Lenstra, Lenstra & Lovasz (LLL).

2. **Ellipsoid packing with applications to chromosome organization**

Caroline Uhler (caroline.uhler@ist.ac.at) IST, Austria, *Stephen J. Wright*

We consider the problem of packing ellipsoids of different size and shape into an ellipsoidal container so as to minimize a measure of total overlap. The motivating application is chromosome organization in the human cell nucleus. We describe a bilevel optimization formulation, together with an algorithm for the general case and a simpler algorithm for the special case in which all ellipsoids are in fact spheres. We prove convergence to stationary points of this non-convex problem, and describe computational experience, including applications to sphere packing and results from the chromosome packing application.

3. **Positive semidefinite matrix completion, universal rigidity and the strong Arnold property**

Antonios Varvitsiotis (antonios@cwi.nl) Centrum Wiskunde & Informatica, Amsterdam, The Netherlands, *Monique Laurent*

This talk addresses the following three topics: positive semidefinite (psd) matrix completions, universal rigidity of frameworks, and the Strong Arnold Property (SAP). We show some strong connections among these topics, using semidefinite programming as unifying theme. Our main contribution is a sufficient condition for constructing partial psd matrices which admit a unique completion to a full psd matrix. Such partial matrices are an essential tool in the study of the Gram dimension $gd(G)$ of a graph G, a recently studied graph parameter related to the low rank psd matrix completion problem. We show some connections with Connelly's sufficient condition for the universal rigidity of Euclidean frameworks. We also give a geometric characterization of psd matrices satisfying the Strong Arnold Property in terms of nondegeneracy of an associated semidefinite program and as the extreme points of a certain spectrahedron. These characterizations are used to establish links between the Gram dimension $gd(G)$ and the Colin de Verdiere type graph parameter $\nu^{=}(G)$.

■ Mon.A.22

Monday, 11:30-13:00, Room 2.2, Organized Session

Stochastic methods and applications

Cluster: Convex and nonsmooth optimization
Session organized by: *Stephen J. Wright*

1. **Convergence of a stochastic algorithm for subspace identification**

   Stephen J. Wright (swright@cs.wisc.edu) University of Wisconsin, Madison, USA, *Laura Balzano*

GROUSE is an incremental stochastic algorithm for subspace identification based on incomplete information. This talk discusses recent results on the local convergence behavior of GROUSE, showing an expected linear convergence rate. Stronger results are possible when the full data vector is available. We describe too an equivalence between GROUSE and an incremental method based on the singular value decomposition.

2. **Mini-batch primal and dual methods for support vector machines**

   Peter Richtarik (peter.richtarik@ed.ac.uk) University of Edinburgh, UK, *Martin Takac*, *Avleen Bijral*, *Nathan Srebro*

We address the issue of using mini-batches in Stochastic optimization of support vector machines. We show that the same quantity, the spectral norm of the data, controls the parallelization speedup obtained for both primal stochastic subgradient descent (SGD) and stochastic dual coordinate ascent (SCDA) methods and use it to derive novel variants of mini-batched SDCA. Our guarantees for both methods are expressed in terms of the original nonsmooth primal problem based on the hinge-loss.

■ Mon.A.24

Monday, 11:30-13:00, Room 2.4, Organized Session

Multilevel and adaptive methods for PDE-constrained optimization

Cluster: PDE-constrained optimization
Session organized by: *Drew Kouri, Sven Leyffer*

1. **An approach for the adaptive solution of optimization problems governed by PDEs with uncertain coefficients**

   Drew Kouri (dpkouri@mcs.anl.gov) Argonne National Laboratory, USA

The numerical solution of optimization problems governed by partial differential equations (PDEs) with random coefficients is computationally challenging because of the large number of deterministic PDE solves required at each optimization iteration. In this talk, we introduce an efficient algorithm for solving such problems based on a combination of adaptive and hierarchical sparse-grid collocation for the discretization of the PDE in the stochastic space and a trust-region framework for optimization and fidelity management of the stochastic discretization. The overall algorithm adapts the collocation points based on the progress of the optimization algorithm and the impact of the random variables on the solution of the optimization problem. It frequently uses few collocation points initially and increases the number of collocation points only as necessary, thereby keeping the number of deterministic PDE solves low while guaranteeing convergence. Currently an error indicator is used to estimate gradient errors due to adaptive stochastic collocation. The algorithm is applied to three examples, and the numerical results demonstrate a significant reduction in the total number of PDE solves required to obtain an optimal solution when compared with a Newton conjugate gradient algorithm applied to a fixed high-fidelity discretization of the optimization problem.

2. **An affine covariant composite step method for nonlinear optimization in function space**

   Anton Schiela (schiela@math.tu-berlin.de) TU Berlin, Germany, *Martin Weiser*, *Lars Lubkoll*

We consider an algorithm for non-linear equality constrained optimization in function space, which is taylored for optimization problems with nonlinear PDEs. As a distinguishing feature, our algorithm uses quantities, defined on the domain space only, and is thus affine covariant. The algorithm computes inexact steps in function space, where inexactness arises from the discretization of a PDE. Discretization errors are controlled by an a-posteriori error estimation and adaptive grid refinement.

3. **Adaptive multilevel SQP method for state constrained optimization with Navier-Stokes equations**

   Stefanie Bott (bott@gsc.tu-darmstadt.de) TU Darmstadt, Graduate School CE, Germany, *Stefan Ulbrich*, *Jan Carsten Ziems*

We consider adaptive multilevel methods for optimal control problems with state constraints. In order to overcome the low regularity of the Lagrange multiplier associated with the state we combine the Moreau Yosida regularization technique with the adaptive multilevel trust-region SQP method of [1],[2]. More precisely, we introduce a multilevel SQP algorithm for state constraints where adaptive mesh refinement conditions and the penalty parameter update of the Moreau Yosida regularization are combined in an appropriate way. Based on the convergence theory of the Moreau Yosida regularization of Meyer and Yousept and the adaptive multilevel SQP method of Ziems and Ulbrich, we present a new first-order convergence result for the multilevel SQP method for state constraints. Moreover, we apply our results to flow control problems. To this end, we present a first-order necessary and a second-order sufficient optimality condition for optimal control problems with the Navier-Stokes equations. We conclude with numerical results for a parabolic optimal control problem. [1] J.C. Ziems, S. Ulbrich: Adaptive multilevel inexact SQP methods for PDE-constrained optimization. SIAM J. Optim. 21 no. 1, 1-40, 2011 [2] J. C. Ziems, S. Ulbrich, Adaptive Multilevel Generalized SQP-Methods for PDE-constrained optimization, submitted, 2011 The work of Stefanie Bott is supported by the 'Excellence Initiative' of the German Federal and State Governments and the Graduate School of CE at TU Darmstadt.

■ Mon.A.25

Monday, 11:30-13:00, Room 2.5, Organized Session

Variational analysis and its applications to finance and engineering

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Samir Adly*

1. **Newton's method for solving generalized equations using set-valued approximations**

   Radek Cibulka (cibi@kma.zcu.cz) XLIM University of Limoges, France, *Samir Adly*, *Huynh Van Ngai*

Given Banach spaces X and Y, a single-valued mapping $f : X \to Y$ and a multivalued mapping $F : X \rightrightarrows Y$, we investigate the convergence properties of Newton-type iterative process for solving the generalized equation. The problem is to

$$\text{find} \quad x \in X \quad \text{such that} \quad 0 \in f(x) + F(x).$$

This model has been used to describe in a unified way various problems such as equations, inequalities, variational inequalities, and in particular, optimality conditions. We study the following iterative process: *Choose a sequence of set-valued mappings $A_k : X \times X \rightrightarrows Y$ approximating the function f and a starting point $x_0 \in X$, and generate a sequence (x_k) in X iteratively by taking x_{k+1} to be a solution of the auxiliary generalized equation*

$$0 \in A_k(x_{k+1}, x_k) + F(x_{k+1}) \quad \textit{for each} \qquad k \in \{0, 1, 2, \dots\}. \tag{1}$$

In the first part, we present a result concerning the stability of metric regularity under set-valued perturbations. In the latter, this statement is applied in the study of (super-)linear convergence of the iterative process (1). Also some particular cases are discussed in detail.

2. **Some sensitivity results for optimal control problems**

   Francisco J. Silva (francisco.silva@unilim.fr) Université de Limoges, France

In this talk I will review some classical aspects in sensitivity analysis for optimization problems with an special emphasis on optimal control problems. Next, I will present some precise results for the particular convex linear-quadratic case with constraints perturbed with a small noise. Relations with numerical approximations will be discussed.

3. **CANCELLED**

■ Mon.A.AB

Monday, 11:30-13:00, Amphitheater B, Organized Session

Nonlinear optimization I

Cluster: Nonlinear optimization

Session organized by: *Daniel P. Robinson, Philip E. Gill, Nick Gould*

1. **A practical dual gradient-projection method for large-scale, strictly-convex quadratic programming**

   Nick Gould (nick.gould@stfc.ac.uk) STFC-Rutherford Appleton Laboratory, UK

We consider solving a given large-scale strictly convex quadratic program by applying the well-known accelerated gradient-projection method to its dual. While this might seem at first sight to be inadvisable since the dual Hessian is defined in terms of the inverse of the primal one, it turns out that all operations may be performed very efficiently so long as a sparse Cholesky factorization of the primal Hessian may be found. In particular, the gradient-projection part of each iteration requires a sequence of "Cholesky forward solves"with sparse right-hand sides, while the acceleration part may be achieved using, for example, a suitably preconditioned conjugate gradient method. Much use is made of the Fredholm alternative. We illustrate performance of this approach on standard large-scale QP examples, and highlight the methods' use for warm-starting. A new package DQP will shortly be available as part of GALAHAD.

2. **Stochastic quasi-Newton methods**

   Jorge Nocedal (nocedal@eecs.northwestern.edu) Northwestern University, USA, *Samantha Hansen*, *Richard Byrd*

The question of how to incorporate curvature information in the stochastic gradient method of Robbins-Monro is challenging. Some attempts made in the literature involve a direct extension of quasi-Newton updating techniques for deterministic optimization. We argue that such an approach is not sound, and present a new formulation based on the minimization of gradient variances. In the second part of the talk we discuss how to make a quasi-Newton method robust in an asynchronous distributed computing environment.

3. **A restoration free filter method with unified step computation for nonlinear programming**

   Daniel P. Robinson (daniel.p.robinson@gmail.com) Johns Hopkins University, USA, *Nick Gould*, *Yueling Loh*

I present a filter method for solving general nonlinear and nonconvex constrained optimization problems. The method is of the filter variety, but utilizes an exact penalty function for computing a trial step. Particular advantages of our approach include that (i) all subproblems are feasible and regularized; (ii) a typical restoration phase that focuses exclusively on improving feasibility is replaced by a penalty mode that accounts for the objective function and feasibility; and (iii) a single uniform step computation is used during every iteration of the algorithm. An additional contribution is a strategy for defining the so-called filter margin based on local feasibility estimates available as a byproduct of our step computation procedure.

■ Mon.B.11

Monday, 14:30-16:00, Room 1.1, Organized Session

Semidefinite optimization: Geometry and applications II

Cluster: Conic and polynomial optimization

Session organized by: *João Gouveia, Rekha Thomas*

1. **Handelman's hierarchy for the maximum stable set problem**

   Zhao Sun (z.sun@uvt.nl) Tilburg University, The Netherlands, *Monique Laurent*

The maximum stable set problem is a well-known NP-hard problem in combinatorial optimization, which can be reformulated as the maximization of a quadratic square-free polynomial over the (Boolean) hypercube. A popular approach to polynomial optimization problems is to build a hierarchy of convex tractable relaxations, based on replacing the (hard to test) positivity condition for a polynomial by a tractable, sufficient condition for positivity. One may for instance search for positivity certificates in the form of a combination of products of constraints where the multipliers could be sums of squares of polynomials or simply nonnegative numbers. This leads respectively to SDP and LP relaxations. Although SDP hierarchies are stronger, they are more difficult to analyze and computationally more expensive. This motivates our study of the linear programming hierarchy for the maximum stable set problem, based on Handelman's representation result for positive polynomials on a polytope. Using Bernstein polynomials Park and Hong (2012) could show some error bounds for the approximate solutions obtained at any order in the hierarchy. We further investigate this hierarchy. In particular, we show a relation to fractional clique covers of graphs, we give bounds for the rank of the Handelman hierarchy (i.e., the smallest order needed to obtain the true optimum), and we point out links to some other LP and SDP hierarchies (of Sherali-Adams, Lasserre, and Lovasz-Schrijver).

2. **Hyperbolic polynomials and sums of squares**

   Daniel Plaumann (Daniel.Plaumann@uni-konstanz.de) University of Konstanz, Germany, *Mario Kummer*, *Cynthia Vinzant*

Hyperbolic polynomials are real polynomials with a simple reality condition on the zeros, reminiscent of characteristic polynomials of symmetric matrices. These polynomials appear in different areas of mathematics, including optimization, combinatorics and differential equations. We investigate the relation between a hyperbolic polynomial and the set of polynomials that interlace it. This set of interlacers is a convex cone, which we realize as a linear slice of the cone of nonnegative polynomials. In this way we obtain information about determinantal representations and explicit sums-of-squares relaxations of hyperbolicity cones.

3. **Bad semidefinite programs: they all look the same**

   Gabor Pataki (gabor@unc.edu) UNC Chapel Hill, USA

Duality theory is a central concept in semidefinite programming (SDP), just like it is in linear programming, since in optimization algorithms a dual solution serves as a certificate of optimality. However, in SDP, unlike in LP, "pathological" phenomena occur: nonattainment of the optimal value, and positive duality gaps between the primal and dual problems. This research was motivated by the curious similarity of pathological SDP instances appearing in the literature. We prove an exact, combinatorial type characterization of badly behaved semidefinite systems, i.e., show that "all bad SDPs look the same". We also prove that all badly behaved semidefinite systems can be reduced to a minimal such system with just one variable, and two by two matrices in a well defined sense. Our characterizations imply that recognizing badly behaved semidefinite systems is in NP and co-NP in the real number model of computing. For general conic linear programs we give a geometric "sandwich theorem" to characterize well- and badly-behaved systems; this result yields an exact characterization for the class of nice cones, of which the SDP result is a special case.

■ Mon.B.12

Monday, 14:30-16:00, Room 1.2, Organized Session

Algorithms for eigenvalue optimization

Cluster: Sparse optimization and information processing

Session organized by: *Zaiwen Wen*

1. **Trace-penalty minimization for large-scale eigenspace computation**

   Xin Liu (liuxin@lsec.cc.ac.cn) Academy of Mathematics and Systems Science, Chinese Academy of Sciences, China, *Zaiwen Wen*, *Chao Yang*, *Yin Zhang*

The Rayleigh-Ritz (RR) procedure, including orthogonalization, constitutes a major bottleneck in computing relatively high-dimensional eigenspaces of large sparse matrices. Although operations involved in RR steps can be parallelized to a certain level, their parallel scalability, which is limited by some inherent sequential steps, is lower than dense matrix-matrix multiplications. The primary motivation of this talk is to introduce a methodology that reduces the use of the RR procedure in exchange for matrix-matrix multiplications. We propose an unconstrained penalty model and establish its equivalence to the eigenvalue problem. This model enables us to deploy gradient-type algorithms that makes heavy use of dense matrix-matrix multiplications. Although the proposed algorithm does not necessarily reduce the total number of arithmetic operations, it leverages highly optimized operations on modern high performance computers to achieve parallel scalability. Numerical results based on a preliminary implementation, parallelized using OpenMP, show that our approach is promising.

2. **A preconditioner for accelerating a fixed point iteration in electronic structure calculations**

   Chao Yang (CYang@lbl.gov) Lawrence Berkeley National Laboratory, USA, *Lin Lin*

The ground state electron density of a many-electron system can be obtained by seeking the fixed point of a nonlinear map from the electron density to itself. This map can be derived from the Kohn-Sham density function theory. We analyze properties of this map and its Jacobian. These properties can be used to develop a nonlinear preconditioner for accelerating a fixed point iteration often known in the electronic structure calculation community as the self-consistent field iteration for solving this type problem. We show that such a preconditioner can be constructed by solving a variable coefficient elliptic partial differential equation with a proper choice of the coefficients. Such a preconditioner can work equally well for metallic and insulating systems. It is also effective for more complex materials that contain both metal and insulators. We will demonstrate the effectiveness of such a preconditioner by numerical examples.

3. **Adaptive regularized self-consistent field iteration with exact Hessian**

   Zaiwen Wen (zw2109@sjtu.edu.cn) Shanghai Jiaotong University, China, *Andre Milzarek*, *Michael Ulbrich*, *Hongchao Zhang*

The self-consistent field (SCF)iteration has been used ubiquitously for solving the Kohn-Sham (KS) equation or the minimization of the KS total energy functional with respect to orthogonality constraints in electronic structure calculations. Although SCF with heuristics such as charge mixing often works remarkably well on many problems, it is well known that its convergence can be unpredictable and there is no general theoretical analysis on their performance. We regularize the SCF iteration and establish rigorous global convergence to the first-order optimality conditions. The Hessian of the total energy functional is further exploited. By adding the part of the Hessian which is not considered in SCF, our methods can always achieve a high accurate solution on problems for which SCF fails and even exhibit quadratic or superlinear convergence on most test problems in the KSSOLV toolbox under the Matlab environment.

■ Mon.B.13

Monday, 14:30-16:00, Room 1.3

Sequential and pivoting approaches

Cluster: Nonlinear optimization
Session chair: *Le Hong Trang*

1. **A new proof for the fineness of the quadratic simplex method**

   Adrienn Nagy (adriennnagy@fico.com) FICO, *Tibor Illés*

We present a new proof for the fineness of the classical quadratic simplex method for convex quadratic, linear constrained problems. Our proof is based on showing that any instance that is cycling under the quadratic simplex method is degenerate not just in the traditional sense, but also in the sense that the transformed pivot columns in the Karush-Kuhn-Tucker system do not contain any non-zero values for those primal variables in the basis that have a non-zero coefficient in the quadratic objective. Our proof implies that any index selection rules that is finite for the linear programming problem and relies only on the sign structure of the transformed right hand side and objective is also finite for the quadratic simplex method.

2. **A sequential convex programming algorithm for minimizing a sum of Euclidean norms with non-convex constraints**

   Le Hong Trang (lhtrang@math.ist.utl.pt) CEMAT, Instituto Superior Técnico, Lisboa, Portugal and Department of Electrical Engineering, Katholieke Universiteit Leuven, Belgium, *Moritz Diehl*, *Phan Thanh An*, *Attila Kozma*

Based on sequential convex programming, we introduce an approximate algorithm for solving efficiently the problem of minimizing a sum of Euclidean norms on the boundaries of convex polygons in 3D. Numerical tests are shown and some applications in facilities location area are discussed.

■ Mon.B.14

Monday, 14:30-16:00, Room 1.4, Organized Session

Numerics and theory of dynamic MPECs

Cluster: Complementarity and variational inequalities
Session organized by: *Kathrin Hatz, Sven Leyffer*

1. **Inverse optimal control problems for the analysis of human motions**

   Sebastian Albrecht (albrecht@ma.tum.de) Mathematics Department, Technical University of Munich, Germany, *Marion Leibold*, *Michael Ulbrich*

In various experimental settings it has been observed that human motions are highly stereotyped. A common assumption is that they are (approximately) optimal with respect to an unknown cost function. We use an bilevel optimization approach to investigate the following inverse problem: Which cost function out of a parameterized family composed from basic cost functions suggested in literature reproduces the recorded human motions best? The lower level problem is an optimal control problem governed by a nonlinear model of the human dynamics and the upper level problem is the data matching problem comparing the optimal control output with the recorded human data. We propose a solution technique for this class of inverse optimal control problems that is based on a collocation approach and a reformulation of the resulting bilevel problem using optimality conditions. Selected modeling aspects and numerical results are discussed for three application examples: human arm motions, human-steered lane changes of a car and human navigation problems.

2. **A parametric active-set method for linear programs with complementarity and vanishing constraints**

   Christian Kirches (christian.kirches@iwr.uni-heidelberg.de) Interdisciplinary Center for Scientific Computing (IWR), Heidelberg University, Germany, *Sven Leyffer*

Recent progress in direct methods for fast mixed-integer optimal control has led to an appreciation of linear programs with additional nonconvex structure as the core subproblems to be solved. In this talk, we are interested in the fast solution of a sequence of linear programs with complementarity constraints (LPCCs) and vanishing constraints (LPVCs). Addressing this issue, we present a new parametric active-set method and its implementation. We discuss stationarity properties of the obtained limit points, and give an outlook on the use of this method within a sequential linear-quadratic solver for MPCCs and MPVCs.

■ Mon.B.15

Monday, 14:30-16:00, Room 1.5, Organized Session

Advances in derivative free optimization II

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Margaret H. Wright*

1. **Using surrogates to calculate sensitivities and improve optimization-based calibration routines**

   Genetha Gray (gagray@sandia.gov) Sandia National Laboratories, USA, *John Siirola*

As computational models have improved in fidelity and increased in complexity, surrogate-based optimization has become increasingly important. Surrogates, or response surface models, are often used to decrease the total computational cost of finding an optimal design point and make a problem computational tractable. In addition, they may be used to guide the optimal search process. In this talk, we will focus on the problem of model calibration (i.e. the process of inferring the values of model parameters so that the results of the simulations best match observed behavior), and describe how surrogates can be also be used to incorporate parameter sensitivity information. The resulting new algorithm is a hybrid of traditional optimization and statistical analysis techniques that presents the user with a choice of solutions and corresponding confidence intervals. We will describe the methodology, discuss its open source software implementation, and give some results for calibration problems from electrical and mechanical engineering.

2. **Derivative-free optimization methods for the surface structure determination problem**

   Juan C. Meza (jcmeza@ucmerced.edu) University of California, Merced, USA

Many material and electronic properties of systems depend on the atomic configuration at the surface. This problem can be viewed as a mixed variable optimization problem for the chemical identity of the atoms as well as their spatial coordinates. One common technique used for determining surface structures is based on solving an inverse problem to match some known data. An example arises in the determination of nanostructures where a technique known as low energy electron diffraction (LEED) method is used. We will describe the use of pattern search methods and simplified physics surrogates for determining the surface structure of nanosystems. The pattern search methods have the property of being able to handle both continuous and categorical variables, which allows the simultaneous optimization of the atomic coordinates as well as the chemical identity.

3. **Diagonal methods in Lipschitz global optimization**

   Dmitri Kvasov (kvadim@si.deis.unical.it) University of Calabria, Italy, and N.I.Lobachevsky State University of Nizhni Novgorod, Russia, *Yaroslav Sergeyev*

The global optimization problem of a function satisfying the Lipschitz condition over a multidimensional hyperinterval with an unknown Lipschitz constant is considered. It is supposed that the function can be black-box, multiextremal, and hard to evaluate. Various approaches for solving this problem can be distinguished, e.g., from the following three viewpoints: (a) the way of obtaining the Lipschitz constant information; (b) the rule used to select subregions for partitioning; (c) the strategy for partitioning the chosen subregions. The main attention is dedicated to the last aspect (c). Particularly, the diagonal algorithms are examined, since they have a number of attractive theoretical properties and have proved to be efficient in solving applied problems. In these methods, the search hyperinterval is adaptively partitioned into smaller ones and the function is evaluated only at two vertices corresponding to the main diagonals of the generated hyperintervals. It is shown that traditional diagonal strategies are not so efficient due to many redundant function evaluations. A new adaptive diagonal partition strategy that allows one to avoid such computational redundancy is described. A number of multidimensional global optimization algorithms based on the new strategy are illustrated. They differ in both (a) the Lipschitz constant estimating and (b) the hyperintervals selection procedure. Results of their numerical verification on GKLS-generator test classes are discussed

■ Mon.B.17

Monday, 14:30-16:00, Room 1.7, Organized Session

Stochastic optimization of complex systems

Cluster: Applications of continuous optimization in science and engineering

Session organized by: *Mihai Anitescu*

1. **Global optimization of optimal power flow (OPF) problems**

   Arvind U. Raghunathan (raghunathan@merl.com) Mitsubishi Electric Research Laboratories, USA, *Ajit Gopalakrishnan*, *Daniel Nikovski*, *Lorenz T. Biegler*

We propose a semidefinite relaxation based spatial branch and bound algorithm for the solution of Optimal Power Flow (OPF) problem to global optimality. We show that this approach can solve to global optimality the general form of the OPF problem including: generation power bounds, apparent and real power line limits, voltage limits and thermal loss limits. The approach makes no assumption on the topology or resistive connectivity of the network and also removes some of the restrictive assumptions of earlier SDP approaches. We present test cases where solutions fail to satisfy the SDP rank condition and have a non-zero duality gap. The proposed branch and bound algorithm is able to solve these cases to global optimality.

2. **On the convergence of decomposition methods for multistage stochastic convex program**

   Vincent Leclere (vincent.leclere@cermics.enpc.fr) Université Paris-Est, École des Ponts Paristech, France, *P. Girardeau*, *A. Philpott*

We prove the almost-sure convergence of a class of sampling-based nested decomposition algorithms for multi-stage stochastic convex programs in which the stage costs are convex non necessarily linear functions of the decisions and the state, and uncertainty is modelled by a scenario tree. As a special case, our results imply the almost-sure convergence of SDDP, CUPPS and DOASA when applied to problems with general convex cost functions.

3. **Contingency generation by interior point methods for optimal power flow**

   Andreas Grothey (A.Grothey@ed.ac.uk) School of Mathematics, University of Edinburgh, UK, *Naiyuan Chiang*

Security Constrained Optimal Power Flow is an important problem for power systems operators. The structure of the problem resembles stochastic programming problems in that one aims to find a cost optimal operation schedule that is feasible for all possible equipment outage scenarios (contingencies). Due to the presence of AC power flow constraints, the resulting problem is a large scale nonlinear programming problem. However it is known that only a small subset of the contingencies is active at the solution. We present an Interior Point based scheme that starts with the (small scale) base problem, generates likely active contingencies on-the-fly and integrates them into the algorithm using IPM warmstarting techniques. The final problem solved by this scheme is significantly smaller than the full contingency constrained problem, resulting in substantial speed gains. Numerical and theoretical results of our algorithm will be presented.

■ Mon.B.21

Monday, 14:30-16:00, Room 2.1, Organized Session

Bilevel programming and MPECs

Cluster: Convex and nonsmooth optimization

Session organized by: *Stephan Dempe, Alain B. Zemkoho*

1. **Stationarity concepts for strong and weak Stackelberg problems**

   Alain B. Zemkoho (a.zemkoho@bham.ac.uk) School of Mathematics, University of Birmingham, UK

In this talk, we consider the strong and weak Stackelberg problems in a single framework. We discuss links between both problems and introduce various stationarity concepts and their justifications.

2. **The price of inexactness: Convergence properties of relaxation methods for mathematical programs with equilibrium constraints revisited**

   Alexandra Schwartz (schwartz@mathematik.uni-wuerzburg.de) University of Würzburg, Germany, *Christian Kanzow*

Mathematical programs with equilibrium (or complementarity) constraints, MPECs for short, form a difficult class of optimization problems. The feasible set has a very special structure and violates most of the standard constraint qualifications. Therefore, one typically applies specialized algorithms in order to solve MPECs. One prominent class of specialized algorithms are the relaxation (or regularization) methods. The first relaxation method for MPECs is due to Scholtes [SIOPT], but in the meantime, there exist a number of different regularization schemes which try to relax the difficult constraints in different ways. Among the most recent examples for such methods are the ones from Kadrani, Dussault, and Benchakroun [SIOPT] and Kanzow and Schwartz [SIOPT]. Surprisingly, although these recent methods have better theoretical properties than Scholtes' relaxation, numerical comparisons show that this method is still among the fastest and most reliable ones, see for example Hoheisel et al. [Mathematical Programming]. To give a possible explanation for this, we consider the fact that, numerically, the regularized subproblems are not solved exactly. In this light, we analyze the convergence properties of a number of relaxation schemes and study the impact of inexactly solved subproblems on the kind of stationarity we can expect in a limit point.

3. **Bilevel programming — ons formulation and optimality conditions**

   Stephan Dempe (dempe@tu-freiberg.de) TU Bergakademie Freiberg, Germany

Bilevel programming problems are optimization problems where the feasible set is implicitly determined by the graph of a (second, parametric) optimization problem, called the lower level problem. To solve them it is necessary to replace this graph using either the Karush-Kuhn-Tucker conditions of the lower level problem, the optimal value function of this problem or some generalized equation. In the talk these problems are formulated, the relations between them as well as related necessary optimality conditions are described.

■ Mon.B.22

Monday, 14:30-16:00, Room 2.2, Organized Session

Recent advances in coordinate descent methods

Cluster: Convex and nonsmooth optimization

Session organized by: *Martin Takac*

1. **On the rate of convergence of block coordinate descent type methods**

   Amir Beck (becka@ie.technion.ac.il) Faculty of Industrial Engineering and Management, Technion, Haifa, Israel, *Luba Tetruashvili*

We consider smooth convex programming problems where the decision variables vector is split into several blocks of variables. Sublinear rate of convergence results for the cyclic block coordinate gradient projection method as well as the alternating minimization method are derived. When the objective function is also assumed to be strongly convex, linear rate of convergence is established.

2. **CANCELLED**

3. **Convex reparameterization of a large class of biconvex functions**

   Pradeep Ravikumar (pradeep.ravikumar@gmail.com) University of Texas at Austin, USA, *Eunho Yang*

We consider the minimization of biconvex functions: whose domains consists of a cartesian product of two components, and where the functions are convex in one component while keeping the other fixed and vice versa. Such biconvex functions arise in many settings in contemporary machine learning, such as sparse coding and conditional random fields, among others. For a large subclass of such biconvex functions, we are able to provide an equivalent convex reparameterization: so that one can now solve these both efficiently and tractably. This is in contrast to existing methods that obtain convex upper bounds for such biconvex functions. We also empirically demonstrate the utility of our approach in two applications involving sparse coding and a Gaussian conditional random fields.

■ Mon.B.23

Monday, 14:30-16:00, Room 2.3

Game theory and stochastic control

Cluster: Robust optimization and optimization in finance
Session chair: *Alexander S. Belenky*

1. **Probabilistic safety reachability analysis**

   Mohamed Assellaou (mohamed.assellaou@polytechnique.edu) ENSTA PARISTECH, Paris, France, *Hasnaa Zidani*, *Olivier Bokanowski*

Let $W(.)$ be a given Brownian motion in a filtered probability space, and $T > 0$. Denote by $\mathscr{U}$ the set of controls valued in $U \in R^d$. Let $\{X^u_{t,x}(s), t \le s \le T\}$ be a controlled process valued in R^d solution of the following system:

$$\begin{cases} dX(s) = b(s, X(s), u(s))ds + \sigma(s, X(s), u(s))dW(s), & \forall s \in [t, T] \\ X(t) = x, \end{cases} \tag{2}$$

where σ and b are two continuous functions satisfying some regularity assumptions.
Let $\mathscr{C}$ be a nonempty closed set of R^d. Let $\rho \in [0,1[$. Define the catch basin under probability of success ρ as the set of initial points x from which starts a trajectory $X^u_{t,x}$ solution of (2), associated with an admissible control $u \in \mathscr{U}$ such that the probability to reach $\mathscr{C}$ is at least ρ:

$$\Omega^\rho_t = \{x \,|\, \exists u \in \mathscr{U}, \mathbb{P}[X^u_{t,x}(T) \in \mathscr{C}] > \rho\} \tag{3}$$

The motivation of analyzing these sets, is to have, not only, the initial data such that one remains in safety regions, but also, the field of risk split into several domains corresponding each one to some probability.
In our approach, sets Ω^ρ_t will be characterized using the value function of an adequate optimal control problem. Numerical results related to some interesting models will be presented.

2. **Application of continuous optimization techniques for calculating equilibriums in large-scale three-person public procurement games**

   Alexander S. Belenky (abelenky@mit.edu) The National Research University Higher School of Economics, Moscow, Russia, and Center for Engineering Systems Fundamentals, Massachusetts Institute of Technology, Cambridge, USA

A public administration acting on behalf of a state or of a municipality and procuring goods and services tenders contracts for fulfilling a set of orders and needs to calculate an initial price for each contract while knowing only approximately the expenses that the potential tender participants would bear to fulfill a particular order. In allocating large-scale contracts, the administration deals with a developer and with an operator, whose interests may or may not coincide. The proposed underlying idea of setting the initial contract prices consists of a) considering a hypothetical situation in which the administration deals with only one developer and with only one operator with whom it needs to “find consensus” on the prices for all the projects that it plans to tender, and b) to set the initial prices for the contracts as those under which the above consensus is reached. A hypothetical three-person game in which the administration, the developer, and the operator are the players is considered, and it is proposed to view that the above consensus is attainted if the game is solvable. The proposed verifiable necessary and sufficient conditions of the equilibria allow one to use nonlinear programming techniques in calculating the equlibria in solvable games in which the potential of each player is described by a compatible system of linear inequalities, and the payoff functions of the players are sums of linear and bilinear functions of vector arguments.

■ Mon.B.24

Monday, 14:30-16:00, Room 2.4

Model reduction and discretization

Cluster: PDE-constrained optimization
Session chair: *Ekkehard Sachs*

1. **Approximations of semilinear elliptic optimal control problems in a convex domain with controls in the coefficients multiplying the highest derivatives**

   Aygul Manapova (aygulrm@yahoo.com) Bashkir State University, Russia, *Fedor Lubyshev*

Nonlinear optimal control problems for partial differential equations (PDEs) are among the most complicated optimization problems. In the scientific literature, Nonlinear optimization problems have been least studied (especially in the case of nonlinearity caused by controls involved in the equation coefficients, including ones multiplying the highest derivatives). Before solving optimization problems numerically, they have to be approximated by problems of a simpler nature. Tasks of primary importance are the design of algorithms, their convergence analysis with respect to the state, functional, and control; and the regularization of approximations. In the work we construct and examine difference approximations of nonlinear optimal control problems described by Dirichlet problems for non-self-adjoint semilinear elliptic equations in a convex domain. The controls are contained in the coefficients multiplying the highest derivatives. The convergence rate of the approximations with respect to the state and the functional is estimated, weak convergence with respect to the control is established, and the approximations are regularized. The results are obtained assuming that the state possesses the natural non-overstated degree of smoothness guaranteed by the solvability theorem for a state in the Sobolev class.

2. **Reduced order models for the optimal control of contact problems**

   Daniela Koller (koller@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

The numerical simulation of sheet metal forming processes and their optimization plays a major role in the product development of sheet metal products. Contact problems with friction appear in different kinds of sheet metal forming. From the mathematical point of view the contact problem with friction leads to a quasi-variational inequality. In this presentation we will consider contact problems with Coulomb friction. We use higher order finite elements with dual Lagrange multiplier spaces for the numerical simulation. The finite element simulation of the contact problem with friction is computationally expensive, hence we adopt model reduction techniques. We use Proper Orthogonal Decomposition (POD) and a reduced basis method for the constrained states in combination with a semismooth Newton method to obtain a low-order model. Numerical results for an optimal control problem based on the developed reduced order models will be presented.

3. **Model Reduction in the Calibration of Nonlinear PDEs**

   Ekkehard Sachs (sachs@uni-trier.de) University of Trier, Germany, *M. Schneider*

We consider an example from derivative pricing where the calibration of a local volatility model is considered using the implied volatilities as output parameters. Three approaches are outlined for the formulation of the problem and its pros and cons are discussed. In addition, we show how POD using DEIM can dramatically reduce the computation time for a model evaluation. All approaches are also compared numerically and the efficiency of the last approach is documented.

■ Mon.B.25

Monday, 14:30-16:00, Room 2.5, Organized Session

Variational analysis and optimal control

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Térence Bayen*

1. **Leukemia and optimal control**

Xavier Dupuis (xavier.dupuis@cmap.polytechnique.fr) CMAP, École Polytechnique & Inria Saclay, France

We are interested in optimizing the co-administration of two drugs for some acute myeloid leukemias (AML), and we are looking for in vitro protocols as a first step. This issue can be formulated as an optimal control problem. The dynamics of leukemic cell populations in culture is given by age-structured partial differential equations, which can be reduced to a system of delay differential equations, and where the controls represent the action of the drugs. The objective function relies on eigenelements of the uncontrolled model and on general relative entropy, with the idea to maximize the efficiency of the protocols. The constraints take into account the toxicity of the drugs. We present the modeling aspects, as well as theoretical and numerical results on the optimal control problem that we get.

2. **Sensitivity analysis for relaxed optimal control problems with final-state constraints**

Laurent Pfeiffer (laurent.pfeiffer@polytechnique.edu) Inria-Saclay and CMAP, École Polytechnique, France, *J. Frédéric Bonnans*, *Oana Silvia Serea*

In this talk, we consider a family of relaxed optimal control problems with final-state constraints, indexed by a perturbation variable y. Our goal is to compute a second-order expansion of the value $V(y)$ of the problems, near a reference value of y. We use relaxed controls, i.e., the control variable is at each time a probability measure. Under some conditions, a constrained optimal control problem has the same value as its relaxed version. The specificity of our study is to consider bounded strong solutions [2], i.e., local optimal solutions in a small neighborhood (for the L^∞-distance) of the trajectory. To obtain a sharp second-order upper estimate of V, we derive two linearized problems from a wide class of perturbations of the control (e.g., small perturbations for the L^1-distance). Relaxation permits a very convenient linearization of the problems. Using the decomposition principle [1], we prove that the upper estimate is an exact expansion. [1] J.F. Bonnans, N.P. Osmolovskii. Second-order analysis of optimal control problems with control and final-state constraints. 2010. [2] A.A. Milyutin, N.P. Osmolovskii. Calculus of variations and optimal control. 1998.

3. **New approach for stochastic target problems with state-constraints**

Athena Picarelli (athena.picarelli@inria.fr) INRIA Saclay & École Polytechnique ParisTech., France, *Olivier Bokanowski*, *Hasnaa Zidani*

This work is concerned with stochastic optimal control problems with a cost depending on a running maximum. A direct approach based on dynamic programming techniques is proposed and a characterization of the value function as unique solution of a second order Hamilton-Jacobi-Bellman equation with oblique derivative boundary conditions is obtained. A numerical scheme is presented and error bounds provided. This work is strongly motivated by the will of developing an alternative and numerically effective way for dealing with state-constraints in stochastic control and in particular in stochastic target problems. In fact optimal control problems with a maximum cost arise in the characterization of the backward reachable set for a system of controlled stochastic differential equation applying the level set approach together with an exact penalization technique.

■ Mon.B.AB

Monday, 14:30-16:00, Amphitheater B, Organized Session

Nonlinear optimization II

Cluster: Nonlinear optimization
Session organized by: *Daniel P. Robinson, Philip E. Gill, Nick Gould*

1. **Stabilized SQP methods for nonlinear optimization**

Philip E. Gill (pgill@ucsd.edu) University of California, San Diego, USA, *Vyacheslav Kungurtsev*, *Daniel P. Robinson*

Sequential quadratic programming (SQP) methods are a popular class of methods for the solution of Nonlinear optimization problems. They are particularly effective for solving a sequence of related problems, such as those arising in mixed-integer nonlinear programming and the optimization of functions subject to differential equation constraints. Recently, there has been considerable interest in the formulation of stabilized SQP methods, which are specifically designed to give rapid convergence on degenerate problems. Existing stabilized SQP methods are essentially local, in the sense that both the formulation and analysis focus on a neighborhood of an optimal solution. In this talk we discuss an SQP method that has favorable global convergence properties yet is equivalent to a conventional stabilized SQP method in the neighborhood of a solution. Discussion will focus on the formulation of a method designed to converge to points that satisfy the second-order necessary conditions for optimality.

2. **Regularized methods for large-scale quadratic programming**

Elizabeth Wong (elwong@ucsd.edu) University of California, San Diego, USA, *Philip E. Gill*

We consider the formulation and analysis of a regularized active-set method for large-scale convex and nonconvex quadratic programming. The method is based upon minimizing a primal-dual augmented Lagrangian function subject to upper and lower bounds on the variables. Discussion will focus on: (i) the formulation and solution of the large system of equations that defines the primal-dual search direction, (ii) the treatment of infeasible quadratic programs, and (iii) methods for estimating the optimal active set when the starting point is far from the solution. The results of extensive numerical experiments on quadratic programs from the CUTEr test collections will be presented.

3. **Inexact search directions in very large-scale optimization**

Jacek Gondzio (J.Gondzio@ed.ac.uk) School of Mathematics, University of Edinburgh, UK

In this talk we are concerned with the second-order methods for optimization (which naturally include interior point algorithms). Many large-scale problems cannot be solved with methods which rely on exact directions obtained by factorizing matrices. For such problems, the search directions have to be computed using iterative methods. We address the problem of how much of inexactness is allowed without noticeably slowing down the convergence compared with the exact second-order method. We argue that (except for some very special problems) matrix-free approaches have to be applied to successfully tackle truly large scale problems. We provide new theoretical insights and back them up with computational experience.

■ Mon.C.11

Monday, 16:30-18:00, Room 1.1, Organized Session

Algebraic geometry and semidefinite programming I

Cluster: Conic and polynomial optimization
Session organized by: *Lek-Heng Lim, Cordian Riener*

1. **Positive semidefinite rank of polytopes and matrices**

Rekha Thomas (rrthomas@uw.edu) University of Washington, USA, *João Gouveia*, *Richard Robinson*

The positive semidefinite rank of a nonnegative matrix is an example of a cone rank of the matrix extending nonnegative rank. This new rank comes with many open questions and applications. In the context of polytopes, the smallest possible SDP representation of the polytope is controlled by the psd rank of the slack matrix of the polytope. In this talk I will explain recent results on this rank in the context of SDP representability of polytopes.

2. **New lower bounds on nonnegative rank using conic programming**

Hamza Fawzi (hfawzi@mit.edu) Laboratory for Information and Decision Systems, MIT, USA, *Pablo Parrilo*

The nonnegative rank of an entrywise nonnegative matrix A of size $m \times n$ is the smallest integer r such that A can be written as $A = UV$ where U is $m \times r$ and V is $r \times n$ and U and V are both nonnegative. The nonnegative rank arises in different areas such as combinatorial optimization and communication complexity. Computing this quantity is NP-hard in general and it is thus important to find efficient bounding techniques especially in the context of the aforementioned applications. In this paper we propose a new lower bound on the nonnegative rank which, unlike most existing lower bounds, does not explicitly rely on the matrix sparsity pattern and applies to nonnegative matrices with arbitrary support. Our lower bound is expressed as the solution of a copositive programming problem and can be relaxed to obtain polynomial-time computable lower bounds using semidefinite programming. The idea involves computing a certain nuclear norm with nonnegativity constraints which allows to lower bound the nonnegative rank, in the same way the standard nuclear norm gives lower bounds on the standard rank. We compare our lower bound with existing ones, and we show examples of matrices where our lower bound performs better than currently known ones.

3. **Symmetric mean inequalities and sums of squares**

   Cordian Riener (cordian.riener@gmail.com) Aalto University, Finland, *G. Blekherman*

A polynomial is called sums of squares (SOS) if it can be written as a sum of squares of polynomials. Clearly any such polynomial is nonnegative. Although Hilbert could show that the converse is in general false, Hurwitz could certify that the geometry mean is dominated by the arithmetic mean using sum of squares decompositions. In this talk we will present results on the relation between symmetric mean inequalities and sums of squares. In particular we will show that such inequalities of degree 4 can be always verified using sums of squares.

■ Mon.C.13

Monday, 16:30-18:00, Room 1.3

Augmented Lagrangian methods for nonlinear optimization

Cluster: Nonlinear optimization
Session chair: *Philip E. Gill*

1. **New augmented Lagrangian filter methods**

   Sven Leyffer (leyffer@mcs.anl.gov) Argonne National Laboratory, USA

We present a new two-phase augmented Lagrangian filter method that has the potential to exploit scalable parallel subproblem solvers. In the first phase, we approximately minimize the augmented Lagrangian to estimate the optimal active set. In the second phase, we solve an equality-constrained QP. An augmented Lagrangian filter determines the accuracy of the augmented Lagrangian minimization and ensures global convergence. We present a convergence analysis and preliminary numerical results.

2. **Local convergence of a primal-dual augmented Lagrangian algorithm with a stabilized SQP subproblem**

   Vyacheslav Kungurtsev (vkungurt@math.ucsd.edu) KU Leuven, Belgium, *Philip E. Gill*, *Daniel P. Robinson*

The primal-dual augmented Lagrangian function provides a link between augmented Lagrangian methods and stabilized sequential quadratic programming (sSQP) methods. Each sSQP iteration requires the solution of a (possibly nonconvex) quadratic program defined in terms of both the primal and the dual variables. Until recently, research on sSQP has focused primarily on their rate of convergence to a local solution. In this talk we discuss the local convergence properties of a globally convergent primal-dual SQP method that uses the primal-dual augmented Lagrangian merit function in conjunction with a descent direction and a direction of negative curvature. If necessary, the algorithm convexifies the QP subproblem, but, under certain weak assumptions, it can be shown that the solution of the subproblem is eventually identical to a solution of the conventional sSQP subproblem. As a result, the strong local convergence results of sSQP are shown to apply to the proposed globally convergent method.

3. **A primal-dual augmented Lagrangian and log-barrier penalty algorithm for nonlinear optimization**

   Riadh Omheni (riadh.omheni@unilim.fr) Université de Limoges - Laboratoire XLIM, France, *Paul Armand*, *Joel Benoist*

We propose a new primal-dual algorithm for solving nonlinearly constrained minimization problems. This is a Newton-like method applied to a perturbation of the optimality system that follows from a reformulation of the initial problem by introducing an augmented Lagrangian and a log-barrier penalty to handle both equality and bound constraints. Two kinds of iterations are used. The outer iterations at which the different parameters, such as the Lagrange multipliers and the penalty parameters, are updated. The inner iterations to get a sufficient decrease of a given primal-dual penalty function. Both iterations use the same kind of coefficient matrix and the corresponding linear system is solved by means of a symmetric indefinite factorization including an inertia-controlling technique. The globalization is performed by means of a line search strategy on a primal-dual merit function. An important aspect of this approach is that, by a choice of suitable update rules of the parameters, the algorithm reduces to a regularized Newton method applied to a sequence of optimality systems derived from the original problem. The global convergence and the asymptotic properties of the algorithm are presented. In particular, we show that the algorithm is q-superlinear convergent. In addition, this method is able to solve the well known example of Wachter and Biegler, for which some interior point methods based on a line search strategy fail.

■ Mon.C.14

Monday, 16:30-18:00, Room 1.4, Organized Session

Numerical aspects of dynamic MPECs

Cluster: Complementarity and variational inequalities
Session organized by: *Kathrin Hatz, Sven Leyffer*

1. **AMPL/PATH tutorial introduction to solving regularized complementarity problems with a case study from CIM-EARTH**

   Sou-Cheng (Terrya) Choi (sctchoi@uchicago.edu) University of Chicago/Argonne National Laboratory, USA

AMPL is an expressive programming language for modeling and solving algebraic problems in optimization. The de facto AMPL solver of choice for solving complementarity problems is PATH developed by Dirkse, Ferris, and Munson. This tutorial introduces basic elements in AMPL (version 20120629) and showcases sample programs for solving large-scale complementarity problems via PATH (version 4.7.03), applying regularization techniques available from the solver when necessary. We feature a case study from CIM-EARTH (Elliott et al. 2010), a framework for solving computable general equilibrium models with applications in climate change and economic policies.

2. **Ordinary differential equations with discontinuous right-hand sides as complementarity systems. Application to gene regulatory networks.**

   Vincent Acary (vincent.acary@inria.fr) INRIA, France

Ordinary Differential Equations (ODE) with discontinuous right-hand side appear as dynamical models in various fields ranging from automatic control (sliding mode and optimal control, hybrid systems), electrical and mechanical engineering (ideal electrical components, saturation, friction, piecewise linear models) to biology (gene regulatory networks). To deal with ODEs with discontinuities, a concept of solution has to be firstly defined, since standard Caratheodory solutions do no longer apply. Filippov's framework (notion of solutions and extension as differential inclusions) is generally invoked. If the latter is a powerful tool for the existence analysis of solutions, it is not an amenable approach for the numerical computation of solutions. We propose in this work to embed ODEs with discontinuities in the framework of complementarity systems and Differential Variational Inequalities (DVI). We show that this embedding is equivalent to a special differential inclusion extension alternative to the Filippov classical one. This reformulation enables the design of a time-stepping scheme for which it is possible to show that the variational inequality that we have to solve at each time-step is solvable. It also makes possible an efficient computation of equilibrium points and theirs stability analysis. The approach will be illustrated on the simulation of gene regulatory networks in cell Biology.

3. **Bilevel problems with Nash equilibrium constraints under perturbations**

   Jacqueline Morgan (morgan@unina.it) DISES & CSEF, University of Naples Federico II, Italy, *M. Beatrice Lignola*

We consider bilevel problems where a leader solves a MPEC or a MinSup problem with constraints defined by Nash equilibria of a non-cooperative game. We show that, in general, the infimal values of these problems are not stable under perturbations, in the sense that the sequence of the infimal values for the perturbed problems may not converge to the infimal value of the original problem even in presence of nice data. So, we introduce different types of approximate values, close to the exact value under suitable assumptions, and we investigate their asymptotic behavior under perturbations.

■ Mon.C.15

Monday, 16:30-18:00, Room 1.5, Organized Session

Model based methods for derivative-free optimization

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Sébastien Le Digabel*

1. **Trust region calculations with linear constraints**

   M. J. D. Powell (mjdp@cam.ac.uk) University of Cambridge, UK

We consider the following problem, which occurs in the software being developed by the author for minimizing a general function $F(x)$, when derivatives of $F(x)$ are not available and when there are linear constraints on the vector of variables x. Let $M(x)$ be a quadratic approximation to $F(x)$, and let X be the set of vectors x that satisfy the constraints. Having chosen a trust region centre c in X and a trust region radius r, we seek a relatively small value of $M(x)$ subject to x in X and $\|x-c\| \leq r$. Active sets are employed, which give an unconstrained trust region problem in fewer variables for each active set. Only low accuracy is required. Examples show that major difficulties arise if one attempts to calculate a global solution instead of a local solution to the trust region problem with linear constraints.

2. **Derivative-free optimization via proximal point methods**

   Yves Lucet (yves.lucet@ubc.ca) University of British Columbia, Canada, *Warren Hare*

Many standard techniques in Derivative-Free Optimization (DFO) are based on using model functions to approximate the objective function, and then applying classic optimization methods on the model function. For example, the details behind adapting steepest descent, conjugate gradient, and quasi-Newton methods to DFO have been studied in this manner. In this paper we demonstrate that the proximal point method can also be adapted to DFO. To that end, we provide a derivative-free proximal point (DFPP) method and prove convergence of the method in a general sense. In particular, we give conditions under which the gradient values of the iterates converge to 0, and conditions under which an iterate corresponds to a stationary point of the objective function.

3. **Model-based optimization methods with many simultaneous function evaluations**

   Stefan M. Wild (wild@mcs.anl.gov) Argonne National Laboratory, USA

Derivative-free optimization algorithms are often employed in settings where the evaluation of an objective function (or constraint functions) is a computational bottleneck. For such problems, heuristics are still widely used in practice, often because they admit natural parallelism that allows a user to perform many simultaneous evaluations. In this talk we present our experiences in developing zero-order, model-based methods that perform a user-specified number of simultaneous evaluations. We also discuss gaps between convergence guarantees and performance in practice.

■ Mon.C.16

Monday, 16:30-18:00, Room 1.6, Organized Session

Integer and mixed-integer nonlinear optimization

Cluster: Global optimization and mixed-integer programming
Session organized by: *Christoph Buchheim*

1. **A direct search algorithm for determining the well location and on/off status for reservoir engineering**

   Claire Lizon (claire.lizon@ifpen.fr) IFPEN, France, *Claudia D'Ambrosio*, *Leo Liberti*, *Delphine Sinoquet*

Optimizing the well configuration of an oil field in reservoir engineering consists in maximizing the Net Present Value function, which couples drilling/operational costs and production profits, associated with produced oil as well as with produced and injected water volumes. Such profits are computed from fluid flow reservoir simulations. The decision variables are the number of active wells, their type (producer/injector) and their location. Standard MINLP formulation of such a problem involving complex PDE leads to a huge discretized equation system, which cannot be solved in practice. Thus, we separate the computation of the NPV objective function for a given well configuration and the optimization phase. We delegate the former to the fluid flow simulator and the latter to a black-box optimizer. We present computational optimization results on a 3D realistic reservoir case by using the direct search implementation of NOMAD solver. The impact of tailored exploration phase and adapted surrogate models are illustrated.

2. **Exploiting facets of the cut polytope for sparse betweenness problems**

   Andreas Schmutzer (schmutzer@informatik.uni-koeln.de) FAU Erlangen, Germany, *Frauke Liers*

Given a sequence of objects and costs for triples of objects i, k and j that apply iff k occurs between i and j in the sequence, the betweenness problem asks for a minimum cost permutation of all objects. For many applications sparse models of betweenness problems are preferable. We generalize for sparse formulations the result that betweenness polytopes are faces of the cut polytope. Further we derive a combinatorial characterization of cuts in an associated graph that correspond to betweenness solutions. Finally we give computational results that exploit facets of sparse cut polytopes.

3. **The rounding property for nonlinear mixed integer optimization problems**

   Ruth Hübner (r.huebner@math.uni-goettingen.de) University of Göttingen, Germany, *Anita Schöbel*

Nonlinear mixed integer optimization problems combine the difficulties of nonlinear and (mixed) integer optimization. If the values for its integer variables are already known, the MINLP reduces to a continuous optimization problem for which we assume that it is easier to solve than the original MINLP. We identify special cases where the optimal values for the integer variables can be determined by rounding (up or down) a solution of the continuous relaxation. This property is called the "rounding property". (Compare also the rounding property for INLP introduced by Hübner and Schöbel, 2012.) Having this rounding property we could solve the original $n+m$-dimensional MINLP (n integer variables, m continuous) by solving up to 2^n m-dimensional continuous problems. In case the continuous relaxation can be solved in polynomial time this gives us a polynomial approach in fixed dimension. In order to use an improved solution procedure, we also investigate cases where the optimal value for the integer variables can be found by rounding the values of an optimal solution for the continuous relaxation to their closest integers — what we call the "strong rounding property". To identify (in both cases) these special problems we analyse the geometric properties of the intersection of the level sets of the objective function with the feasible region. In doing so we are also interested which properties the MINLP inherits from the corresponding INLP where all variables have to be integer.

■ Mon.C.17

Monday, 16:30-18:00, Room 1.7, Organized Session

Optimization of dynamic systems II

Cluster: Applications of continuous optimization in science and engineering
Session organized by: *Victor M. Zavala*

1. **Embedded optimization in fixed-point arithmetic**

   Juan L. Jerez (juan.jerez-fullana@imperial.ac.uk) Imperial College, UK

Implementation of complex optimization-based real-time decision making is often not possible due to the limited computational capabilities of embedded computing platforms. Compared to widespread floating-point arithmetic, fundamentally more efficient fixed-point arithmetic can enable implementation in low cost devices and can result in significant performance improvements for meeting tight real-time deadlines. However, fixed-point arithmetic presents additional challenges, such as having to bound the peak value of each variable to prevent overflow errors. First, we show how the linearized KKT system, the solution of which forms the computational bottleneck in interior-point and active-set methods, can be altered to allow for reliable overflow-free fixed-point implementation. We then focus on first-order methods and present an analysis that enables one to predict a priori the numerical error introduced by a given word-length fixed-point implementation. For instance, this approach can allow for the implementation of online optimization-based controllers at megahertz sampling rates on a low cost device.

2. **Sensitivity-based decomposition for moving finite elements with direct transcription formulations**

   Lorenz T. Biegler (biegler@cmu.edu) Carnegie Mellon University, USA, *Weifeng Chen*, *Zhijiang Shao*

This study explores an alternate direct transcription strategy where moving finite elements are embedded within the solution of the optimization problem. The approach also requires a mesh refinement stage, but it contains two important features: direct determination of the break-point as part of the finite element mesh, and a stopping criterion based on the profile of the Hamiltonian function. The incorporation of moving finite elements also introduces a number of additional difficulties. Because a variable mesh introduces additional nonlinearity into the equality constraints, and therefore (additional) nonconvexity into the NLP formulation, we explore a decomposition strategy where the inner problem deals with a fixed mesh, and the outer problem adjusts the finite elements in the mesh based on a number of criteria. This two level approach leverages NLP sensitivity capabilities for the inner problem and allows for flexible problem formulations in the outer problem for mesh placement. As a result, it decomposes a difficult, poorly posed problem into two parts: a large-scale problem that is easier to solve, and a smaller, more difficult problem that can be tailored to specific problem classes and challenges. Several optimal examples are considered to demonstrate the effectiveness of this approach.

3. **Decoding complex cardiac arrhythmia using mathematical optimization**

   Sebastian Sager (sager@ovgu.de) Otto-von-Guericke-Universität Magdeburg, Germany, *Florian Kehrle*, *Eberhard Scholz*

It is an open clinical problem to distinguish atrial flutter from atrial fibrillation. The discrimination is imperative, as atrial fibrillation is the most frequent arrhythmia in the adult (6 million individuals across Europe) and both types have to be treated differently in the interest of the patient. Atrial flutter is underrecognized in clinical practice. Especially in cases of irregular ventricular response it is often misinterpreted as atrial fibrillation. Caused by an increasing number of left atrial catheter ablations (pulmonary vein isolations), the number of left atrial flutter is increasing at an alarming rate, making the mentioned decoding task an ubiquitous one. Whereas atrial flutter is characterized by rapid regular electric impulses (constant frequency) in the atria, electrical activation exhibits high irregularity in atrial fibrillation (non-constant frequency). Electric impulses from the atria are conducted via the atrioventricular (AV) node to the ventricles. Using the electrocardiogram (ECG) it is easy to identify the electric activation of the ventricles, but in clinical practice often difficult to determine the exact electrical activation of the atria. We follow an optimization approach to identify the underlying rhythm. For the resulting non-standard optimization problems we present tailored solution strategies and encouraging results from a transfer to clinical practice.

■ Mon.C.18

Monday, 16:30-18:00, Room 1.8, Organized Session

Modeling and algorithmic developments in stochastic programming

Cluster: Stochastic optimization
Session organized by: *Miguel Lejeune*

1. **Clustering-based interior point strategies for stochastic programs**

   Victor M. Zavala (vzavala@mcs.anl.gov) Argonne National Laboratory, USA

We present interior-point strategies for convex stochastic programs in which inexpensive inexact Newton steps are computed from compressed Karush-Kuhn-Tucker (KKT) systems obtained by clustering block scenarios. Using Schur analysis, we show that the compression can be characterized as a parametric perturbation of the full-space KKT matrix. This property enables the possibility of retaining superlinear convergence without requiring matrix convergence. In addition, it enables an explicit characterization of the residual and we use this characterization to derive a clustering strategy. We demonstrate that high compression rates of 50 − −90% are possible and we also show that effective preconditioners can be obtained.

2. **Boolean reformulation method for probabilistically constrained stochastic programming problems**

   Miguel Lejeune (mlejeune@gwu.edu) George Washington University, USA

We present a Boolean programming method to model and efficiently solve stochastic programming problems that have a joint probabilistic constraint with multi-row random technology matrix and/or random right-hand side. The method involves the binarization of the probability distribution of the random variables in such a way that we can extract a threshold partially defined Boolean function (pdBf) representing the satisfiability of the probabilistic constraint. We then construct a tight threshold Boolean minorant for the pdBf. Any separating structure of the tight threshold Boolean minorant defines sufficient conditions for the satisfaction of the probabilistic constraint and takes the form of a system of linear constraints. We use the separating structure to derive several deterministic formulations equivalent to the studied stochastic problem. A crucial feature of the integer formulations derived with the Boolean approach is that the number of integer variables does not depend on the number of scenarios used to represent uncertainty. Computational results will be presented.

■ Mon.C.21

Monday, 16:30-18:00, Room 2.1, Organized Session

Dual and coordinate descent methods

Cluster: Convex and nonsmooth optimization
Session organized by: *Martin Takac*

1. **Universal gradient methods**

   Yurii Nesterov (Yurii.Nesterov@uclouvain.be) CORE, UCL, Belgium

In Convex Optimization, numerical schemes are always developed for some specific problem classes. One of the most important characteristics of such classes is the level of smoothness of the objective function. Methods for nonsmooth functions are different from the methods for smooth ones. However, very often the level of smoothness of the objective is difficult to estimate in advance. In this talk we present algorithms which adjust their behavior in accordance to the actual level of smoothness observed during the minimization process. Their only input parameter is the required accuracy of the solution.

2. **Parallel block coordinate descent methods for huge-scale partially separable problems**

   Martin Takac (martin.taki@gmail.com) University of Edinburgh, UK, *Peter Richtarik*

In this work we show that randomized block coordinate descent methods can be accelerated by parallelization when applied to the problem of minimizing the sum of a partially block separable smooth convex function and a simple block separable convex function. We give a generic algorithm and several variants thereof based on the way parallelization is performed. In all cases we prove iteration complexity results, i.e., we give bounds on the number of iterations sufficient to approximately solve the problem with high probability. Our results generalize the intuitive observation that in the separable case the theoretical speedup caused by parallelization must be equal to the number of processors. We show that the speedup increases with the number of processors and with the degree of partial separability of the smooth component of the objective function. Our analysis also works in the mode when the number of blocks being updated at each iteration is random, which allows for modelling situations with variable (busy or unreliable) number of processors. We conclude with some encouraging computational results applied to huge-scale LASSO and sparse SVM instances.

3. **A random coordinate descent method on large optimization problems with linear constraints**

   Ion Necoara (ion.necoara@acse.pub.ro) Automation and Systems Engineering Department, University Politehnica Bucharest, Romania, *Yurii Nesterov*, *François Glineur*

We present a random block coordinate descent method suited for large convex optimization problems in networks where the information cannot be gather centrally, but rather the information is distributed over the network. Moreover, we focus on optimization problems with linearly coupled constraints (i.e. the constraint set is coupled). Due to the coupling in the constraints we introduce a 2-block variant of random coordinate descent method, that involves at each iteration the closed form solution of an optimization problem only with respect to two block variables while keeping all the other fixed. We prove for the new algorithm an expected convergence rate of order $O(1/k)$ for the function values, where k is the number of iterations. We focus on how to design the probabilities to make this algorithm to converge as fast as possible and we prove that this problem can be recast as a sparse SDP. We also show that for functions with cheap coordinate derivatives the new method is much faster than schemes based on full gradient information. Analysis for rate of convergence in probability is also provided. For strongly convex functions we prove that the new method converges linearly. While the most obvious benefit of randomization is that it can lead to faster algorithms, there are also other benefits of our algorithm. For example, the use of randomization leads to a simpler algorithm, produces a more robust output and can be organized to exploit modern computational architectures.

■ Mon.C.22

Monday, 16:30-18:00, Room 2.2

First order methods

Cluster: Convex and nonsmooth optimization
Session chair: *Marc Teboulle*

1. **A unified framework of subgradient algorithms for convex optimization problems**

   Masaru Ito (ito1@is.titech.ac.jp) Tokyo Institute of Technology, Japan

We firstly consider subgradient algorithms for non-smooth convex optimization problems whose feasible region is simple enough. We propose an extended version of the Mirror-Descent (MD) algorithm which was originally proposed by Nemirovsky and Yudin. We also consider some ideas of Nesterov's Dual-Averaging (DA) algorithm. These algorithms have similar complexity bounds for the number of iterations as the original algorithms. Our approach provides more simple analysis for the DA algorithm than original one and yields similar results for the extended MD algorithm. This assertion is also valid for algorithms which we develop for other problem classes. Secondly, we can solve structured convex optimization problems, which include the smooth optimization problem whose objective function has a Lipschitz continuous gradient, by these new algorithms. These algorithms solve only one auxiliary subproblem at each iteration.

2. **A novel approach for analyzing the performance of first-order methods**

   Yoel Drori (dyoel@post.tau.ac.il) Tel-Aviv University, Israel, *Marc Teboulle*

We introduce a novel approach for analyzing the performance of first-order black-box optimization methods. Following the seminal work of Nemirovski and Yudin (1983) in the complexity analysis of convex optimization methods, we measure the computational cost based on the oracle model of optimization. Building on this model, our approach relies on the observation that by definition, the worst case behavior of a black-box optimization method is by itself an optimization problem, which we call the Performance Estimation Problem (PEP). We analyze the properties of the resulting PEP for various black-box first order schemes. This allows us to prove a new tight analytical bound for the classical gradient method, as well as to derive numerical bounds that can be efficiently computed for a broad class of first order schemes. Moreover, we derive an efficient procedure for finding step sizes which produces a first-order black-box method that achieves best performance.

3. **Regularized interior proximal alternating directions method**

   Natalia Ruiz (nruiz@dim.uchile.cl) Universidad de Chile, Chile, *Felipe Alvarez*

We consider convex constrained optimization problems with a special separable structure. We propose a class of alternating directions methods (ADM) where their subproblems are regularized with a general interior proximal metric which covers double regularization proposed by Silva and Eckstain. Under standard assumptions, global convergence of the primal-dual sequences produced by the algorithm is established.

■ Mon.C.24

Monday, 16:30-18:00, Room 2.4, Organized Session

Computational methods for inverse problems II

Cluster: PDE-constrained optimization
Session organized by: *Noemi Petra, Antoine Laurain*

1. **A generalized Chambolle and Pock algorithm for Tikhonov regularization in Banach spaces and application to phase-retrieval problems**

   Carolin Homann (c.homann@math.uni-goettingen.de) Georg-August-Universität Göttingen, Institut für Numerische und Angewandte Mathematik, Germany, *Thorsten Hohage*

For solving linear ill-posed problems $Tx = y$ in Banach spaces X, Y, with linear, continuous operator T mapping from X to Y, Tikhonov regularization is a commonly used method. We consider Tikhonov functionals of the general form $F(x) = S(y; Tx) + aR(x)$, where S describes the data fidelity functional, R the penalty term (both assumed to be proper, convex and lower semicontinuous) and $a > 0$ is the regularization parameter. If X and Y are Hilbert spaces the Tikhonov functional can be efficiently minimized by the first-order primal-dual algorithm of Chambolle and Pock. In this talk we present a generalization of this algorithm to Banach spaces. Moreover, under certain conditions we prove strong convergence as well as convergence rates. For a nonlinear Fréchet differentiable operator T the solution of the operator equation $Tx = y$ can be recovered by the iteratively regularized Newton-type method, consisting in the minimization of a Tikhonov functional with the same properties as above in each iteration step, such that the proposed method is applicable as well. In particular, we discuss the use of this method to solve phase-retrieval problems.

2. **Computational methods for Bayesian inverse problems governed by PDEs**

   Noemi Petra (noemi@ices.utexas.edu) University of Texas at Austin, USA, *James Martin*, *Georg Stadler*, *Omar Ghattas*

We address the problem of quantifying uncertainty in the solution of inverse problems governed by Stokes models of ice sheet flows within the framework of Bayesian inference. Our goal is to infer the basal sliding coefficient from surface velocity observations and prior information. Computing the maximum a posteriori (MAP) estimate of the posterior basal sliding distribution requires the solution of a large-scale optimization problem subject to the Stokes equation. The optimization problem is solved with an efficient adjoint-based Newton-conjugate gradient method, which uses first and second derivative information of the negative log posterior. The posterior probability density is explored using a stochastic Newton MCMC sampling method that employs local Gaussian approximations based on gradients and Hessians (of the log posterior) as proposal densities. The method is applied to quantify uncertainties in the inference of basal boundary conditions for ice sheet models.

3. **Optimal actuator and sensor placement for dynamical systems**

   Carsten Schäfer (cschaefer@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

Vibrations occur in many areas of industry and produce undesirable side effects. To avoid respectively suppress these effects actuators and sensors are attached to the structure. Actuators can transfer forces into the structure. This can be used to control the system behavior of the structure in order to achieve, for example, vibration absorption, noise reduction and/or exact positioning. Sensors observe the deformations of the structure. The appropriate positioning of actuators and sensors is of significant importance for the controllability and observability of the structure. In this talk, a method for determining the optimal actuator and sensor placement is presented. We consider applications, where the dynamics of a system can be described by a finite dimensional, controllable and observable state-space model. The concept of controllability and observability by Kálmán forms the basis for the definition of controllability and observability measures. In this context, the controllability and observability gramian matrix plays an important role. In our approach actuators and sensors are placed in such a way that a combination of the selected controllability and observability measure becomes maximal. This leads to an optimization problem with binary and continuous variables and linear matrix inequalities. The numerical results show the optimal actuator and sensor placement for a two dimensional flexible clamped plate.

■ Mon.C.25

Monday, 16:30-18:00, Room 2.5, Organized Session

Variational and convex analysis

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Alejandro Jofré*

1. **The Hahn-Banach Lagrange theorem**

   Stephen Simons (simons@math.ucsb.edu) University of California Santa Barbara, USA

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 proof of Rockafellar's version of the Fenchel duality theorem and, as time permits, an explicit sharp lower bound for the norm of the solutions of the Fenchel duality theorem in terms of elementary geometric concepts.

2. **Conditions for zero duality gap in convex programming**

   Regina Burachik (regina.burachik@unisa.edu.au) School of Information Technology and Mathematical Sciences, University of South Australia, Australia, *Jonathan M. Borwein*, *Liangjin Yao*

We introduce and study a new dual condition which characterizes zero duality gap in nonsmooth convex optimization. We prove that our condition is weaker than all existing constraint qualifications, including the closed epigraph condition. Our dual condition was inspired by, and is weaker than, the so-called Bertsekas' condition for monotropic programming problems. We give several corollaries of our result and special cases as applications. We pay special attention to the polyhedral and sublinear cases, and their implications in convex optimization.

3. **On the calmness property in linear semi-infinite optimization**

   Abderrahim Hantoute (ahantoute@dim.uchile.cl) CMM - Center For Mathematical Modeling - Universidad de Chile, Chile, *M. J. Canovas*, *J. Parra*, *J. Toldeo*

We present a new characterization of the so-called calmness property of the Argmin mapping of a semi-linear linear problem. This criteria is given explicitly by means of the problem data; that is, the linear parts inside the optimization problem. Our tools come from convex analysis due to the natural relationship between the calmness property and the existence of error bounds of some related system.

■ Mon.C.AB

Monday, 16:30-18:00, Amphitheater B, Organized Session

Nonlinear optimization III

Cluster: Nonlinear optimization
Session organized by: *Daniel P. Robinson, Philip E. Gill, Nick Gould*

1. **Sequential quadratic optimization with inexact subproblem solves**

   Frank E. Curtis (frank.e.curtis@gmail.com) Lehigh University, USA, *Travis Johnson*, *Daniel P. Robinson*, *Andreas Waechter*

We present a sequential quadratic optimization algorithm for solving nonlinear constrained optimization problems. The unique feature of the algorithm is that inexactness is allowed when solving the arising quadratic subproblems. Easily implementable inexactness criteria for the subproblem solver are established that ensure global convergence guarantees for the overall algorithm. This work represents a step toward scalable active-set methods for large-scale Nonlinear optimization.

2. **Complementarity formulations for $l0$-norm optimization problems**

   Andreas Waechter (waechter@iems.northwestern.edu) Northwestern University, USA, *John E. Mitchell*, *Jong-Shi Pang*, *Mingbin Feng*, *Lijie Bai*, *Xin Shen*

In a number of applications, such as compressive sensing, it is desirable to obtain sparse solutions. Minimizing the number of nonzeroes of the solution (its $l0$-norm) is a difficult nonconvex optimization problem, and is often approximated by the convex problem of minimizing the $l1$-norm. In contrast, we consider an exact formulation as a mathematical program with complementarity constraints. We discuss properties of the exact formulation such as stationarity conditions, and solution procedures for determining local and global optimality. We compare our solutions with those from an $l1$-norm formulation.

3. **A BFGS-based SQP method for constrained nonsmooth, nonconvex optimization**

   Tim Mitchell (tim.mitchell@cims.nyu.edu) Courant Institute of Mathematical Sciences, New York University, New York, USA, *Frank E. Curtis*, *Michael L. Overton*

We consider constrained nonsmooth, nonconvex optimization problems, where both the objective and the constraints may be nonsmooth and nonconvex and are not assumed to have any special structure. In 2012, Curtis and Overton presented a gradient-sampling-based SQP algorithm with a steering strategy to control exact penalty penalization, proving convergence results that generalize the results of Burke, Lewis and Overton and Kiwiel for the unconstrained problem. This algorithm uses BFGS approximation to define a "Hessian" matrix H that appears in the QPs, but in order to obtain convergence results, upper and lower bounds on the eigenvalues of H must be enforced. On the other hand, Lewis and Overton have argued that in the unconstrained case, a simple BFGS method is much more efficient in practice than gradient sampling, although the Hessian approximation H typically becomes very ill conditioned and no general convergence results are known. We consider an SQP method for the constrained problem based on BFGS approximation without gradient sampling, and ask the question: does allowing ill-conditioning in H lead to the same desirable convergence behavior in practice as in the unconstrained case, or does the disadvantage of solving ill-conditioned QPs overcome any benefit gained by ill-conditioning? We test the algorithm on some simple examples as well as some challenging applied problems from feedback control.

■ Tue.A.11

Tuesday, 11:30-13:00, Room 1.1, Organized Session

Algebraic geometry and semidefinite programming II

Cluster: Conic and polynomial optimization
Session organized by: *Lek-Heng Lim, Cordian Riener*

1. **From approximate factorizations to approximate lifts**

   João Gouveia (jgouveia@mat.uc.pt) University of Coimbra, Portugal, *Pablo Parrilo*, *Rekha Thomas*

Recently there has been a renewed interest on the relationship between efficient conic representations of a polytope and (exact) cone factorizations of its slack matrix. Since in practice, one only obtains numerical approximations of cone factorizations, the question of what do these approximations imply in terms of representing the polytope gains importance. In this talk we will present inner and outer convex approximations of a polytope obtained from approximate cone factorizations of a slack matrix of the polytope, and show that if the quality of the approximated factorization is good, so is the approximated lift.

2. **Positive semidefinite diagonal minus tail forms are sums of squares**

   Alexander Kovačec (kovacec@mat.uc.pt) Department of Mathematics, University of Coimbra, Portugal, *Carla Fidalgo*

By a *diagonal minus tail* form (of even degree) we understand a real homogeneous polynomial $F(x_1,\ldots,x_n) = F(x) = D(x) - T(x)$, where the *diagonal* part $D(x)$ is a sum of terms of the form $b_i x_i^{2d}$ with all $b_i \geq 0$ and the *tail* $T(x)$ a sum of terms $a_{i_1 i_2 \cdots i_n} x_1^{i_1} \cdots x_n^{i_n}$ with $a_{i_1 i_2 \cdots i_n} > 0$ and at least two $i_\nu \geq 1$. We show that an arbitrary change of the signs of the tail terms of a positive semidefinite diagonal minus tail form will result in a sum of squares of polynomials. We also give an easily tested sufficient condition for a polynomial to be a sum of squares of polynomials (sos) and show that the class of polynomials passing this test is wider than the class passing Lasserre's recent conditions. Another sufficient condition for a polynomial to be sos, like Lasserre's piecewise linear in its coefficients, is also given. This work was completed in 2011. We also will report on refinements found a year later by Ghasemi and Marshall.

3. **Conic programming: Genericity results and order of solution**

   Bolor Jargalsaikhan (b.jargalsaikhan@rug.nl) University of Groningen, The Netherlands, *Mirjam Dür*, *Georg Still*

We consider generic properties of conic programs like SDPs and copositive programs. In this context, a property is called generic, if it holds for "almost all" problem instances. Genericity of properties like non-degeneracy and strict complementarity of solutions has been studied before. In this talk, we discuss genericity of Slater's condition in conic programs. We also discuss the order of the solutions in SDP and copositive problems, which has important consequences for the convergence rate in discretization methods.

■ Tue.A.12

Tuesday, 11:30-13:00, Room 1.2, Organized Session

Regularization with polyhedral norms

Cluster: Sparse optimization and information processing
Session organized by: *Dirk Lorenz*

1. **Exact regularization of polyhedral norms**

   Frank Schöpfer (frank.schoepfer@uni-oldenburg.de) Universität Oldenburg, Germany

We are concerned with linearly constrained convex programs with polyhedral norm as objective function. Friedlander and Tseng [SIAM J. Optim., 18 (2007), pp. 1326–1350] have shown that there exists an exact regularization parameter for the associated regularized problems. Possible values of the exact regularization parameter will in general depend on the given right-hand sides of the linear constraint and are a priori unknown. We show that by taking the square of a polyhedral norm in the regularized objective function there exists an exact regularization parameter independent of the given right-hand sides. In the 1-norm case, where one is interested in finding sparse solutions of underdetermined systems of equations, we give explicit expressions for exact regularization parameters, provided that the expected number of nonzeros of the solution is less than some upper bound. Furthermore we show that in general an analogues result does not hold for the nuclear norm, but that exact regularization is still possible in certain cases for low rank solutions of matrix equations.

2. **Multiscale methods for polyhedral regularizations**

   Michael Möller (m.moeller@gmx.net) WWU Münster, Germany, *Martin Burger*, *Stanley Osher*

This talk deals with the differential inclusion called the inverse scale space flow, which can be interpreted as the continuous formulation of Bregman iteration. We will derive a numerical method that uses the flow to compute ℓ^1 minimizing solutions to linear systems very efficiently. It will be shown that the same concept of the inverse scale space flow yielding piecewise constant solutions applies to arbitrary polyhedral functions. We analyze the convergence of the numerical method that solves the inverse scale space flow and include the well known (forward) scale space flow in our analysis by interpreting it as the inverse scale space flow on the convex conjugate functional.

3. **The linearized Bregman method and its generalizations as an algorithm for split feasibility problems**

   Dirk Lorenz (d.lorenz@tu-braunschweig.de) TU Braunschweig, Germany, *Frank Schöpfer*

This talk deals with the differential inclusion called the inverse scale space flow, which can be interpreted as the continuous formulation of Bregman iteration. We will derive a numerical method that uses the flow to compute ℓ^1 minimizing solutions to linear systems very efficiently. It will be shown that the same concept of the inverse scale space flow yielding piecewise constant solutions applies to arbitrary polyhedral functions. We analyze the convergence of the numerical method that solves the inverse scale space flow and include the well known (forward) scale space flow in our analysis by interpreting it as the inverse scale space flow on the convex conjugate functional.

■ Tue.A.13

Tuesday, 11:30-13:00, Room 1.3

Nonlinear optimization: Optimality conditions

Cluster: Nonlinear optimization
Session chair: *Olga Brezhneva*

1. **Optimality conditions in nonconvex nonsmooth optimization**

   Refail Kasimbeyli (rkasimbeyli@anadolu.edu.tr) Anadolu University, Eskişehir, Turkey

This talk presents an extension of the concept of dual cones and introduces the notion of augmented dual cones. We show that the supporting and separation philosophy based on hyperplanes can be extended to a nonconvex analysis by using elements of these cones. A special class of monotone sublinear functions is introduced with the help of elements of augmented dual cones. We introduce the separation property and present the separation theorem which enables to separate two cones (one of them is not necessarily convex, having only the vertex in common) by a level set of some monotonically increasing sublinear function. By using the new separation philosophy, we introduce the notions of radial epiderivatives and weak subgradients for nonconvex real-valued functions and study relations between them and the directional derivatives. The well-known necessary and sufficient optimality condition of nonsmooth convex optimization given in the form of variational inequality is generalized to the nonconvex case by using the notion of weak subdifferentials. The equivalent formulation of this condition in terms of weak subdifferentials and augmented normal cones is also presented.

2. **Generalized convexity and local-global minimum property of nonlinear optimization problems**

   Pál Burai (burai@math.tu-berlin.de) Technische Universität Berlin Institut für Mathematik, Germany

We investigate two generalized convexity notations, which contain arcwise connectedness, convexity with respect to a differential equation, and geodesic convexity. The properties and use of these in optimization theory are examined. The corresponding directional derivative notation is introduced and first order optimality condition is derived. Lastly some applications are shown.

3. **Short and elementary proofs of the Karush-Kuhn-Tucker, Lagrange multiplier, and implicit function theorems**

   Olga Brezhneva (brezhnoa@miamioh.edu) Miami University, USA, *Alexey A. Tret'yakov*, *Stephen E. Wright*

We present short and elementary proofs of the Karush-Kuhn-Tucker Theorem for problems with nonlinear inequality constraints and linear equality constraints, the Lagrange Multiplier Theorem for equality-constrained optimization problems, and an Implicit Function Theorem. Most proofs in the literature rely on advanced concepts of analysis and optimization, whereas elementary proofs tend to be long and involved. By contrast, the presented proofs use only basic results from linear algebra and optimization. Our proof of the Karush-Kuhn-Tucker Theorem is based only on facts from linear algebra and the definition of differentiability. The proofs of the Lagrange Multiplier and Implicit Function theorems use a similar approach and are based on the critical-point condition for unconstrained minima (Fermat's Rule), and a single application of the Weierstrass theorem. The simplicity of the proofs makes them particularly suitable for use in a first undergraduate course in optimization or analysis, and also for courses not aimed specifically at optimization theory, such as mathematical modeling, mathematical methods for science or engineering, problems seminars, or any other circumstance where a quick treatment is required.

■ Tue.A.14

Tuesday, 11:30-13:00, Room 1.4, Organized Session

Algorithms and applications of dynamic MPECs

Cluster: Complementarity and variational inequalities
Session organized by: *Kathrin Hatz, Sven Leyffer*

1. **Optimization of deep drawing processes**

   Stefan Ulbrich (ulbrich@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Daniela Koller*

Hydroforming of sheet metals involves elastoplasticity and frictional contact, which can be modeled by an evolutionary quasi-variational inequality (EVI). The aim is to control the blank holder force and the fluid pressure in such a way that no damages occur during the forming process and that the final shape of the sheet metal product coincides with the desired geometry. The resulting optimization problem is a challenging infinite dimensional MPEC, which leads after discretization to very large scale problems. We consider the modeling of the optimization problem, a semismooth FE-discretization of the EVI and discuss model reduction techniques to reduce the complexity of the discretized EVI. Moreover, we show optimization results for a 3D hydroforming process based on the full FE-discretization, evaluate the accuracy of the reduced order model and discuss a strategy towards an efficient reduced order model based optimization approach.

2. **Distributed aggregative Nash-games on graphs**

   Angelia Nedich (angelia@illinois.edu) UIUC, USA, *Jayash Koshal*, *Uday Shanbhag*

We consider a class of Nash games, termed as aggregative games, being played over a distributed networked system. In an aggregative game, an agent's objective function is coupled through a function of the aggregate of all agents' decisions. Every agent maintains an estimate of the aggregate and agents exchange this information locally with their neighbors over a connected network. We study distributed synchronous and asynchronous algorithms for information exchange and computation of equilibrium decisions of agents over the network. Under some standard conditions on the players' communication graph and the players' step-size choices, for both synchronous and asynchronous update rules, we establish the almost-sure convergence of the algorithms to an equilibrium point. In addition, we also present numerical results to assess the performance of the algorithms.

3. **Numerical methods and computational results for solving hierarchical optimal control problems**

   Kathrin Hatz (kathrin.hatz@iwr.uni-heidelberg.de) Interdisciplinary Center for Scientific Computing, Heidelberg University, Germany, *Sven Leyffer*, *Johannes P. Schloeder*, *Hans Georg Bock*

We present numerical methods for hierarchical dynamic optimization problems. The problem setting is the following: A regression objective on the upper level and a nonlinear optimal control problem (OCP) in ordinary differential equations with discontinuities and mixed path-control constraints on the lower level. The OCP can be considered as a model (a so-called optimal control model (OCM)) that describes optimal processes in nature, such as human gait. However, the optimal control model includes unknown parameters that have to be determined by fitting the OCM to measurements (which is the upper level optimization problem). We present an efficient direct all-at once approach for solving this new class of problems. The main idea is the following: We discretize the infinite dimensional bilevel problem where we use multiple shooting for the state discretization, replace the lower level nonlinear program (NLP) by its first order necessary conditions (KKT conditions), and solve the resulting complex NLP, which includes first order derivatives and a complementarity constraint, with a tailored sequential quadratic programming (SQP) method. The complementarity constraint is treated by a new lifting technique that will be discussed in detail. We have implemented this approach and use it to identify an optimal control model for a cerebral palsy patient from real-world motion capture data that has been provided by the Motion Lab of the Orthopaedic Clinics Heidelberg.

■ Tue.A.15

Tuesday, 11:30-13:00, Room 1.5, Organized Session

New derivative-free nonlinear optimization algorithms

Cluster: Derivative-free and simulation-based optimization
Session organized by: *José Mario Martínez*

1. **CANCELLED**

2. **A method for nonlinear least-squares problems based on simplex derivatives**

   Maria A. Diniz-Ehrhardt (cheti@ime.unicamp.br) Department of Applied Mathematics, State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, *V. L. R. Lopes*, *Lucas Garcia Pedroso*

We propose a derivative-free method for nonlinear least-squares problems. It is a Gauss-Newton-like algorithm, in which we use simplex derivatives instead of the Jacobian of the residual function. So, whereas the Gauss-Newton algorithm aproximates F(x) by a first-order Taylor polynomial at the current iterate, our approach utilizes an affine function which interpolates F(x) in n+1 previously chosen points. An analysis about the best choice for these points is done. In order to obtain convergence results, we apply a nonmonotone line-search technique introduced by Diniz-Ehrhardt, Martínez and Raydan, in 2008. Numerical experiments are presented.

3. **A derivative-free trust-region method for nonlinear programming**

   Lucas Garcia Pedroso (lucaspedroso@ufpr.br) UFPR (Federal University of Paraná), Brazil, *Paulo Domingos Conejo*, *Elizabeth Wegner Karas*, *Ademir Alves Ribeiro*, *Mael Sachine*

In this work we propose a trust-region algorithm for the problem of minimizing a function within a convex closed domain. We assume that the objective function is differentiable but no derivatives are available. The algorithm has a very simple structure and allows a great deal of freedom in the choice of the quadratic models. Under reasonable assumptions for derivative-free schemes, we prove global convergence for the algorithm, that is to say, that all accumulation points of the sequence generated by the algorithm are stationary.

■ Tue.A.16

Tuesday, 11:30-13:00, Room 1.6, Organized Session

Global optimization with differential equations embedded

Cluster: Global optimization and mixed-integer programming
Session organized by: *Paul I. Barton*

1. **Relaxing dynamic optimization problems: Convergence, clustering, and the effect of time**

   Joseph K. Scott (jkscott@mit.edu) Process Systems Engineering Laboratory, Massachusetts Institute of Technology, USA, *Paul I. Barton*, *Spencer D. Schaber*, *Achim Wechsung*

Modern global optimization algorithms involve the construction of convex underestimating programs, termed convex relaxations. For dynamic optimization problems, this relaxation procedure poses unique challenges and has been the subject of several recent articles. In this talk, we review some existing relaxation procedures for dynamic problems and investigate the use of a convergence metric for evaluating their usefulness. Using numerical results and recent developments in convergence analysis, we argue that standard metrics for nonlinear programs may not be sufficient; there is a complicating factor, related to time (the independent variable of the dynamic system), that is unique to dynamic problems. This observation is corroborated by recent advances in the analysis of the so-called cluster effect. Combined, these observations suggest a new design goal for dynamic relaxation procedures.

2. **Branch-and-lift algorithm for deterministic global optimization in nonlinear optimal control**

   Benoit Chachuat (b.chachuat@imperial.ac.uk) Imperial College London, UK, *Boris Houska*

We present a branch-and-lift algorithm for solving optimal control problems with smooth nonlinear dynamics and potentially nonconvex objective and constraint functionals to guaranteed global optimality. This algorithm features a direct sequential method and builds upon a spatial branch-and-bound algorithm. It introduces a new operation, called lifting, which refines the control parameterization via a Gram-Schmidt orthogonalization process, while simultaneously eliminating control subregions that are either infeasible or that provably cannot contain any global optima. We discuss conditions under which the image of the control parameterization error in the state space contracts exponentially as the parameterization order is increased, thereby making the lifting operation efficient, and then present a computational technique based on ellipsoidal calculus that satisfies these conditions. We also analyze the convergence properties of the branch-and-lift algorithm. Finally, we illustrate the practical applicability of branch-and-lift with numerical examples.

3. **Global optimal control using direct multiple shooting**

   Holger Diedam (holger.diedam@iwr.uni-heidelberg.de) Interdisciplinary Center for Scientific Computing, Heidelberg University, Germany, *Sebastian Sager*

We present recent results concerning Bock's direct multiple shooting method in the context of deterministic global optimal control. The introduction of artificial intermediate start values lifts the optimization problem to a higher dimensional space, compared to direct single shooting. At first sight, this looks like a very bad idea, as spatial branching schemes need to branch on more variables. Yet this lifting may yield significant advantages concerning the number of nodes to be processed and overall computation time, in addition to well-known features such as possibly improved local convergence rates, an improved stability, use of a-priori information for initial values, and effective parallelization. We shed some light on the issue why the lifting may also be beneficial concerning the size of the branching tree and illustrate the potential by application to benchmark problems from the literature.

■ Tue.A.17

Tuesday, 11:30-13:00, Room 1.7, Organized Session

Optimization for data analysis and assimilation

Cluster: Applications of continuous optimization in science and engineering
Session organized by: *Mihai Anitescu*

1. **Second order methods for sparse signal reconstruction**

   Kimon Fountoulakis (K.Fountoulakis@sms.ed.ac.uk) University of Edinburgh, UK, *Jacek Gondzio*

There has been an increased interest in simple LASSO problems arising in sparse signal reconstruction. The scientific community seems to favour first-order methods to solve these problems. In this talk we will address a broader family of problems which include total-variation minimization, L1-analysis, the combinations of those two and finally other Dantzig-selector alternatives. We will argue that such problems challenge first-order methods but can be solved efficiently with specially designed second-order methods. We will provide theoretical analysis and computational evidence to illustrate our findings.

2. **Parallel solution of large-scale nonlinear parameter estimation problems**

   Daniel P. Word (dword@tamu.edu) Texas A&M University, Department of Chemical Engineering, USA, *Jia Kang*, *Jean-Paul Watson*, *David L. Woodruff*, *Johan Åkesson*, *Carl D. Laird*

Reliable parameter estimation of nonlinear systems can aid scientific discovery, improve understanding of fundamental processes, and provide effective models for subsequent optimization. The success of these nonlinear programming techniques for parameter estimation has led to continued problem size increases as we improve model rigor and complexity. The growth of these optimization problems continues to outpace the capabilities of serial solution approaches to solve these problems on modern desktop computers, which drives the development of efficient parallel solution algorithms. Fortunately, while these problems are large-scale, they are inherently block structured. Common block structures arise in a number of problem types, including dynamic optimization, parameter estimation, and nonlinear stochastic programming. Many tools and algorithms have been developed to exploit the block structure and solve the NLP in parallel. In this presentation, we will present two approaches for efficient parallel solution of very large-scale nonlinear parameter estimation problems; a progressive hedging approach, and an implicit Schur-complement decomposition based on parallel solution of the KKT system arising in interior-point methods. We will show timing and speedup results for several estimation problems on both shared and distributed computing architectures, and provide conclusions regarding the implementation and performance of these two methods.

3. **Preconditioning of linear systems with multiple right hand sides**

   Selime Gurol (gurol.selime@gmail.com) ECMWF / CERFACS, France, *Serge Gratton*, *Philippe Toint*

We consider to apply the preconditioned conjugate-gradient method to a convergent sequence of symmetric and positive definite linear systems with multiple right hand sides where preconditioning is achieved by using the Limited Memory Preconditioners (LMPs). The LMP for each system matrix is obtained by using directions generated during solving the previous linear systems. These linear systems can be equivalently solved by using a dual approach, which can yield gains in terms of both memory usage and computational effort. A dual-space counterpart of the LMPs generating mathematically equivalent iterates to those of the primal approach is derived. After briefly presenting the particular LMPs such as the Ritz LMP, the spectral LMP and the quasi-Newton LMP for the dual approach, we focus on the quasi-Newton LMP and analyze its properties. Numerical experiments are finally presented using a toy problem based on a data assimilation system.

■ Tue.A.18

Tuesday, 11:30-13:00, Room 1.8, Organized Session

Recent advances in stochastic programming

Cluster: Stochastic optimization
Session organized by: *Nilay Noyan*

1. **OR inspirations for stochastic shape optimisation**

   Ruediger Schultz (ruediger.schultz@uni-due.de) University of Duisburg-Essen, Faculty of Mathematics, Germany

The talk deals with shape optimization of elastic bodies with linearized elasticity under stochastic volume and surface loads. Following analogues from finite-dimensional stochastic programming we develop risk neutral and risk averse stochastic shape optimization models. With focus on stochastic dominance relations we present model variants together with algorithms and preliminary computational results.

2. **Bounds in mulststage stochastic programming**

   Francesca Maggioni (francesca.maggioni@unibg.it) Department of Management, Economics and Quantitative Methods, University of Bergamo, Italy, *Elisabetta Allevi*, *Marida Bertocchi*

Multistage stochastic programs, which involve sequences of decisions over time, are usually hard to solve in realistically sized problems. Providing bounds for their optimal solution, may help in evaluating whether it is worth the additional computations for the stochastic program versus simplified approaches. In this talk we generalize the value of information gained from deterministic, pair solutions and rolling-horizon approximation in the two-stage linear case [1]-[2] to the multistage stochastic formulation both in the linear [3] and non-linear cases [5]. We show that theorems proved for two stage case are valid also in the multi-stage case. New measures of quality of the average solution are of practical relevance [4]. Numerical results on a transportation problem illustrate the relationships. References 1. Birge, J.R.: The Value of the Stochastic Solution in Stochastic Linear Programs with Fixed Recourse, Math. Prog., 24, 314–325 (1982). 2. Escudero, L.F., Garín, A., Merino, M., Pérez, G.: The Value of the Stochastic Solution in Multistage Problems, Top, 15, 48–64 (2007). 3. Maggioni, F. Allevi, E. Bertocchi, M. The Value of Information in Multistage Linear Stochastic Programming (submitted to JOTA). 4. Maggioni, F., Wallace, W.S.: Analyzing the Quality of the Expected Value Solution in Stochastic Programming, AOR, 200(1), 37–54 (2012). 5. Maggioni, F., Pflug, G.: Bounds and Approximations for Multistage Stochastic Programs (in preparation).

3. **Optimization with multivariate conditional value-at-risk constraints**

   Nilay Noyan (nnoyan@sabanciuniv.edu) Sabanci University, Turkey, *Gabor Rudolf*

For many decision making problems under uncertainty, it is crucial to develop risk-averse models and specify the decision makers' risk preferences based on multiple stochastic performance measures. Incorporating such multivariate preference rules into optimization models is a fairly recent research area. Existing studies focus on extending univariate stochastic dominance rules to the multivariate case. However, enforcing multivariate stochastic dominance constraints can often be overly conservative in practice. As an alternative, we focus on the widely-applied risk measure conditional value-at-risk (CVaR), introduce a multivariate CVaR relation, and develop an optimization model with multivariate CVaR constraints based on polyhedral scalarization. To solve such problems for finite probability spaces we develop a finitely convergent cut generation algorithm, where each cut is obtained by solving a mixed integer problem. We show that our results can be naturally extended to a wider class of coherent risk measures. The proposed approach provides a flexible, and computationally tractable way of modeling preferences in stochastic multi-criteria decision making. We conduct a computational study for a budget allocation problem to illustrate the effect of enforcing multivariate CVaR constraints and demonstrate the computational performance of the proposed solution methods.

■ Tue.A.21

Tuesday, 11:30-13:00, Room 2.1, Organized Session

Structural aspects in nonsmooth optimization

Cluster: Convex and nonsmooth optimization
Session organized by: *Vladimir Shikhman*

1. **Smoothness properties of a regularized gap function for quasi-variational inequalities**

   Oliver Stein (stein@kit.edu) Institute of Operations Research, Karlsruhe Institute of Technology (KIT), Germany, *Nadja Harms*, *Christian Kanzow*

We study continuity and differentiability properties for a reformulation of a finite-dimensional quasi-variational inequality (QVI) problem using a regularized gap function approach. Since the regularized gap function is nonsmooth in general, we take a closer look at its nondifferentiability points and show, in particular, that under mild assumptions all locally minimal points of the reformulation are, in fact, differentiability points. The results are specialized to generalized Nash equilibrium problems, and consequences for numerical methods are discussed.

2. **Global optimization of generalized semi-infinite programs via restriction of the right hand side**

   Alexander Mitsos (amitsos@alum.mit.edu) RWTH Aachen University, Germany, *Angelos Tsoukalas*

An algorithm is proposed for the global solution of generalized semi-infinite programs (GSIPs) without convexity assumptions. It is an extension of the algorithm in [A. Mitsos. Global optimization of semi-infinite programs via restriction of the right hand side. Optimization, 60(10-11):1291–1308, 2011] which in turn can be seen as a feasible-point adaptation of [J. W. Blankenship and J. E. Falk. Infinitely constrained optimization problems. Journal of Optimization Theory and Applications, 19(2):261–281, 1976.]. Under mild assumptions compared to alternative algorithms, the algorithm terminates finitely with a guaranteed feasible point, and a certificate of ε^f-optimality. It is based on solving a series of regular nonlinear programs (NLP), thus shifting the nonconvexity to the global NLP solver. The main idea of generating feasible points is a restriction of the constraints right-hand-side by progressively smaller $\varepsilon^g > 0$ and a successively finer discretization of the parameter set. The theoretical properties are discussed and numerical results are given.

■ Tue.A.22

Tuesday, 11:30-13:00, Room 2.2, Organized Session

Distributed algorithms for constrained convex problems over networks

Cluster: Convex and nonsmooth optimization

Session organized by: *Ion Necoara*

1. **Random projection algorithms for distributed optimization**

   Soomin Lee (lee203@illinois.edu) University of Illinois, Urbana-Champaign, USA, *Angelia Nedich*

We develop and analyze efficient distributed algorithms for a constrained convex optimization problem over a multi-agent network where each agent has its own objective function and constraint set. We propose gradient descent algorithms with random projections under various communication protocols. With standard assumptions, we prove that the iterates of all agents converge to the same point in the optimal set with probability 1. In addition, we consider a variant of the method that uses a mini-batch of consecutive random projections and establish its convergence. We also provide experimental results to demonstrate the efficiency of the algorithms.

2. **Fast decomposition algorithms for large-scale separable convex optimization**

   Quoc Tran Dinh (quoc.trandinh@epfl.ch) Laboratory for Information and Inference Systems, EPFL, Lausanne, Switzerland, *Ion Necoara*, *Moritz Diehl*

In this talk we propose a new dual decomposition algorithm for solving large-scale separable convex optimization problems. This algorithm is a combination of three techniques: dual Lagrangian decomposition, smoothing and excessive gap. The algorithm requires only one primal step and two dual steps at each iteration. While the primal step of the algorithm can be done in parallel, the dual step is only matrix vector multiplication. Moreover, the algorithmic parameters are updated automatically without any tuning strategy as in augmented Lagrangian approaches. We analyze the convergence of the algorithm and estimate its $O(1/e)$ worst-case complexity. We then combine this algorithm and the two primal step scheme to obtain a primal-dual switching variant. We discuss the implementation of these algorithms such as distributed implementation as well as inexact variants. Numerical examples are implemented to verify the theoretical development.

3. **Linear convergence rate of a class of distributed augmented Lagrangian algorithms**

   Dusan Jakovetic (djakovet@andrew.cmu.edu) Instituto Superior Técnico, ISR, Lisbon, Portugal; and Carnegie Mellon University, Pittsburgh, Pennsylvania, USA, *José M. F. Moura*, *João Xavier*

We consider distributed optimization where N nodes in a network minimize the sum of their individual convex costs subject to a global optimization variable. Such problems encompass many relevant applications like distributed inference, source localization in sensor networks, and distributed machine learning. We show a globally linear convergence rate for a class of distributed augmented Lagrangian algorithms, when the nodes' local costs are twice continuously differentiable and have a bounded Hessian. Further, unlike most of the existing work, we give explicitly the dependence of the convergence rate on the topology (algebraic connectivity) of the underlying network. Numerical simulations confirm the analytical results.

■ Tue.A.24

Tuesday, 11:30-13:00, Room 2.4, Organized Session

Computational methods for inverse problems I

Cluster: PDE-constrained optimization

Session organized by: *Noemi Petra, Antoine Laurain*

1. **Sparse tomography**

   Ville Kolehmainen (Ville.Kolehmainen@uef.fi) University of Eastern Finland, Finland, *Kati Niinimäki*, *Samuli Siltanen*, *Matti Lassas*

We propose a wavelet-based sparsity-promoting reconstruction method to x-ray tomography with limited projection data. The reconstruction method is based on minimizing a sum of a data discrepancy term based on 2-norm and a regularizing term consisting of 1-norm of the wavelet coefficients of the unknowns. Depending on viewpoint, the method can be considered (i) as finding the Bayesian MAP estimate using a sparsity promoting Besov space prior, or (ii) as deterministic regularization with a Besov norm penalty. The minimization is performed using a tailored primal-dual path following interior-point method, which is applicable to large-scale problems. The choice of "regularization parameter" is done by a novel technique called the S-curve method, which can be used to incorporate prior information on the sparsity of the unknown target to the reconstruction process. Numerical results are presented using both simulated and experimental x-ray projection data.

2. **Borrowing methods from optimization for the solution of large-scale statistical inverse problems**

   Georg Stadler (georgst@ices.utexas.edu) University of Texas at Austin, USA, *Noemi Petra*, *Marc Hesse*, *Omar Ghattas*

I will discuss the use of optimization methods to approximate the solution of Bayesian statistical inverse problems governed by partial differential equations. Methods based on first and second derivatives are used to locally approximate the posterior densities for the parameters. I will focus on a large-scale subsurface inverse problem.

3. **A shape optimization method for magnetic induction tomography**

   Antoine Laurain (laurain@math.tu-berlin.de) Technical University of Berlin, Germany, *Michael Hintermüller*, *Irwin Yousept*

Magnetic induction tomography (MIT) is a novel technique for non-contacting measurement of electric properties of conducting materials. Potential applications of MIT can be found in medicine such as in brain imaging. The technology of MIT involves an oscillating magnetic field generated by a transmitter coil, which in turn induces an eddy current inside the conducting materials. Then, the magnetic field arising from the eddy current is detected by a receiver coil, which provides measurements of the corresponding electric conductivity. The use of eddy current model in MIT is justified by the small wavelength for its operating frequencies. Typically, the frequencies lie between 10 and 100 MHz, i.e. in the range of some micrometers, so that the wavelength is small compared to the size of the conductor. We study the inverse problem of reconstructing the electric conductivity from measurements in the receiver coil, for an MIT system governed by time-harmonic eddy current equations. The electric conductivity is assumed to be piecewise constant, so that the problem may be recast as a shape optimization problem, where the unknown is the shape of the inclusion whose conductivity is different from the background. The evolution of the shape during the optimization process is achieved using a level set method.

■ Tue.A.25

Tuesday, 11:30-13:00, Room 2.5, Organized Session

Variational analysis and variational inequalities

Cluster: Variational analysis, set-valued and vector optimization

Session organized by: *Jiri Outrata*

1. **Sensitivity analysis of MPECs**

   Michal Cervinka (cervinka@utia.cas.cz) Institute of Information Theory and Automation, Czech Academy of Sciences, Czech Republic, *Miroslav Pistek*, *Jiri Outrata*

We consider parameterized Mathematical Programs with Equilibrium Constraints, where the equilibrium constraints are in the form of nonlinear complementarity conditions. Such problems arise e.g. in Equilibrium problems with Equilibrium Constraints that can be used for modeling deregulated electricity markets. Using coderivative calculus under calmness constraint qualification conditions we analyze the stability of solutions to the respective M-stationarity conditions. To this end, we introduce the second-order coderivative of mappings and provide formula for the second order coderivative to the normal cone mapping of $\mathbb{R}^m_+$.

2. **Optimal control of a rate-independent variational inequality**

   Lukas Adam (lukas.adam@yahoo.com) Czech Academy of Sciences, Czech Republic, *Jiri Outrata*

We study optimal control problems governed by a differential equation and differential rate-independent variational inequality, both with given initial conditions. Under certain conditions, the variational inequality can be reformulated as a differential inclusion with discontinuous right-hand side. This inclusion is known as sweeping process. We perform a discretization scheme and prove the convergence of optimal solutions of the discretized problems to the optimal solution of the original problem. For the discretized problems we study the properties of the solution map and compute its coderivative. Employing an appropriate chain rule, this enables us to compute the subdifferential of the objective function and to apply suitable optimization technique to solve the discretized problems.

■ Tue.A.AB

Tuesday, 11:30-13:00, Amphitheater B, Organized Session

Nonlinear optimization IV

Cluster: Nonlinear optimization

Session organized by: *Daniel P. Robinson, Philip E. Gill, Nick Gould*

1. **A new L-BFGS trust-region subproblem solver**

   Jennifer B. Erway (erwayjb@wfu.edu) Wake Forest University, USA, *Roummel F. Marcia*

The More £-Sorensen sequential (MSS) method computes the minimizer of a quadratic function defined by a limited-memory BFGS matrix subject to a two-norm trust-region constraint. This solver is an adaptation of the More £-Sorensen direct method into an L-BFGS setting for large-scale optimization. The MSS method is a matrix-free iterative method that makes use of a recently proposed stable fast direct method for solving large shifted BFGS systems of equations. Numerical results will be presented.

2. **A primal-dual active set algorithm for nonlinear optimization with polyhedral constraints**

   William Hager (hager@ufl.edu) University of Florida, USA, *Hongchao Zhang*

A primal-dual active set algorithm is developed for Nonlinear optimization with polyhedral constraints. The algorithm consists of a nonmonotone gradient projection phase implemented by dual active set techniques, an unconstrained optimization phase in the subspace determined by the active set, and a set of rules for branching between the two phases. Global convergence to a stationary point is established. For a nondegenerate stationary point, the algorithm eventually reduces to an unconstrained optimization in a subspace without restarts. Similarly, for a degenerate stationary point where the strong second-order sufficient optimality condition holds, the algorithm eventually reduces to unconstrained optimization in a subspace. A specific implementation of the algorithm is given which exploits a new dual active set algorithm for the gradient projection step and the limited memory CG_DESCENT algorithm for unconstrained optimization. Numerical results are presented.

3. **Fast local convergence of interior-point methods in the absence of strict complementarity**

   Dominique Orban (dominique.orban@gerad.ca) GERAD and École Polytechnique de Montréal, Canada, *Zoumana Coulibaly*, *Nick Gould*

We show that when strict complementarity fails to hold at a local solution, appropriate scaling of the primal-dual Lagrange multiplier estimates allows for recovering superlinear convergence in interior-point methods for Nonlinear optimization. The scaling relies on indicator sets that identify strongly active, weakly active and inactive constraints. The rate of convergence can be anywhere between 1 and 3/2 and is determined by the rate of decrease of the barrier parameter.

■ Tue.C.11

Tuesday, 16:30-18:00, Room 1.1, Organized Session

Algebraic geometry and semidefinite programming III

Cluster: Conic and polynomial optimization

Session organized by: *Lek-Heng Lim, Cordian Riener*

1. **Approximation quality of SOS relaxations**

   Pablo Parrilo (parrilo@mit.edu) Massachusetts Institute of Technology, USA

Sums of squares (SOS) relaxations provide efficiently computable lower bounds for minimization of multivariate polynomials. Practical experience has shown that these bounds usually outperform most other available techniques, but a fully satisfactory theoretical justification is still lacking. In this talk, we discuss several results (new and old) about the approximation quality of these SOS bounds, focusing on the case of polynomial optimization on the sphere.

2. **Scaling relationships between the copositive cone and the cone of sum of squares polynomials**

   Luuk Gijben (l.gijben@rug.nl) University of Groningen, The Netherlands, *Peter J. C. Dickinson*, *Mirjam Dür*, *Roland Hildebrand*

Several NP-complete problems can be turned into convex problems by formulating them as optimization problems over the copositive cone. Unfortunately checking membership in the copositive cone is a co-NP-complete problem in itself. To deal with this problem, several approximation schemes have been developed. One of them is a hierarchy of cones introduced by P. Parrilo. Membership of these cones can be checked by deciding whether a certain polynomial can be written as a sum of squares, which can be done via semidefinite programming. It is known that for matrices of order $n < 5$ the zero order Parrilo cone is equal to the copositive cone. In this talk we will investigate the relation between the hierarchy and the copositive cone for order $n > 4$. In particular a surprising result is found for the case $n = 5$, establishing a direct link between the copositive cone and the semidefinite cone of that order.

3. **On the set-semidefinite representation of nonconvex quadratic programs**

   Gabriele Eichfelder (Gabriele.Eichfelder@tu-ilmenau.de) Institute of Mathematics, Ilmenau University of Technology, Germany, *Peter J. C. Dickinson*, *Janez Povh*

In this talk we look on conic reformulations of non-convex optimization problems over some closed set K with a quadratic objective function and with additional linear and binary constraints. We provide a detailed study of two different situations where such an optimization problem can be reformulated as a linear optimization problem over the dual cone of the cone of $(1 \times K)$-semidefinite matrices. Thereby, a matrix M is denoted set-semidefinite w.r.t. some set S if the quadratic form of the matrix is nonnegative on S. The first situation, which assures such a reformulation, requires the boundedness of the optimal value of the conic problem while the second situation requires some assumption on the asymptotic cone of K. These assumptions are for instance satisfied if K is a bounded or convex. They are also satisfied if K is defined by one, possibly non-convex, quadratic inequality. This is a generalization of the completely positive representation results by Burer for K the nonnegative orthant [Mathematical programming 2009] and connects to a result originally provided by Sturm and Zhang [Math. Oper. Res. 2003].

■ Tue.C.12

Tuesday, 16:30-18:00, Room 1.2, Organized Session

Recent advances in conic programming

Cluster: Conic and polynomial optimization

Session organized by: *Imre Pólik*

1. **Rounding solutions in second-order cone programming**

Imre Pólik (imre.polik@gmail.com) SAS Institute

Rounding a nearly optimal solution to an exact optimal one is well-researched in linear programming, but is not straightforward to do in SOCP and SDP in general, mostly due to the fact that those exact solutions may not be representable with algebraic numbers of low degree. In this talk we discuss the peculiarities of the optimal partition in SOCP and show a few ways to round solutions. Numerical experiments show that these techniques apply to a wide range of problems. In particular, we formulate some conjectures on the convergence properties of interior-point methods applied to SOCPs.

2. **CANCELLED**

3. **On the identification of the optimal partition of second order cone optimization problems**

   Tamás Terlaky (terlaky@lehigh.edu) Dept. ISE, Lehigh University, Bethlehem, Pennsylvania, USA, *Zhouhong Wang*

We discuss the identification of the optimal partition of second order cone optimization (SOCO). By giving definitions of two condition numbers which only depend on the SOCO problem itself, we derive some bounds on the magnitude of the blocks of variables along the central path, and prove that the optimal partition $\mathscr{B}$, $\mathscr{N}$, $\mathscr{R}$, and $\mathscr{T}$ for SOCO problems can be identified along the central path when the barrier parameter μ is small enough. Then we generalize the results to a specific neighborhood of the central path.

■ Tue.C.13

Tuesday, 16:30-18:00, Room 1.3, Organized Session

Parallelism and optimality conditions

Cluster: Nonlinear optimization

Session organized by: *Jonathan Eckstein, Paulo J. S. Silva*

1. **Object-parallel implementation of a bound-constrained conjugate gradient solver**

   Jonathan Eckstein (jeckstei@rci.rutgers.edu) Rutgers University, USA

We describe an object-oriented approach to implementing optimization software in C++, and in particular an adaptation of Hager and Zhang's CG_Descent bound-constrained conjugate gradient solver. The goal is to allow the fundamental algorithm to be expressed almost as concisely and naturally as in MATLAB, but with efficient execution both in serial and in parallel, adaptable to different applications and parallel hardware environments. The idea is that the same simple code base may be used both serially and in a variety of parallel applications, without sacrificing efficiency. We describe our use of object-oriented design and operator overloading to attain this design goal, with minimal run-time overhead and avoiding creation of unnecessary temporary vectors. We also describe how the bound-constrained implementation will be incorporated into a more general-purpose solver allowing general nonlinear constraints, using an approximate augmented Lagrangian algorithm.

2. **The role of constant rank in second order constraint qualifications**

   Paulo J. S. Silva (pjssilva@ime.unicamp.br) State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, *Roberto Andreani*, *Roger Behling*, *Gabriel Haeser*

It is well known, at least under the presence of inequality constraints, that strong first order constraint qualifications like Mangasarian-Fromovitz do not ensure the validity of a second order necessary condition. Recent works try to remedy this situation using constant rank assumptions that are weaker than linear independence of all active gradients. Such assumptions usually involve the gradients of all subsets of active inequality constraints. In this work we discuss the role of such constant rank conditions, showing that they can be greatly relaxed even in the presence of inequalities. In particular, it is possible to select a single subset of active inequalities whose good behavior together with all equalities is enough to show that a necessary second order condition holds at a local minimum for any given multiplier.

3. **Slack variables in nonlinear second-order cone programming**

   Ellen H. Fukuda (ellen@ime.usp.br) State University of Campinas, Brazil, *Masao Fukushima*

The use of squared slack variables is well-known in nonlinear programming, making possible to convert a problem with inequality constraints into a problem containing only equality constraints. It is an avoided technique in the optimization community, since the advantages usually do not compensate for the disadvantages, like the increase of the dimension of the problem, the numerical instabilities, and the singularities. The situation changes, however, in nonlinear second-order cone programming, where the strategy has a reasonable advantage. The reformulated problem with squared slack variables has no longer conic constraints, which enables us to deal with the problem as an ordinary nonlinear programming problem. In this work, we establish the relation between the Karush-Kuhn-Tucker points of the original and the reformulated problems by means of the second-order sufficient conditions and regularity conditions.

■ Tue.C.14

Tuesday, 16:30-18:00, Room 1.4, Organized Session

Topics in variational inequalities and Nash games

Cluster: Complementarity and variational inequalities

Session organized by: *Jong-Shi Pang*

1. **Lemke's method for strictly positive linear complementarity problems**

   Todd S. Munson (tmunson@mcs.anl.gov) Argonne National Laboratory, USA

In this talk, we consider computing a nonzero solution to the linear complementarity problem $0 \le x \perp Mx + q \ge 0$ where $q > 0$. We present several formulations of this problem and their properties including one reformulation with a strictly positive matrix for which Lemke's method with appropriate degeneracy resolution is guaranteed to compute a solution. We then apply the standard Lemke method with a ray start as implemented in PATH to random sparse instances from this problem class and detect physical cycles of nonzero length in the path constructed. We then discuss randomization methods to address the degeneracy and show that these problem can be effectively solved.

2. **Complex variational inequalities and applications**

   Francisco Facchinei (facchinei@dis.uniroma1.it) University of Roma La Sapienza, Italy, *Gesualdo Scutari*, *Jong-Shi Pang*, *Daniel P. Palomar*

We introduce and study variational inequalities in the complex domain, along with some technical tools useful in their study. We then extend to the complex domain some recent developments in the field of the distributed solution of (generalized) Nash equilibrium problems. In order to illustrate our techniques we consider some new MIMO games over vector Gaussian Interference Channels, modeling some distributed resource allocation problems in MIMO cognitive radio systems and femtocells. These games are examples of Nash equilibrium problems that can not be handled by current methodologies.

3. **On the maximum attainable system sum-rate in distributed Gaussian interference channels with unbounded budgets**

   Alberth Alvarado (alvarad3@illinois.edu) University of Illinois at Urbana-Champaign, USA, *Jong-Shi Pang*

Interference is a challenging problem faced by communication systems where multiple users share a common spectrum. When the spectrum is managed dynamically, this problem has been addressed using two approaches. First, a centralized solution based on the maximization of the system sum-rate subject to individual power constraints. Second, a distributed approach based on game theory, where each user maximizes its rate selfishly. In this talk, we analyze the maximum attainable system sum-rate obtained from the Nash solutions as the power budget is increased towards infinity. The analysis is based on an optimization problem formulation, in particular a MPCC (mathematical program with linear complementarity constraints), in which we seek to maximize the system sum-rate over the set of Nash equilibria. To examine the desired asymptotic behavior of the maximum system sum-rates, we introduce a homogenization of this problem and provide sufficient conditions for the maximum objective value of the homogenized problem to equal the limit of decentralized maximum sum-rates as the users' power budgets tend to infinity. We also characterize when such a limit is equal to infinity and provide a constructive test for this to hold. Finally, we present a simplified analysis for the case of two users, and a special case that rules out the presence of the Braess-type paradox.

■ Tue.C.15

Tuesday, 16:30-18:00, Room 1.5, Organized Session

Model-based trust-region methods

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Afonso S. Bandeira*

1. **Probabilistic model based derivative free methods**

Katya Scheinberg (katyascheinberg@gmail.com) Department of Industrial and Systems Engineering Lehigh University, USA, *Afonso S. Bandeira*, *Ruobing Chen*, *Luis Nunes Vicente*

Traditional analysis of model based derivative free optimization methods relies on the worst case behavior of the algorithmic steps and the models involved. There are conditions that the models and the iterates have to satisfy to guarantee convergence. Such requirements are difficult or costly to satisfy in practice and are often ignored in practical implementations. We will present a probabilistic view point for such algorithms, showing that convergence still holds even if some properties fail with some small enough probability. We will discuss several settings where this approach is useful and we will discuss advantages of using regularized models in the derivative free setting.

2. **On sparse Hessian recovery and trust-region methods based on probabilistic models**

Afonso S. Bandeira (ajsb@math.princeton.edu) Princeton University, USA, *Katya Scheinberg*, *Luis Nunes Vicente*

In many application problems in optimization, one has little or no correlation between problem variables, and such (sparsity) structure is unknown in advance when optimizing without derivatives. We will show that quadratic interpolation models computed by partial l1-minimization recover the Hessian sparsity of the function being modeled. Given a considerable level of sparsity in the unknown Hessian of the function, such models often achieve the accuracy of second order Taylor ones with very few random sample points. Due to the randomness in the sampling process the accuracy of the models is also random, we will discuss how to show convergence of Trust-Region methods when the performance of the models is random. Inspired by the fact that the sparsity on the model should only be in the quadratic terms we discuss the setting of sparse recovery with partially known support.

3. **A subspace decomposition framework for nonlinear optimization: Global convergence and global rates**

Luis Nunes Vicente (lnv@mat.uc.pt) Department of Mathematics, University of Coimbra, Portugal, *Serge Gratton*, *Zaikun Zhang*

We discuss a general subspace decomposition framework for optimization (for the moment without constraints). Two versions of the framework are presented, namely a Levenberg-Marquardt version and a trust-region one. We establish global (asymptotic) convergence and derive global rates for both of them. We also discuss how to exploit the framework to design parallel and multilevel derivative-free algorithms for large-scale problems.

■ Tue.C.16

Tuesday, 16:30-18:00, Room 1.6

Branch-and-bound algorithms and global optimization

Cluster: Global optimization and mixed-integer programming
Session chair: *Peter Kirst*

1. **A fast branch-and-bound algorithm for box-constrained integer polynomial optimization**

Christoph Buchheim (christoph.buchheim@tu-dortmund.de) TU Dortmund, Germany, *Claudia D'Ambrosio*

We consider the problem of minimizing a general polynomial of degree d over the integers subject to box-constraints. We propose to underestimate the polynomial objective function by a separable polynomial of degree at most $d+1$, which is computed by underestimating each monomial independently in the best-possible way, subject to a given touching point. For $d \le 4$, the local minimizers of the separable underestimator can be computed very quickly by a closed form formula, even in the integer case, while in the case $d \ge 5$ we need numerical methods to minimize the underestimator. We embed the resulting bounds into a branch-and-bound scheme for solving the problem to optimality. Branching consists in splitting up the domain of one of the variables, allowing to compute a tighter separable underestimator given by a new touching point; the latter is chosen as the center of the feasible region. Computationally, our approach compares favorably with various state-of-the-art optimization software, in particular in the sparse case where the number of monomials remains small. This is mostly due to the fast enumeration of the branch-and-bound nodes.

2. **An enhanced spatial branch-and-bound method in global optimization with nonconvex constraints**

Peter Kirst (peter.kirst@kit.edu) Karlsruhe Institute of Technology, Germany, *Oliver Stein*, *Heinz-Paul Steuermann*

We discuss some difficulties in determining valid upper bounds in spatial branch-and-bound methods for global minimization in the presence of nonconvex constraints. In fact, an example illustrates that standard techniques for the construction of upper bounds may fail in this setting. Instead, we propose to perturb infeasible iterates along Mangasarian-Fromovitz directions to feasible points whose objective function values serve as upper bounds. These directions may be calculated by the solution of a single linear optimization problem per iteration.

■ Tue.C.17

Tuesday, 16:30-18:00, Room 1.7, Organized Session

Applications for practical planning problems

Cluster: Applications of continuous optimization in science and engineering
Session organized by: *Frédéric Messine*

1. **New lower and upper bounding techniques for the pooling problem**

Dag Haugland (dag.haugland@ii.uib.no) University of Bergen, Norway

The pooling problem is a network flow problem with applications in oil refining, petrochemical, and food industry. Resembling the traditional minimum cost flow problem, the objective is to assign flow to the arcs in a network in such a way that the total cost is minimized, and such that supply, demand and capacity bounds are respected. Input data for the pooling problem includes, besides the input required for the minimum cost flow problem, flow qualities for each network source and quality bounds for each network terminal. Quality is typically specified in terms of one or more contaminating component, such as CO2, SO2, etc. When flow streams meet at any network node, the resulting quality becomes the weighted mean value of the qualities of the entering flow streams, where the flow values constitute the weights, and consequently, the problem is naturally formulated as a bilinear program. This extension from the minimum cost flow problem makes the pooling problem strongly NP-hard. In this work, we demonstrate that the strong NP-hardness of the pooling problem persists even when quality is measured in terms of a single parameter. We then suggest some novel lower and upper bounding techniques. The lower bounds are developed through strengthening of certain linear relaxations available in the literature, and the upper bounds are provided by devising fast but not necessarily exact procedures for identifying and improving feasible solutions. Computational experiments are reported.

2. **Combining direct and indirect methods to solve aircraft conflict avoidance problems**

Frédéric Messine (Frederic.Messine@n7.fr) ENSEEIHT-IRIT, France, *Sonia Cafieri*, *Loic Cellier*

Aircraft conflict avoidances can be formulated as optimal control problems (the control are the accelerations of the aircraft). Some particular formulations yield convex optimal control problems under some concave inequality constraints including state variables (this is the main difficulty on the resolution of these types of problems). We propose here an original approach combining direct and indirect methods to solve this optimal control problem. This approach is based on the decomposition into zones where the concave inequality constraints could be active and moreover these constraints are proved to be inactive outside. Thus, the problem is then solved by using a direct shooting method inside the zone and, outiside the zone, a solution is analytically provided by directly applying the Pontyagin Maximum Principle. Numerical experiments validated the great efficiency of this approach.

3. **A differential equation-based method for solving nonlinearly constrained nonlinear programming problems**

   M. Montaz Ali (Montaz.Ali@wits.ac.za) School of Computational and Applied Mathematics, University of the Witwatersrand, Johannesburg, South Africa, *Terry Pliphant*

A trajectory based method is suggested. The method differs conceptually from the gradient methods in that the minimization problem is solved via consideration of the analogous physical problem of the motion of a particle in a conservative force field. The potential energy of the particle is represented by the function to be minimized. The method proposed simulates the motion of the particle by monitoring its potential and kinetic energies. The motion of the particle can be represented by a system of second order nonlinear ordinary differential equations where the state and co-state variables are represented by primal and dual variables, respectively. The iterative process involves the solution of the system of equations via a method known as “leap-frog". Extensive numerical results are presented showing the robustness of the method. Convergence properties are being investigated.

■ Tue.C.18

Tuesday, 16:30-18:00, Room 1.8, Organized Session

Robust optimization I

Cluster: Robust optimization and optimization in finance

Session organized by: *Daniel Kuhn*

1. **Distributionally robust control of linear dynamical systems**

   Bart Paul Gerard Van Parys (bart.vanparys@control.ee.ethz.ch) ETH Zürich, Germany, *Daniel Kuhn*, *Paul James Goulart*, *Manfred Morari*

We investigate constrained control for stochastic linear systems when faced with the problem of only having limited information regarding the disturbance process, i.e. knowing only the first two moments of the disturbance distribution. We consider two types of distributionally robust constraints. In the first type, the constraints should hold with a given probability level for all disturbance distributions sharing the known moments. These constraints are usually referred to as distributionally robust chance constraints with second-order moment specification. In the second, and generalizing constraint type, we impose CVaR constraints to bound the expected constraint violation for all disturbance distributions consistent with the given moment information. Such constraints are denoted as distributionally robust CVaR constraints with second-order moment specification. We argue that the considered constraint types are both practically meaningful and computationally tractable for both infinite and finite horizon control design problems proposed in this talk. The discussed methods are illustrated for a wind turbine blade control design case study where flexibility issues play an important role and in which this distributionally robust framework makes practical sense.

2. **The risk of empirical costs in min-max sample-based optimization**

   Simone Garatti (simone.garatti@polimi.it) Politecnico di Milano, Italy, *Algo Carè*, *Marco C. Campi*

An approach to uncertain convex Stochastic optimization consists of sampling from the uncertainty domain and then computing the min-max solution over the sampled uncertainty instances. In this context, a major challenge is that of evaluating the reliability of the solution with respect to all of the potential uncertainty outcomes, those that have not been seen during the sampling phase. In this talk, we consider the costs incurred by the min-max sample-based solution in correspondence of each sampled instance of the uncertainty and we evaluate the risks associated to the various costs, that is, the probabilities with which the costs are exceeded when a new uncertainty instance is seen. Our main result is that the probability distribution of the risks is always an ordered Dirichlet distribution, irrespective of the probability distribution of the uncertainty. This result provides a full-fledged characterization of the risks and can be used to support decisions in min-max sample-based optimization.

3. **Distributionally robust convex optimization**

   Daniel Kuhn (dkuhn@imperial.ac.uk) Imperial College London, UK, *Wolfram Wiesemann*, *Melvyn Sim*

Distributionally robust optimization is a paradigm for decision-making under uncertainty where the uncertain problem data is governed by a probability distribution that is itself subject to uncertainty. The distribution is then assumed to belong to an ambiguity set comprising all distributions that are compatible with the decision maker’s prior information. In this paper, we propose a unifying framework for modeling and solving distributionally robust optimization problems. We introduce standardized ambiguity sets that contain all distributions with prescribed conic representable confidence sets and with mean values residing on an affine manifold. These ambiguity sets are highly expressive and encompass many ambiguity sets from the recent literature as special cases. They also allow us to characterize distributional families in terms of several classical and/or robust statistical indicators that have not yet been studied in the context of robust optimization. We determine sharp conditions under which distributionally robust optimization problems based on our standardized ambiguity sets are computationally tractable. We also provide tractable conservative approximations for problems that violate these conditions.

■ Tue.C.21

Tuesday, 16:30-18:00, Room 2.1, Organized Session

Structural aspects of nonsmooth optimization II

Cluster: Convex and nonsmooth optimization

Session organized by: *Vladimir Shikhman*

1. **Generic first-order necessary optimality conditions for a general class of optimization problems**

   Dominik Dorsch (dorsch@mathc.rwth-aachen.de) RWTH Aachen University, Germany

We consider the general problem of minimizing a function f on a feasible set M where M is given as the preimage of a constraint set Z under a constraint mapping g, i.e., $M = g^{-1}(Z)$.This class of optimization problems includes for example nonlinear programming (NLP), mathematical programs with complementarity constraints (MPCCs) and (nonlinear) semidefinite programming (SDP). Since in practice the constraint set Z is typically defined by (finitely many) polynomial (in-)equalities we assume that Z is semialgebraic. As a main result we obtain first-order necessary optimality conditions which apply for generic constraint mappings g. These optimality conditions are generalizations of analog results for NLPs, MPCCs and SDPs. Thus we obtain the well-known Karush-Kuhn-Tucker (KKT) conditions for NLPs as a special case.
We point out that our result has implications on the development of solution algorithms. Indeed in practice — given a concrete problem instance — it is not possible to verify a constraint qualification at the (unknown) minimizer x^*. Our result however guarantees that the first-order necessary optimality conditions hold for “almost all” problem instances. This means that in practice the necessary optimality conditions typically apply at all minimizers x^*.

2. **On a class of generalized Nash equilibrium problems in Banach space with applications to multiobjective PDE-constrained optimization**

   Thomas Surowiec (surowiec@math.hu-berlin.de) Humboldt-Universitaet zu Berlin, Germany, *Michael Hintermüller*

We present a class of generalized Nash equilibrium problems (GNEP) in Banach space. Issues concerning the existence of equilibria and constraint qualifications will be discussed. Using a class of convex penalty functions, we reduce the question of solving the GNEP to solving a sequence of approximations in the form of classical Nash equilibrium problems. Finally, we apply the theoretical results to a class of problems whose constraint sets are partially governed by a linear parabolic partial differential equation. An algorithm for this class of problems will be presented and illustrated by a few examples.

3. **Convergence of nonsmooth descent methods using the Kudyka-Lojasiewicz inequality**

Dominikus Noll (noll@mip.ups-tlse.fr) University of Toulouse, France

We investigate algorithmic conditions which in combination with the Kurdyka-Lojasiewicz inequality assure convergence of non-smooth descent methods to a single critical point. A related question concerns finite length and convergence of discrete sub-gradient trajectories, and convergence of the Talweg. Our findings are somewhat surprising: contrary to the smooth case, convergence and finite length of the trajectories are no longer linked. Additional structural properties of the non-smooth objective function are required to give convergence.

■ Tue.C.22

Tuesday, 16:30-18:00, Room 2.2, Organized Session

Coordinate descent and incremental gradient methods for nonsmooth optimization

Cluster: Convex and nonsmooth optimization

Session organized by: *Olivier Fercoq*

1. **Conditional gradient algorithm for machine learning with non-smooth loss and decomposable regularization**

Federico Pierucci (federico.pierucci@inria.fr) INRIA, LEAR team and LJK, Laboratoire Jean Kuntzmann, France, *Zaid Harchaoui*, *Juditsky Anatoli*, *Malick Jérôme*

We consider the problem of optimizing machine learning objectives with a decomposable regularization penalty and a non-smooth loss function. For several important learning problems, state-of-the-art optimization approaches such as proximal gradient algorithms are difficult to apply and do not scale up to large datasets. We propose a new conditional-type algorithm, with theoretical guarantees, for such problems. Promising experimental results are presented on real-world datasets.

2. **Incrementally updated gradient methods for nonsmooth minimization**

Sangwoon Yun (yswmathedu@skku.edu) Sungkyunkwan University, South Korea, *Paul Tseng*

We consider incrementally updated gradient methods for minimizing the sum of smooth functions and a convex function. This method can use a (sufficiently small) constant stepsize or, more practically, an adaptive stepsize that is decreased whenever sufficient progress is not made. We show that if the gradients of the smooth functions are Lipschitz continuous on R^n, then every cluster point of the iterates generated by the method is a stationary point. If in addition a local Lipschitz error bound assumption holds, then the method is linearly convergent. We also propose a new incrementally updated gradient method that uses much less storage and prove global convergence of the method.

3. **Smoothed parallel coordinate descent method for huge-scale optimization problems**

Olivier Fercoq (olivier.fercoq@ed.ac.uk) University of Edinburgh, UK, *Peter Richtarik*

We study the problem of minimizing nonsmooth convex functions with max structure in huge dimensions. We identify a max-type partial separability property that implies the existence of a quadratic separable overapproximation for the smoothed function obtained by Nesterov's smoothing. We then use this overapproximation to define a parallel coordinate descent method and we provide a theoretical parallelization speedup factor that depends on the degree of partial separability of the function. This work applies as well to structured smooth functions and we present a parallel version of the machine learning algorithm Adaboost. We compare the parallel coordinate descent method with other approaches on public large scale datasets.

■ Tue.C.23

Tuesday, 16:30-18:00, Room 2.3

Optimal control

Cluster: PDE-constrained optimization

Session chair: *Stefan Ulbrich*

1. **Optimal control of nonlinear hyperbolic conservation laws at a junction**

Sebastian Pfaff (pfaff@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

Hyperbolic conservation laws arise in many different applications such as traffic modeling or fluid mechanics. The presence of moving discontinuities, so-called shocks, in the entropy solution leads to difficulties in the optimal control of hyperbolic balance laws. In particular, non-differentiability of the control-to-state mapping in the usual sense is an issue. The concept of shift-differentiability already turned out to be very useful when dealing with optimal control problems of an initial(-boundary) value problem on $\mathbb{R}$ or an interval $I = (a, b)$, respectively. Indeed, since the solution operator for these problems is shift-differentiable, its composition with a tracking-type functional can shown to be Fréchet-differentiable. In this talk we consider optimal control problems of scalar conservation laws on simple networks, namely networks consisting of only one junction. We analyze the generalized differentiability properties of the solution operator w.r.t. initial data. We also discuss the case where the controls are the switching times between different modes of the node condition.

2. **Optimal control of PDAEs**

Hannes Meinlschmidt (meinlschmidt@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

In this talk, we consider optimal control problems constrained by Partial Differential-Algebraic Equations (PDAEs). While there exist various notions of PDAEs, we follow the classical point of view from analysis: in the same way as one may consider a PDE as an abstract ODE on a suitable Banach space, we consider PDAEs as abstract DAEs on suitable Banach spaces. We give a short survey about the idea of an DAE and its index and define what we call a PDAE and a PDAE-constrained optimal control problem. Since arbitrary nonlinear PDAEs are, of course, too general to establish a satisfying theory, we consider so-called semi-explicit PDAEs of index one or two. These correspond to (possibly nonlinearly coupled) systems of PDEs of mixed type (e.g. parabolic-elliptic). Here, we introduce a general framework for a large class of problems and establish the usual optimality theory. Finally, we discuss the correspondence of the PDAE index and the underlying model dynamics.

3. **Infinite horizon problems on stratifiable state constraints sets**

Cristopher Hermosilla (hermosilla@ensta.fr) ENSTA ParisTech & Inria Saclay, France, *Hasnaa Zidani*

When dealing optimal control problems with state constraints it is usual to assume some pointing qualification hypothesis. These kind of conditions are imposed to obtain a characterization of the value function as the unique solution to a Hamilton-Jacobi equation among a certain class of functions. Nevertheless, this type of assumptions are quite restrictive and do not allow to treat, for instance, cases where the only option for the trajectories is to stay on the boundary of the set of constraints. In this work we attempt to cover this kind of situation by assuming that the state constraints set admits a sufficiently regular partition into smooth manifolds of different dimensions. We center our study in the value function for the infinite horizon problem and we present a characterization of this function as the unique l.s.c. solution to a bilateral Hamilton-Jacobi equation written in terms of the stratification.

■ Tue.C.24

Tuesday, 16:30-18:00, Room 2.4, Organized Session

Preconditioning in PDE-constrained optimization

Cluster: PDE-constrained optimization

Session organized by: *Martin Stoll, Andreas Potschka*

1. **Newton-Picard preconditioning for time-periodic PDE constrained optimization**

Andreas Potschka (potschka@iwr.uni-heidelberg.de) Interdisciplinary Center for Scientific Computing, Heidelberg University, Germany, *Falk M. Hante*, *Mario S. Mommer*

We present a class of symmetric indefinite preconditioners for the solution of linear saddle-point problems that arise in optimal control with time-periodic parabolic partial differential equations. The preconditioners are based on rather coarse approximations of compact operators occuring in the (2,1) and (1,2) blocks of the saddle point system. Based on semi-group and spectral theory, we carry out a convergence analysis for a preconditioned fixed-point iteration in function space and its dependence on a control regularization parameter in the objective function. We present numerical results for a periodic 3D instationary distributed optimal control problem that we obtained with a two-grid variant of the Newton-Picard preconditioner. An outlook on nonlinear problems shall conclude the talk.

2. **Preconditioned iterative methods for time-dependent optimal control problems**

   John Pearson (john.pearson@worc.ox.ac.uk) University of Oxford, UK

An active area of research in numerical analysis and optimization is the study of optimal control problems. In particular, a natural and important field of study is the development of efficient solvers for such problems. In this talk, we consider the derivation of preconditioned iterative methods for matrix systems that arise from time-dependent optimal control problems, which are generally very large and sparse. We develop preconditioners for these problems using well-known results from saddle point theory, along with effective approximations of the (1,1)-block and Schur complement of the matrix systems. The specific problems we examine include the optimal control of the heat equation, a Stokes control problem, and an optimal control problem arising from chemical processes. In each case, we motivate and derive our suggested preconditioners for the saddle point systems involved, and present numerical results demonstrating the effectiveness of our solvers in practice.

3. **CANCELLED**

■ Tue.C.25

Tuesday, 16:30-18:00, Room 2.5, Organized Session

Variational analysis and its applications

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Alejandro Jofré*

1. **Variational analysis and financial equilibrium**

   Alejandro Jofré (ajofre@dim.uchile.cl) Center for Mathematical Modeling and DIM, Univ. of Chile, Chile, *R. T. Rockafellar*, *R. J.-B. Wets*

Convexity has long had an important role in economic theory, but some recent developments have featured it all the more in problems of equilibrium. Here the tools of convex analysis are applied to a basic model of financial markets in which assets are traded and money can be lent or borrowed between the present and future. The existence of an equilibrium is established with techniques that include bounds derived from the duals to problems of utility maximization. Composite variational inequalities furnish the modeling platform. Models with and without short-selling are handled, moreover in the absence of any requirement that agents must initially have a positive amount of every asset, as is typical in equilibrium work in economics.

2. **Forward-partial inverse method for solving monotone inclusions: Application to land-use planning**

   Luis M. Briceño Arias (lbriceno@dim.uchile.cl) Universidad Técnica Federico Santa María, Chile

In this talk we provide a method for solving the monotone inclusion

$$\text{find} \quad x \in H \quad \text{such that} \quad 0 \in N_V x + Ax + Bx, \tag{4}$$

where H is a real Hilbert space, V is a closed vectorial subspace of H, N_V is the normal cone to V, $A\colon H \to 2^H$ is a maximally monotone operator, and $B\colon H \to H$ is a cocoercive operator on V. The proposed method exploits the structure of the problem by activating explicitly the operator B and by taking into advantage the vectorial subspace involved. The algorithm is a particular case of the forward-backward splitting when the proximal step includes the partial inverse of A with respect to V. In the particular case when $B \equiv 0$, the algorithm becomes the method of partial inverses (Spingarn, 1983), which solves

$$\text{find} \quad x \in H \quad \text{such that} \quad 0 \in N_V x + Ax. \tag{5}$$

On the other hand, when $V = H$, the algorithm reduces to the forward-backward splitting (Combettes, 2004), which solves

$$\text{find} \quad x \in H \quad \text{such that} \quad 0 \in Ax + Bx. \tag{6}$$

In addition, we deduce relation with a forward-Douglas-Rachford method and we derive the method proposed by Raguet, Fadili, and Peyré as a particular case. Finally, in a variational framework we apply the method for computing the optimal subsidies in order to obtain a desired land-use allocation.

3. **Stochastic programs without duality gaps**

   Ari-Pekka Perkkiö (ari-pekka.perkkio@aalto.fi) Aalto University, Finland, *Teemu Pennanen*

This talk is on dynamic Stochastic optimization problems parameterized by a random variable. Such problems arise in many applications in operations research and mathematical finance. We give sufficient conditions for the existence of solutions and the absence of a duality gap. Our proof uses extended dynamic programming equations, whose validity is established under new relaxed conditions that generalize certain no-arbitrage conditions from mathematical finance.

■ Tue.C.AB

Tuesday, 16:30-18:00, Amphitheater B, Organized Session

Algorithms I

Cluster: Nonlinear optimization
Session organized by: *Ernesto G. Birgin*

1. **An inexact restoration method with Lagrange multipliers and applications in multiobjective optimization**

   Luís Felipe Bueno (lfelipebueno@gmail.com) Federal University of São Paulo, Brazil, *Gabriel Haeser*, *José Mario Martínez*

In Inexact-Restoration (IR) methods each iteration is divided in two phases. In the first phase one aims to sufficiently improve the feasibility with a bounded deterioration of the optimality. In the second phase one minimizes a suitable objective function without loosing much of the improvement obtained in the previous phase. In this work we introduce an improved line search IR algorithm, combining the basic ideas of the Fischer-Friedlander method with the use of Lagrange multipliers. We present a new option to obtain a range of search directions in the optimization phase and we introduce the use of the sharp Lagrangian as merit function. Furthermore, we introduce a more flexible way to handle with the requirement of the sufficient feasibility improvement and a more efficient way to deal with the penalty parameter. These modifications increase the chances that more promising steps be acceptable by the algorithm. Examples of the numerical behavior of the algorithm in multi-objective problems are reported.

2. **An inexact and nonmonotone proximal method combining trust region and line search for unconstrained minimization**

   Sandra A. Santos (sandra@ime.unicamp.br) State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, *Roberto C. M. Silva*

A proximal point trust region line search (PPTRLS) algorithm is proposed for the smooth unconstrained minimization problem. At each iteration, the algorithm solves approximately a quadratic subproblem by a truncated Newton method with step length control. We have established (i) a rule for updating the proximal parameter; (ii) a nonmonotone criterion for accepting the iterate; (iii) a related scheme for updating the quadratic model. The global convergence analysis is presented, together with comparative numerical results that validate the proposed approach.

3. **CANCELLED**

■ Wed.A.11

Wednesday, 11:30-13:00, Room 1.1, Organized Session

Conic programming and related problems II

Cluster: Conic and polynomial optimization
Session organized by: *Masakazu Muramatsu*

1. **Adaptive SDP relaxation for polynomial optimization**

   Masakazu Muramatsu (muramatu@cs.uec.ac.jp) The University of Electro-Communications, Japan, *Hayato Waki*, *Levent Tuncel*

We consider a property of positive polynomials on a compact set with a small perturbation. When applied to a Polynomial Optimization Problem (POP), the property implies that the optimal value of the corresponding SemiDefinite Programming (SDP) relaxation with sufficiently large relaxation order is bounded from below by $f^* - \epsilon$ and from above by $f^* + \epsilon(n+1)$, where f^* is the optimal value of the POP. We propose a new SDP relaxation, adaptive SDP relaxation, for POP based on modifications of existing sums-of-squares representation theorems. An advantage of our SDP relaxations is that in many cases they are of considerably smaller dimension than those originally proposed by Lasserre. We present some applications and the results of our computational experiments.

2. **An LP-based algorithm to test copositivity**

   Akihiro Tanaka (tanakas1120@gmail.com) University of Tsukuba, Japan, *Akiko Yoshise*

A symmetric matrix is called copositive if it generates a quadratic form taking no negative values over the positive orthant, and the linear optimization problem over the set of copositive matrices is called the copositive programming problem. Recently, many studies have been done on the copositive programming problem (cf, Dur (2010)). Among others, several branch and bound type algorithms have been provided to test copositivity since it is known that the problem for deciding whether a given matrix is copositive is co-NP-complete (cf. Murty and Kabadi (1987)). In this talk, we propose a new branch and bound type algorithm for this testing problem. Our algorithm is based on solving linear optimization problems over the nonnegative orthant, repeatedly. Numerical experiments suggest that our algorithm is promising for determining upper bounds of the maximum clique problem.

3. **Towards efficient higher-order semidefinite relaxations for max-cut**

   Miguel F. Anjos (anjos@stanfordalumni.org) École Polytechnique de Montréal, Canada, *Elspeth Adams*, *Franz Rendl*, *Angelika Wiegele*

The basic semidefinite relaxation for max-cut underlying the Goemans-Williamson hyperplane rounding procedure can be tightened in different ways. A straightforward approach is to add facet-defining inequalities for the metric polytope, or more generally valid inequalities for the convex hull of incidence vectors of cuts, known as the cut polytope. Other approaches are hierarchical and build a sequence of relaxations that increasingly better approximate the cut polytope but at an increasingly greater computational cost. A natural systematic hierarchy was introduced by Lasserre. For a max-cut problem of size n, the first step in this hierarchy corresponds to the basic semidefinite relaxation which optimizes over the set of correlation matrices of order n. The second step is a relaxation with a matrix of order n^2, and so on. We start with the basic semidefinite relaxation intersected with the metric polytope, and propose to iteratively refine this relaxation using semidefiniteness and/or linear constraints derived from selected submatrices of the Lasserre matrix of order n^2. We present theoretical insights as well as computational results.

■ Wed.A.12

Wednesday, 11:30-13:00, Room 1.2, Organized Session

Recent advances in first order optimization methods

Cluster: Sparse optimization and information processing
Session organized by: *Marc Teboulle*

1. **A first order method for finding minimal norm-like solutions of convex optimization problems**

   Shoham Sabach (ssabach@gmail.com) School of Mathematical Sciences, Tel-Aviv University, Israel, *Amir Beck*

We consider a general class of convex optimization problems in which one seeks to minimize a strongly convex function over a closed and convex set which is by itself an optimal set of another convex problem. We introduce a gradient-based method, called the minimal norm gradient method, for solving this class of problems, and establish the convergence of the sequence generated by the algorithm as well as a rate of convergence of the sequence of function values. Several numerical examples are given in order to illustrate our results.

2. **Rate of convergence analysis for proximal-Lagrangian methods**

   Ron Shefi (ronshefi@post.tau.ac.il) School of Mathematical Sciences, Tel-Aviv University, Israel, *Marc Teboulle*

Augmented Lagrangians based methods have attracted renewed interest recently due to their relevance for solving large scale convex structured minimization problems arising in many applications. This talk presents two generic classes of Proximal Lagrangian Methods (PLM) and focuses on their theoretical efficiency. We first show that the PLM framework is a natural vehicle to build and analyze novel schemes, and is at the root of many past and recent algorithmic variants suggested in the literature. We then prove various types of global convergence rate results for the two proposed generic classes. Our approach relies on elementary convex analytic arguments and allows to revisit seemingly different algorithms for which new and refined rate of convergence results are established within a unifying framework.

3. **A first order algorithm for a class of nonconvex-nonsmooth minimization**

   Marc Teboulle (teboulle@post.tau.ac.il) School of Mathematical Sciences, Tel-Aviv University, Israel, *J. Bolte*, *S. Sabach*

We introduce a new first order algorithm for solving a broad class of nonconvex and nonsmooth problems. The resulting scheme involves simple iterations and is particularly adequate for solving large scale nonsmooth and nonconvex problems arising in a wide variety of fundamental applications. We outline a self contained convergence analysis framework describing the main tools and methodology to prove that the sequence generated by the proposed scheme globally converges to a critical point. Our results are illustrated on challenging sparse optimization models arising in data analysis applications.

■ Wed.A.13

Wednesday, 11:30-13:00, Room 1.3

Nonlinear optimization and linear algebra

Cluster: Nonlinear optimization
Session chair: *Anders Forsgren*

1. **Using spectral information to precondition saddle-point systems**

   Annick Sartenaer (annick.sartenaer@unamur.be) University of Namur, Belgium, *Daniel Ruiz*, *Charlotte Tannier*

For nonsingular indefinite matrices of saddle-point (or KKT) form, Murphy, Golub and Wathen (2000) have proposed an ń ideal ż block diagonal preconditioner based on the exact Schur complement. In this talk, assuming a zero (2,2) block, we focus on the case where the (1,1) block is symmetric positive definite and (eventually) very badly conditioned, but with only a few very small eigenvalues. Under the assumption that a good approximation of these eigenvalues and their associated eigenvectors is available, we consider different approximations of the block diagonal preconditioner of Murphy, Golub and Wathen. We analyze the spectral properties of the preconditioned matrices and show how it is possible to appropriately recombine the available spectral information from the (1,1) block through a particular Schur complement approximation that allows to build an efficient block diagonal preconditioner with little extra cost. We finally illustrate the performance of the proposed preconditioners with some numerical experiments.

2. **Singular value decomposition computations in matrix optimisation problems**

   Sheng Fang (fang@maths.ox.ac.uk) University of Oxford, UK, *Raphael Hauser*

Singular value decompositions form a basic building block in numerical linear algebra and appear in several optimization algorithms, notably in nuclear norm minimization problems and in optimization problems that occur in the context of machine learning models. In several cases the SVD calculations form the computational bottleneck that dominates the computational costs. We discuss a loosely coupled, communication poor parallel algorithm for computing the leading part singular value decomposition of very large scale matrices and its convergence, through theoretical analysis, numerical experiments and comparison with other competitive approaches. Applications in optimization problems are also presented.

3. **On the connection between the conjugate gradient method and quasi-Newton methods on quadratic problems**

   Tove Odland (odland@kth.se) Optimization and Systems Theory, Department of Mathematics, KTH Royal Institute of Technology, Stockholm, Sweden, *Anders Forsgren*

It is well known that the conjugate gradient method and a quasi-Newton method, using any well-defined update matrix from the one-parameter Broyden family of updates, produce the same iterates on a quadratic problem with positive-definite Hessian. This equivalence does not hold for any quasi-Newton method. We discuss more precisely the conditions on the update matrix that give rise to this behavior, and show that the crucial fact is that the components of each update matrix are chosen in the last two dimensions of the Krylov subspaces defined by the conjugate gradient method. In the framework based on a sufficient condition to obtain mutually conjugate search directions, we show that the one-parameter Broyden family is complete. We also show that the update matrices from the one-parameter Broyden family is almost always well-defined on a quadratic problem with positive-definite Hessian. The only exception is when the symmetric rank-one update is used and the unit steplength is taken in the same iteration, in this case it is the Broyden parameter that becomes undefined.

■ Wed.A.14

Wednesday, 11:30-13:00, Room 1.4, Organized Session

Variational inequalities and equilibrium problems I

Cluster: Complementarity and variational inequalities
Session organized by: *Patrizia Daniele*

1. **Recent advances in variational inequalities**

   Patrizia Daniele (daniele@dmi.unict.it) Department of Mathematics and Computer Science - University of Catania, Italy

In this talk we present some problems as transportation networks with capacity constraints on the path flows, spatially distributed economic markets in the presence of supply and demand excesses, supply chain network models with different levels of decision makers, financial equilibrium problems with a general utility function, static electric power supply chain networks, which can be studied in the framework of variational inequalities.

2. **Environmental regulations and competitiveness in the steel industry**

   Rossana Riccardi (riccardi@eco.unibs.it) University of Brescia, Dept. Economics and Management, Italy, *Elisabetta Allevi*, *Claudia Avanzi*, *Francesca Bonenti*, *Adriana Gnudi*

In this work, a spatial equilibrium problem is formulated for analysing the impact of the application of the EU-ETS on the energy and industrial sectors, such as the steel industry that has historically seen Europe as one of its major producers. The developed model allows us to simultaneously represent the interactions of several market players and to endogenously determine output and CO2 allowance prices. In addition, the proposed models support the evaluation of the CO2 emission costs on the basis of Directive 2009/29/EC, the "20-20-20" targets, and the Energy Roadmap 2050.

3. **A new method for solving eigenvalue complementarity problems**

   Samir Adly (samir.adly@unilim.fr) University of Limoges, France

In this talk, we introduce a new method, called the Lattice Projection Method (LPM), for solving eigenvalue complementarity problems. The original problem is reformulated to find the roots of a nonsmooth function. A semismooth Newton type method is then applied to approximate the eigenvalues and eigenvectors of the complementarity problems. The LPM is compared to SNM_min and SNM_FB, two methods widely discussed in the literature for solving nonlinear complementarity problems, by using the performance profiles as a comparing tool. The performance measures, used to analyze the three solvers on a set of matrices mostly taken from the Matrix Market, are computing time, number of iterations, number of failures and maximum number of solutions found by each solver. The numerical experiments highlight the efficiency of the LPM and show that it is a promising method for solving eigenvalue complementarity problems.

■ Wed.A.15

Wednesday, 11:30-13:00, Room 1.5, Organized Session

Probabilistic derivative free optimization

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Anne Auger*

1. **A principled, stochastic approach to continuous black-box Optimization**

   Nikolaus Hansen (hansen@lri.fr) Inria, Research Centre Saclay, France

We approach the problem to find better solutions in an iterated optimization procedure from a stochastic viewpoint. We consider three principal objectives. First, we want to impose the least prior assumptions by maintaining maximal entropy, unbiasedness, and invariance. Second, while being constrained to the prior point, we like to exploit all information available in the black-box scenario. Third, we want to solve at least simple functions reasonably fast. Pursuing this idea, information geometry suggests to follow the natural gradient in the parameter space of distributions to sample new solutions. More specifically, the so-called Covariance Matrix Adaptation Evolution Strategy (CMA-ES) can be derived from these principles. The CMA-ES is a comparatively well-established evolutionary numerical optimization method which, surprisingly, complies with information geometric principles. The CMA-ES can be viewed as variable-metric approach, performs well on ill-condition problems and is particularly robust to rugged search landscapes.

2. **Information-geometric optimization: Introduction and theoretical foundations**

   Youhei Akimoto (y_akimoto@shinshu-u.ac.jp) Shinshu University, Japan

Information-Geometric Optimization (IGO) is a generic framework of probabilistic model based derivative free search algorithms for any type of optimization problems. Given a probabilistic model, i.e., a family of probability distributions, IGO defines another maximization problem on the space of the model parameter and takes a gradient step to maximize it. When computing the gradient on the parameter space, we take into account the intrinsic metric on the parameter space of probability distributions, namely the Fisher metric, and the gradient reads the so-called natural gradient. IGO implementations repeat to estimate the natural gradient by using samples from the current distribution and update the parameter by the natural gradient so that the probability distribution converges towards the Dirac-delta distribution concentrated at the optimum of the original problem. It has been realized that IGO recovers several known algorithms such as the covariance matrix adaptation evolution strategy (CMA-ES), which is a state-of-the-art evolutionary algorithms for continuous optimization, and the population based incremental learning (PBIL) for binary optimization. In this talk, we introduce the framework of IGO, followed by theoretical aspects of IGO including a linear convergence proof for an IGO implementation given the family of isotropic Gaussian distributions through the theory of stochastic approximation.

3. **The dynamical systems approach applied to the analysis of evolutionary strategies for constrained optimisation**

   Dirk Arnold (dirk@cs.dal.ca) Dalhousie University, Canada

The dynamical systems approach to the analysis of evolutionary strategies considers environments that result in time invariant limit behaviour of the underlying processes. An approximation to the stationary state allows inferring how the algorithms' performance scales with parameters of the problem as well as of the strategies. In this talk we present results obtained by applying the dynamical systems approach to the analysis of the behaviour of evolutionary strategies for several simple constrained problems. A comparison between constraint handling techniques is drawn and the interaction between constraint handling and step size adaptation is examined.

■ Wed.A.16

Wednesday, 11:30-13:00, Room 1.6, Organized Session

Aircraft conflict detection and resolution

Cluster: Global optimization and mixed-integer programming
Session organized by: *Laureano F. Escudero*

1. **Aircraft conflict detection and resolution: A mixed-integer nonlinear optimization model by turn change maneuvers**

   Laureano F. Escudero (laureano.escudero@urjc.es) Universidad Rey Juan Carlos, Móstoles (Madrid), Spain, *Antonio Alonso-Ayuso*, *F. Javier Martin-Campo*

The aircraft collision detection and resolution problem in air traffic management by turn change maneuvers is presented. A two-step approach is presented. The first step consists of a nonconvex Mixed Integer Nonlinear Optimization (MINLO) model based on geometric constructions. The second step consists of a set of quadratic optimization models where aircraft are forced to return to their original flight plan as soon as possible once there is no aircraft in conflict. The main results of extensive computation are reported by comparing the performance of state-of-the-art nonconvex MINLO solvers and an approximation by discretizing the possible angles of motion for solving a Sequence of Integer Linear Optimization (SILO) models in an iterative way. Minotaur, one of the nonconvex MINLO solvers experimented with, gives better solutions but requires more computing time than the SILO approach. However, the latter requires only a short time to obtain a good feasible solution. Its value in the objective function has a reasonable goodness gap from the Minotaur solution.

2. **Aircraft conflict detection and resolution by mixed-integer nonlinear optimization models by turn change maneuvers using a variable neigborhood search approach**

   F. Javier Martin-Campo (javier.martin.campo@ccee.ucm.es) Universidad Complutense de Madrid, Spain, *Antonio Alonso-Ayuso*, *Laureano F. Escudero*, *Nenad Mladenovic*

The aircraft Conflict Detection and Resolution (CDR) problem in air traffic management consists of finding a new configuration for a set of aircraft such that their conflict situations are avoided. A conflict situation occurs if two or more aircraft violate the safety distances that they have to keep during the flight. A geometric construction is used in order to detect the conflict situations between each pair of aircraft under consideration. In this paper we propose a VNS approach for solving the CDR by turn changes based on the reformulation of the problem as an unconstrained one by an exterior penalty function method. The first improvement local search and the shaking operator consist of changing direction of the aircraft by a given parameter and moving several aircraft at once by a random parameter based on the k-value of the VNS approach, respectively. This metaheuristic compares favourably with previous best known methods. It is worth to point out the astonishing time required to obtain the first feasible solution, which is crucial for this specific problem whose response time should be almost in real time in order to be useful in a real-life problem. A comparative study with up to 25 aircraft is presented.

3. **Aircraft conflict avoidance by mixed-integer nonlinear optimization models combining turn and velocity change maneuvers**

   Sonia Cafieri (sonia.cafieri@enac.fr) École Nationale de l'Aviation Civile, France, *Antonio Alonso-Ayuso*, *Laureano F. Escudero*, *F. Javier Martin-Campo*

Aircraft conflict detection and resolution is crucial in Air Traffic Management to guarantee air traffic safety. When aircraft sharing the same airspace are too close to each other according to their predicted trajectories, separation maneuvers have to be performed to avoid risks of collision. We propose new mixed-integer Nonlinear optimization models combining turn-changes and velocity-changes separation maneuvers. These separation maneuvers are performed by each aircraft at instant times which are decision variables of the problem, and each aircraft is allowed to perform only one type of maneuver. The pros and cons of the models are discussed.

■ Wed.A.17

Wednesday, 11:30-13:00, Room 1.7, Organized Session

Applications in design problems

Cluster: Applications of continuous optimization in science and engineering
Session organized by: *Jordi Castro*

1. **Improvements of sequential and parallel bi-blending algorithms**

   Juan F. R. Herrera (juanfrh@ual.es) University of Almería, Spain, *Leocadio G. Casado*, *Eligius M. T. Hendrix*, *Inmaculada García*

The semi-continuous quadratic mixture design problem is a bi-objective problem where the best robust design of a product has to be found. The design is based on mixing raw materials, subject to quadratic constraints and semi-continuity of the variables. The Pareto solution minimizes both the cost and the number of used raw materials. In the Quadratic Bi-Blending (QBB) problem, the Pareto front is determined by the simultaneous design of two products sharing raw materials, with their material availability limits. A specific Branch-and-Bound (B&B) algorithm for the QBB problem implies two B&B algorithms, one for each product, sharing the Pareto front and capacity constraints. In this way, the dimension of the search region for each B&B procedure is smaller than the combined search space. The algorithm aims at finding all solutions and determining the subspace where better designs can be found using higher accuracy of the solutions. The most time consuming part of the procedure is the combination of the finally obtained feasible sets of the two products. Here, we investigate a new B&B search strategy for QBB problems. The strategy performs a stepwise search with an iteratively increasing accuracy. Experimental results show an average improvement of 32% in the execution time when several combination steps are done, instead of just the final one. Additionally, a parallel version is presented, showing a better improvement in the execution time.

2. **Protecting three-dimensional tables of data: An application of interior-point methods to statistical disclosure control**

   Jordi Castro (jordi.castro@upc.edu) Dept. of Statistics and Operations Research, Universitat Politècnica de Catalunya, Barcelona, Spain, *Jordi Cuesta*

National Statistical Agencies (NSAs) have to guarantee that disseminated data do not provide individual confidential information. To achieve this goal, statistical disclosure control techniques have to be applied to real data before publication. In this work we consider a particular technique for tabular data named "controlled tabular adjustment"(CTA). Given a statistical table, CTA looks for the closest safe table using some particular distance. In this work we focus on three-dimensional (3D) tables (i.e., tables obtained by crossing three variables) using the L1 distance. We show that L1-CTA in 3D tables can be formulated as a large linear optimization problem with block-angular structure. These problems are solved by a specialized interior-point algorithm for block-angular constraints matrices, which solves the normal equations by a combination of Cholesky factorization and preconditioned conjugate gradients. Computational results are reported for large instances, resulting in linear optimization problems of up to 50 millions variables and 25 millions constraints.

3. **A global optimization method to solve engineering design problems**

   Ana Maria A. C. Rocha (arocha@dps.uminho.pt) Centre Algoritmi, University of Minho, Portugal, *M. Fernanda P. Costa*, *Edite M. G. P. Fernandes*

Distribution based artificial fish swarm is a new heuristic for continuous global optimization. Based on the artificial fish swarm paradigm, the new algorithm generates trial points from the Gaussian distribution, where the mean is the target point and the standard deviation is the difference between the current and the target point. A local search procedure is incorporated into the algorithm aiming to improve the quality of the solutions. The adopted approach for handling the constraints of problem relies on a simple heuristic that uses feasibility and dominance rules. A comparison with a previous version, where the mean of the Gaussian distribution is the midpoint between the current and the target point, is investigated using a set of engineering design problems.

■ Wed.A.18

Wednesday, 11:30-13:00, Room 1.8, Organized Session

Robust optimization II

Cluster: Robust optimization and optimization in finance
Session organized by: *Huan Xu*

1. **Efficient design of robust SVMs**

   Chiranjib Bhattacharyya (chiru@csa.iisc.ernet.in) Department of CSA, Indian Institute of Science, India

Support vector machines(SVMs) have emerged as a tool of choice for classification problems, well studied in the area of Machine Learning. On a dataset, SVMs define a positive semidefinite matrix, called the kernel matrix. In this paper we study the problem of designing SVM classifiers when the kernel matrix, K, is affected by uncertainty. Specifically K is modeled as a positive affine combination of given positive semi definite kernels, with coefficients ranging in a norm-bounded uncertainty set. We treat the problem using the Robust Optimization methodology, which reduces the uncertain SVM problem into a deterministic conic quadratic problem solvable in principle by Interior Point (IP) methods. However, for large-scale classification problems, IP methods become intractable and one has to resort to first-order gradient type methods. We reformulate the robust counterpart of the uncertain SVM problem as a saddle point problem and employ a special gradient scheme which works directly on the convex-concave saddle function. The algorithm achieves an $O(1/T^2)$ reduction of the initial error after T iterations. A comprehensive empirical study on both synthetic data and real-world protein structure data sets shows that the proposed formulations achieve the desired robustness, and the saddle point based algorithm outperforms the IP method significantly.

2. **Robust optimization and robust estimation in provable object instance verification**

   John Wright (johnwright@ee.columbia.edu) Department of Electrical Engineering, Columbia University, USA, *Cun Mu*, *Yuqian Zhang*, *Henry Kuo*

Convex optimization plays an important role in both the study of optimization under uncertainty, and the modern study of robust estimation in high dimensions. In this talk, we describe how these two notions of robustness interact in an application problem drawn from computational vision. In this problem, the goal is to recognize objects in two dimensional images, given information about their physical properties. Searching for efficient algorithms with guaranteed performance for this problem forces us to draw on both notions of robustness: robust optimization for ensuring our approximations are uniformly good over all possible illumination conditions, and robust estimation for ensuring that the fitted model has low enough complexity to enable computation. We show how optimization techniques from both of these areas, together with new bounds on the sample complexity of illumination, can yield algorithms that provably accept any valid image of an object of interest, and provably reject any invalid image. We sketch connections to more general problems of separation or recovery of multiple low-dimensional structures, and learning dictionaries for sparse approximation.

3. **Data-driven distributionally robust polynomial optimization**

   Jia Yuan Yu (jiayuanyu@ie.ibm.com) IBM Research, USA, *Martin Mevissen*, *Emanuele Ragnoli*

We consider robust optimization for polynomial optimization problems where the uncertainty set is a set of candidate probability density functions. These distributional uncertainties set are balls around a density function estimated from data samples, i.e. data-driven. We use a polynomial density estimate and a histogram density estimate depending on whether the uncertainty is multivariate or univariate. Polynomial optimization problems are inherently hard optimization problems with nonconvex objectives and constraints. An additional source of hardness comes from the distributional uncertainty set. We show that the solution to the distributionally robust problem is the limit of a sequence of tractable semidefinite programming relaxations. We further give finite-sample consistency guarantees for the data-driven uncertainty sets. Finally, we apply our model and solution method in a real water network problem.

■ Wed.A.21

Wednesday, 11:30-13:00, Room 2.1, Organized Session

Geometry in nonsmooth optimization

Cluster: Convex and nonsmooth optimization

Session organized by: *Dmitriy Drusvyatskiy*

1. **Optimization and intrinsic geometry**

   Dmitriy Drusvyatskiy (dd379@cornell.edu) Cornell University, USA, *Alexander D. Ioffe*, *Adrian S. Lewis*

Modern optimization — both in its driving theory and in its classical and contemporary algorithms — is illuminated by geometry. I will present two case studies of this approach. The first example — seeking a common point of two convex sets by alternately projecting onto each — is classical and intuitive, and widely applied (even without convexity) in applications like image processing and low-order control. I will sketch some nonconvex cases, and relate the algorithm's convergence to the intrinsic geometry of the two sets. The second case study revolves around "partly smooth manifolds"— a geometric generalization of the active set notion fundamental to classical Nonlinear optimization. I emphasize examples from eigenvalue optimization. Partly smooth geometry opens the door to acceleration strategies for first-order methods, and is central to sensitivity analysis. Reassuringly, given its power as a tool, this geometry is present generically in semi-algebraic optimization problems.

2. **Non-convex feasibility problems: Qualitative and quantitative characterizations of set intersections**

   Robert Hesse (hesse@math.uni-goettingen.de) Georg-August-Universitaet Goettingen, Germany, *Russell Luke*

Projection algorithms for solving (non-convex) feasibility problems in Euclidean spaces provide powerful and computationally efficient schemes for a wide variety of applications. We focus on the Method of Alternating Projections (MAP) and the Averaged Alternating Reflection Algorithm (AAR) which are the foundation of the state of the art algorithms in imaging and signal processing, our principle application. In the last several years the regularity requirements for linear convergence of these algorithms have come into sharper relief. We focus on two different approaches dealing with nonconvex feasibility. One approach (Bauschke, Luke, Phan, Wang 2012) that uses normal cone techniques achieving optimal convergence rates for MAP. The other approach (H.-Luke 2012) deals with direct/primal techniques achieving sufficient and even necessary conditions for linear convergence of both MAP and AAR, however this strategy does not yield optimal quantitative rates. An adequate description of the relation between these two approaches remains open. Closing this gap requires a good understanding of qualitative and quantitative characterizations of set intersections. An overview over different concepts of regularity (e.g. linear regularity, strong regularity, Friedrichs angle,...) will be given in this talk.

3. **The convex set intersection problem: Supporting hyperplanes and quadratic programming**

   C. H. Jeffrey Pang (matpchj@nus.edu.sg) Dept. Mathematics, National University of Singapore, Singapore

We study how the supporting hyperplanes produced by the projection process can complement the method of alternating projections and its variants for the convex set intersection problem. Based on this idea, we propose an algorithm that, like Dykstra's algorithm, converges strongly in a Hilbert space to the intersection of finitely many convex sets. An analogue of the alternating projection algorithm can converge superlinearly with few added conditions, or quadratically under additional regularity. Under a conical condition, the convergence is finite. We present results of our numerical experiments.

■ Wed.A.22

Wednesday, 11:30-13:00, Room 2.2, Organized Session

Structured convex and nonconvex optimization

Cluster: Convex and nonsmooth optimization

Session organized by: *Zhaosong Lu, Guanghui Lan*

1. **On minimal valid inequalities for mixed integer conic programs**

   Fatma Kilinc-Karzan (fkilinc@andrew.cmu.edu) Carnegie Mellon University, USA

We study structured mixed integer sets with a regular cone such as nonnegative orthant, Lorentz cone or positive semidefinite cone. In a unified framework, we introduce minimal inequalities and show that under mild assumptions, minimal inequalities together with the trivial conic inequalities provide complete convex hull description. We also provide a characterization of minimal inequalities by establishing necessary conditions for an inequality to be minimal. This characterization leads to a more general class of generalized subadditive inequalities, which includes minimal inequalities as a subclass. We establish relations between generalized subadditive inequalities and the support functions of sets with certain structure. Our framework generalizes the results from the mixed integer linear case, so whenever possible we highlight the connections to the existing literature.

2. **Complexity of large-scale convex optimization under linear minimization oracle**

Guanghui (George) Lan (glan@ise.ufl.edu) University of Florida, USA

We consider a generic class of iterative convex optimization algorithms which can only perform linear optimization over the feasible region in each iteration. We present the low complexity bounds for these algorithms under both smooth and nonsmooth cases, and establish the optimality of the classic conditional gradient (CG) method. We also introduce some new variants of the CG method and demonstrate their advantages for solving certain convex optimization problems, e.g., those with box-type constraints.

■ Wed.A.24

Wednesday, 11:30-13:00, Room 2.4, Organized Session

Error estimates for optimal control of PDEs

Cluster: PDE-constrained optimization
Session organized by: *Christian Clason, Eduardo Casas*

1. **Numerical analysis of nonconvex elliptic optimal control problems with state constraints**

Ira Neitzel (neitzel@ma.tum.de) Technische Universität München, Germany, *Johannes Pfefferer*, *Arnd Rösch*

We discuss properties of discretized optimal control problems governed by a semilinear elliptic state equation and subject to pointwise state constraints. We prove a rate of convergence for discrete local solution when the state equation is discretized by finite elements. Since the problem is nonconvex due to the nonlinearity of the state equation, second order sufficient conditions (SSC) play a role in the numerical analysis. SSC are also important for i.e. the convergence of numerical solution algorithms and local uniqueness of solutions. With this motivation, we prove that the SSC transfer from the continuous to the discrete problem formulation.

2. **Pointwise convergence of the feasibility violation for Moreau-Yosida regularized optimal control problems and applications to the finite element error of problems with gradient state constraints**

Winnifried Wollner (winnifried.wollner@math.uni-hamburg.de) University of Hamburg, Germany

In this talk we are concerned with an analysis of Moreau-Yosida regularization of pointwise state constrained optimal control problems. As recent analysis has already revealed that the convergence of the primal variables is dominated by the reduction of the feasibility violation in the maximum norm. We will use a new method to derive convergence of the feasibility violation in the maximum norm giving improved the known convergence rates. The analysis can be extended to certain cases where the pointwise violation does not vanish in the limit. This will be employed to analyze the finite element error of optimal control problems governed by elliptic PDEs with pointwise constraints on the gradient of the state on non smooth polygonal domains. For these problems, standard analysis fails because the control to state mapping does not yield sufficient regularity for the states to be continuously differentiable on the closure of the domain. Nonetheless, these problems are well posed. In particular, the results of the first part will be used to derive convergence rates for the primal variables of the regularized problem.

3. **Finite element error analysis for optimal control of the obstacle problem**

Christian Meyer (cmeyer@math.tu-dortmund.de) TU Dortmund, Germany

We consider the finite element approximation of an optimal control problem governed by a variational inequality of first kind. Based on first- and second-order optimality conditions a-priori error estimates will be established, which relate the finite element error of the optimal control problem to the L^2-error associated with the variational inequality. As the well-known Aubin-Nitsche trick is not available for variational inequalities, the L^2-error is estimated by the L^∞-error for discretizations which fulfill a discrete maximum principle. For two-dimensional problems this leads to quasi-optimal error estimates. Numerical results confirm these theoretical findings. Moreover, preliminary numerical results concerning a posteriori error estimates will be presented.

■ Wed.A.25

Wednesday, 11:30-13:00, Room 2.5

Set valued mapping and sensitivity analysis

Cluster: Variational analysis, set-valued and vector optimization
Session chair: *Gabor Kassay*

1. **Paratingent derivative applied to the measure of the sensitivity in multiobjective differential programming**

Fernando García Castaño (Fernando.gc@ua.es) University of Alicante, Spain, *Miguel Ángel Melguizo Padial*

The objective of this talk is to speak about some recently obtained results by the authors concerning analyse of sensitivity of differential programs of the form Min $f(x)$ subject to $g(x) = b$, x belongs to D, where f and g are C^1 maps whose respective images lie in ordered Banach spaces. On those, it is analysed the behaviour of some non-singleton sets of T-optimal solutions according to changes of the parameter b in the problem. Our main result states that the sensitivity of the program is measured by a Lagrange multiplier plus a projection of its derivative. This sensitivity is measured by means of the paratingent derivative. The talk will begin recalling some previous results on this matter, after that the new results will be stated and we will speak about what they contribute. These new results constitute a manuscript which has been accepted to be published in the special issue “Variational Analysis, Optimization, and Fixed Point Theory"of Abstract and Applied Analysis, http://www.hindawi.com/journals/aaa/si/858754/.

2. **Existence results for variational inequalities with surjectivity consequences related to generalized monotone operators**

Livia-Mihaela Berchesan (mihaela.miholca@yahoo.com) Babes-Bolyai University, Cluj-Napoca, Romania, *Gabor Kassay*

We present existence results for variational inequalities given by generalized monotone operators. As a consequence we deduce the existence of zeroes, or even more, surjectivity of some classes of set-valued operators. We show that by strengthening the continuity assumptions, similar surjectivity results can be obtained without any monotonicity assumption. In the framework of reflexive Banach spaces, we extend a related result due to Inoan and Kolumban (Nonlinear Analysis, 68(2008), pp. 47–53).

3. **An inverse map result and some applications to sensitivity of generalized equations**

Gabor Kassay (kassay@math.ubbcluj.ro) Babes-Bolyai University, Cluj-Napoca, Romania, *Monica Bianchi*, *Rita Pini*

This work deals with non-global inverse map results for the sum of two maps. We prove two theorems which shed some new light on this aspect. Some implications in terms of sensitivity of parametric generalized equations are investigated. Finally, a class of well-conditioned operators is identified.

■ Wed.A.AB

Wednesday, 11:30-13:00, Amphitheater B, Organized Session

Sparse and low-rank optimization

Cluster: Nonlinear optimization
Session organized by: *Coralia Cartis*

1. **Worst case complexity of nonconvex non-Lipschiz minimization**

Xiaojun Chen (maxjchen@polyu.edu.hk) Hong Kong Polytechnic University, Hong Kong, *Wei Bian*, *Dongdong Ge*, *Zizhou Wang*, *Yinyu Ye*

We consider evaluation complexity of minimization problems with nonconvex, non-Lipschitz regularization terms. For $L_2 - L_p$ non-Lipschitz regularized minimization, we show that finding a global optimal solution is strongly NP-hard. We propose a smoothing quadratic regularization algorithm for unconstrained problems and a first-order interior point algorithm for a class of problems with box constraints. Both algorithms are easy to implement and the worst-case iteration complexity for finding an ϵ scaled first-order stationary point is $O(\epsilon^{-2})$. Moreover, we develop a second-order interior point algorithm using the Hessian matrix, and solve a quadratic program with a ball constraint at each iteration. Although the second-order interior point algorithm costs more computational time than that of the first-order algorithm in each iteration, its worst-case iteration complexity for finding an ϵ (scaled) second-order stationary point is reduced to $O(\epsilon^{-3/2})$. Examples are presented to illustrate the theory and algorithms.

2. **Matrix completion at the edge of optimal**

Jared Tanner (tanner@maths.ox.ac.uk) University of Oxford, UK, *Ke Wei*

Matrix completion and low rank matrix recovery is a technique by which a low rank matrix is measured either by sampling entries of the matrix or through matrix products. Rank r matrices of size $m \times n$ have $r(m+n-r)$ degrees of freedom, requiring at least the same number of entries to be known. Computationally efficient algorithms, such as semidefinite programming, have been shown to be able to recover a rank r matrix from a modest multiple of the number of degrees of freedom. In this talk we present new non-convex algorithms for matrix completion and present empirical evidence that these algorithms are able to recover low rank matrices from a multiple of the oracle rate where the multiple is observed to converge towards one, giving the optimal rate.

3. **The geometry of phase transitions in convex optimization**

   Martin Lotz (martin.lotz@manchester.ac.uk) University of Manchester, UK, *Dennis Amelunxen*, *Michael McCoy*, *Joel Tropp*

Recent empirical research indicates that many convex optimization problems with random constraints exhibit a phase transition as the number of constraints increases. For example, this phenomenon emerges in the l_1 minimization method for identifying a sparse vector from linear samples. We present a rigorous analysis that explains why phase transitions are ubiquitous in convex optimization. It also describes tools for making reliable predictions about the quantitative aspects of the transition, including the location and the width of the transition region. These techniques apply to regularized linear inverse problems, to demixing problems, and to cone programs with random affine constraints. These applications depend on a new summary parameter, the statistical dimension of cones, that canonically extends the dimension of a linear subspace to the class of convex cones.

■ Wed.B.11

Wednesday, 14:30-16:00, Room 1.1, Organized Session

Conic programming and related problems I

Cluster: Conic and polynomial optimization
Session organized by: *Akiko Yoshise*

1. **A gradient method for the sparse least squares problem**

   Yu Xia (yxia@lakeheadu.ca) Lakehead University, Canada, *Paul McNicholas*

We adapt Nesterov's fast gradient method to the monotone fused LASSO model. The LASSO model is a special case of the fused LASSO model. The LASSO technique improves prediction accuracy and reduces the number of predictors, while the fused LASSO procedure also encourages flatness of the regression predictors. The monotone fused LASSO model describes regression with monotonic constraints better than the fused LASSO model. We give closed-form solutions for each iteration and prove the boundedness of the optimal solution set, and we show that the algorithm converges in polynomial time with respect to the input data size. Numerical examples are provided and discussed. Our approach can easily be adapted to related problems, such as the monotone regression and the fused LASSO model.

2. **On the positive definite matrix approximation with condition number constraint**

   Mirai Tanaka (tanaka.m.aa@m.titech.ac.jp) Tokyo Institute of Technology, Japan, *Kazuhide Nakata*

Positive definite matrix approximation with a condition number constraint is an optimization problem to find the nearest positive definite matrix whose condition number is smaller than a given constant. We demonstrate that this problem can be converted to a simpler one when we use a unitary similarity invariant norm as a metric, and to a univariate piecewise convex optimization problem when we use a Ky Fan p-k norm. We show that we can solve the resulting problem easily by the binary search. We also present an analytical solution to the problem whose metric is the spectral norm and the trace norm.

3. **A barrier-based smoothing proximal point algorithm for nonlinear complementarity problems over closed convex cones**

   Chek Beng Chua (cbchua@ntu.edu.sg) Nanyang Technological University, Singapore, *Zhen Li*

We present a new barrier-based method of constructing smoothing approximations for the Euclidean projector onto closed convex cones. These smoothing approximations are used in a smoothing proximal point algorithm to solve monotone nonlinear complementarity problems (NCPs) over a convex cone via the normal map equation. The smoothing approximations allow for the solution of the smoothed normal map equations with Newton's method, and do not require additional analytical properties of the Euclidean projector. The use of proximal terms in the algorithm adds stability to the solution of the smoothed normal map equation, and avoids numerical issues due to ill-conditioning at iterates near the boundary of the cones. We prove a sufficient condition on the barrier used that guarantees the convergence of the algorithm to a solution of the NCP. The sufficient condition is satisfied by all logarithmically homogeneous barriers. Preliminary numerical tests on semidefinite programming problems (SDPs) show that our algorithm is comparable with the Newton-CG augmented Lagrangian algorithm (SDPNAL) proposed in [X. Y. Zhao, D. Sun, and K.-C.Toh, SIAM J. Optim. 20 (2010), 1737–1765].

■ Wed.B.12

Wednesday, 14:30-16:00, Room 1.2, Organized Session

Exploiting structure in machine learning applications

Cluster: Sparse optimization and information processing
Session organized by: *Mark Schmidt*

1. **Block-coordinate Frank-Wolfe optimization for machine learning**

   Simon Lacoste-Julien (slacoste@di.ens.fr) École Normale Supérieure / INRIA, France, *Martin Jaggi*, *Mark Schmidt*, *Patrick Pletscher*

The Frank-Wolfe optimization algorithm (also called conditional gradient) is making a recent revival in machine learning, thanks to its ability to exploit well the structure of the machine learning optimization problems such as the sparse expansion of the solution. In this talk, I will present a simple randomized block-coordinate variant of the Frank-Wolfe algorithm for convex optimization with block-separable constraints. Despite its lower iteration cost, we show that it achieves a similar convergence rate in duality gap as the full Frank-Wolfe algorithm. We demonstrate its usefulness by applying it on the dual of a popular non-smooth optimization problem appearing in machine learning for structured prediction and which contains an exponential number of variables organized in n blocks, where n is the number of training examples and can be very large. The algorithm we obtain has the same low iteration complexity as primal stochastic subgradient methods for this problem, but with the added advantage of optimal step-size selection and duality gap certificates, yielding a significant optimization speed-up compared to the state-of-the-art solvers for this problem.

2. **Proximal Newton-type methods for minimizing composite functions**

   Yuekai Sun (yuekai@stanford.edu) Stanford University, USA, *Jason D. Lee*, *Michael A. Saunders*

We generalize Newton-type methods to minimize a sum of two convex functions: one is smooth and the other is simple, but not necessarily smooth. We show these proximal Newton methods inherit the desirable convergence properties of Newton-type methods for minimizing smooth functions. Many popular methods tailored to problems arising in bioinformatics, machine learning, signal processing are cases of proximal Newton-type methods, and our results yield new convergence guarantees for some of these methods.

3. **Lower bounds on the oracle complexity of convex optimization using information theory**

   Cristobal Guzman (cguzman@gatech.edu) Georgia Institute of Technology, USA, *Sebastian Pokutta*, *Gábor Braun*

The oracle complexity of convex programming is an important tool in the analysis of optimization methods, as it provides a complete understanding of the running time of algorithms in the worst-case. While in many cases lower bounds can be proved by providing a resisting oracle, this technique is hard to generalize to other settings. We provide a new, information theoretic framework for analyzing the oracle complexity of convex programming problems by means of information acquisition and learning of instances.

■ Wed.B.13

Wednesday, 14:30-16:00, Room 1.3

Complexity of convex/nonsmooth/nonlinear optimization methods

Cluster: Convex and nonsmooth optimization
Session chair: *Clovis Gonzaga*

1. **Worst-case complexity of adaptive cubic with regularization algorithm for nonsmooth objective functions using smoothing approach**

   Rohollah Garmanjani (nima@mat.uc.pt) Department of Mathematics, University of Coimbra, Portugal, *Suvendu Ranjan Pattanaik*

Recently, Cartis, Gould, and Toint have introduced an adaptive cubic with regularization for minimizing unconstrained optimization problems with smooth non-convex objective functions. Inspired by their work and using a smoothing approach, an adaptive cubic with regularization method for minimizing an unconstrained optimization problem with locally Lipschitz objective function is introduced. The global convergence and worst-case complexity of the introduced method will also be discussed.

2. **Optimal subgradient-based algorithms for large-scale convex optimization**

   Masoud Ahookhosh (masoud.ahookhosh@univie.ac.at) Faculty of Mathematics, University of Vienna, Austria, *Arnold Neumaier*

This study considers some algorithms for solving wide classes of convex optimization problems based on first-order information where the underlying function has a large number of variables. The primary idea is to introduce an optimal subgradient-based algorithm by proposing a novel fractional subproblem and explicitly solve it to be appropriate for employing in applications like signal and image processing, machine learning, statistics and so on. Then we develop the basic algorithm by carefully incorporating an affine term and a multidimensional subspace search into it to improve implementations of the algorithm when considered problems involve composition of an expensive linear mapping along with a computationally inexpensive function. The next aim is to introduce some prox function for unconstrained version of problems and effectively solve the corresponding subproblem. We also prove that the proposed algorithms are optimal in the sense of complexity for both smooth and nonsmooth functions. Considering an unconstrained version of some highly practical problems in signal and image processing, machine learning and statistics, we report some numerical results and compare with some state-of-the-art solvers.

3. **On the complexity of steepest descent algorithms for minimizing quadratic functions**

   Clovis Gonzaga (ccgonzaga1@gmail.com) Federal University of Santa Catarina, Brazil

We discuss the performance of the steepest descent algorithm for minimizing a quadratic function with Hessian eigenvalues between $a > 0$ and A. Steepest descent methods differ exclusively on the choice of step length at each iteration. We examine patterns in the distribution of these step lengths, showing that a large number of short steps are needed, and how these relate to the much smaller number of large steps. We develop a scheme for choosing the step lengths and try to prove the following result: the number of iterations needed to reduce the distance to an optimal solution by a fixed amount depends on the square root of A/a, in contrast with the linear dependence predicted by Kantorovich's analysis.

■ Wed.B.14

Wednesday, 14:30-16:00, Room 1.4, Organized Session

Variational inequalities and equilibrium problems II

Cluster: Complementarity and variational inequalities
Session organized by: *Patrizia Daniele*

1. **Solving generalized Nash games with shared constraints through evolutionary variational inequalities**

   Monica Gabriela Cojocaru (mcojocar@uoguelph.ca) University of Guelph, Guelph, Ontario, Canada

We show in this talk how a new parametrization technique can be introduced via the so-called evolutionary variational inequality (EVI) problems, such that by restricting the solution sets of such specialized EVI problems, together with complementarity conditions, we obtain a clear description of the solution set of a generalized Nash (GN) game with shared constraints. As a consequence, the stability of GN equilibria can be studied. We give examples of how the technique is used and show that it solves GN previously not solved by existing VI parametrization techniques.

2. **Variational inequalities in set-optimization**

   Giovanni Paolo Crespi (g.crespi@univda.it) University of Valle d'Aosta, Italy, *Carola Schrage*

We study necessary and sufficient conditions to attain solutions of set-optimization problems in therms of variational inequalities of Stampacchia and Minty type. The notion of a solution we deal with has been introduced by F. Heyde and A. Lohne, for convex set-valued objective functions. To define the set-valued variational inequality, we introduce a set-valued directional derivative and we relate it to the Dini derivatives of a family of linearly scalarized problems. The optimality conditions are given by Stampacchia and Minty type variational inequalities, defined both by the set valued directional derivative and by the Dini derivatives of the scalarizations. The main results allow to obtain known variational characterizations for vector valued optimization problems.

3. **Variational problems with gradient constraints**

   Sofia Giuffrè (sofia.giuffre@unirc.it) D.I.I.E.S. "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy, *Antonino Maugeri*

The aim of the talk is to present some recent improvements on the theory of elastic-plastic torsion problem, specially characterizing the Lagrange Multiplier associated to the problem and showing the relationship with the obstacle problem. The existence of the Lagrange multiplier for the elastic-plastic torsion problem will be shown in more general settings with respect to the results in literature, and considering nonlinear monotone operators. Moreover these questions will be studied for variational problems with nonconstant gradient constraints. The main tool for the study is a recently developed strong duality theory, based on a constraint qualification assumption. This theory holds in infinite-dimensional settings and allows to apply the Lagrangian multipliers method to infinite-dimensional problems.

■ Wed.B.15

Wednesday, 14:30-16:00, Room 1.5, Organized Session

Advances in derivative free optimization III

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Anke Tröltzsch*

1. **GLODS: Global and local optimization using direct search**

   Ana Luísa Custódio (alcustodio@fct.unl.pt) Universidade Nova de Lisboa, Portugal, *J. F. A. Madeira*

Locating and identifying points as global minimizers is, in general, a hard and time-consuming task. Difficulties increase when the derivatives of the functions defining the problem are not available for use. In this work, we present a new algorithm suited for bound constrained, derivative-free, global optimization. Using direct search of directional type, the method alternates between a search step, where potentially good regions are located, and a poll step where the previously located regions are explored. This exploitation is made through the launching of several pattern search methods, one in each of the regions of interest. Differently from a multistart strategy, the several pattern search methods will merge between them when sufficiently close to each other. The goal is to end with as many pattern searches as the number of local minimizers, which would allow to easily locating the possible global extreme value. We describe the algorithmic structure considered, present the corresponding convergence analysis and report numerical results, showing that the proposed method is competitive with currently commonly used solvers.

2. **Equality-constrained derivative-free optimization**

   Phillipe R. Sampaio (phillipe.sampaio@math.fundp.ac.be) University of Namur, Belgium, *Philippe Toint*

In this work, we look into new derivative-free methods to solve equality-constrained optimization problems. Of particular interest, are the trust-region techniques, which have been investigated for the unconstrained and bound-constrained cases. For solving equality-constrained optimization problems, we introduce a derivative-free adaptation of the trust-funnel method combined with a self-correcting geometry scheme and present some encouraging initial numerical results.

3. **Globally convergent evolution strategies and CMA-ES**

   Youssef Diouane (diouane@cerfacs.fr) CERFACS Toulouse, France, *Serge Gratton*, *Luis Nunes Vicente*

In this talk we show how to modify a large class of evolution strategies (ES) to rigorously achieve a form of global convergence. The modifications consist essentially of the reduction of the size of the steps whenever a sufficient decrease condition on the function values is not verified. When such a condition is satisfied, the step size can be reset to the step size maintained by the ES themselves, as long as this latter one is sufficiently large. Adapting the ES algorithms to handle linearly constrained problems has been also investigated. Our numerical experiments have shown that a modified version of CMA-ES (a relevant instance of the considered ES) is capable of further minimization progress within moderate budgets. Moreover, we have observed that such an improvement in efficiency comes without deteriorating significantly the behavior of the underlying method in the presence of nonconvexity.

■ Wed.B.16

Wednesday, 14:30-16:00, Room 1.6, Organized Session

Algorithms for MINLP: Theory and practice

Cluster: Global optimization and mixed-integer programming

Session organized by: *Giacomo Nannicini*

1. **Mirror-descent methods in mixed-integer convex optimization**

Michel Baes (michel.baes@ifor.math.ethz.ch) Institute for Operations Research, ETH Zurich, Switzerland, *Timm Oertel*, *Christian Wagner*, *Robert Weismantel*

We address the problem of minimizing a convex function f over a convex set, with the extra constraint that some variables must be integer. This problem, even when f is a piecewise linear function, is NP-hard. We study an algorithmic approach to this problem, postponing its hardness to the realization of an oracle. If this oracle can be realized in polynomial time, then the problem can be solved in polynomial time as well. For problems with two integer variables, we show with a novel geometric construction how to implement the oracle efficiently. Our algorithm can be adapted to find the k-th best point of a purely integer convex optimization problem in two dimensions.

2. **Hybrid SDP bounding procedure**

Emiliano Traversi (emiliano.traversi@gmail.com) TU Dortmund, Germany, *Fabio Furini*

The principal idea of this paper is to exploit Semidefinite Programming (SDP) relaxation within the framework provided by Mixed Integer Nonlinear Programming (MINLP) solvers when tackling Binary Quadratic Problems. We included the SDP relaxation in a state-of-the-art MINLP solver as an additional bounding technique and demonstrated that this idea could be computationally useful. The Quadratic Stable Set Problem is adopted as the case study. The tests indicate that the Hybrid SDP Bounding Procedure allows an average 50% cut of the overall computing time and a cut of more than one order of magnitude for the branching nodes.

3. **Algorithms for the minimum volume ellipsoid estimator**

Selin Damla Ahipasaoglu (ahipasaoglu@sutd.edu.sg) Singapore University of Technology and Design, Singapore

The MVE estimator is an important tool in robust regression and outlier detection in statistics. Given a set of points, MVE estimator is based on an ellipsoid which encloses a fixed number of points (usually at least half of them) and has the smallest possible volume. Finding such an ellipsoid is computationally very challenging especially for large data sets. This paper develops a 2-exchange heuristic and a branch-and-bound algorithm for computing the MVE estimator. Comparative computational results are provided which demonstrate the strength of the algorithm.

■ Wed.B.17

Wednesday, 14:30-16:00, Room 1.7, Organized Session

Applications in location problems

Cluster: Applications of continuous optimization in science and engineering

Session organized by: *Pilar M. Ortigosa*

1. **On bi-level thinking in continuous competitive location**

Eligius M. T. Hendrix (eligius.hendrix@wur.nl) Wageningen University, The Netherlands, and Universidad de Málaga, Spain

When locating a new facility, a company should take into account the reaction of possible competitors. In continuous location, this leads to challenging Global Optimization problems. The competition can also enhance price competition, or competing with quality to attract more customers. We observe that in location science this is typically dealt with from a bi-level way of thinking, where optimization of the competitive prices and quality is done on a second level and substituted into a first level decision. Moreover, the reaction of the competitor can be considered a second level decision in a so-called leader-follower (Stackelberg) setting leading potentially to tri-level analysis. One can also focus on Nash equilibria from the location perspective where one tries to find whether stable market situations in terms of competition, location or quality competition exist. This setting gives rise to many studies that focus on optimality conditions and algorithms that make use of these conditions in order to find the best location for the competing firm. We will sketch several interesting cases that lead to multiple studies on the subject.

2. **A multiobjective optimization algorithm for locating a semi-obnoxious facility in the plane**

Pilar M. Ortigosa (ortigosa@ual.es) Dept. of Informatics, University of Almeria, Spain, *Juana L. Redondo*, *Aránzazu G. Arrondo*, *Jose Fernandez*

Most decision-making problems involve more than one objective. The decision about where to set up a new facility is not an exception. This is particularly true when the facility to be located is semi-obnoxious, that is, it is attractive to some of the demand points with which it will interact, and repulsive to others. In this paper we present a new multi-objective facility location model. The first objective is the classical minsum one, where one seeks to minimize the sum of weighted distances from the facility to the demand points that perceive the facility as attractive. The second one is the minimization of the global repulsion of the demand points that consider the facility as obnoxious. The third one (Gini coefficient) is an equity measure, and seeks that the differences among the individual repulsions is minimized. We are interested in obtaining a finite set of points which cover the complete Pareto-front and evenly distributed over it. In this paper we present a general-purpose multi-objective evolutionary algorithm, called FEMOEA, whose aim is to obtain a fix size approximation of the Pareto-front quickly. FEMOEA combines ideas from different multi- and single-objective optimization evolutionary algorithms, although it also incorporates new devices, namely, a new method to improve the efficiency of points and a new stopping rule to stop the algorithm as soon as a good approximation of the Pareto-front is obtained.

3. **A parallel algorithm for solving a bi-objective location problem**

Aránzazu G. Arrondo (agarrondo@um.es) Dept. Statistics and Operations Research, University of Murcia, Spain, *Juana L. Redondo*, *José Fernández*, *Pilar M. Ortigosa*

Most of real-life competitive location models include conflicting objectives. Recently, a new multi-objective evolutionary algorithm, called FEMOEA, which can be applied to many nonlinear multi-objective optimization problems, has been proposed. It combines ideas from different multi- and single-objective optimization evolutionary algorithms, although it also incorporates a new method to improve the efficiency of points and a new stopping rule, which help to improve the quality of the obtained approximation of the Pareto-front and to reduce the computational requirements. FEMOEA has been compared to an interval branch-and-bound algorithm able to obtain an enclosure of the true Pareto-front as well as to the reference NSGA-II, SPEA2 and MOEA/D algorithms . Comprehensive computational studies have shown that, among the studied algorithms, FEMOEA provides better approximations. The computational time needed by FEMOEA may be not negligible at all when the set approximating the Pareto-front must have many points, because a high precision is required. Furthermore, the computational resources needed may be so high that a PC may run out of memory. In those cases, parallelizing the algorithm and run it in a supercomputer may be the best way forward. In this work, a parallelization of FEMOEA, called FEMOEA-Paral, is presented. To show its applicability, a bi-objective franchisor-franchisee facility location, already proposed in literature, is solved.

■ Wed.B.18

Wednesday, 14:30-16:00, Room 1.8, Organized Session

Robust optimization III

Cluster: Robust optimization and optimization in finance

Session organized by: *Xuan Vinh Doan*

1. **Optimization under probabilistic envelope constraints**

Huan Xu (mpexuh@nus.edu.sg) National University of Singapore, Singapore, *Constantine Caramanis*, *Shie Mannor*

Optimization under chance constraints is a standard approach to ensure that bad events such as portfolio losses, are unlikely to happen. They do nothing, however, to protect more against terrible events (e.g., deep portfolio losses, or bankruptcy). In this talk, we will propose a new decision concept, termed "probabilistic envelop constraint", which extends the notion of chance constraints, to a formulation that provides different probabilistic guarantees at each level of constraint violation. Thus, we develop a notion of guarantee across the spectrum of disasters, or rare events, ensuring these levels of protection hold across the curve, literally. We further show that the corresponding optimization problem can be reformulated as a semi-infinite optimization problem, and provide conditions that guarantee its tractability. Interestingly, the resulting formulation is what is known as a comprehensive robust optimization in literature. This work thus provides a new fundamental link between two main methodologies in optimization under uncertainty: Stochastic optimization and robust optimization.

2. **Adjustable robust parameter design with unknown distributions**

Ihsan Yanikoglu (i.yanikoglu@uvt.nl) Tilburg University, The Netherlands, *Dick den Hertog*, *Jack P.C. Kleijnen*

This article presents a novel combination of robust optimization developed in mathematical programming, and robust parameter design developed in statistical quality control. Robust parameter design uses metamodels estimated from experiments with both controllable and environmental inputs (factors). These experiments may be performed with either real or simulated systems; we focus on simulation experiments. For the environmental inputs, classic robust parameter design assumes known means and covariances, and sometimes even a known distribution. We, however, develop a robust optimization approach that uses only experimental data, so it does not need these classic assumptions. Moreover, we develop 'adjustable' robust parameter design which adjusts the values of some or all of the controllable factors after observing the values of some or all of the environmental inputs. We also propose a new decision rule that is suitable for adjustable integer decision variables. We illustrate our novel method through several numerical examples, which demonstrate its effectiveness.

3. **Distributionally robust optimization with a general Fréchet class of distributions**

Xuan Vinh Doan (Xuan.Doan@wbs.ac.uk) University of Warwick, UK, *Xiabo Li*, *Karthik Natarajan*

We investigate effects of a Fréchet class of distributions with general overlapping multivariate marginals in the context of robust optimization. We discuss the computational tractability of the model and the construction of the worst-case distributions. Numerical results are presented for a portfolio optimization problem with worst-case conditional value-at-risk.

■ Wed.B.21

Wednesday, 14:30-16:00, Room 2.1, Organized Session

Convex programming: Theoretical results

Cluster: Convex and nonsmooth optimization

Session organized by: *Roland Hildebrand*

1. **Conditional gradient algorithms for norm-regularized smooth convex optimization**

Zaid Harchaoui (zaid.harchaoui@inria.fr) INRIA and LJK, Grenoble, France, *Anatoli Juditsky*, *Arkadi Nemirovski*

Motivated by some applications in signal processing and machine learning, we consider two convex optimization problems where, given a cone K, a norm and a smooth convex function f, we want either 1) to minimize the norm over the intersection of the cone and a level set of f, or 2) to minimize over the cone the sum of f and a multiple of the norm. We focus on the case where (a) the dimension of the problem is too large to allow for interior point algorithms, (b) the norm is "too complicated" to allow for computationally cheap Bregman projections required in the first-order proximal gradient algorithms. On the other hand, we assume that it is relatively easy to minimize linear forms over the intersection of K and the unit-ball corresponding to the norm. Motivating examples are given by the nuclear norm with K being the entire space of matrices, or the positive semidefinite cone in the space of symmetric matrices, and the Total Variation norm on the space of 2D images. We discuss versions of the Conditional Gradient algorithm (aka Frank-Wolfe's algorithm) capable to handle our problems of interest, provide the related theoretical efficiency estimates and outline some applications.

2. **Some versions of a strong maximum principle for an elliptic functional with the generalized symmetry assumption**

Telma J. Santos (tjfs@uevora.pt) Universidade de Évora, Portugal, *Vladimir V. Goncharov*

We continue research by A. Cellina who formulated the variational version of the Strong Maximum Principle (SMP) for a functional rotationally symmetric and depending on the gradient. He proved that for such type of functionals SMP is valid if and only if the real function $f(\cdot)$ is strict convex and smooth at the origin. Generalizing the symmetry assumption we prove, in particular, that the same conditions are necessary and sufficient for validity of SMP for a more general functional, symmetric with respect to a gauge function associated to a closed convex bounded set F with zero in its interior. On the other hand, by using some a priori local estimates we establish a generalized version of SMP in the case when $f(\cdot)$ is no longer supposed to be strictly convex at the origin.

3. **Convex projective programming**

Roland Hildebrand (roland.hildebrand@imag.fr) Laboratory Jean Kuntzmann, University Grenoble 1 / CNRS, France

We study the counterparts of conic linear programs, i.e., problems of optimization of linear functions on intersections of a convex cone with an affine subspace, in a projective setting. The projective theory is in many respects more neat and symmetric than the affine one. The classification of projective programs with respect to boundedness and feasibility is simpler and more transparent, providing interpretations which are obscured in the affine setting. A central feature of this classification is the equivalence between infeasibility of the primal program and the appearance of singularities in the dual program and vice versa. The cost function and the linear constraint cannot anymore be separated and fuse into a single object. Since infinity is an ordinary point on the projective line, infinite values of the objective function are no more conceptually different from finite ones. This erases in some cases the difference between bounded and unbounded problem instances and reveals symmetries which were hidden in the affine setting.

■ Wed.B.22

Wednesday, 14:30-16:00, Room 2.2, Organized Session

Recent developments on first-order methods for large-scale convex optimization

Cluster: Convex and nonsmooth optimization

Session organized by: *Renato D. C. Monteiro, Camilo Ortiz*

1. **Low-rank tensor optimization problems**

Shiqian Ma (sqma@se.cuhk.edu.hk) Chinese University of Hong Kong, Hong Kong, *Bo Jiang*, *Shuzhong Zhang*

In this talk, we will discuss several tensor optimization problems that require the resulting solution to have a low-rank structure. These problems include low-rank tensor completion, low-rank and sparse tensor separation and tensor principal component analysis. We show that although these problems are all nonconvex and NP-hard in general, they can be approximated very well in practice by certain structured convex optimization problems. Numerical results on applications arising from computer vision and portfolio selection with higher-order moments will be presented.

2. **A first-order block-decomposition method for solving two-easy-block structured semidefinite programs**

Renato D. C. Monteiro (monteiro@ isye.gatech.edu) Georgia Institute of Technology, USA, *Camilo Ortiz*, *Benar F. Svaiter*

We consider a first-order block-decomposition method for minimizing the sum of a convex differentiable function with Lipschitz continuous gradient, and two other proper closed convex (possibly, nonsmooth) functions with easily computable resolvents. The method presented contains two important ingredients from a computational point of view, namely: an adaptive choice of stepsize for performing an extragradient step; and the use of a scaling factor to balance the blocks. We then specialize the method to the context of conic semidefinite programming (SDP) problems consisting of two easy blocks of constraints. Without putting them in standard form, we show that four important classes of graph-related conic SDP problems automatically possess the above two-easy-block structure, namely: SDPs for θ-functions and θ_+-functions of graph stable set problems, and SDP relaxations of binary integer quadratic and frequency assignment problems. Finally, we present computational results on the aforementioned classes of SDPs showing that our method outperforms the three most competitive codes for large-scale conic semidefinite programs, namely: the boundary point (BP) method introduced by Povh et al., a Newton-CG augmented Lagrangian method, called SDPNAL, by Zhao et al., and a variant of the BP method, called the SPDAD method, by Wen et al.

■ Wed.B.23

Wednesday, 14:30-16:00, Room 2.3

Derivatives calculation

Cluster: Optimization software: Modeling tools and engines
Session chair: *Joaquim R. R. A. Martins*

1. **Third-order methods and third-order derivatives with AD**

   Robert Gower (gowerrobert@gmail.com) Maxwell Institute for Mathematical Sciences, University of Edinburgh, UK

What can be gained by incorporating third-order information in the Newton direction? The third-order derivative is a third order tensor: a cube. Calculating and operating on such an object becomes a fundamental deterrent as dimension grows. We investigate methods that incorporate a handful of tensor-vector products. Each Tensor-vector product is a sparse matrix, thus no three dimensional object is formed. Furthermore, we present novel Automatic Differentiation method for efficiently calculating such slices of the tensor, at a cost comparable to state-of-the-art methods used for calculating sparse Hessians.

2. **Analytic derivatives: Symbolic versus automatic**

   Zsolt Csizmadia (zsoltcsizmadia@fico.com) FICO

Automatic differentiation is an efficient and often the only viable method for calculating dense or large Hessian matrices. Symbolic derivatives are easy to interpret, efficient to recalculate if only a certain position needs to be perturbed and recognizing repetitions is straightforward. The talk will compare the challenges in implementing efficient first and second order symbolic and automatic differentiation tools. We will provide some insights into how to select the best tool for a non-linear solver, assuming the solver has full access to the derivative engine.

3. **A matrix-free approach to large-scale nonlinear constrained optimization**

   Joaquim R. R. A. Martins (jrram@umich.edu) University of Michigan, USA, *Andrew Lambe*

In many problems within structural and multidisciplinary optimization, the computational cost is dominated by computing gradient information for the objective and all constraints. If the problem contains both a large number of design variables and a large number of constraints, analytic gradient computation methods become inefficient. Constraint aggregation may be used together with the adjoint method to reduce the cost of the gradient computation at the expense of problem conditioning and the quality of the final solution. An alternative approach is proposed in which a specialized optimizer is employed that only requires products of the constraint Jacobian with appropriate vectors rather than the full Jacobian itself. These matrix-vector products can be formed for a fraction of the cost of forming the full matrix, allowing the original set of constraints to be used without aggregation. We regard the resulting optimizer as 'matrix-free' in that it does not require the Hessian or Jacobian matrices of the optimization problem to be explicitly formed. Results on two simple structural optimization problems are presented.

■ Wed.B.24

Wednesday, 14:30-16:00, Room 2.4, Organized Session

Optimality conditions in optimal control of PDEs

Cluster: PDE-constrained optimization
Session organized by: *Francisco J. Silva*

1. **Optimality conditions for VI constrained optimization**

   Juan Carlos De los Reyes (juan.delosreyes@epn.edu.ec) Research Center on Math. Modelling, EPN Quito, Ecuador

We discuss optimality conditions for control problems governed by a class of variational inequalities of the second kind. Applications include the optimal control of Bingham viscoplastic materials and simplified friction problems. If the problem is posed in $\mathbb{R}^n$ an optimality system has been derived by J. Outrata (2000). When considered in function spaces, however, the problem presents additional difficulties. We propose an alternative approximation approach based on a Huber type regularization of the governing variational inequality. By using a family of regularized optimization problems and performing an asymptotic analysis, an optimality system for the original optimal control problem (including complementarity relations between the variables involved) is obtained.

2. **Strong minima for optimal control problems governed by semi linear parabolic equations**

   Térence Bayen (tbayen@math.univ-montp2.fr) Université Montpellier 2, Montpellier, France, *Francisco Silva*

We study an optimal control problem governed by a semilinear parabolic equation with bound constraints on the distributed control, and integral constraints on the final state. First and second order optimality conditions for characterizing weak solutions of the problem can be found in the literature. Our aim is to characterize local quadratic growth for the cost function in the sense of strong solutions, which means that local optimality is considered in the state space only. Under standard assumptions on the system and the cost functional, we prove a decomposition result of the cost function using classical Sobolev embeddings for parabolic linear equations. This decomposition result provides a second-order expansion of the cost function, and allows to characterize local quadratic growth of the cost function in the strong sense in presence of bound constraints on the control and integral constraints on the final state. The study of strong solutions for optimal control problems governed by a semilinear parabolic equation seems to be new to our knowledge.

3. **Optimal control of viscosity solutions to first-order Hamilton-Jacobi equations**

   Jameson Graber (jameson.graber@ensta-paristech.fr) ENSTA Paristech, Inria Saclay, France

As is well-known, viscosity solutions to the Hamilton-Jacobi equations can be used to model front propagation using the level-set approach. A natural question is to ask, can we control said front propagation to achieve desirable outcomes while simultaneously minimizing a given cost? For instance, we might consider the basic problem of slowing the spread of a fire or containing an oil spill while minimizing the cost of constructing a barrier. In this study we seek (1) the existence of optimal solutions, (2) a characterizations of optimizers, and (3) algorithms for computing optimizers numerically.

■ Wed.B.25

Wednesday, 14:30-16:00, Room 2.5

Optimization on manifolds and functional spaces

Cluster: Variational analysis, set-valued and vector optimization
Session chair: *Paulo Roberto Oliveira*

1. **Convergence analysis of a proximal Gauss-Newton method**

   Saverio Salzo (saverio.salzo@unige.it) DIBRIS, Università di Genova, Italy, *Silvia Villa*

An extension of the Gauss-Newton algorithm is proposed to find local minimizers of penalized nonlinear least squares problems, under generalized Lipschitz assumptions. Convergence results of local type are obtained, as well as an estimate of the radius of the convergence ball. Some applications for solving constrained nonlinear equations are discussed and the numerical performance of the method is assessed on some significant test problems.

2. **A robust Kantorovich's theorem on the inexact Newton method with relative residual error tolerance**

   Orizon P. Ferreira (orizon@mat.ufg.br) Universidade Federal de Goiás, Brazil, *Benar F. Svaiter*

We prove that under semi-local assumptions, the inexact Newton method with a fixed relative residual error tolerance converges Q-linearly to a zero of the nonlinear operator under consideration. Using this result we show that the Newton method for minimizing a self-concordant function or to find a zero of an analytic function can be implemented with a fixed relative residual error tolerance.

3. **Proximal point method on Finslerian manifolds**

Paulo Roberto Oliveira (poliveir@cos.ufrj.br) PESC/COPPE-Federal University of Rio de Janeiro, Brazil, *Pedro Antonio Soares Junior*, *João Xavier da Cruz Neto*, *Antoine Soubeyran*

In this paper we consider minimization problems with constraints. We extend the proximal point method to Finslerian manifold of non positive flag curvature, where the objective function is differentiable and satisfies the Kurdyka-Lojasiewicz property. We present some examples of Finsler manifolds, and some applications. We show that the sequence generated by the method is well defined and converges to a minimizer point. Besides, we present a rate of convergence result.

■ Wed.B.AB

Wednesday, 14:30-16:00, Amphitheater B, Organized Session

Linear algebra and optimization

Cluster: Nonlinear optimization

Session organized by: *Coralia Cartis*

1. **Updating techniques for sequences of KKT systems in quadratic programming**

Benedetta Morini (benedetta.morini@unifi.it) Università di Firenze, Italy, *Stefania Bellavia*, *Valentina De Simone*, *Daniela di Serafino*

The problem of solving sequences of linear systems is a key issue in many optimization techniques. Recently, in the iterative solution of large-scale systems there has been a growing interest in improving the solution of the overall sequence by sharing some computational effort throughout the sequence. To this end, cheap updates of an existing preconditioner for one matrix of the sequence have been proposed in order to build preconditioners for subsequent matrices. In this talk we address the problem of solving sequences of KKT systems arising in large-scale optimization methods for quadratic programming and focus on Constraint Preconditioners (CPs). Though CPs are very effective in the iterative solution of KKT systems, their setup may still account for a significant part of the computational cost of the optimization procedure, thus motivating the interest towards cheaper CP approximations. We discuss some techniques to build approximate CPs for KKT sequences arising in interior point methods for quadratic programming, through low-cost updates of a seed CP preconditioner. Both updates and low-rank corrections of the factorization of the seed preconditioner are considered. Numerical results showing the performance of these techniques are presented.

2. **Dual space techniques for nonlinear least-squares in data assimilation**

Philippe Toint (philippe.toint@unamur.be) University of Namur, Belgium, *Serge Gratton*, *Selime Gurol*

We consider the well-known 4D-VAR problem in data assimilation and present some new techniques for handling the solution of the involved subproblem. The problem is first briefly reviewed, and the relation of the standard method with the nonlinear Gauss-Newton algorithm recalled, including the need of its globalization (for instance using a trust-region technique). The solution of the subproblem is then considered and it is shown how this solution may be viewed (and economically computed) in the dual space. The strategy is then applied to the GLTR technique for trust-regions. The problem of loss of symmetry is discussed with a tentative solution. Some results are finally presented for MATLAB experiments, but also for versions implemented in the NEMOVAR and ROMS systems.

3. **Branching and bounding improvements for Lipschitz global optimization**

Jaroslav M. Fowkes (jaroslav.fowkes@ed.ac.uk) University of Edinburgh, UK, *Coralia Cartis*, *Nick Gould*

We present improved bounding procedures in the context of a recent global optimization algorithm based on cubic regularization. The bounding procedures are general and can be applied to any branch and bound algorithm that uses estimates of the spectrum of the Hessian or derivative tensor, as they are constructed using generalisations of Gershgorin's theorem and other spectral approaches. In order to improve the branching aspects of the algorithm, and using the proposed bounding procedures, we develop parallel variants based on both data parallel and task parallel paradigms and address important performance issues that arise such as doubling of work and load balancing. Numerical testing of the bounding techniques and parallel approaches on a HPC cluster is presented with promising results.

■ Wed.C.11

Wednesday, 16:30-18:00, Room 1.1, Organized Session

Extended formulations and matrix factorizations

Cluster: Conic and polynomial optimization

Session organized by: *João Gouveia, Rekha Thomas*

1. **Support-based lower bounds for the positive semidefinite rank of a nonnegative matrix**

Dirk Oliver Theis (dotheis@ut.ee) University of Tartu, Estonia

The positive semidefinite rank of a nonnegative $m \times n$-matrix S is the minimum number q such that there exist positive semidefinite $q \times q$ matrices $A_1, \ldots, A_m, B_1, \ldots, B_n$ such that $S(k,\ell) = \operatorname{tr} A_k^* B_\ell$. Just as the nonnegative rank characterizes the minimum size of formulations of combinatorial optimization problems as linear programs, the positive semidefinite rank characterizes their minimum size as positive semidefinite programs. The most important lower bound technique on nonnegative rank only uses the zero/non-zero pattern of the matrix. We characterize the power of lower bounds on positive semidefinite rank based on the zero/non-zero pattern. We then use this characterization to prove lower bounds on the positive semidefinite ranks of families of matrices which arise from the Traveling Salesman and Max-Cut problems.

2. **Robust near-separable nonnegative matrix factorization using linear optimization**

Nicolas Gillis (nicolas.gillis@uclouvain.be) Université Catholique de Louvain, Belgium, *Robert Luce*

Nonnegative matrix factorization (NMF) has been shown recently to be tractable under the separability assumption, which amounts for the columns of the input data matrix to belong to the convex cone generated by a small number of columns. Bittorf, Recht, R'e and Tropp ('Factoring nonnegative matrices with linear programs', NIPS 2012) proposed a linear programming (LP) model, referred to as HottTopixx, which is robust under any small perturbation of the input matrix. However, HottTopixx has two important drawbacks: (i) the input matrix has to be normalized, and (ii) the factorization rank has to be known in advance. In this talk, we generalize HottTopixx in order to resolve these two drawbacks, that is, we propose a new LP model which does not require normalization and detects the factorization rank automatically. Moreover, the new LP model is more flexible, significantly more tolerant to noise, and can easily be adapted to handle outliers and other noise models. We show on several synthetic datasets that it outperforms HottTopixx while competing favorably with two state-of-the-art methods.

3. **Common information and unique disjointness**

Sebastian Pokutta (sebastian.pokutta@isye.gatech.edu) Georgia Tech, USA, *Gábor Braun*

We provide a new framework to lower bound the nonnegative rank of a matrix in terms of common information and information theory. In this framework we can improve on recent results for the correlation polytope. We also compute the exact common information of the unique disjointness patterns and we provide the first family of polytopes that has high approximate extension complexity, both in the average case as well as in the adversarial case. These new results are proven by showing that the UDISJ patterns are extremely robust towards noise and adversarial changes by means of an information theoretic analysis.

■ Wed.C.13

Wednesday, 16:30-18:00, Room 1.3, Organized Session

Optimality conditions and algorithms

Cluster: Nonlinear optimization

Session organized by: *Ernesto G. Birgin*

1. **Applications of the approximate-KKT optimality condition**

   Gabriel Haeser (gabriel.haeser@unifesp.br) Federal University of São Paulo, Brazil

In this work we present some applications of the Approximate-Karush-Kuhn-Tucker (AKKT) optimality condition. In contrast with the usual KKT condition, AKKT is a strong optimality condition regardless of constraint qualifications. When a very weak constraint qualification is present, AKKT implies the usual KKT condition. We have used the AKKT condition and others so-called Sequential Optimality Conditions to provide adequate stopping criteria for iterative solvers. The AKKT condition has also been used as a theoretical tool to provide new very weak constraint qualifications associated to the convergence of Augmented Lagrangian, Sequential Quadratic Programming, Interior Point and Inexact Restoration methods. When approximate Lagrange multipliers are not generated by the solver, we can also use AKKT to define a stopping criterion. This has been applied to a Genetic Algorithm framework.

2. **Constant rank of subspace component: A new constraint qualification**

   Roberto Andreani (andreani@ime.unicamp.br) State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, *Gabriel Haeser*, *M. L. Schuverdt*, *Paulo J. S. Silva*

We present a new constraint qualification that extends the relaxed constant rank constraint qualification. We relax the assumption that the rank of all subsets of gradients of active inequality constraints and equalities constraints must remain constant, to a single subset of such gradients which is easily computed. Our new constraint qualification also extends the relaxed constant positive linear dependence condition recently proposed and ensures the convergence of penalty based methods, like the augmented Lagrangian. We present theoretical properties and potential applications for perturbed problems and convergence of algorithms.

3. **On convergence to infeasible points in augmented Lagrangian methods**

   Leandro F. Prudente (lfprudente@gmail.com) Federal University of Goiás, Brazil, *José Mario Martínez*

Practical Nonlinear Programming algorithms may converge to infeasible points, even when feasible points exist. It is sensible to detect this situation as quickly as possible, in order to have time to change initial approximations and parameters, with the aim of obtaining convergence to acceptable solutions in further runs. Sometimes, on the other hand, the feasible set of an optimization problem that one aims to solve is empty. In this case, two characteristics of the algorithm are desirable: the algorithm should converge to a minimizer of some infeasibility measure and one may wish to find a point with minimal infeasibility for which some optimality condition, with respect to the objective function, holds. Ideally, the algorithm should converge to a minimizer of the objective function subject to minimal infeasibility. We present an Augmented Lagrangian algorithm that, with minor modifications, may achieve the goals of both cases. In the first one, the probability of quick detection of asymptotic infeasibility is enhanced and, in the second one, the method satisfies, as much as possible, the two desirable properties.

■ Wed.C.14

Wednesday, 16:30-18:00, Room 1.4

MPEC and applications

Cluster: Complementarity and variational inequalities
Session chair: *Joaquim João Júdice*

1. **Inverse eigenvalue complementarity problem**

   Carmo P. Brás (mb@fct.unl.pt) CMA, FCT-UNL, Portugal, *Joaquim João Júdice*, *Hanif D. Sherali*

In this talk, we discuss the solution of an Inverse Eigenvalue Complementarity Problem (IEiCP). Some applications of the IEiCP are first described. Two nonlinear formulations, NLP1 and NLP2, of the IEiCP are presented. A necessary and sufficient condition for a stationary point of NLP1 to be a solution of the IEiCP is established. An enumerative algorithm is designed for the solution of the IEiCP by finding a global minimum of NLP2. The use of additional implied constraints for enhancing the efficiency of the algorithm is also discussed. Computational results are provided to highlight the performance of the algorithm in practice.

2. **Robust nonlinear programming with discretized PDE constraint using quadratic approximations**

   Adrian Sichau (sichau@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

We present a second-order approximation for the robust counterpart of general uncertain NLP with state equation that is given by a discretized PDE. This approach is an extension of the first-order robust approximations that have been proposed by M. Diehl, H. G. Bock and E. Konstina and by Y. Zhang. We show how the approximated worst-case functions, which are the essential part of the approximated robust counterpart, can be formulated as trust-region problems that can be solved efficiently. Also, the gradients of the approximated worst-case functions can be computed efficiently combining a sensitivity and an adjoint approach. However, there might be points where these functions are nondifferentiable. Hence, we introduce an equivalent formulation of the approximated robust counterpart as an MPEC, in which the objective and all constraints are differentiable. We present numerical results that show the efficiency of the described method when applied to shape optimization in structural mechanics in order to obtain optimal solutions that are robust with respect to uncertainty in acting forces. The robust formulation can further be extended to model the presence of actuators that are capable of applying forces to a structure in order to counteract the effects of uncertainty. Also the robust optimization problem with additional actuators can be solved efficiently.

3. **Solving a MPEC problem with a partial penalization**

   Matthieu Marechal (mmarechal@dim.uchile.cl) Laboratory Centro de Modelamiento Matematico, Universidad de Chile, Chile, *Rafael Correa*

The talk deals with the numerical resolution of MPEC problems (Mathematical Programming with Equilibrium Constraints). The algorithm proposed is based on a penalization of the complementary constraint, and the use of a DC method (Difference of Convex functions) to solve the penalized problem. The talk studies the convergence of this algorithm, the feasibility of the limits of the sequence generated by this algorithm and their stationarity properties.

■ Wed.C.15

Wednesday, 16:30-18:00, Room 1.5, Organized Session

Derivative free methods for nonsmooth and noisy problems

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Giampaolo Liuzzi*

1. **A class of derivative-free nonmonotone algorithms for unconstrained nonlinear optimization**

   Francesco Rinaldi (rinaldi@math.unipd.it) Dipartimento di Matematica, Universitá di Padova, Italy, *Luigi Grippo*

In this paper we study a class of derivative-free unconstrained minimization algorithms employing nonmonotone inexact linesearch techniques along a set of suitable search directions. In particular, we define globally convergent nonmonotone versions of some well-known derivative-free methods and we propose a new algorithm combining coordinate rotations with approximate simplex gradients. Through extensive numerical experimentation, we show that the proposed algorithm is highly competitive in comparison with some of the most efficient direct search methods and model based methods on a large set of test problems.

2. **Derivative-free methods for multiobjective Lipschitz problems**

   Giampaolo Liuzzi (giampaolo.liuzzi@iasi.cnr.it) IASI - Consiglio Nazionale delle Ricerche, Italy, *Giovanni Fasano*, *Stefano Lucidi*, *Francesco Rinaldi*

This work focuses on the solution of a constrained multiobjective optimization problem, with both nonlinear inequality constraints and bound constraints. We assume that the vector of the objective functions and the constraints are Lipschitz continuous. We issue the equivalence between the original constrained multiobjective problem, and a multiobjective problem with simple bounds, by means of an exact penalty function approach. We study the Pareto-Clarke stationary points of the multiobjective problem with bound constraints, and state their correspondence with the Pareto-Clarke stationary points of the original constrained multiobjective problem. We propose a line search based derivative free framework to issue the latter correspondence. We also report some numerical results proving the effectiveness of the proposed approach.

3. **A derivative-free approximate gradient sampling algorithm for finite minimax problems**

Julie Nutini (julie.nutini@ubc.ca) University of British Columbia, Canada, *Warren Hare*

In this talk, we present a derivative-free optimization algorithm that exploits the smooth substructure of the finite minimax problem. Following the research of Burke, Lewis and Overton (2005), we use the framework of their gradient sampling algorithm. The algorithm calculates an approximate gradient for each of the active functions of the finite max function and uses these to generate an approximate subdifferential. The negative projection of 0 onto this set is used as a descent direction in an Armijo-like line search. We also present a robust version of the algorithm, which includes the 'almost active' functions, i.e., those active within a sampling ball of the current iteration, in the calculation of the approximate subdifferential. The steepest descent-like framework enables us to analyze the convergence of both algorithms directly, showing that either $f(x^k)$ goes to ∞ or every cluster point is a Clarke stationary point. A stopping condition is presented for both the regular and robust versions of the algorithm, and using the Goldstein approximate subdifferential, extended analysis is presented for a robust stopping condition. Numerical results are presented and a performance comparison is made between the regular and robust versions of the algorithm for three specific approximate gradients.

■ Wed.C.16

Wednesday, 16:30-18:00, Room 1.6, Organized Session

Copositive and quadratic optimization

Cluster: Global optimization and mixed-integer programming
Session organized by: *Immanuel Bomze*

1. **Relaxations for convex quadratic programming with binary indicator variables**

   Hongbo Dong (hdong6@wisc.edu) University of Wisconsin-Madison, USA, *Jeff Linderoth*

We consider convex relaxations for quadratic programming with continuous variables and their binary indicators, which has applications in sparse linear regression, sparse principal component analysis, digital filter design, etc. Based on a decomposition that splits a positive semidefinite (PSD) matrix into two PSD matrices, where one of them has a chosen sparsity pattern, we construct several convex relaxations. Some of them can be solved by second order cone programming, and others can be written as semidefinite programming over a sparse PSD cone (with a fixed sparsity pattern). Further we add linear inequalities that come from exploiting low dimensional convex hulls of quadratic forms including the indicator variables. We test on various problems to illustrate the trade-off between the speed of computing the relaxations and the strength of lower bounds.

2. **Copositive optimization based bounds on standard quadratic optimization**

   E. Alper Yildirim (alperyildirim@ku.edu.tr) Koc University, Turkey, *Gizem Sagol*

A standard quadratic optimization problem (StQOP) can be formulated as an instance of a linear optimization problem over the cone of completely positive matrices. Using an inner and outer hierarchy of polyhedral approximations of the cone of completely positive matrices, we study the properties of the lower and upper bounds on the optimal value of an StQOP that arise from these approximations. In particular, we give characterizations of instances for which the bounds are exact at a finite level of the hierarchy and of those instances for which the bounds are exact in the limit.

3. **Narrowing the difficulty gap for the Celis-Dennis-Tapia problem**

   Immanuel Bomze (immanuel.bomze@univie.ac.at) University of Vienna, Austria, *Michael L. Overton*

We study the so-called Celis-Dennis-Tapia (CDT) problem to minimize a non-convex quadratic function over the intersection of two ellipsoids. Contrasting with the well-studied trust region problem where the feasible set is just one ellipsoid, the CDT problem seems to be not yet fully understood. Our main objective in this paper is to narrow the difficulty gap defined by curvature of the Lagrangian. We propose apparently novel sufficient and necessary conditions for global optimality and hint at algorithmic possibilities to exploit these.

■ Wed.C.17

Wednesday, 16:30-18:00, Room 1.7, Organized Session

Applications in geometry design

Cluster: Applications of continuous optimization in science and engineering
Session organized by: *Phan Thanh An*

1. **Optimization methods for computational geometry**

   Phan Thanh An (thanhan@math.ist.utl.pt) Institute of Mathematics, Hanoi and CEMAT/IST, Lisbon, Portugal, *Dinh T. Giang*, *N. N. Hai*, *T. V. Hoai*, *Le Hong Trang*

The talk deals with the use of the ideas of two optimization methods, namely, the Method of Orienting Curves (introduced by H. X. Phu, 1987) and the Direct Multiple Shooting Method (introduced by H. G. Bock, 1984) for solving optimal control problems with state constraints, for finding shortest paths between two points inside a domain in 2D or in 3D. New algorithms and their implementations are presented.

2. **Exact solutions for minimizing a sum of Euclidean norms**

   Dinh T. Giang (dtgiang@math.ist.utl.pt) CEMAT, IST, Lisbon, Portugal, *Phan Thanh An*, *Le Hong Trang*

So far, to solve the problem of minimizing a sum of Euclidean norms, it is rewritten as a second-order cone program then solved by interior-point methods. Then its solutions are approximate. In this paper, the problem is treated as a shortest path problem in computational geometry and we introduce an exact algorithm for solving it. The concepts “final lines"and “orienting lines"are introduced and the exact solution of the problem is determined by points on orienting lines and a final line. A numerical example is presented.

3. **On simplex longest edge bisection for solving blending problems**

   Leocadio G. Casado (leo@ual.es) University of Almeria, Spain, *G. Aparicio*, *B. G.-Tóth*, *Eligius M. T. Hendrix*, *Inmaculada García*

Blending problems are global optimization problems where the cheapest product has to be determined. A product is as mixture of raw materials having quadratic constraints in its design. These problems are characterized by an initial search space determined by a regular $n+1$ dimensional simplex (n-simplex). Branch and bound algorithms have been used to perform an exhaustive search of the solution. This search divides the problem into smaller sub-problems by partitioning the search space until a given precision on the solution is reached. The search avoids visiting some subproblems when it is known they do not contain the best solution. In this work we study the longest edge (LE) partition method for the unit simplex. This division method avoids the generation of needle or non-rounded shapes of sub-simplices, guaranteeing the convergence. We are interested in determining the number of generated simplices in the worst case, i.e., no subspace is rejected. This number is unique for $n < 3$ because the generated sub-simplices are regular or they have just one LE, but this is not the case for $n > 2$. We are interested in knowing the best LE partition in terms of the number of generated sub-simplies, their roundeness and the number of their different shapes. Results of our preliminary studies will be shown in ICCOPT 2013.

■ Wed.C.18

Wednesday, 16:30-18:00, Room 1.8

Robust optimization

Cluster: Robust optimization and optimization in finance
Session chair: *Luis F. Zuluaga*

1. **Measuring systemic risk: Robust ranking techniques approach**

   Amirhossein Sadoghi (A.Sadoghi@fs.de) Frankfurt School of Finance and Management, Germany

The recent economic crisis has raised a wide awareness that the financial system should be considered as a complex network with financial institutions and financial dependencies respectively as nodes and links between these nodes. Systemic risk is defined as the risk of default of a large portion of financial exposures among institution in the network. Indeed, the link structure of this network is an important element to measure systemic risk and there is no widely accepted methodology to determine the systemically important nodes in a large financial network. In this research, our focus is on application of eigenvalue problems, as a robust approach to the ranking techniques, to measure systemic risk. Recently, the efficient algorithm has been developed for robust eigenvector problem to reduce to a nonsmooth convex optimization problem. We applied this technique and studied the performance and convergence behavior of the algorithm with different structure of the network.

2. **Robust approaches for intertemporal consistency in production planning**

   Jorge R. Vera (jvera@ing.puc.cl) Dept. of Industrial Engineering, Universidad Católica de Chile, Santiago, Chile, *Pamela Alvarez*

In many industries, production planning is done first in a tactical horizon, under aggregated information and then the detail is managed in short term planning. Generally tactical decisions impose constraints to the options in the short term planning. Optimization models have been used for long in this area and one typical problem is how to deal with the inconsistencies that arise from the fact that tactical decisions are aggregated, face greater uncertainty than operational decisions, and the assumptions made for the tactical environment might have changed when the short term arises. This work is motivated by a problem in production planning for sawmills in the forest industry, in which inconsistencies arise also from the natural variation of the raw material and the production process. The objective is to improve the short term implementability of tactical decisions, given available information. We have addressed this problem using the Robust Optimization paradigm and in this work we show some results and comparisons, both for the Bertsimas Sim approach as well as for Ben-Tal and Nemirovski formulation. In both cases, robust solutions at the tactical level improve consistency. We also provide some estimates of probabilities of consistency. We also show how some other approaches based on "Fabrication Adaptive Optimization", or "Robust Regularization" could be used to also address this problems. These results should be relevant in other situations where consistency is desirable.

3. **Mean semi-deviation from a target and robust portfolio choice under distribution and mean return ambiguity**

   Mustafa C. Pinar (mustafap@bilkent.edu.tr) Bilkent University, Turkey, *A. Burak Pac*

We consider the problem of optimal portfolio choice using the lower partial moments risk measure for a market consisting of n risky assets and a riskless asset. When the mean return vector and variance/covariance matrix of the risky assets are specified without specifying a return distribution, we derive distributionally robust portfolio rules. We then address potential uncertainty (ambiguity) in the mean return vector as well, in addition to distribution ambiguity, and derive a closed-form portfolio rule when the uncertainty in the return vector is modelled via an ellipsoidal uncertainty set. Our result also indicates a choice criterion for the radius of ambiguity of the ellipsoid. Using the adjustable robustness paradigm we extend the single period results to multiple periods, and derive closed-form dynamic portfolio policies which mimic closely the single period policy.

■ Wed.C.21

Wednesday, 16:30-18:00, Room 2.1, Organized Session

First-order methods, boosting and related issues

Cluster: Convex and nonsmooth optimization

Session organized by: *Robert M. Freund*

1. **New results and analysis for the Frank-Wolfe method**

   Paul Grigas (pgrigas@mit.edu) MIT Operations Research Center, USA, *Robert M. Freund*

We present new results for the Frank-Wolfe (also known as the "conditional gradient") method. Using proof techniques motivated from dual averaging methods, we derive computational guarantees for arbitrary step-size sequences. Our results include guarantees for both duality gaps and the so-called Wolfe gaps. We then examine these guarantees for several different step-size sequences, including those that depend naturally on the warm-start quality of the initial (and subsequent) iterates. Furthermore, we present complexity bounds in the presence of approximate computation of gradients and subproblems.

2. **Online learning for loss functions with memory and applications to statistical arbitrage**

   Oren Anava (soanava@tx.technion.ac.il) Technion, Haifa, Israel, *Elad Hazan*, *Shie Mannor*

We address a classical problem in finance of constructing mean reverting portfolios. A new proxy for mean reversion is proposed. As our proxy for mean reversion is not convex, we define a semi-definite relaxation along with an online algorithm tailored for the relaxation with provable performance guarantees compared to the non-convex optimum. As part of our investigation, we consider the general framework of online learning with memory, for which we give a the first efficient algorithm with optimal performance guarantees.

3. **The first-order view of boosting methods: Computational complexity and connections to regularization**

   Robert M. Freund (rfreund@mit.edu) MIT Sloan School of Management, USA, *Paul Grigas*, *Rahul Mazumder*

Boosting methods are supervised learning methods that combine weak learning models into more accurate and predictive models. We connect some well-known boosting methods — AdaBoost and Incremental Forward Stagewise Regression (FS-epsilon) and its variants with adaptive shrinkage parameters — to first-order methods for convex optimization, and we present new computational guarantees for these boosting methods. In particular, we show that AdaBoost is an instance of Mirror Descent which, through duality, solves the maximum margin problem. Furthermore, we show that Forward Stagewise Regression is an instance of the classical subgradient descent method to minimize the correlation between residuals and predictors. For both AdaBoost and Forward Stagewise Regression, we show that a minor variant of the algorithm, which requires no new assumptions and falls into the same convex optimization family as the original algorithm, corresponds to the Frank-Wolfe method on a constraint-regularized problem, whereby the modified boosting procedures converge to optimal solutions of the appropriate regularized problems at an $O(1/k)$ rate. The flexible variant of FS-epsilon yields an $O(1/k)$ convergent algorithm for the least squares LASSO fit for *any* regularization parameter and *any* data-set — thereby quantitatively characterizing the nature of regularization implicitly induced by Forward Stagewise Regression and its flexible variants.

■ Wed.C.22

Wednesday, 16:30-18:00, Room 2.2, Organized Session

Sparse optimization and its applications

Cluster: Convex and nonsmooth optimization

Session organized by: *Necdet Serhat Aybat*

1. **A dual approach to sparse optimization**

   Michael P. Friedlander (mpf@cs.ubc.ca) University of British Columbia, Canada, *Ives Macedo*

A feature common to many sparse optimization problems is that the number of variables may be significantly larger than the number of constraints—e.g., the standard matrix-lifting approach for binary optimization results in a problem where the number of variables is quadratic in the number of constraints. We consider a duality framework applicable to a wide range of nonsmooth sparse optimization problems, and leverage the relatively small number of constraints. Preliminary numerical results illustrate our approach and its flexibility.

2. **A hybrid quasi-Newton projected-gradient method with application to Lasso and basis-pursuit denoise**

   Ewout van den Berg (ewout@stanford.edu) Stanford University, USA

In this talk I present a new algorithm for the optimization of convex functions over a polyhedral set. The algorithm is based on the spectral projected-gradient method, but switches to quasi-Newton iterations whenever possible. A practical application of the framework is the Lasso problem, which also appears as a subproblem in the basis-pursuit denoise solver SPGL1. Other important applications that could benefit from the proposed algorithm include bound-constrained optimization and optimization over the simplex.

3. **Sparse rank-one matrix approximations: Convex relaxations, direct approaches, and applications to text data**

   Ronny Luss (rluss@us.ibm.com) IBM T.J. Watson Research Center, USA, *Marc Teboulle*

The sparsity constrained rank-one matrix approximation problem, also known as sparse PCA, is a difficult mathematical optimization problem which arises in a wide array of useful applications in engineering, machine learning and statistics, and the design of algorithms for this problem has attracted intensive research activities. We survey a variety of approaches for solving this problem including convex relaxations and direct approaches to the original nonconvex formulation. Convex relaxations are solved by applying fast first-order methods, while the direct approach builds on the conditional gradient method. Its simplicity allows for solving large scale problems where our usual convex relaxation techniques are limited. We show that a variety of recent and novel sparse PCA methods which have been derived from disparate approaches can all be viewed as special instances of our approach. Numerical experiments and applications with text data will be given.

■ Wed.C.23

Wednesday, 16:30-18:00, Room 2.3, Organized Session

Continuous optimization solvers within mixed-integer frameworks

Cluster: Optimization software: Modeling tools and engines
Session organized by: *Hande Y. Benson*

1. **Customizing COIN-OR's LP and MIP solvers with Python**

   Mehdi Towhidi (mehdi.towhidi@gerad.ca) École Polytechnique de Montréal, GERAD, Canada, *Dominique Orban*

It is often necessary to customize the solution process of linear and mixed-integer linear programming solvers depending on the problem at hand, for example to provide a customized branching strategy. On the software side, open source solvers are often implemented in low-level programming languages like C, C++ and FORTRAN, making the process of customizing the solver a daunting task for the average programmer. In this talk we present CyLP, which allows using the Python programming language to customize COIN-OR's CLP and CBC (written in C++). We demonstrate how using a high-level programming language makes it relatively easy to customize a solver. We also introduce CyLP's modeling tool and illustrate it on a real-world nurse-scheduling problem.

2. **Recent developments in column generation and interior point methods**

   Pablo González-Brevis (P.Gonzalez-Brevis@sms.ed.ac.uk) University of Edinburgh, UK, *Jacek Gondzio*

In this talk the latest developments on combining column generation (CG) and interior point methods (IPMs) will be addressed. It is well-known that the standard CG suffers from an unstable behaviour due to the use of optimal dual solutions that are extreme points of the restricted master problem. We will discuss how to exploit the way IPMs approach optimality to obtain a stabilized column generation and we will introduce the primal-dual column generation method (PDCGM). This method dynamically adjusts its tolerance as it approaches optimality and relies on a symmetric neighbourhood of the central path so suboptimal and well-centred solutions are obtained. Although large benefits can be observed by employing IPMs within CG, warmstarting IPMs is still a non-trivial task and therefore we present a new warmstarting technique in this context. The one step primal-dual feasibility restoration procedure restores primal and dual feasibilities after the addition of new columns. The restoration direction is determined so that the small components at a particular solution are not largely modified. Additionally, this warmstarting strategy controls the new duality gap. Computational experiments show that this combined approach (PDCGM and warmstarting strategy) offers large savings in both, iterations and CPU time when solving the root node of a variety of mixed-integer programming problems.

3. **MILANO: Mixed-integer linear and nonlinear optimizer**

   Hande Y. Benson (benson@drexel.edu) Drexel University, USA

In this talk, we present details of MILANO (Mixed-Integer Linear and Nonlinear Optimizer), a Matlab-based toolbox for solving mixed-integer optimization problems. For MINLP, it includes implementations of branch-and-bound and outer approximation algorithms and solves the nonlinear subproblems using an interior-point penalty method introduced by Benson and Shanno (2005) for warmstarts. Special consideration is given for problems with cone constraints. Numerical results will be presented.

■ Wed.C.24

Wednesday, 16:30-18:00, Room 2.4, Organized Session

Optimization of free boundary problems I

Cluster: PDE-constrained optimization
Session organized by: *Juan Carlos de los Reyes, Christian Meyer*

1. **Optimal control of incompressible two-phase flows**

   Benjamin Tews (tews@math.uni-kiel.de) University of Kiel, Ukraine, *Malte Braack*

We consider an optimal control problem of two incompressible and immiscible Newtonian fluids. The motion of the interface between these fluids can be captured by a phase field model or level set model. Both methods are subject of this talk. The state equation includes surface tension and is discretized by a discontinuous Galerkin scheme in time and a continuous Galerkin scheme in space. In order to resolve the interface propagation we also apply adaptive finite elements in space and time. We derive first order optimality conditions including the adjoint equation which is also formulated in a strong sense. The optimality system on the discrete level is solved by Newton's method. In the numerical example we compare level sets with a phase field model.

2. **Second-order sufficient conditions for optimal control of elastoplasticity**

   Thomas Betz (tbetz@mathematik.tu-dortmund.de) TU Dortmund, Germany, *Christian Meyer*

An optimal control problem governed by an elliptic variational inequality (VI) of first kind in mixed form is considered. This VI models the static problem of infinitesimal elastoplasticity with linear kinematic hardening. An optimization of elastoplastic deformation processes thus leads to the optimal control problem under consideration. It is well known that the control-to-state map associated to VIs is in general not Gateaux-differentiable. The same applies in our particular case. Thus standard techniques to derive optimality conditions for optimal control problems cannot be employed. It can however be shown that the control-to-state operator is Bouligand differentiable. Based on this result, we establish second-order sufficient optimality conditions by means of a Taylor expansion of a particularly chosen Lagrange function.

3. **Relating phase field and sharp interface approaches to structural topology optimization**

   M. Hassan Farshbaf-Shaker (Hassan.Farshbaf-Shaker@wias-berlin.de) WIAS, Germany, *Luise Blank*, *Harald Garcke*, *Vanessa Styles*

A phase field approach for structural topology optimization which allows for topology changes and multiple materials is analyzed. First order optimality conditions are rigorously derived and it is shown via formally matched asymptotic expansions that these conditions converge to classical first order conditions obtained in the context of shape calculus. Finally, we present several numerical results for mean compliance problems and a cost involving the least square error to a target displacement.

■ Wed.C.25

Wednesday, 16:30-18:00, Room 2.5, Organized Session

Variational analysis in nonlinear optimization

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Héctor Ramirez*

1. **Proximal decomposition method for convex symmetric cone programming**

   Julio López (julio.lopez@udp.cl) Universidad Diego Portales, Chile, *Erik Papa*

This work is devoted to the study of a decomposition algorithm for solving convex symmetric cone programming with separable structure. The algorithm considered is based on the decomposition method proposed by Chen and Teboulle and the proximal generalized distance defined by Auslender and Teboulle. Under suitable assumptions, first it is proven that each limit point of the primal-dual sequences generated by the algorithm solves the problem. Then, the global convergence is established. Some examples of proximal distances are also presented.

2. **Design of robust truss structures for minimum weight using the sequential convex approximation method**

   Miguel Carrasco (migucarr@gmail.com) Universidad de los Andes, Chile, *Alfredo Canelas*, *Julio Lopez*

We study the design of robust truss structures under mechanical equilibrium, displacements and stress constraints. Then, our main objective is to minimize the total amount of material or weight, for the purpose of finding the most economic structure, which is robust under load perturbations. Therefore, we obtain a non-convex bilevel mathematical program. In order to solve this problem, we use the sequential convex approximation method proposed by A. Beck, A. Ben-Tal, and L. Tetruashvili (2010), in which we approximate the original problem by a sequence of differentiable convex ones.

3. **Second-order analysis in conic programming with applications**

   Héctor Ramirez (hramirez@dim.uchile.cl) Center for Mathematical Modeling, Universidad de Chile, Chile

In this talk we review some recent results obtained for conic programs from the application of a second-order generalized differential approach. It is used to calculate appropriate derivatives and coderivatives of the corresponding solution maps. These developments allow us to obtain verifiable conditions for the strong regularity, the Aubin property and isolated calmness of the considered solution maps, sharp necessary optimality conditions for a class of mathematical programs with equilibrium constraints, and characterizations of tilt-stable local minimizers for cone-constrained problems. The main results obtained in the general conic programming setting are specified for and illustrated by the second-order cone programming. References: J. F. Bonnans and H. Ramírez C., Perturbation analysis of second-order cone programming problems. Math. Program., 104 (2005), pp. 205–227. J. V. Outrata and H. Ramírez C., On the Aubin property of critical points to perturbed second-order cone programs, SIAM J. Optim., 21 (2011), pp. 798–823. B. Mordukhovich, J. V. Outrata and H. Ramírez C., Second-order variational analysis in conic programming with application to optimality and stability. Submitted (2013).

■ Wed.C.AB

Wednesday, 16:30-18:00, Amphitheater B, Organized Session

Nonlinear optimization and applications I

Cluster: Nonlinear optimization
Session organized by: *Ya-xiang Yuan*

1. **Limited-memory methods with shape changing trust region**

   Spartak Zikrin (spartak.zikrin@liu.se) Linköping University, Sweden, *Oleg Burdakov*, *Lujin Gong*, *Ya-xiang Yuan*

Limited-memory quasi-Newton methods and trust-region methods represent two efficient approaches used for solving unconstrained optimization problems. A straightforward combination of them deteriorates the efficiency of the former approach, especially in the case of large-scale problems. For this reason, the limited memory methods are usually combined with a line-search. The trust region is usually determined by a fixed vector norm, typically, scaled l_2 or l_∞ norms. We present a trust-region approach where the model function is based on a limited-memory quasi-Newton approximation of the Hessian, and the trust region is defined by a specially designed norm. Since this norm depends on certain properties of the Hessian approximation, the shape of the trust region changes with every iteration. This allows for efficiently solving the subproblem. We prove global convergence of our limited-memory methods with shape changing trust region. We also present results of numerical experiments that demonstrate the efficiency of our approach in the case of large-scale test problems.

2. **The limited memory conjugate gradient method**

   Hongchao Zhang (hozhang@math.lsu.edu) Department of Mathematics, Center for Computation and Technology, Louisiana State University, Baton Rouge, Louisiana, USA, *William Hager*

In theory, the successive gradients generated by the conjugate gradient method applied to a quadratic should be orthogonal. However, for some ill-conditioned problems, orthogonality is quickly lost due to rounding errors, and convergence is much slower than expected. A limited memory version of the conjugate gradient method will be presented. The memory is used to both detect the loss of orthogonality and to restore orthogonality. Numerical comparisons to the limited memory BFGS method (L-BFGS) will be also discussed.

3. **On solving L-BFGS trust-region subproblems**

   Roummel F. Marcia (rmarcia@ucmerced.edu) University of California, Merced, USA, *Jennifer B. Erway*

We present a new method called the More-Sorensen Sequential (MSS) method for computing the minimizer of a quadratic function defined by a limited-memory BFGS matrix subject to a two-norm trust-region constraint. This solver is an adaptation of the More-Sorensen direct method into a L-BFGS setting for large-scale optimization. The MSS method uses a recently proposed fast direct method for solving large shifted BFGS systems of equations.

■ Wed.D.11

Wednesday, 18:00-19:30, Room 1.1, Organized Session

Optimization of polynomials in commutative and non-commutative variables

Cluster: Conic and polynomial optimization
Session organized by: *Janez Povh*

1. **Positive polynomials in matrix unknowns which are dimension-free and NCSOStools**

   Igor Klep (igor.klep@auckland.ac.nz) Department of Mathematics, The University of Auckland, New Zealand

One of the main applications of semidefinite programming (SDP) lies in linear systems and control theory. Many problems in this subject, certainly the textbook classics, have matrices as variables, and the formulas naturally contain non-commutative polynomials in matrices. These polynomials depend only on the system layout and do not change with the size of the matrices involved, hence such problems are called "dimension-free". Analyzing dimension-free problems has led to the development recently of free real algebraic geometry (RAG). The main branch of free RAG, free positivity and inequalities, is an analog of classical real algebraic geometry, a theory of polynomial inequalities embodied in algebraic formulas called Positivstellensätze; often free Positivstellensätze have cleaner statements than their commutative counterparts. In this talk we present some of the latest theoretical advances, with focus on algorithms and their implementations in our computer algebra system NCSOStools. The talk is based on joint works with the following co-authors: J. Povh, K. Cafuta, S. Burgdorf, J. W. Helton, S. McCullough, M. Schweighofer.

2. **Polynomial optimization over the NC unit ball**

   Sabine Burgdorf (sabine.burgdorf@epfl.ch) EPFL, Switzerland

In this talk we consider optimization of polynomials in non-commuting variables. More precisely, we are interested in maximal or minimal eigenvalues or traces a polynomial can reach by being evaluated at symmetric or self-adjoint matrices of norm at most 1, or even being evaluated at bounded operators. Those problems are of interest e.g. in Quantum Mechanics as shown by Pironio, Navscués and Acín, as well as in Quantum Statistics. Like the Lasserre relaxation in the case of polynomial optimization in commuting variables, our optimization problem can be relaxed by using sum of squares equivalents for NC polynomials or more general by representations lying in an appropriate quadratic module; both resulting in an SDP. We will present the relaxation scheme and present the current knowledge on the question of convergence of this relaxation scheme in the matrix and in the operator case.

3. **A new convex reformulation and approximation hierarchy for polynomial optimization**

   Janez Povh (janez.povh@fis.unm.si) Faculty of Information Studies in Novo Mesto, Slovenia, *Peter J. C. Dickinson*

In this talk we provide a generalization of two well-known positivstellensatze, namely the positivstellensatz from Pólya and the positivestellensatz from Putinar and Vasilescu. We show that if a homogeneous polynomial is strictly positive over the intersection of the non-negative orthant and a given basic semialgebraic cone, then there exists a "Pólya type" certificate for non-negativity. In the second part of the talk we demonstrate how to use this result to construct new approximation hierarchies for polynomial optimization problems over semialgebraic subsets of non-negative orthant.

■ Wed.D.12

Wednesday, 18:00-19:30, Room 1.2, Organized Session

Semi-continuous sparse reconstruction

Cluster: Sparse optimization and information processing
Session organized by: *Dirk Lorenz*

1. **A result on the spike localization from inaccurate samplings**

   Yohan de Castro (yohann.decastro@math.u-psud.fr) Université Paris-Sud 11, France

In this talk, we study the recovery of a discrete measure (spike train) from few noisy observations (Fourier samples, moments, Stieltjes transformation …). This problem can be seen as an application of the inverse problems theory in Banach spaces in the frame of "Continuous Compressed Sensing". In particular, we provide an explicit quantitative localization of the spikes using a tractable algorithm (a "continuous"version of the Lasso). Moreover, our result does not depend on the true amplitudes of the spike train, and can be seen as an intrinsic guarantee of sparse recovery from noisy samples. This result is based on the paper (ArXiv:1301.5873) "Spike Detection from Inaccurate Samplings"(with Jean-Marc Azaïs, Fabrice Gamboa) and the paper (ArXiv:1203.5871) "Towards a Mathematical Theory of Super-Resolution"(of E. Candès and C. Fernandez-Granda).

2. **Robust super-resolution via convex programming**

   Carlos Fernandez-Granda (cfgranda@stanford.edu) Stanford University, USA, *Emmanuel Candes*

Broadly speaking, super-resolution is the problem of recovering the fine details of an object — the high end of its spectrum — from coarse scale information only — from samples at the low end of the spectrum. Suppose we have many point sources at unknown locations and with unknown complex-valued amplitudes. We only observe Fourier samples of this object up until a frequency cut-off F. We show that one can super-resolve these point sources with infinite precision — i.e., recover the exact locations and amplitudes — by solving a simple convex optimization problem, which can essentially be reformulated as a semidefinite program. This holds provided that the distance between sources is at least $2/F$. In addition, we introduce a framework for understanding the stability of our theory and methods, which establishes that super-resolution via convex optimization is robust to noise.

3. **Finite element error analysis for an optimal control problem with sparse solutions**

   Konstantin Pieper (pieper@ma.tum.de) TU München, Germany, *Boris Vexler*

We consider an optimal control problem of the form

$$\min_q \|S(q)-\hat{u}\|^2_{L^2} + \alpha\|q\|_{\mathcal{M}(\Omega)},$$

where the unknown q is searched for in the space of regular Borel measures $\mathcal{M}(\Omega)$. The solutions to this problem are sparse: under the right conditions we can expect the optimal solution to consists of a finite sum of Dirac delta functions. This has applications for the optimal placement of actuators and in the context of compressed sensing. In this talk we are going to consider the case where S is the solution operator for an elliptic PDE. In practical computations, S is replaced by a finite element solution, and the measure q is discretized by Dirac delta functions in the grid points. We provide an a-priori error analysis, where we improve on previously obtained results. We will also discuss an a-posteriori error estimation strategy.

■ Wed.D.13

Wednesday, 18:00-19:30, Room 1.3, Organized Session

Algorithm advances for convex quadratic programming

Cluster: Nonlinear optimization

Session organized by: *Coralia Cartis*

1. **A primal-dual active-set method for convex quadratic programming**

   Anders Forsgren (andersf@kth.se) KTH Royal Institute of Technology, Sweden, *Philip E. Gill*, *Elizabeth Wong*

We consider the formulation and analysis of a primal-dual active-set method for a convex quadratic program. We present a primal-dual symmetric formulation that allows treatment of a primal and a dual active-set method in the same framework. A shifting of the constraints is introduced so as to give a method that does not need a separate phase for getting feasible.

2. **An algorithmic framework for convex ℓ_1-regularized optimization**

   Stefan Solntsev (stefans@u.northwestern.edu) Northwestern University, USA, *Jorge Nocedal*, *Richard Byrd*

We present a framework for designing second order methods for minimizing an objective that is the sum of a convex quadratic function f and an ℓ_1 regularization term. The four crucial components are: finding a good starting point for subspace minimization, subspace identification, an inexact subspace minimization procedure, and a correction step. An iterative thresholding step with an intelligently chosen stepsize (as used in SPARSA) proved to work well in the first phase, but other options are discussed. Our framework incorporates algorithmic ideas presented by Dostal and Schoeberl for bound constrained quadratic programming: specifically some nontrivial termination criteria for the subspace phase. Extensive numerical experiments on real as well as randomly generated data were conducted to identify methods with good practical performance; theoretical guarantees are provided as well. Possible extensions to scenarios where f is non-quadratic are demonstrated.

3. **Optimal active-set prediction for interior point methods**

   Yiming Yan (yiming.yan@ed.ac.uk) University of Edinburgh, UK, *Coralia Cartis*

When applied to an inequality constrained optimization problem, interior point methods generate iterates that belong to the interior of the set determined by the constraints, thus avoiding/ignoring the combinatorial aspect of the solution. This comes at the cost of difficulty in predicting the optimal active constraints that would enable termination. We propose the use of controlled perturbations to address this challenge. Namely, in the context of linear programming with only nonnegativity constraints as the inequality constraints, we consider perturbing the nonnegativity constraints so as to enlarge the feasible set. Theoretically, we show that if the perturbations are chosen appropriately, the solution of the original problem lies on or close to the central path of the perturbed problem and that a primal-dual path-following algorithm applied to the perturbed problem is able to predict the optimal active-set of the original problem when the duality gap (for the perturbed problem) is not too small. Encouraging preliminary numerical experience is obtained when comparing the perturbed and unperturbed interior point algorithms' active-set predictions for the purpose of cross-over to simplex.

■ Wed.D.14

Wednesday, 18:00-19:30, Room 1.4, Organized Session

Decomposition and cone geometry

Cluster: Convex and nonsmooth optimization

Session organized by: *François Glineur, Peter Richtarik*

1. **Separable approximations to the augmented Lagrangian**

   Rachael Tappenden (r.tappenden@ed.ac.uk) University of Edinburgh, UK, *Burak Buke*, *Peter Richtarik*

Recently there has been much interest in block coordinate descent methods because of their ability to tackle large-scale optimization problems. Multistage stochastic programming problems are an example of very large optimization problems (where the size of the problem grows rapidly with the number of scenarios and time horizon) that display particular structure and sparsity patterns. This work proposes the use of a separable overapproximation to the augmented Lagrangian, which enables a block coordinate descent approach to solving these large convex optimization problems. Preliminary numerical results will also be presented.

2. **Intrinsic volumes of convex cones and applications in convex programming**

   Dennis Amelunxen (damelunx@gmail.com) ORIE Cornell, USA, *Peter Bürgisser*

Analyzing the average behavior of conic programs on Gaussian random data, though not to be confused with analyzing their behavior on "real-world"data, is arguably a first cautious step towards this goal. It turns out that this step finds a firm ground in the theory of intrinsic volumes of convex cones. We showcase this mathematical connection by answering the intriguing question: What is the probability that the solution of a random semidefinite program has rank r? More precisely, we will give closed formulas for this probability in terms of certain integrals that decompose Mehta's integral, but for which no simple expression is known yet. Along the way we will mention further results that hold for any cone program (under the Gaussian random model), a generality that counterbalances the restrictive character of the random model. These general results include estimates on the average condition of a cone program, a quantity that can be used to bound the running time of interior-point algorithms that solve this program.

3. **Information geometry of symmetric cone programs**

   Takashi Tsuchiya (tsuchiya@grips.ac.jp) National Graduate Institute for Policy Studies, Japan, *Satoshi Kakihara*, *Atsumi Ohara*

We develop an information geometric approach to symmetric cone programming. Information geometry is a differential geometric framework specifically tailored to deal with convexity arising in statistics, machine learning and signal processing, etc. In information geometry, Riemannian metric is defined as the Hessian of a convex potential function, and two mutually dual connections are introduced. We introduce an information geometric structure to convex programs by choosing the normal barrier function as the potential function. The two connections correspond to primal and dual problems. We focus on symmetric cone programs and demonstrate that the iteration-complexity of Mizuno-Todd-Ye predictor-corrector primal-dual path-following interior-point algorithm is expressed rigorously as an information geometric integral over the central path. Through extensive numerical experiments, we confirm that the iteration-complexity of the algorithm is explained quite well with the integral even for fairly large LP and SDP problem with thousands of variables. Endorsed by these numerical results, we claim that "the number of iterations of the interior-point algorithm is a differential geometric quantity."

■ Wed.D.15

Wednesday, 18:00-19:30, Room 1.5, Organized Session

Constrained derivative free optimization

Cluster: Derivative-free and simulation-based optimization
Session organized by: *Warren Hare*

1. **Some applications solved with the MADS algorithm**

   Sébastien Le Digabel (sebastien.le.digabel@gerad.ca) École Polytechnique de Montréal, Canada

The mesh adaptive direct search (MADS) algorithm is designed to solve blackbox optimization problems for which the structure of the involved functions is unknown. This presentation focuses on recent applications for which MADS was applied via the NOMAD software. These problems include the optimal positioning of snow monitoring devices over a large territory, the calibration of hydrological models in a climate change context, the optimization of alloys with the FactSage thermodynamic database, and finally biobjective optimization of aircraft trajectories.

2. **Derivative free methods for approximating normal cones**

   Warren Hare (Warren.Hare@ubc.ca) University of British Columbia, Canada

Normal cones provide powerful information about projections, tangent directions, and stopping conditions in constrained optimization. When the constraint set is defined through a collection of (well-behaved) analytic functions, normal cones are easily computed. In this talk we consider the situation where the constraint set is provided through an oracle function or collection of oracle functions. Methods for approximating normal cones under these conditions are provided and compared.

3. **A new algorithm for solving equality- and bound-constrained optimization problems without derivatives**

   Anke Tröltzsch (anke.troeltzsch@dlr.de) German Aerospace Center, Germany

Derivative-free optimization (DFO) has enjoyed renewed interest over the past years and especially model-based trust-region methods have been shown to perform well on these problems. We want to present a new interpolation-based trust-region algorithm which can handle nonlinear and nonconvex optimization problems involving equality constraints and simple bounds on the variables. The equality constraints are handled by a trust-region SQP approach, where each SQP step is decomposed into a normal and a tangential step to account for feasibility as well as for optimality. Special care must be taken in case an iterate is infeasible with respect to the models of the derivative-free constraints. Globalization is handled by using an Augmented Lagrangian penalty function as the merit function. Furthermore, our new algorithm uses features of the algorithm BCDFO, proposed by Gratton et. al. (2011), which handles bound constraints by an active-set method and has shown to be very competitive for bound-constrained problems. It relies also on the technique of self-correcting geometry, proposed by Scheinberg and Toint (2010), to maintain poisedness of the interpolation set. The objective and constraint functions are approximated by polynomials of varying degree (linear or quadratic). We present numerical results on a test set of equality-constrained problems from the CUTEr problem collection.

■ Wed.D.16

Wednesday, 18:00-19:30, Room 1.6, Organized Session

Global optimization with applications to machine learning

Cluster: Global optimization and mixed-integer programming
Session organized by: *Panos Parpas*

1. **Estimating time series models with heuristic methods: The case of economic parity conditions**

   Dietmar Maringer (dietmar.maringer@unibas.ch) Economics and Business Faculty, University of Basel, Switzerland, *Sebastian Deininger*

Time series models are a common approach in economic and econometric analysis. A special case are Vector Error Correction models where several economic variables are assumed to depend on their own and each other's recent developments. While they facilitate economically sound modeling, their actual application is often hampered by technical difficulties: Finding the optimal parameter values is usually based on maximizing some likelihood function or "information criterion" with no closed-form solution. Even more importantly, the number of parameters to estimate increases quickly when allowing for more lags, i.e., including past observations — which is highly desirable, e.g., when seasonalities, delayed reactions, or long memory need to be catered for. In this case, it is desirable to keep the model still as parsimonious as possible to avoid over-fitting. Ideally, one can "cherry-pick" the parameters which one does and doesn't want to include; this, however, makes parameter estimation even harder as it adds challenging combinatorial problems. In this paper, we investigate how Differential Evolution (DE), a nature-inspired search heuristic, can solve the parameter selection and estimation problem. The empirical part considers data for the US, Euro-Area and Switzerland and compares different model selection criteria. Results emphasize the importance of careful modeling and reliable estimation methods.

2. **Sparse principal component analysis: A mixed integer nonlinear approach**

   Vanesa Guerrero (vguerrero@us.es) Universidad de Sevilla, Spain, *Emilio Carrizosa*

Principal Component Analysis is a popular Data Analysis dimensionality reduction technique, aiming to project with minimum error a given data set into a subspace of smaller dimension. In order to improve interpretability, different variants of the method have been proposed in the literature, in which, besides error minimization, sparsity is sought. In this talk, the problem of finding a subspace with a sparse basis is formulated as a Mixed Integer Nonlinear Program, where the sum of squares of distances between the points and their projections is minimized. Contrary to other attempts in the literature, with our model the user can fix the level of sparseness of the resulting basis vectors. Variable Neighborhood Search is proposed to solve the MINLP. Our numerical experience on test sets shows that our procedure outperforms benchmark methods in the literature. The strategy proposed attempts to minimize errors while keeping sparseness above a given threshold value. A problem of simultaneous optimization of sparseness and error minimization, parametrized by the total number of non-zero coordinates in the resulting principal components, is also studied. Numerical experiments show that this biobjective approach provides sparser components with less error than competing approaches.

3. **Global optimisation using gentlest ascent dynamics**

   Panos Parpas (p.parpas@imperial.ac.uk) Imperial College London, UK

It is well known that under mild conditions any two local minima can be connected via an alternating sequence of local minima and index-1 saddle points. Starting from a system of ODEs whose fixed points are index-1 saddle points we propose a global optimisation algorithm. The algorithm constructs a graph of the local minima and saddle points of a differentiable function. Different strategies are proposed that enable the algorithm to escape from stationary points that are already in the graph.

■ Wed.D.17

Wednesday, 18:00-19:30, Room 1.7

Optimization in practice I

Cluster: Applications of continuous optimization in science and engineering
Session chair: *Victor M. Zavala*

1. **Optimal location and size of heliostats in solar power tower systems**

   Carmen-Ana Domínguez-Bravo (carmenanadb@us.es) Instituto de Matemáticas de la Universidad de Sevilla, Spain, *Emilio Carrizosa*, *Enrique Fernández-Cara*, *Manuel Quero*

A method for optimizing solar power tower systems is proposed, in which the heliostats location and size are simultaneously considered. Maximizing the efficiency of the plant, i.e., optimizing the energy generated per unit cost, leads to a difficult high dimensional global optimization problem with an objective function hard to compute and non convex constraints as well. The optimization problem and a greedy-based heuristic procedure to solve the problem will be described.

2. **Mixed integer nonlinear models in wireless networks**

   Anne Philipp (aphilipp@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

Within the LOEWE Priority Program Cocoon (Cooperative Sensor Communication) the utilization of mixed-integer Nonlinear optimization in wireless telecommunication networks is explored. We focus on applications that can be modeled as (nonconvex) quadratically constrained quadratic problems (QCQP) featuring “on/off"constraints. Solution strategies for solving the underlying QCQPs include the consideration of the semidefinite programming relaxation as well as sequential second-order cone programming, and a local rank reduction heuristic. The “on/off"-constraints are dealt with within a Branch-and-Bound framework. As an interesting application we consider the successive interference cancellation model. We assume a downlink communication system comprising one multi-antenna base station and single-antenna users which have multiuser detection receivers. That is, a receiver is capable of decoding and cancelling an interfering signal before decoding the desired signal, if it is received strongly enough. The goal is to jointly find a transmission strategy at the base station and an interference cancellation order for each receiver which minimizes the total transmission power while insuring signal-to-interference-plus-noise ratio requirements at each user. We conclude by presenting some first numerical results.

3. **Linear matrix inequality formulation of stabilizability of networks of identical linear systems**

   Anna von Heusinger (Heusinger@mathematik.uni-wuerzburg.de) University of Wurzburg, Germany, *Uwe Helmke*

Networks of identical linear time-invariant single-input single-output appear, for instance, in models for gene regulatory networks. A given set of node systems is called network stabilizable, if there exists an interconnection structure such that the network is input-output stable. Using frequency domain analysis and the Hermite-Fujiwara theorem, we reformulate this problem into a linear matrix inequality with nonlinear constraint. Equivalently, we cast the problem as a rank-constrained linear matrix inequality, which can be solved by a Newton method. Similar techniques are applied to the synchronizability problem.

■ Wed.D.18

Wednesday, 18:00-19:30, Room 1.8, Organized Session

Optimization in finance I

Cluster: Robust optimization and optimization in finance
Session organized by: *Pedro Júdice*

1. **Enhanced indexation based on second-order stochastic dominance**

   Gautam Mitra (gautam@optirisk-systems.com) OptiRisk-Systems and Director CARISMA, Brunel University, UK, *Diana Roman*, *Victor Zverovich*

Second order Stochastic Dominance (SSD) has a well recognised importance in portfolio selection, since it provides a natural interpretation of the theory of risk-averse investor behaviour. Recently, SSD-based models of portfolio choice have been proposed; these assume that a reference distribution is available and a portfolio is constructed, whose return distribution dominates the reference distribution with respect to SSD. We present an empirical study which analyses the effectiveness of such strategies in the context of enhanced indexation. Several datasets, drawn from FTSE 100, SP 500 and Nikkei 225 are investigated through portfolio rebalancing and backtesting. Three main conclusions are drawn. First, the portfolios chosen by the SSD based models consistently outperformed the indices and the traditional index trackers. Secondly, the SSD based models do not require imposition of cardinality constraints since naturally a small number of stocks are selected. Thus, they do not present the computational difficulty normally associated with index tracking models. Finally, the SSD based models are robust with respect to small changes in the scenario set and little or no rebalancing is necessary. In this paper we present a unified framework which incorporates (a) SSD, (b) downside risk (Conditional Value-at-Risk) minimisation and (c) enhanced indexation.

2. **Extensions of abridged nested decomposition for serially dependent structures**

   John Birge (jbirge@chicagobooth.edu) University of Chicago Booth School of Business, USA

Abridged nested decomposition and related multistage Stochastic optimization procedures generally rely on serial independence or simple dependence structure in the constant terms in the constraints. This talk will discuss extensions of these procedures for more complex dependence structures within the transition matrices of linear dynamic equations.

3. **Long-term bank balance sheet management: Estimation and simulation of risk-factors**

   Pedro Júdice (pedro_judice@yahoo.com) Montepio Geral/ISCTE Business School, Portugal, *John Birge*

We propose a dynamic framework which encompasses the main risks in balance sheets of banks in an integrated fashion. Our contributions are fourfold: 1) solving a simple one-period model that describes the optimal bank policy under credit risk; 2) estimating the long-term stochastic processes underlying the risk factors in the balance sheet, taking into account the credit and interest rate cycles; 3) simulating several scenarios for interest rates and charge-offs; and 4) describing the equations that govern the evolution of the balance sheet in the long run. The models that we use address momentum and the interaction between different rates. Our results enable simulation of bank balance sheets over time given a bank’s lending strategy and provide a basis for an optimization model to determine bank asset-liability management strategy endogenously.

■ Wed.D.21

Wednesday, 18:00-19:30, Room 2.1, Organized Session

Methods for tensor optimization

Cluster: Convex and nonsmooth optimization
Session organized by: *Zhening Li, Yanqin Bai*

1. **Applications of maximum block improvement method**

   Bilian Chen (blchen@xmu.edu.cn) Xiamen University, China, *Zhening Li*, *Shuzhong Zhang*

This talk is concerned with some algorithms based on the so-called maximum block improvement (MBI) method for non-convex block optimization. We mainly discuss its application in finding a Tucker decomposition for tensors. Traditionally, solution methods for Tucker decomposition presume that the size of the core tensor is specified in advance, which may not be a realistic assumption in some applications. Here we propose a new computational model where the configuration and the size of the core become a part of the decisions to be optimized. Also, we briefly mention its application in other fields, e.g., gene expression data, signal processing. Some numerical results will be presented.

2. **Convergence of first-order techniques in tensor optimization**

   Andre Uschmajew (andre.uschmajew@epfl.ch) EPFL, Lausanne, Switzerland

Thanks to multi-linearity of tensor representations (canonical format, hierarchical Tucker format, TT format), block coordinate techniques which act on the separate factors of tensor products are of even more particular interest in tensor optimization than in general. The simplest and most famous example is the alternating least squares algorithm for tensor approximation (PARAFAC-ALS), but other methods like the recently proposed maximum block improvement also have their merits. The convergence analysis can choose between a viewpoint in the redundant parameter space of the factors (nonuniqueness of tensor representations) or on the set/manifold of parametrized tensors. Within the later viewpoint other techniques like the projected gradient method can be treated. The talk will survey some recent local convergence results in this field.

3. **Eigenvalues of complex tensors and their approximation methods**

   Zhening Li (zheningli@gmail.com) University of Birmingham, UK, *Bo Jiang*, *Shuzhong Zhang*

Eigenvalues of real tensors were introduced by Lim and Qi in 2005, and attracted much attention due to their applications or links with polynomial optimization, quantum mechanics, statistical data analysis, medical imaging, etc. However, the study for complex tensors is at starting stage. In this talk, we propose conjugate partial-symmetric tensors and conjugate super-symmetric tensors, which generalize the classical concept of Hermitian matrices. Necessary and sufficient conditions for their complex forms taken real values are justified, based on which we propose several definitions for eigenvalues of complex tensors. Approximation methods for computing the largest eignevalue and related complex polynomial optimization models are discussed as well.

■ Wed.D.22

Wednesday, 18:00-19:30, Room 2.2, Organized Session

Stochastic and randomized gradient methods for convex optimization

Cluster: Convex and nonsmooth optimization
Session organized by: *Simon Lacoste-Julien*

1. **Large-scale learning revisited**

   Leon Bottou (leon@bottou.org) MSR, USA

This presentation shows how large-scale data sets challenge traditional machine learning in fundamental ways.

- Traditional machine learning describes tradeoffs associated with the scarcity of data. Qualitatively different tradeoffs appear when we consider instead that computing time is the bottleneck. As a consequence, one needs to reconsider the relations between the machine learning problem, its optimization formulation, and the optimization algorithms.
- Traditional machine learning optimize average losses. Increasing the training set size cannot improve such metrics indefinitely. However these diminishing returns vanish if we measure instead the diversity of conditions in which the trained system performs well. In other words, big data is not an opportunity to increase the average accuracy, but an opportunity to increase coverage.
- Since the benefits of big data are related to the diversity of big data, we need conceptual tools to build learning systems that can address all the (changing) aspects of real big data problems. Multitask learning, transfer learning, and deep learning are first steps in this direction.

2. **Minimizing finite sums with the stochastic average gradient**

   Mark Schmidt (mark.schmidt@inria.fr) École Normale Superieure, France, *Nicolas Le Roux*, *Francis Bach*

We propose a new method in the spirit of stochastic gradient methods for optimizing the sum of a finite set of smooth functions, where the sum is strongly convex. While standard stochastic gradient methods converge at sublinear rates for this problem, the proposed method incorporates a memory of previous gradient values in order to achieve a linear convergence rate. Further, we show that in many cases the convergence rate of the new method (in terms of evaluating individual gradients) will be faster than the lower-bound for methods that evaluate the full sum. Numerical experiments indicate that the new algorithm can dramatically outperform standard algorithms.

3. **A linearly convergent conditional gradient algorithm with applications to online and stochastic optimization**

   Dan Garber (dangar@tx.technion.ac.il) Technion - Israel Institute of Technology, Israel, *Elad Hazan*

The conditional gradient method is a long-studied first-order optimization method for smooth convex optimization. Its main appeal is the low computational complexity: the conditional gradient method requires only a single linear optimization operation per iteration. In contrast, other first-order methods require a projection computation every iteration, which is the computational bottleneck for many large scale optimization tasks. The drawback of the conditional gradient method is its relatively slow convergence rate. In this work we present a new conditional gradient algorithm for smooth and strongly convex optimization over polyhedral sets with a linear convergence rate — an exponential improvement over previous results. We extend the algorithm to the online and stochastic settings, and give the first conditional gradient algorithm that attains optimal regret bounds for both arbitrary convex losses and strongly convex losses. Our online and stochastic algorithms require a single linear optimization step over the domain per iteration.

■ Wed.D.23

Wednesday, 18:00-19:30, Room 2.3, Organized Session

Interior point methods for conic optimization

Cluster: Optimization software: Modeling tools and engines
Session organized by: *Joachim Dahl, Erling D. Andersen*

1. **Modeling and solving conic optimization problems using MOSEK**

   Joachim Dahl (joachim.dahl@mosek.com) MOSEK ApS

We discuss recent algorithmic developments in the MOSEK conic solver including extensions to handle semidefinite optimization. Another contribution is the development of a new modeling API tailored specifically for conic optimization.

2. **Decomposition and partial separability in conic optimization**

   Lieven Vandenberghe (lieven.vandenberghe@ucla.edu) University of California Los Angeles, USA, *Martin S. Andersen*, *Yifan Sun*

We discuss linear conic optimization problems with partially separable cones, that is, cones with partially separable indicator functions. The most important example is sparse semidefinite programming with chordal sparsity patterns. Here partially separability follows from the clique decomposition theorems that characterize positive semidefinite and positive-semidefinite-completable matrices with a chordal sparsity pattern. In the talk we will discuss a decomposition method that exploits partial separability. The method is based on a monotone operator splitting method, combined with a fast interior-point method for evaluating resolvents.

3. **A custom interior-point method for matrix-fractional minimization**

   Martin S. Andersen (mskan@dtu.dk) Technical University of Denmark, Denmark, *Tianshi Chen*, *Lieven Vandenberghe*

In this talk, we discuss a custom interior-point method for second-order cone programming formulations of matrix-fractional minimization problems. By carefully exploiting the structure in the Newton equations, we obtain an interior-point method, for which the per-iteration cost grows at the same rate as that of evaluating the gradient of the matrix-fractional cost function. Furthermore, the cost of a single iteration grows only linearly with the number of variables, and hence for large problems, our method can be orders of magnitude faster than general-purpose interior-point methods for conic optimization. We also discuss some applications, including empirical Bayes estimation with multiple kernels, multitask learning, and truss topology design.

■ Wed.D.24

Wednesday, 18:00-19:30, Room 2.4, Organized Session

Optimization of free boundary problems II

Cluster: PDE-constrained optimization
Session organized by: *Juan Carlos de los Reyes, Christian Meyer*

1. **Multi-material structured topology optimization based on a phase field ansatz: H^1 -gradient projection and SQP method**

   Christoph Rupprecht (christoph.rupprecht@mathematik.uni-regensburg.de) University of Regensburg, Germany, *Luise Blank*

A phase field approach for structural topology optimization with multiple materials is numerically considered. First the problem formulation is introduced. The choice of an obstacle potential leads to an optimization problem with mass constraints and inequality constraints. Then, an H^1-gradient projection method in function space is deduced, where convergence is given. The realization of determining the H^1 projection of the discretized problem is presented and numerical results are given. Better efficiency is attained by an SQP method which will be presented along with numerical results.

2. **A phase-field approach for shape optimization in fluid mechanics**

   Claudia Hecht (claudia.hecht@mathematik.uni-regensburg.de) Universität Regensburg, Germany, *Harald Garcke*

We consider the problem of shape optimization with a general objective functional using the incompressible stationary Navier-Stokes equations as a state constraint. Therefore, we describe the situation by a phase-field variable and discuss well-posedness and optimality conditions. Moreover, we relate the phase-field model to the sharp interface model by Gamma-convergence.

3. **Optimal control of quasilinear H(curl)-elliptic PDEs**

   Irwin Yousept (yousept@gsc.tu-darmstadt.de) TU Darmstadt, Germany

Strong material parameter dependence on electromagnetic fields is a well-known physical phenomenon. In the context of magnetism, for instance, there is a wide variety of ferromagnetic materials whose physical properties can be significantly influenced by magnetic fields. The governing PDEs for such phenomena feature a quasilinear curl-curl structure. In this talk, recent mathematical and numerical results on the optimal control of such issues are presented.

■ Wed.D.25

Wednesday, 18:00-19:30, Room 2.5, Organized Session

Variational analysis in differential and mean field games

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Francisco J. Silva*

1. **First order mean field games with density constraints**

   Alpár Richárd Mészáros (alpar.meszaros@math.u-psud.fr) University of Paris-Sud, France, *Francisco J. Silva*

The purpose of this talk is to present some initial works regarding first order Mean Field Games (MFG) under density constraints. The model was proposed by Filippo Santambrogio using ideas and recent results from crowd motion modeling. The main idea is to work with admissible velocities of the agents, defined through a well-chosen projection operator, in order to fulfill the density constraint. This will introduce into the model a natural pressure field. We will present the continuous model and a first approach based on time discretization. In both cases we will underline some advantages and also some difficulties (arising because of the low regularity on the pressure field) which prevent us for the moment to obtain final results regarding the existence of a solution to such a MFG system.

2. **Semi-Lagrangian schemes for mean field game models**

   Elisabetta Carlini (carlini@mat.uniroma1.it) Sapienza Università di Roma, Italy, *Francisco J. Silva*

In this work we consider first and second order Mean Field Games (MFGs) systems. For the first order case, we prove that the resulting discretization admits at least one solution and, in the scalar case, we prove a convergence result for the scheme. We propose the natural extension of this scheme for the second order case. Finally, we present some numerical simulations.

3. **Accelerated schemes for optimal control and pursuit-evasion games**

   Dante Kalise (kalise@mat.uniroma1.it) Johann Radon Institute for Computational and Applied Mathematics, Linz, Austria, *Maurizio Falcone*

In this talk we present an accelerated scheme for the solution of Hamilton-Jacobi-Bellman and Isaacs equations arising in optimal control and differential games. The scheme is based on a semi-Lagrangian, policy iteration algorithm featuring a pre-processing step yielding faster convergence and robustness properties. We present numerical experiments assessing the performance of the method.

■ Wed.D.AB

Wednesday, 18:00-19:30, Amphitheater B, Organized Session

Nonlinear optimization and applications II

Cluster: Nonlinear optimization
Session organized by: *Ya-xiang Yuan*

1. **Gridded tomographic velocity analysis using nonsmooth regularization**

   Yanfei Wang (yfwang@mail.iggcas.ac.cn) Institute of Geology and Geophysics, Chinese Academy of Sciences, China

Simultaneous estimation of velocity gradients and anisotropic parameters from reflection data is one of the main challenges in VTI (transversely isotropic with a vertical symmetry axis) media migration velocity analysis. Migration velocity analysis usually constructs the objective function according to the l_2 norm, and uses a linear conjugate gradient scheme to solve the inversion problem. However, it has been proved that the above inversion results may be unstable and may not reach better results in finite time. In order to ensure the uniform convergence of parameters inversion and improve the efficiency of migration velocity analysis, this paper considers establishing nonsmooth regularization model and the optimizing solution methods. The model is based on the combination of the l_2 norm and the Huber norm. In pursuing solving the minimization problem, a limited memory BFGS method is utilized to make the iterative process to be stable. Numerical simulations indicate that this method can generate fast convergence to the true model with high accuracy. Therefore, the proposed method is very promising for practical anisotropy media migration velocity analysis.

2. **A buildup-based error minimization method with application to protein structure determination**

   Zhenli Sheng (szl@lsec.cc.ac.cn) Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences, China

Geometric buildup method is a fast algorithm particularly designed for distance geometry problem with exact or extremely small noise distances. We incorporate it with error minimization procedure to handle large noise given distances, which are the real-world cases. A new error function has been proposed, and a fast algorithm is designed to minimize the error function. Besides, extensive numerical experiments have been finished on a variety number of proteins, from several hundreds to several thousands, which proves that it is a powerful algorithm for this problem. It provides very accurate conformations of these proteins quickly.

3. **An efficient truncated Newton-CG algorithm for the smallest enclosing ball problem of huge dimensions**

   Ya-Feng Liu (yafliu@lsec.cc.ac.cn) Chinese Academy of Sciences, China

Consider the problem of computing the smallest enclosing ball of a set of m balls in $\mathbb{R}^n$. In this presentation, we propose a computationally efficient truncated Newton-CG algorithm for the smallest enclosing ball (SEB) problem of huge dimension mn. The proposed algorithm is based on the log-exponential aggregation function, which transforms the non-differentiable SEB problem into a series of smoothing approximation problems. By exploiting the special structure of the log-exponential aggregation function, we find its gradient and Hessian-vector product can be efficiently computed in a truncated way by judiciously neglecting some small terms. In such a way, the computational cost is dramatically reduced compared to exact computation of the gradient and Hessian-vector product. We are therefore motivated to propose the truncated Newton-CG algorithm for solving the smoothing approximation problem. At each iteration of the proposed algorithm, we compute the search direction by applying the CG method to solve the truncated Newton equations in an inexact fashion. We give some adaptive truncation criteria, concerning only computation of function values, and analyze their truncation error. We also establish global convergence and locally superlinear/quadratic convergence rate of the proposed algorithm. We illustrate the efficiency of the proposed algorithm by using the algorithm from [Zhou. et al. in Comput. Opt. & Appl. 30, 147–160 (2005)] as the benchmark.

■ Thu.A.11

Thursday, 9:00-10:30, Room 1.1, Organized Session

New bounds for combinatorial problems using copositive and semidefinite optimization

Cluster: Conic and polynomial optimization
Session organized by: *Juan C. Vera*

1. **Old vs new SDP bounds for the quadratic assignment problem**

   Uwe Truetsch (U.Truetsch@uvt.nl) Tilburg University (UVT), The Netherlands, *Etienne de Klerk*, *Renata Sotirov*

In order to solve the quadratic assignment problem of moderate and large size to optimality within a branch-and-bound framework, one needs to implement a "good" lower bound. For us, a "good" bound is the one that provides a promising compromise between its quality and computational time. Clearly, compromises should take into the consideration sizes of the problem instances. In this talk, we first introduce a new SDP-based eigenspace relaxation that turns to be good for problems of moderate size. Then, we compare our relaxation with SDP relaxations introduced by Zhao, Karisch, Rendl and Wolkowicz, and by Peng, Zhu, Luo and Toh. Our comparison results with the size-dependent choice of an appropriate relaxation that can be successfully used within a branch-and-bound framework.

2. **Copositive formulation for the stability number of infinite graph**

   Cristian Dobre (c.dobre@rug.nl) University of Groningen, The Netherlands, *Mirjam Dür*, *Frank Vallentin*

We show that the stability number (independence number) of an infinite graph is the optimal solution of some infinite dimensional copositive program. For this a duality theory between the primal convex cone of copositive kernels and the dual convex cone of completely positive measures is developed. We compare this new theory with the well known approach on finite graphs and point out the main differences between the finite and infinite setting.

3. **Exploiting symmetry in copositive programs**

   Juan C. Vera (j.c.veralizcano@tilburguniversity.edu) Tilburg University, The Netherlands, *Cristian Dobre*

Several authors have proposed approximation hierarchies for Copositive Programming. These hierarchies converge to the optimal value, but they grow exponentially in size and quickly become unsolvable. We show that if the original problem has symmetry, this symmetry can be used to reduce the size of each level of the hierarchy, which allows to solve higher levels of the hierarchy. As a result of our approach we are able to compute new best-bounds for the crossing number of the complete bipartite graph $K_{7,n}$.

■ Thu.A.12

Thursday, 9:00-10:30, Room 1.2, Organized Session

Robust formulations and algorithms for large scale sparse programs

Cluster: Sparse optimization and information processing
Session organized by: *Aleksandr Y. Aravkin*

1. **Matrix-free solvers for systems of inclusions**

   Hao Wang (haw309@gmail.com) Lehigh University, USA, *James V. Burke*, *Frank E. Curtis*, *Jiashan Wang*

Matrix free alternating direction and reweighting methods are proposed for solving systems of inclusions. The methods attain global convergence guarantees under mild assumptions. Emphasis is placed on their ability to rapidly find good approximate solutions, and to handle large-scale problems. Numerical results are presented for elastic QP subproblems arising in NLP algorithms.

2. **A fast randomized Kaczmarz algorithm for sparse solutions of consistent linear systems**

   Hassan Mansour (hassanm@cs.ubc.ca) University of British Columbia, Canada, *Ozgur Yilmaz*

The Kaczmarz algorithm is a popular solver for overdetermined linear systems due to its simplicity and speed. In this paper, we propose a modification that speeds up the convergence of the randomized Kaczmarz algorithm for systems of linear equations with sparse solutions. The speedup is achieved by projecting every iterate onto a weighted row of the linear system while maintaining the random row selection criteria of Strohmer and Vershynin. The weights are chosen to attenuate the contribution of row elements that lie outside of the estimated support of the sparse solution. While the Kaczmarz algorithm and its variants can only find solutions to overdetermined linear systems, our algorithm surprisingly succeeds in finding sparse solutions to underdetermined linear systems as well. We present empirical studies which demonstrate the acceleration in convergence to the sparse solution using this modified approach in the overdetermined case. We also demonstrate the sparse recovery capabilities of our approach in the underdetermined case and compare the performance with that of ℓ_1 minimization.

3. **Sparse/robust estimation with nonsmooth log-concave densities**

   Aleksandr Y. Aravkin (saravkin@us.ibm.com) IBM T.J. Watson Research Center, USA, *James V. Burke*, *Gianluigi Pillonetto*

We introduce a class of quadratic support (QS) functions, which play a crucial role in a variety of applications, including machine learning, robust statistical inference, sparsity promotion, and Kalman smoothing. Well known examples include the l2, Huber, l1 and Vapnik losses. We build a statistical interpretation for QS loss functions, and for a subclass of QS functions called piecewise linear quadratic (PLQ) penalties, we also develop efficient numerical estimation schemes using interior point (IP) methods. IP methods solve nonsmooth optimization problems by working directly with smooth systems of equations characterizing their optimality. The efficiency of the IP approach depends on the structure of particular applications, and we show that for inference on dynamic systems (Kalman smoothing), the proposed framework preserves computational efficiency of classic Kalman smoothers, while enabling a variety of new applications that exploit nonsmooth density modeling.

■ Thu.A.13

Thursday, 9:00-10:30, Room 1.3, Organized Session

Algorithms II

Cluster: Nonlinear optimization
Session organized by: *Ernesto G. Birgin*

1. **Inexact restoration for unconstrained optimization**

   Natasa Krejic (natasak@uns.ac.rs) University of Novi Sad, Serbia, *José Mario Martínez*

Methods within Inexact Restoration framework are two phase iterative methods for constrained optimization problems. In the first phase one considers only the constraints in order to improve the feasibility. In the second phase a suitable objective function is minimized. The problem we are considering in this work is an unconstrained optimization problem with the objective function given in the form of sum of a very large number of functions. Such problems appear in many situations like sample path approximation of the mathematical expectation or data fitting for example. Working with the full objective function is very often prohibitively costly. Clearly one does not need a very good approximation for the objective function when far away form the solution and the precision should increase as the solution is approached. Therefore the question of sample sizes (or the number of sum elements in other contents) that are used in the optimization procedure is quite important. In this work we reformulate the original problem as a constrained optimization problem, taking the difference between the original objective function and the approximate objective function as unfeasibility. The sequence of the approximate objective functions is then determined by the merit function that connects two phases of an inexact restoration iteration. This way we achieved a good balance between the costs and precision during the optimization procedure.

2. **Recent developments in Algencan**

   Ernesto G. Birgin (egbirgin@ime.usp.br) University of São Paulo, Brazil

Algencan is an optimization software that implements an augmented Lagrangian method for nonlinear programming. In this talk we aim to describe some recent developments and applications. Numerical results will be presented.

3. **Some optimization in electronic structure calculations**

   José Mario Martínez (martinez@ime.unicamp.br) State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, *Juliano Francisco*, *Leandro Martínez*, *Feodor Pisnitchenko*, *Ernesto G. Birgin* , *Gerd B. Rocha*

After simplifications and the employment of Pauli's principle, the Schroedinger equation gives rise to the minimization of $E(P)$ $(= \text{Trace}[F(P)P])$ subject to $PP = P$ and $\text{Trace}(P) = N$ in the space of symmetric $K \times K$ matrices. The Fock Matrix $F(P)$ is such that the gradient of $E(P)$ is $2F(P)$. (Usually N is between $K/10$ and $K/2$.) The most popular method for solving this problem consists on minimize, iteratively, $\text{Trace}[A\ P]$ subject to $PP = P$ and $\text{Trace}(P) = N$, where A is $F(P_k)$ or some regularization of that matrix. A solution of this subproblem is the projection matrix on the subspace generated by the eigenvectors associated with the N lowest eigenvalues of A. In large-scale problems, however, eigenvalue decompositions are not effective and alternative scalable algorithms are necessary. Some approaches consist on minimizing a cubic matricial function whose unique local (but not global!) solution solves the subproblem. Other approaches guarantee global convergence to the desired solution but are not able to take advantage of possibly good initial approximations. Advantages and disadvantages of both approaches will be discussed.

■ Thu.A.14

Thursday, 9:00-10:30, Room 1.4, Organized Session

Complementarity problems: Algorithms and applications

Cluster: Complementarity and variational inequalities
Session organized by: *Francisco Facchinei*

1. **Solving nonsmooth equations with nonisolated solutions**

   Andreas Fischer (Andreas.Fischer@tu-dresden.de) TU Dresden, Germany, *Francisco Facchinei*, *Markus Herrich*

The problem of solving a system of possibly nonsmooth equations with nonisolated solutions appears in several applications. For example, complementarity problems, necessary conditions for generalized Nash equilibrium problems, or Karush-Kuhn-Tucker conditions of an inequality constrained optimization problem can be written in this way. An iterative framework for solving such systems and appropriate conditions for local superlinear convergence will be presented. Moreover, different algorithms belonging to the framework will be described. Particular emphasis is placed on the piecewise smooth case.

2. **Approximately shrinking operators and their applications to variational inequalities**

   Rafał Zalas (r.zalas@wmie.uz.zgora.pl) University of Zielona Góra, Faculty of Mathematics, Computer Science and Econometrics, Poland, *Andrzej Cegielski*

Variational inequality problem, denoted by $VIP(F,C)$, is one of the fundamental problems in optimization theory. Very often the subset C has a special structure. This subset is often the intersection of simpler to handle closed convex subsets or a sublevel set of a convex function or, more generally, a set of fixed points of a quasi-nonexpansive operator. In this talk we will consider an abstract variational inequality in a real Hilbert space, which covers all of these three cases. For this purpose we will introduce a class of approximately shrinking (AS) operators and discuss their basic properties. Moreover, we will present a few examples of iterative methods with application of AS operators, which can be used to solve $VIP(F,C)$. Iterative schemes which are going to be presented are mostly based on the hybrid steepest descent method introduced by Isao Yamada in 2001 and extended by A. Cegielski and R. Zalas in 2013. These iterative schemes are related to cyclic, sequential and also to string averaging procedures of construction of operators, which are more general.

3. **Non-cooperative computation offloading in mobile cloud computing**

   Veronica Piccialli (piccialli@disp.uniroma2.it) DICII-University of Rome Tor Vergata, Italy, *Valeria Cardellini*, *Vittoria De Nitto Personè*, *Valerio Di Valerio*, *Vincenzo Grassi*, *Francesco Lo Presti*

We consider a three-tier architecture for mobile and pervasive computing scenarios, consisting of a local tier (mobile nodes), a middle tier (cloudlets) of nearby computing nodes, typically located at the mobile nodes access points (APs) but characterized by a limited amount of resources, and a remote tier of distant cloud servers, which have practically infinite resources. This architecture has been proposed to get the benefits of computation offloading from mobile nodes to external servers without resorting to distant servers in case of delay sensitive applications, which could negatively impact the performance. In this paper, we consider a scenario where no central authority exists and multiple non-cooperative mobile users share the limited computing resources of a close-by cloudlet and can decide to compute on each of the three tiers of the envisioned architecture. We define a model to capture the users interaction and to investigate its dynamics, formulate the problem as a Generalized Nash Equilibrium Problem and show existence of an equilibrium. We present an algorithm for the computation of an equilibrium which is amenable to distributed implementation. Through numerical examples, we illustrate its behavior and the characteristic of the achieved equilibria.

■ Thu.A.15

Thursday, 9:00-10:30, Room 1.5

Derivative-free optimization: Algorithms and applications I

Cluster: Derivative-free and simulation-based optimization
Session chair: *Yves Lucet*

1. **Parallel extensions of algorithms for derivate-free optimization**

   Per-Magnus Olsson (per-magnus.olsson@liu.se) Linkoping University, Sweden, *Kaj Holmberg*

In this talk we present parallelization and extensions of model-building algorithms for derivative-free optimization. Such algorithms are inherently sequential, and these are the first steps towards a fully parallel algorithm. In each iteration, we run several instances of an optimization algorithm with different trust region parameters, and each instance generates at least one point for evaluation. All points are kept in a priority queue and the most promising points are evaluated in parallel when computers are available. We use models from several instances to prioritize the points and allow dynamic prioritization of points to ensure that computational resources are used efficiently in case new information becomes available. A database is used to avoid reevaluation of points. Together, these extensions make it easier to find several local optima and rank them against each other, which is very useful when performing robust optimization. The initial model has so far been built sequentially, and here we present the first results of completely parallel model-building. Empirical testing reveals considerable decreases in the number of function evaluations as well as in the time required to solve problems. We show test results from testing a variety of different parameter settings, most notably different trust region transformations. The intention of these is to make the trust-region sub-problem easier to solve and/or allow longer steps in certain directions.

2. **Direct search based on probabilistic descent**

   Clément W. Royer (clement.royer@etu.enseeiht.fr) ENSEEIHT-IRIT, France, *Serge Gratton*, *Luis Nunes Vicente*, *Zaikun Zhang*

Direct-search methods are a class of popular derivative-free algorithms which are based on (polling) directions, typically extracted from positive spanning sets when applied to the minimization of smooth functions. A positive spanning set must have at least $n+1$ vectors, n being the dimension of the variable space. Besides, to ensure the global convergence of these algorithms, the positive spanning sets used throughout the iterations must be uniformly nondegenerate in the sense of having a positive (cosine) measure bounded away from zero.
However, recent numerical results indicated that randomly generating the polling directions without imposing the positive spanning property can improve the performance of these methods, especially when the number of polling directions is chosen considerably less than $n+1$.
In this talk, we analyze direct-search algorithms when the polling directions are probabilistic descent, meaning that with a significantly positive probability at least one of them is of descent type. Almost-sure global convergence is established following an argument known for trust-region methods. The worst-case complexity is addressed by deriving a suitable global rate but now under an appropriate probability. Our analysis helps understand the observed numerical behaviour and links the choice of the number of polling directions to the tradeoff between robustness and efficiency.

3. **SQA: A generic trust region derivative free optimization method for black box industrial applications**

   Delphine Sinoquet (delphine.sinoquet@ifpen.fr) IFPEN, France, *Hoël Langouët*

Derivative free optimization takes place in various application fields and often requires dedicated techniques to limit the number of evaluations of the usually time consuming simulator. We propose the Sequential Quadratic Approximation method (SQA) based on a trust region method with quadratic interpolation models. This method based on NEWUOA algorithm (Powell, 2004) is extended to constrained problems (derivative based and derivative free constraints) and to least-square and multi-objective formulations. A parallel version of this algorithm is studied to accelerate the convergence (in terms of CPU time) to a local minimum by using adapted model improvement steps and multi-model approach (incomplete quadratic models based on varying number of interpolation points). We show applications of SQA on classical DFO test problems and to an industrial application in reservoir characterization.

■ Thu.A.16

Thursday, 9:00-10:30, Room 1.6, Organized Session

Recent advances in global optimization

Cluster: Global optimization and mixed-integer programming
Session organized by: *Evrim Dalkiran*

1. **Eigenvalue complementarity problem: Applications and algorithms**

Luís Merca Fernandes (Luis.Merca@aim.estt.ipt.pt) Instituto Politécnico de Tomar and Instituto de Telecomunicações, Portugal, *Joaquim João Júdice*, *Hanif D. Sherali*

The Eigenvalue Complementarity Problem (EiCP) finds important applications in different areas of science and engineering and differs from the traditional Eigenvalue Problem on the existence of nonnegative constraints on its variables and complementarity constraints between pairs of variables. In this talk the EiCP is first introduced together with some of its extensions and most important applications. The symmetric case is next considered and assumes that all the matrices involved in the definition of the EiCP are symmetric. The symmetric EiCP reduces to the problem of finding a stationary point of an appropriate nonlinear merit function on the simplex. A projected-gradient algorithm is recommended to deal with the symmetric EiCP by exploiting this nonlinear programming formulation. An enumerative algorithm is introduced to deal with the asymmetric EiCP. The method looks for a global minimum of an appropriate nonlinear program and requires in each node the computation of stationary points for this program. Computational experience for the solution of EiCPs is reported to highlight the efficiency of the projected-gradient and enumerative algorithms in practice.

2. **Continuous dynamical systems for global optimization**

Amir Ali Ahmadi (aaa@us.ibm.com) IBM Watson Research Center, USA, *Sanjeeb Dash*, *Oktay Gunluk*

We explore connections between stability of equilibrium points of cubic differential equations and feasibility of basic semialgebraic sets. This allows for (i) a methodology for providing certificates of infeasibility of such sets presented as Lyapunov functions and obtained by semidefinite programming, and (ii) a methodology for (“often") finding feasible solutions to a broad class of constraint satisfaction problems by simulating the solution of a differential equation. We present preliminary work in this direction and demonstrate applications to (intractable) problems such as that of finding Nash equilibria in games, or Euclidean embeddings given pairwise distances.

3. **RLT-POS: Reformulation-linearization technique-based optimization software for solving polynomial programming problems**

Evrim Dalkiran (evrimd@wayne.edu) Wayne State University, USA, *Hanif D. Sherali*

In this talk, we introduce a Reformulation-Linearization Technique-based open-source optimization software for solving polynomial programming problems (RLT-POS). We present algorithms and mechanisms that form the backbone of RLT-POS, including constraint filtering techniques, reduced RLT representations, semidefinite cuts, and bound-grid-factor constraints. When implemented individually, each model enhancement has been shown to significantly improve the performance of the standard RLT procedure. However, coordination between model enhancement techniques becomes critical for an improved overall performance since special structures in the original formulation may be lost after implementing a particular model enhancement. More specifically, we discuss the coordination between 1) constraint elimination via filtering techniques and reduced RLT representations, and 2) semidefinite cuts and bound-grid-factor constraints. We present computational results using instances from the literature as well as randomly generated problems to demonstrate the improvement over standard RLT, and compare the performances of the software packages BARON, SparsePOP, and Couenne with RLT-POS.

■ Thu.A.17

Thursday, 9:00-10:30, Room 1.7

Optimization in practice II

Cluster: Applications of continuous optimization in science and engineering
Session chair: *Eligius M. T. Hendrix*

1. **Topology optimization for the design of electromagnetic devices**

Satafa Sanogo (satafa.sanogo@laplace.univ-tlse.fr) LAPLACE-ENSEEIHT, France, *Frédéric Messine*, *Carole Henaux*, *Raphël Vilamot*

We bring methods and approaches to mathematically formulate the Inverse Problem into an Topology Optimization one. For instance, with a target magnetic induction or field B0, we want to design a device which will be able to produce this value at some fixed points. In this case, the objective is to minimize the gap between a computed value B and B0 at these points. For such a problem the variables are the device sizes, the material properties and the sources. Without lost of generality, we consider as variables the material properties, and the process is to fill the design domain with iron (value 1) and void (value 0); it is why this type of problem is called a 0-1 problem. The magnetic field B values are obtained by solving Maxwell's Equations via the Finite Element software FEMM (Finite Element Method Magnetics). This 0-1 problem is relaxed into the interval [0, 1], then the obtained continuous problem is solved with steepest descent algorithms. We compute it by using the Adjoint Variable Method of design Sensitivity Analysis for magnetic circuits. Numerical resolutions of our Topological Optimization is performed with a function of Matlab's Optimization Toolbox: fmincon. In general, the numerical results contain some intermediary values and these solutions are not manufacturable. Then, we avoid these intermediary values by using the SIMP method (Solid Isotropic Material with Penalization). This method combined with the relaxed problem give us binary solutions.

2. **Optimizing the geometry of branched sheet metal structures using cubic regularization**

Thea Göllner (goellner@opt.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

We consider the geometry optimization of branched sheet metal structures which may exhibit an arbitrary curvature. With the new technologies linear flow splitting and linear bend splitting, developed within the framework of the Collaborative Research Centre 666, such structures can be produced continuously and in integral style. For an appropriate description of the free form geometry, a parameterization by tensor products of cubic B-splines is used, and the mechanical behaviour of the structure under load is given by the three dimensional linear elasticity equations. We formulate the resulting PDE-constrained problem for optimizing the stiffness of the considered structure. Then, an algorithm for solving these shape optimization problems is presented. Its globalization strategy is based on cubic regularization and the exact constraints of the problem are used. We conclude by showing numerical results for an engineering application.

3. **On using a conical interior point method in large scale soil simulations including friction**

Jan Kleinert (jan.kleinert@itwm.fraunhofer.de) Fraunhofer Institute for Industrial Mathematics ITWM, Germany, *Bernd Simeon*

For the simulation of soil, the Non-Smooth Contact Dynamics Method (NSCD) has become a popular alternative to classical Discrete Element Methods. In NSCD a contact between two particles is modeled using a complementarity condition: Either the particles are in contact and a reaction must be enforced that keeps them from penetrating, or the contact is separating and no contact force is required. A configuration must be found where the complementarity conditions hold for all contacts simultaneously. Introducing friction leads to a conical complementarity problem that is hard to solve numerically. Yet, a frictional contact model is indispensable in soil mechanical simulations. Popular iterative methods for this class of problems are given by the projected Gauss-Seidel and Gauss-Jacobi schemes. They deliver results that are faithful to the eye, even when reaction forces are still far from the expected result. The convergence rate stalls quickly, which can be a problem in large scale simulations where the values of the reaction forces are of interest. Interior point methods (IPM), on the other hand, supply iterative schemes for complementarity problems that are known to converge superlinearly. We propose an IPM based on Jordan algebraic properties of cones, that is closely related to the one presented by Kojima et al for linear complementarity problems in 1991. The possibility of using such a method in soil mechanical simulations is discussed as well as some numerical implications.

■ Thu.A.18

Thursday, 9:00-10:30, Room 1.8, Organized Session

Optimization in finance II

Cluster: Robust optimization and optimization in finance
Session organized by: *Javier Nogales*

1. **Multiperiod portfolio selection with transaction and market impact costs**

Xiaoling Mei (xmei@est-econ.uc3m.es) UC3M, Department of Statistics, Spain, *Victor DeMiguel*, *Javier Nogales*

We carry out an analytical investigation on the optimal portfolio policy for a multiperiod mean-variance investor facing multiple risky assets. We consider the case with proportional, market impact, and quadratic transaction costs. For proportional transaction costs, we find that a buy-and-hold policy is optimal: if the starting portfolio is outside a parallelogram-shaped no-trade region, then trade to the boundary of the no-trade region at the first period, and hold this portfolio thereafter. For market impact costs, we show that the optimal portfolio policy at each period is to trade to the boundary of a state-dependent movement region. Moreover, we find that the movement region shrinks along the investment horizon, and as a result the investor trades throughout the entire investment horizon. Finally, we show numerically that the utility loss associated with ignoring transaction costs or investing myopically may be large.

2. **Performance-based regularization in mean-CVaR portfolio optimization**

   Gah-Yi Vahn (gvahn@london.edu) London Business School, UK, *Noureddine El Karoui*, *Andrew E. B. Lim*

We introduce performance-based regularization (PBR), a new approach to addressing estimation risk in data-driven optimization, to mean-CVaR portfolio optimization. The method regularizes portfolios with large variability in the mean and CVaR estimations. The resulting problem is a combinatorial optimization problem, but we prove its convex relaxation, a quadratically constrained quadratic program (QCQP), is tight. We derive the asymptotic behavior of the PBR solution by extending asymptotic analysis of M-estimators, which leads to the insight that the first-order effect of penalization is through Hájek projections. We show via simulations that the PBR method substantially improves the average Sharpe ratio of the portfolios for three different population models of asset log-returns.

3. **Optimal multiperiod portfolio selection with trading costs and parameter uncertainty**

   Alberto Martin-Utrera (amutrera@est-econ.uc3m.es) University Carlos III of Madrid, Spain, *Victor DeMiguel*, *Francisco J. Nogales*

We address the effects of parameter uncertainty in multiperiod portfolio selection in the presence of transaction costs. In particular, we characterize the impact of parameter uncertainty on the performance of a multiperiod mean-variance investor. This allows us to define the investor's expected loss as a function of several relevant parameters. Concretely, we observe that the investor's expected loss reduces with trading costs and the investor's impatience factor, as well as with the investor's risk aversion parameter and the number of available observations as in the static portfolio model. We propose a novel four-fund portfolio that takes parameter uncertainty optimally into account. This portfolio diversifies the effects of estimation risk across four different funds and mitigates the impact of parameter uncertainty in the investor's expected utility. Finally, we find in an empirical application that four-fund portfolios may obtain a risk-and-cost-adjusted expected return up to three times larger with simulated data, and up to ten times larger with a real dataset of commodity futures.

■ Thu.A.21

Thursday, 9:00-10:30, Room 2.1, Organized Session

Semidefinite and conic optimization: Models and methods

Cluster: Convex and nonsmooth optimization
Session organized by: *Yu Xia*

1. **Applications of algebraic sum-of-squares cones in optimal geometric design**

   Farid Alizadeh (farid.alizadeh@rutgers.edu) Rutgers University, USA, *David Papp*

We examine the applications of cones whose elements are from linear functions spaces, and their applications in optimal geometric design. For instance, the set of symmetric matrix polynomials $P(t)$ which are positive semidefinite for every value of t, or the set of vectors $v(t)$ which belong to the second order cone for every of value of t, are known to be semidefinite representable. In addition, such sets arise in geometric problems. For instance in design of paths with constraints on the curvature, or in computing balls or ellipsoids of minimum volume containing a set of closes paths. We will discuss these connections and other related applications.

2. **CANCELLED**

3. **Second-order cone representations of positive semidefinite cones**

   François Glineur (Francois.Glineur@uclouvain.be) Université Catholique de Louvain, Belgium, *Pablo Parrilo*, *James Saunderson*

Yannakakis established a link between extended formulations of a given polytope and nonnegative factorizations of its slack matrix. In particular, the size of the smallest extended formulation is given by the nonnegative rank of that slack matrix. This was recently generalized by Gouveia et al. and Fiorini at al., where cone lifts of convex bodies are linked to factorization of slack operators. In this work, we investigate the use of this framework to answer the question of the second-order cone representability of the positive semidefinite cone. It is well-known that second-order cones can be represented with positive semidefinite cones: more specifically second-order cones are specific slices (i.e. intersection with a linear subspace) of the positive semidefinite cone. Not too much is known about the converse relationship. For example, we are not aware of any second-order representation of the 3×3 positive semidefinite cone (although some specific slices of that cone admit such a representation). Note that two distinct questions can be considered: representation using slices of a product of second-order cones, or representation as a projection (linear map) of such a slice (which allows more freedom). We will provide a negative answer to the first question, and discuss the second.

■ Thu.A.22

Thursday, 9:00-10:30, Room 2.2, Organized Session

Efficient first-order methods for convex optimization

Cluster: Convex and nonsmooth optimization
Session organized by: *Shiqian Ma*

1. **Very large-scale parallel sparse optimization**

   Wotao Yin (wotao.yin@rice.edu) Rice University, USA, *Ming Yan*, *Zhiming Peng*, *Hui Zhang*

Sparse optimization has found interesting applications in many areas such as machine learning, signal processing, compressive sensing, medical imaging, etc. This talk introduces a "smoothing"approach to sparse optimization that does not directly generate a smooth function but produces an unconstrained dual problem whose objective is differentiable and enjoys a "restricted"strongly convex property. Not only can one apply a rich set of classic techniques such as gradient descent, line search, and quasi-Newton methods to this dual problem, exact sparse solutions and global linear convergence are guaranteed. In addition, parallelizing the algorithm becomes very easy. Numerical examples with tera-scale data are presented.

2. **An augmented Lagrangian method for conic convex programming**

   Necdet Serhat Aybat (nsa10@psu.edu) Industrial Engineering Dept., The Pennsylvania State University, USA, *Garud Iyengar*

We propose a new first-order augmented Lagrangian algorithm ALCC to solve conic convex programs of the form $\min\{r(x)+g(x) : Ax-b \in K; x \in Q\}$; where $r : R^n \to R \cup +\infty$ and $g : R^n \to R$ are closed, convex functions and g has a Lipschitz-continuous gradient; A is an $m \times n$ matrix, K is a closed convex cone, and Q is a subset of dom(r) such that Q is a "simple"convex compact set in the sense that optimization problems of the form $\min\{r(x)+\|x-x_0\|_2^2 : x \in Q\}$ can be efficiently solved. We show that any limit point of the primal ALCC iterate sequence is an optimal solution of the conic convex problem, and the dual ALCC iterate sequence has a unique limit point which is a KKT point of the conic problem. We also show that for all $\epsilon > 0$, the primal ALCC iterates are ϵ-feasible and ϵ-optimal after $O(\log(1/\epsilon))$ iterations, which require $O(1/\epsilon \log(1/\epsilon))$ oracle calls to solve problems of the form $\min\{r(x)+\|x-x_0\|_2^2 : x \in Q\}$.

3. **Matrix recovery with special structures**

   QingNa Li (qnl@bit.edu.cn) Beijing Institute of Technology, China

Matrix recovery has find many applications in different areas, including video surveillance, face recognition and so on. The generic RPCA model though nonconvex, can well describe these applications, and under certain conditions, the convex relaxation problem can recover the solution of the RPCA model. In this talk, we study its application in moving target indication, where the problem enjoys its own sparse structure. Due to such special structure, there will be difficulties for the exact recovery of the original nonconvex model. This motivates our work in this talk where we discuss how to set up better models to solve the problem. We propose two models, the structured RPCA model and the row-modulus RPCA model, both of which will better fit the problem and take more use of the special structure of the sparse matrix. Simulation results confirm the improvement of the generic RPCA model.

■ Thu.A.23

Thursday, 9:00-10:30, Room 2.3, Organized Session

Extending the power and expressiveness of optimization modeling languages

Cluster: Optimization software: Modeling tools and engines
Session organized by: *Robert Fourer*

1. **Convex quadratic programming in AMPL**

   Robert Fourer (4er@ampl.com) Northwestern University and AMPL Optimization, USA, *Jared Erickson*

A surprising variety of optimization applications can be written in terms of convex quadratic objectives and constraints that are handled effectively by extensions to linear solvers. “Elliptical” convex quadratic programs are easily recognized once the matrices of quadratic coefficients are extracted, through a test for positive-semidefiniteness. “Conic” problems are also convex quadratic and can in principle also be detected numerically, but are more commonly recognized by their equivalence to certain canonical forms. Additionally, varied combinations of sums-of-squares, Euclidean norms, quadratic-linear ratios, products of powers, p-norms, and log-Chebychev terms can be identified symbolically and transformed to quadratic problems that have conic formulations. The power and convenience of an algebraic modeling language may be extended to support these cases, with the help of a recursive tree-walk approach that detects and (where necessary) transforms arbitrarily complex instances; modelers are thereby freed from the time-consuming and error-prone work of maintaining the equivalent canonical formulations explicitly. We describe the challenges of creating the requisite detection and transformation routines for the AMPL language, and report computational tests that suggest the usefulness of these routines.

2. **Stochastic programming in GAMS**

   Michael C. Ferris (ferris@cs.wisc.edu) University of Wisconsin, Madison, USA, *Martha Loewe*, *Michael Bussieck*, *Lutz Westermann*

Extended Mathematical Programming (EMP) is a mechanism to annotate existing GAMS models to describe additional structural information. EMP/SP is a subset of these annotations for stochastic programming and provides the notions of random variables and their distributions, stages, risk measures and chance constraints. We demonstrate how these features can be used via a series of examples and pay particular attention to sampling for random variables with continuous distributions.

3. **PSMG: A parallel problem generator for a structure conveying modelling language for mathematical programming**

   Feng Qiang (F.Qiang@sms.ed.ac.uk) University of Edinburgh, UK, *Andreas Grothey*

In this talk, we present PSMG — Parallel Structured Model Generator — a parallel implementation of a model generator for the structure conveying modelling language — SML. PSMG analyses the structure of an optimization problem given as an SML model file and uses this information to parallelise the model generation process itself. As far as we are aware PSMG is the only algebraic modelling language that can perform parallel problem generation. PSMG offers an interface that can be linked in parallel with many different categories of structure exploiting optimization solvers such as interior point or decomposition based solvers. One of the features of this interface is that the decision on how to distribute problem parts to processors can be delegated to the solver thus enabling better data locality and load balancing. We also present performance benchmark result for PSMG. The results show that PSMG achieves good parallel efficiency on upto 256 processes. They also show that exploitation of parallelism enables the generation of problems that cannot be processed on a single node due to memory restrictions.

■ Thu.A.24

Thursday, 9:00-10:30, Room 2.4, Organized Session

Optimization with partial differential equations

Cluster: PDE-constrained optimization
Session organized by: *Ronald Hoppe*

1. **A Stokes free boundary problem with surface tension effects**

   Harbir Antil (hantil@gmu.edu) George Mason University, Fairfax Virginia, USA, *Ricardo H. Nochetto*, *Patrick Sodré*

We consider a Stokes free boundary problem with surface tension effects in variational form. This model is an extension of the coupled system proposed by P. Saavedra and L. R. Scott, where they consider a Laplace equation in the bulk with Young-Laplace equation on the free boundary to account for surface tension. The two main difficulties for the Stokes free boundary problem are: the vector curvature on the interface, which causes problem to write a variational form of the free boundary problem and the existence of solution to Stokes equations with Navier-slip boundary conditions for $W_p^{2-1/p}$ domains (minimal regularity). We will demonstrate the existence of solution to Stokes equations with Navier-slip boundary conditions using a perturbation argument for the bended half space followed by standard localization technique. The $W_p^{2-1/p}$ regularity of the interface allows us to write the variational form for the entire free boundary problem. We conclude with the well-posedness of this system using a fixed point iteration.

2. **Multilevel methods based on adaptive finite elements for elliptic mathematical programs with complementarity constraints**

   Michael Hintermüller (hint@math.hu-berlin.de) Humboldt-Universitaet zu Berlin, Germany

The dual weighted residual approach in goal-oriented mesh adaptivity is developed for two classes of optimization problems with elliptic complementarity constraints. The first problem class relies on an L^2-type tracking objective, whereas the second class contains the matching of point evaluations of the state in the objective. For each class, stationarity conditions are highlighted, and corresponding error estimators, inducing a multilevel treatment of the underlying problem, are derived. The talk ends by a report on the numerical performance of the newly derived error estimators.

3. **Fast solution of Cahn-Hilliard variational inequalities**

   Martin Stoll (stollm@mpi-magdeburg.mpg.de) MPI Magdeburg, Germany, *Jessica Bosch*, *Peter Benner*

In this talk consider the efficient solution of the Cahn-Hilliard variational inequality using an implicit time discretization, which is formulated as an optimal control problem with pointwise constraints on the control. We apply a semi-smooth Newton method combined with a Moreau-Yosida regularization technique for handling the control constraints. At the heart of this method lies the solution of large and sparse linear systems for which we propose the use of preconditioned Krylov subspace solvers using an effective Schur complement approximation. Numerical results illustrate the competitiveness of this approach.

■ Thu.A.25

Thursday, 9:00-10:30, Room 2.5, Organized Session

Variational analysis techniques

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Dariusz Zagrodny*

1. **Regularity and Lipschitz-like properties of subdifferential : Part I (of parts I and II)**

   Dariusz Zagrodny (d.zagrodny@uksw.edu.pl) Cardinal Stefan Wyszynski University, Poland, *Abderrahim Jourani*

It is known that the subdifferential of a lower semicontinuous convex function f over a Banach space X determines this function up to an additive constant in the sense that another function of the same type g whose subdifferential coincides with that of f at every point is equal to f plus a constant, i.e., $g = f + c$ for some real constant c. Recently, Thibault and Zagrodny introduced a large class of directionally essentially smooth functions for which the subdifferential determination still holds. More generally, for extended real-valued functions in that class, they provided a detailed analysis of the enlarged inclusion

$$\partial f(x) \subset \partial g(x) + \gamma B_X \quad \text{for all } x \in X,$$

where γ is a nonnegative real number and B_X is the closed unit ball of the topological dual space. The aim of the presentation is to show how results concerning such an enlarged inclusion of subdifferentials allow us to establish the $\mathscr{C}^1$ or $\mathscr{C}^{1,\omega(\cdot)}$ property of an essentially directionally smooth function f whose subdifferential set-valued mapping admits a continuous or Hölder continuous selection. The $\mathscr{C}^{1,\omega(\cdot)}$-property is also obtained under a natural Hölder-like behaviour of the set-valued mapping ∂f. Similar results are also proved for another class of functions that we call $\partial^{1,\varphi(\cdot)}$-subregular functions.

2. **Existence of minimizers on drops**

Pedro Gajardo (pedro.gajardo@usm.cl) Universidad Tecnica Federico Santa Maria, Chile, *Rafael Correa*, *Lionel Thibault*, *Dariusz Zagrodny*

For a boundedly generated drop $[a, E]$ (property which holds, for instance, whenever E is bounded), where a belongs to a real Banach space X and $E \subset X$ is a nonempty convex set, we show that for every lower semicontinuous function $h : X \longrightarrow R \cup \{+\infty\}$ such that $h(a)$ is lower than the minimum of h in a neighborhood of E, there exists $\bar{x} \in [a, E]$ such that $h(a) \geq h(\bar{x})$ and $\bar{x}$ is a strict minimizer of h on the drop $[\bar{x}, E]$.

3. **Regularity and Lipschitz-like properties of subdifferential : Part II (of parts I and II)**

Abderrahim Jourani (abderrahim.jourani@u-bourgogne.fr) Institut de Mathématiques de Bourgogne, CNRS, France, *Dariusz Zagrodny*

It is known that the subdifferential of a lower semicontinuous convex function f over a Banach space X determines this function up to an additive constant in the sense that another function of the same type g whose subdifferential coincides with that of f at every point is equal to f plus a constant, i.e., $g = f + c$ for some real constant c. Recently, Thibault and Zagrodny introduced a large class of directionally essentially smooth functions for which the subdifferential determination still holds. More generally, for extended real-valued functions in that class, they provided a detailed analysis of the enlarged inclusion

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where γ is a nonnegative real number and B_X is the closed unit ball of the topological dual space. The aim of the presentation is to show how results concerning such an enlarged inclusion of subdifferentials allow us to establish the $\mathscr{C}^1$ or $\mathscr{C}^{1,\omega(\cdot)}$ property of an essentially directionally smooth function f whose subdifferential set-valued mapping admits a continuous or Hölder continuous selection. The $\mathscr{C}^{1,\omega(\cdot)}$-property is also obtained under a natural Hölder-like behaviour of the set-valued mapping ∂f. Similar results are also proved for another class of functions that we call $\partial^{1,\varphi(\cdot)}$-subregular functions.

■ Thu.A.AB

Thursday, 9:00-10:30, Amphitheater B, Organized Session

Nonlinear optimization and applications III

Cluster: Nonlinear optimization

Session organized by: *Ya-xiang Yuan*

1. **A sequential subspace projection method for extreme Z-eigenvalues of supersymmetric tensors**

Yu-Hong Dai (dyh@lsec.cc.ac.cn) AMSS, Chinese Academy of Sciences, China, *Chunlin Hao*, *Chunfeng Cui*

Z-eigenvalues of tensors, especially extreme ones, are quite interesting and relate to many problems such as automatic control, quantum physics and higher order Markov chain. For supersymmetric tensors, calculating the maximal/minimal Z-eigenvalue is equivalent to solve a global maximization/minimization problem of a homogenous polynomial over the unit sphere. In this paper, we propose a sequential subspace projection method (SSPM) for finding the extreme Z-eigenvalues and their corresponding Z-eigenvectors. The main idea of the SSPM is to form a 2-dimensional subspace at the current point and then solve the original optimization problem in the subspace. The SSPM benefits from the fact that the 2-dimensional subproblem can be solved by a direct method. Global convergence and linear convergence results are established for supersymmetric positive definite tensors. Preliminary numerical results over several testing problems show that the SSPM performs very well. Besides, we find that the strategy of "random phase" can be easily incorporated into the SSPM and can improve the quality of the solution significantly.

2. **Improvement on the Shamanskii-like Levenberg-Marquardt method**

Jinyan Fan (jyfan@sjtu.edu.cn) Shanghai Jiao Tong University, China

The Shamanskii-like Levenberg-Marquardt method presented for singular nonlinear equations computes not only an exact LM step but also some approximate LM steps at every iteration. The number of approximate LM steps is invarious at every interation. In this talk, we will propose a strategy to compute the approximate LM steps adaptively. Though the number of approximate LM steps may be various at different iterations, the new LM method preserves the superlinear convergence under the local error bound condition which is weaker than nonsingularity. Numerical results show that the new method is very efficient and could save more Jacobian evaluations and total calculations.

3. **An augmented Lagrangian affine scaling method for general nonlinear programming**

Xiao Wang (wangxiao@ucas.ac.cn) University of Chinese Academy of Sciences, China

We present an Augmented Lagrangian Affine Scaling (ALAS) method in this paper for solving general nonlinear programming problems. At each iteration, an affine scaling trust region subproblem is constructed. The objective function of the subproblem is a second order approximation of the augmented Lagrangian function associated with equality constraints. Affine scaling techniques are combined to handle the bound constraints. By special strategies of updating Lagrange multipliers and adjusting penalty parameters, this subproblem is designed to reduce the objective function value and the feasibility errors of equality constraints in an adaptive well-balanced way. Global convergence of the ALAS method is established under mild assumptions. Furthermore, we study the boundedness of penalty parameters. Some preliminary numerical results are also reported.

■ Thu.B.11

Thursday, 11:00-12:30, Room 1.1, Organized Session

Modeling and computation in copositive programming

Cluster: Conic and polynomial optimization

Session organized by: *Sam Burer*

1. **A quadratic optimization model for completely positive programming and its application to 0-1 mixed integer linearly constrained quadratic optimization problems**

Naohiko Arima (nao_arima@me.com) Tokyo Institute of Technology, Japan, *Sunyoung Kim*, *Masakazu Kojima*

We propose a class of QOP (quadratic optimization problems) whose exact global optimal values can be obtained by its CPP (completely positive programming relaxation problems). The objective and constraint functions of this QOP model are all represented in terms of quadratic forms, and all constraints are homogeneous equalities except one inhomogeneous equality where the quadratic form is set to be one. It is shown that the QOP model represents fairly general quadratically constrained quadratic optimization problems. First, we provide conditions for the QOP model to have the exactly same global optimal value as its CPP. Next, we consider a linearly constrained QOP in continuous and binary variables as a special case. We reformulate the QOP into a simple QOP with a single equality constraint in nonnegative variables, and derive a CPP and its dual problem CP (copositive programming problem) which all have the same optimal value as the original QOP. We also introduce Lagrangian relaxation problems, with a single positive Lagrangian parameter, of the simplified QOP, and drive its CPP and CP, which have a common optimal value for a fixed positive Lagrangian parameter. We show that the common optimal value of these three Lagrangian relaxation problems monotonically converges to the exact global optimal value of the original QOP as the Lagrangian parameter tends to infinity.

2. **Extension of completely positive cone relaxation to polynomial optimization**

   Sunyoung Kim (skim@ewha.ac.kr) Ewha W. University, South Korea, *Naohiko Arima*, *Masakazu Kojima*

We present the moment cone relaxation for a class of polynomial optimization problems (POPs) to extend the results on the completely positive cone programming relaxation for the quadratic optimization (QOP) model by Arima, Kim and Kojima. The moment cone relaxation is constructed to take advantage of sparsity of the POPs. We establish the equivalence between the optimal value of the POP and that of the moment cone relaxation under conditions similar to the ones assumed in the QOP model. For tractable numerical methods, the doubly nonnegative cone relaxation is derived from the moment cone relaxation. Exploiting sparsity in the doubly nonnegative cone relaxation and its incorporation into Lasserre's semidefinite relaxation are briefly discussed.

3. **Computing a nonnegative decomposition of a matrix**

   Felix Lieder (Felix.lieder@hhu.de) Heinrich Heine Universität Düsseldorf, Germany, *Florian Jarre*

The cone $\mathcal{N}$ of matrices that have a nonnegative decomposition is defined as the set of matrices $X = X_1 + X_2$ with X_1 positive semidefinite and X_2 componentwise nonnegative. The problem of determining whether or not a given matrix $\bar{X}$ lies in $\mathcal{N}$ has gained practical importance by recent publications such as Arima et. al. who show that for a rather general class of nonconvex mixed binary quadratic optimization problems the optimal value can be obtained from an optimization problem over the copositive cone with a single variable. This optimization problem can be relaxed to a problem over $\mathcal{N}$, and the relaxation can be solved by bisection if an efficient code is available for determining whether or not a given matrix $\bar{X}$ lies in $\mathcal{N}$. This problem can be reduced to a semidefinite program with sign-constraints, and thus, standard interior-point solvers are applicable. Here, the special structure of the problem shall be exploited to derive a new algorithm for generating a certificate for the question "$\bar{X} \in \mathcal{N}$?". As a by-product, a new algorithm is presented for solving a variant of the Loavsz-Shrijver relaxation of the max-stable-set problem.

■ Thu.B.12

Thursday, 11:00-12:30, Room 1.2, Organized Session

High performance linear optimization

Cluster: Optimization software: Modeling tools and engines
Session organized by: *Julian Hall*

1. **Parallelizing the revised simplex method: Is it time to give up?**

   Julian Hall (jajhall@ed.ac.uk) University of Edinburgh, UK

This talk reviews the outcomes of recent work on parallelizing the revised simplex method by Hall and co-workers. Despite their best efforts, and other attempts over the past 25 years, very little progress has been made on developing worthwhile parallel implementations of the revised simplex method for general large-scale sparse LP problems. Indeed, current HPC architecture trends and continuing developments in serial simplex techniques have reduced the scope for progress towards this general goal. Reasons for this will be discussed. However, this talk will describe some successes with HPC simplex implementations for particular classes of problems and for large dense LP problems. Also, a by-product of studying the simplex method with a view to exploiting parallelism has been the development of novel serial techniques and a deeper understanding of the phenomenon of hyper-sparsity and its promotion. The former will be discussed and an insight into the latter will be given.

2. **Challenges in linear programming and how SoPlex deals with them**

   Matthias Miltenberger (miltenberger@zib.de) Zuse Institute Berlin, Germany

In this talk we present the latest developments in SoPlex, the LP Solver of the SCIP Optimization Suite. Handling very large and usually extremely sparse linear programs requires to adapt the code to take advantage of this feature. A recent analysis revealed a performance bottleneck that becomes increasingly apparent with growing problem dimensions. We will show the importance of a careful pricing implementation that reduces redundant and unnecessary computations and thereby speeds up the solution process. Furthermore, we like to present our modified presolving approach that can improve the performance of the dual simplex by preserving and creating useful bounds. Finally, we want to discuss our current plans about extending SoPlex towards nonlinear problem formulations.

■ Thu.B.13

Thursday, 11:00-12:30, Room 1.3

Analysis of local convergence

Cluster: Nonlinear optimization
Session chair: *Evgeny I. Uskov*

1. **Local convergence of augmented Lagrangian methods under the sole noncriticality assumption**

   Alexey S. Kurennoy (alex-kurennoy@yandex.ru) Moscow State University, Russia

For equality-constrained variational problems, we establish local convergence and rate of convergence of the augmented Lagrangian method under the sole assumption that the dual starting point is close to a noncritical Lagrange multiplier. Both exact and inexact versions of the method are considered. Depending on how the penalty parameter is controlled, linear or superlinear rate of convergence is established. The result on superlinear convergence is proven under weak smoothness requirements on the problem data. In the context of mathematical programming problems this gives the first local convergence result for the augmented Lagrangian method under assumptions that do not include any constraint qualifications and are weaker than the second-order sufficient optimality condition. We demonstrate, however, that our analysis cannot be extended to the case when inequality constraints are present. At the same time, we present a set of assumptions needed for local superlinear convergence of the multiplier method applied to the problem where inequality constraints are reformulated using slack variables.

2. **Attraction of Newton method to critical Lagrange multipliers**

   Evgeny I. Uskov (ydoom@narod.ru) Moscow State University, Russia, *A. F. Izmailov*

Critical multipliers are special Lagrange multipliers usually forming a thin subset in the set of all multipliers when the latter set is not a singleton. In particular, such multipliers necessarily violate the second-order sufficient optimality conditions. By now, there exists a convincing theoretical and numerical evidence of the following striking phenomena: dual sequences generated by Newton-type methods for optimality systems have a strong tendency to converge to critical multipliers when the latter exist, and moreover, this is precisely the reason for the lack of superlinear convergence rate, which is typical for problems with degenerate constraints. However, the existing theoretical results of this kind are far from giving a complete picture. First, all these results are "negative"by nature: they attempt to give a characterization of what would have happened in the case of convergence to a noncritical multiplier, showing that this scenario is in a sense unlikely. Clearly, this analysis must be complemented by results of a "positive"nature, demonstrating that the set of critical multipliers is indeed an attractor in some sense. Second, the existing results rely on some questionable assumptions, and perhaps the most questionable one is asymptotic stabilization of the primal directions generated by Newtonian subproblems. Obtaining the first result on actual local convergence to a critical multiplier, and avoiding undesirable assumptions, are the main goals of this work.

3. **CANCELLED**

■ Thu.B.14

Thursday, 11:00-12:30, Room 1.4, Organized Session

Advances in algorithms

Cluster: Complementarity and variational inequalities
Session organized by: *Andreas Fischer*

1. **Inexact restoration method for derivative-free optimization with smooth constraints**

   Ana Friedlander (friedlan@ime.unicamp.br) State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, *Luís Felipe Bueno*, *J. M. Martinez*, *F. N. C. Sobral*

We discuss the solution of optimization problems with non-differentiable or very expensive to compute objective function and smooth constraints using an inexact restoration method. Theoretical results and experiments are presented.

2. **A new error bound result for generalized Nash equilibrium problems and its algorithmic application**

   Axel Dreves (axel.dreves@unibw.de) Universität der Bundeswehr München, Germany, *Francisco Facchinei*, *Andreas Fischer*, *Markus Herrich*

This talk is about a new algorithm for the solution of Generalized Nash Equilibrium Problems (GNEPs). The result of the combination of a potential reduction algorithm and a LP-Newton method, is a hybrid method that has robust global convergence properties and a local quadratic convergence rate. The basis for the proof of the local convergence property is a local error bound condition for the KKT system of a GNEP. Since the application of standard error bound results is difficult, due to the peculiar structure of KKT systems arising from GNEPs, a new sufficient condition is provided. This condition does neither imply local uniqueness of the solution nor strict complementarity. The numerical behavior of the new algorithm is promising.

3. **A Levenberg-Marquardt method with approximate projections**

   Roger Behling (rogerbehling@gmail.com) Católica SC, Brazil, *Andreas Fischer*, *Markus Herrich*, *Alfredo Iusem*, *Yinyu Ye*

The projected Levenberg-Marquardt method for the solution of a system of equations with convex constraints is known to converge locally quadratically to a possibly nonisolated solution if a certain error bound condition holds. This condition turns out to be quite strong since it implies that the solution sets of the constrained and of the unconstrained system are locally the same. Under a pair of more reasonable error bound conditions this paper proves R-linear convergence of a Levenberg-Marquardt method with approximate projections. In this way, computationally expensive projections can be avoided. The new method is also applicable if there are nonsmooth constraints having subgradients. Moreover, the projected Levenberg-Marquardt method is a special case of the new method and shares its R-linear convergence.

■ Thu.B.15

Thursday, 11:00-12:30, Room 1.5

Derivative-free optimization: Algorithms and applications II

Cluster: Derivative-free and simulation-based optimization
Session chair: *M. J. D. Powell*

1. **Global optimization based on sparse grid surrogate models for black-box expensive functions**

   Frédéric Delbos (frederic.delbos@ifpen.fr) IFPEN, France, *Eugenio Echague*, *Laurent Dumas*

In this talk we propose a new method in order to solve a general blackbox global optimization problem with bound constraints where function valuations are expensive. Our work was motivated by many problems in the oil industry, coming from several fields like reservoir engineering, molecular modeling, engine calibration and inverse problems in geosciences. In such cases, classical derivative free optimization methods often need too many function evaluations, especially in high-dimension cases. To overcome this difficulty, we propose here a new optimization approach, called GOSGrid (Global Optimization based on Sparse Grid), using sparse grid interpolation as surrogate models.

2. **MOVED TO Mon.B.15**

3. **Optimization by derivative-free multilevel methods**

   Emanuele Frandi (emanuele.frandi@uninsubria.it) Università degli Studi dell'Insubria, Italy, *Alessandra Papini*

The discretization of many continuous models can lead to large-scale optimization problems. As a means to accelerate the process of finding a solution, several multilevel procedures have been investigated, which exploit the solution of smaller problems corresponding to coarser discretization parameters. We consider directional direct-search methods endowed with polling strategies of Jacobi or Gauss-Seidel type along the coordinate directions. While it is well-known that such methods are generally unsuited to solving large-scale problems, we show that they can be dramatically accelerated when embedded in a derivative-free multilevel framework. We discuss some implementation issues, and present experiments on several test problems. We argue that our algorithms obtain competitive performance in practice, and that traditional limitations on the size of the problems tractable by classical direct-search methods can be overcome.

■ Thu.B.16

Thursday, 11:00-12:30, Room 1.6, Organized Session

Distance geometry and applications

Cluster: Global optimization and mixed-integer programming
Session organized by: *Carlile Lavor, Antonio Mucherino*

1. **Discrete approaches to the molecular distance geometry problem**

   Agostinho Agra (aagra@ua.pt) University of Aveiro, Portugal, *Rosa Figueiredo*, *Carlile Clavor*, *António Pereira*, *Nelson Maculan*, *Cristina Requejo*

We consider the Molecular Distance Geometry Problem (MDGP) that arises in nuclear magnetic resonance spectroscopy analysis, which provides a set of inter-atomic distances for certain pairs of atoms of a given protein. Considering this set of distances, the MDGP consists in finding an embedding in R^3 of the molecule atoms. We propose and discuss three different approaches to the MDGP based on a discretization of the solution space. Two of them use integer programming approaches and the third is a constraint programming approach. We compare the three approaches for a set of small size instances. Furthermore we discuss how such approaches can be used to improve branch and prune schemes to solve the MDGP.

2. **Discretizing vertex orders for distance geometry**

   Antonio Mucherino (antonio.mucherino@irisa.fr) IRISA, University of Rennes 1, France

In order to discretize Molecular Distance Geometry Problems (MDGPs), some particular assumptions need to be satisfied, that are mainly related to the order with which the atoms of the molecule are considered. The discretization allows for employing an efficient branch-and-prune algorithm for the solution of MDGPs. This presentation is focused on methods and algorithms for the identification of suitable orders that can allow for the discretization.

■ Thu.B.18

Thursday, 11:00-12:30, Room 1.8, Organized Session

Optimization in finance III

Cluster: Robust optimization and optimization in finance
Session organized by: *Gah-Yi Vahn*

1. **Efficient cardinality/mean-variance portfolios**

   Rui Pedro Brito (rpedro.brito@gmail.com) Department of Mathematics, University of Coimbra, Portugal, *Luis Nunes Vicente*

We suggest a new approach to directly compute sparse portfolios by reformulating the cardinality constrained Markowitz mean-variance optimization model as a biobjective optimization problem, allowing the investor to analyse the efficient tradeoff between mean-variance and cardinality. Recent progress in derivative-free multiobjective optimization allow us to quickly and robustly compute (in-sample) the whole cardinality/mean-variance efficient frontier, for the several data sets obtained from the FTSE 100 index and the Fama/French benchmark collection. Our results show that a significant number of efficient cardinality/mean-variance portfolios can overcome (out-of-sample) the naive strategy, while keeping transaction costs relatively low.

2. **Financial risk minimization-based SVMs and its application to credit rating**

Jun-Ya Gotoh (jgoto@indsys.chuo-u.ac.jp) Chuo University, Japan, *Akiko Takeda*, *Rei Yamamoto*

In financial risk management, classification problems play an important role. In this talk, employing well-known concept of financial risk measures, we develop a generalized criterion for two-class classification. Not only does it include existing criteria, such as the margin maximization and nu-SVC, as special cases, but it also includes distributionally robust SVCs. This extension can also be applied to the other type of machine learning methods such as multi-class classification, regression and outlier detection. Although the new criterion is first formulated as a nonconvex optimization, it results in a convex optimization by employing the nonnegative ℓ_1-regularization. Especially when CVaR (conditional value-at-risk) and MASD (mean-absolute semi-deviation) are employed as risk measures, the optimization problems are rewritten by linear programs. This is advantageous in efficient tuning of parameters involved in the two risk measures. Numerical examples demonstrate how the developed methods work for bond rating. Especially, we see that the employed methods successfully provide sparse solutions, which can be considered as results of variable selection.

3. **Mean-semivariance model for large-scale project selection**

Luis F. Zuluaga (luis.zuluaga@lehigh.edu) Lehigh University, USA

The ubiquitous presence of skewed asset return distributions in the context of practical risk-reward portfolio allocation has resulted in the development of several portfolio allocation models that differentiate between upside and downside deviations from the target portfolio return. One of these models, is the mean-semivariance portfolio allocation model, in which the semivariance of the portfolio returns is used as a measure of risk. Unlike the classical mean-variance model, whose size depends on the number of assets, the size of the mean-semivariance model grows with both the number of assets and samples used to estimate the model parameters. This becomes relevant in terms of solution time when non-liquid assets; for example go/no-go projects, are part of the portfolio. We show how fast solutions for this model can be obtained using a classical Benders decomposition approach.

■ Thu.B.21

Thursday, 11:00-12:30, Room 2.1, Organized Session

Extending the scope of convexity: From finite to infinite dimensional, ordinary to extraordinary, and from convex to nonconvex

Cluster: Convex and nonsmooth optimization

Session organized by: *Tim Hoheisel*

1. **Making flippy floppy**

James V. Burke (jvburke@uw.edu) University of Washington, USA, *Aleksandr Y. Aravkin*, *Michael P. Friedlander*

A general approach to solving hard problems is to solve a sequence of related, but much easier problems. Sequential approximation methods such as Newton's method are exactly of this type. In this talk we discuss such approach to solving certain constrained optimization problems, but where the easier problems are obtained by reversing the roles of the objective and the constraints. That is, we flip-flop the objective and the constraints. This idea was pioneered by Ewout van den Berg and Michael Friedlander in a pair of papers appearing in 2008 and 2011. We review this work and then study the question of just have far these ideas can be taken.

2. **Convex optimization on probability measures**

Christopher Jordan-Squire (cjordan1@uw.edu) University of Washington, USA, *James V. Burke*, *Yeaongcheon Baek*

We consider a class of convex optimization problems over the space of regular Borel measures on a compact subset of n dimensional Euclidean space where the measures are restricted to be probability measures. Applications of this class of problems are discussed including mixing density estimation, maximum entropy, and optimal design. We provide a complete duality theory using perturbational techniques, establish the equivalence of these problems to associated nonconvex finite dimensional problems, and then establish the equivalence between the finite and infinite dimensional optimality conditions.

3. **Epi-convergent smoothing with applications to convex composite functions**

Tim Hoheisel (hoheisel@mathematik.uni-wuerzburg.de) University of Würzburg, USA, *James V. Burke*

Smoothing methods have become part of the standard tool set for the study and solution of nondifferentiable and constrained optimization problems as well as a range of other variational and equilibrium problems. In this talk we synthesize and extend recent results due to Beck and Teboulle on infimal convolution smoothing for convex functions with those of X. Chen on gradient consistency for nonconvex functions. We use epi-convergence techniques to define a notion of epi-smoothing that allows us to tap into the rich variational structure of the subdifferential calculus for nonsmooth, nonconvex, and nonfinite-valued functions. As an illustration of the versatility and range of epi-smoothing techniques, the results are applied to the general constrained optimization for which nonlinear programming is a special case.

■ Thu.B.22

Thursday, 11:00-12:30, Room 2.2, Organized Session

Convex optimization in machine learning

Cluster: Convex and nonsmooth optimization

Session organized by: *Quoc Tran Dinh*

1. **Randomized singular value projection**

Stephen Becker (stephen.beckr@gmail.com) UPMC Paris 6, France, *Volkan Cevher*, *Anastasios Kyrillidis*

Affine rank minimization algorithms typically rely on calculating the gradient of a data error followed by a singular value decomposition at every iteration. Because these two steps are expensive, heuristic approximations are often used to reduce computational burden. To this end, we propose a recovery scheme that merges the two steps with randomized approximations, and as a result, operates on space proportional to the degrees of freedom in the problem. We theoretically establish the estimation guarantees of the algorithm as a function of approximation tolerance. While the theoretical approximation requirements are overly pessimistic, we demonstrate that in practice the algorithm performs well on the quantum tomography recovery problem.

2. **Proximal problems and splitting techniques for learning with composite penalties**

Marco Signoretto (marco.signoretto@esat.kuleuven.be) ESAT-SCD, KU Leuven, Belgium

In recent years sparsity and structured sparsity have emerged as major tools for handling statistical and machine learning problems in high dimensions. It has been shown that in many cases one can formulate heuristics based on non-smooth convex optimization problems. These problems often combine several penalties that each promote a certain desired structure. In this talk we focus on those penalties that are obtained composing a simple convex function with a linear transformation. This setting includes, in particular, group/fused lasso methods, multi-task learning, system identification/realization techniques based on the nuclear norm and learning problems where data can be expressed as tensors. We discuss the solution of proximal problems and present splitting techniques suitable to solve constrained convex optimization problems involving composite penalties.

3. **A random coordinate descent algorithm for optimization problems with composite objective function: Application to SVM problems**

Andrei Patrascu (andrei.patrascu@acse.pub.ro) Automation and Systems Engineering Department, University Politehnica Bucharest, Romania, *Ion Necoara*

We present a random coordinate descent method suited for large scale problems with composite objective function. Moreover, we focus on linearly coupled constrained optimization problems (i.e., the constraint set is coupled through linear equalities). We prove for our method an expected convergence rate of order $O(N^2/k)$, where N is number of blocks and k is the iteration counter. We show that for functions with cheap coordinate derivatives the new method is much faster, either in worst case complexity analysis, or numerical implementation, than schemes based on full gradient information. But our method also offers other important advantages, e.g., due to the randomization, our algorithm is easier to analyze and implement, it leads to more robust output and is adequate for modern computational architectures (e.g. parallel or distributed architectures). Analysis for rate of convergence in probability is also provided. For strongly convex functions we prove that the new method converges linearly. We also provide extensive numerical simulations and compare our algorithm against state-of-the-art methods from the literature on support vector machine problems.

■ Thu.B.23

Thursday, 11:00-12:30, Room 2.3

Convex optimization and related problems

Cluster: Convex and nonsmooth optimization
Session chair: *Salvador Flores*

1. **On solving convex optimization problems with linear ascending constraints**

   Zizhuo Wang (zwang@umn.edu) University of Minnesota, USA

Convex optimization with ascending constraints has wide applications in practice. In this work, we propose two algorithms for solving convex optimization problems with linear ascending constraints. When the objective function is separable, we propose a dual method which terminates in a finite number of iterations. In particular, the worst case complexity of our dual method improves over the best-known result for this problem proposed by Padakandla and Sundaresan [SIAM J. Optimization, 20 (2009), pp. 1185-1204]. We then propose a gradient projection method to solve a more general class of problems. The gradient projection method uses the dual method as a subroutine in each projection step and does not need to evaluate the inverse gradient functions as most dual methods do. Numerical experiments show that both our algorithms work very well in test problems.

2. **A new error correction technique with strong theoretical properties**

   Salvador Flores (sflores@dim.uchile.cl) CMM, Universidad de Chile, Chile, *Luis M. Briceño Arias*

Consider the problem of recovering a vector from corrupted measurements of linear combinations of its components. It is known that when only a relatively small fraction of the measurements is corrupted, and the rest is error-free, the vector can be exactly recovered by l1-norm minimization. We introduce a new, robust, error correction mechanism that covers the case when a fraction of the measurements is corrupted by arbitrary, eventually adversarial, errors and additionally all the measurements carry some noise. We show that, by solving a nonsmooth convex minimization problem, it is possible to recover the least-squares estimate of the vector as if it was contaminated with noise only. Moreover, we show that the fraction of arbitrary errors that the estimator can manage is exactly the same as that the l1-norm minimization can face in the noiseless case. Finally, we present a globally convergent forward-backward algorithm for computing our estimator.

■ Thu.B.24

Thursday, 11:00-12:30, Room 2.4, Organized Session

Bang-bang-type control of PDEs

Cluster: PDE-constrained optimization
Session organized by: *Christian Clason, Eduardo Casas*

1. **Multi-bang control of elliptic systems**

   Christian Clason (christian.clason@uni-graz.at) University of Graz, Austria, *Karl Kunisch*

Multi-bang control refers to optimal control problems for partial differential equations where a distributed control should only take on values from a discrete set of allowed states, which can be promoted by a combination of L^2 and L^0-type control costs. Although the resulting functional is nonconvex and lacks weak lower-semicontinuity, application of Fenchel duality yields a formal primal-dual optimality system that admits a unique solution. This solution is in general only suboptimal, but the optimality gap can be characterized and shown to be zero under appropriate conditions. Furthermore, in certain situations it is possible to derive a generalized multi-bang principle, i.e., prove that the control almost everywhere takes on allowed values except on sets where the corresponding state reaches the target. A regularized semismooth Newton method allows the numerical computation of (sub)optimal controls. Numerical examples illustrate the effectiveness of the proposed approach and the behavior of multi-bang controls.

2. **A minimum effort optimal control problem for the wave equation**

   Axel Kroener (axel.kroener@ricam.oeaw.ac.at) Johann Radon Institute for Computational and Applied Mathematics (RICAM), Austria, *Karl Kunisch*

A minimum effort optimal control problem for the undamped wave equation is considered which involves L^∞-control costs. Since the problem is non-differentiable a regularized problem is introduced. Uniqueness of the solution of the regularized problem is proven and the convergence of the regularized solutions is analyzed. Further, a semi-smooth Newton method is formulated to solve the regularized problems and its superlinear convergence is shown. Thereby special attention has to be paid to the well-posedness of the Newton iteration. Numerical examples confirm the theoretical results.

3. **Regularization and discretization error estimates for control problems with bang-bang solutions**

   Daniel Wachsmuth (daniel.wachsmuth@mathematik.uni-wuerzburg.de) Universität Würzburg, Germany

We investigate control problems subject to partial differential equations, which have bang-bang solutions. We discuss error estimates with respect to the discretization and regularization error. New results on discretization error estimates that are robust with respect to the regularization parameter will be presented.

■ Thu.B.25

Thursday, 11:00-12:30, Room 2.5, Organized Session

Advances in multiobjective optimization

Cluster: Variational analysis, set-valued and vector optimization
Session organized by: *Henri Bonnel*

1. **Optimization over the Pareto set of a multiobjective parabolic control system**

   Henri Bonnel (henri.bonnel@univ-nc.nc) ERIM, University of New Caledonia, France

I will present the problem of optimizing a functional over a Pareto control set associated with a convex multiobjective control problem in Hilbert spaces, namely parabolic system. Some examples will be given. General optimality results will be presented, and a special attention will be paid to the linear-quadratic multiobjective parabolic system.

2. **Numerical methods for multi-objective optimal control**

   C. Yalcin Kaya (yalcin.kaya@unisa.edu.au) University of South Australia, Australia, *Helmut Maurer*

We propose numerical methods for solving nonconvex state- and control-constrained multi-objective optimal control problems. We employ a scalarization technique which reduces the problem to a single-objective optimal control problem. Solutions (obtained via discretization) of a sequence of scalarized problems yield an approximation of the Pareto front. We illustrate our technique on numerically challenging problems involving bang-bang, singular and boundary controls.

3. **Robust multiobjective portfolio optimization**

   Joerg Fliege (J.Fliege@soton.ac.uk) CORMSIS, University of Southampton, UK, *Ralf Werner*

We consider Markowitz portfolio optimization problems under uncertainty in the problem data. For the first time, this uncertainty is treated by a *robust multiobjective formulation* of the Markowitz model. For this novel formulation, we investigate its relationship to the original multiobjective formulation as well as to its scalarizations. Further, we provide a characterization of the location of the *robust efficient frontier* with respect to the corresponding original frontier and show that standard techniques from multiobjective optimization can be employed to characterize this robust efficient frontier.

■ Thu.B.AB

Thursday, 11:00-12:30, Amphitheater B, Organized Session

Advances in nonlinear optimization

Cluster: Nonlinear optimization
Session organized by: *Francesco Rinaldi*

1. **Convergence rates for inexact and accelerated proximal methods**

   Silvia Villa (silvia.villa@iit.it) Laboratory for Computational and Statistical Learning, Massachusetts Institute of Technology, USA, and Istituto Italiano di Tecnologia, Italy, *Saverio Salzo*, *Luca Baldassarre*, *Alessandro Verri*

We propose a convergence analysis of accelerated forward-backward splitting methods for composite function minimization, when the proximity operator is not available in closed form, and can only be computed up to a certain precision. We prove that the $1/k^2$ convergence rate for the function values can be achieved if the admissible errors are of a certain type and satisfy a sufficiently fast decay condition. Furthermore, we give a global complexity analysis, taking into account the cost of computing admissible approximations of the proximal point. An experimental analysis is also presented.

2. **A fresh look at the Frank-Wolfe algorithm, with applications to sparse convex optimization**

Martin Jaggi (m.jaggi@gmail.com) École Polytechnique, Paris, France

Sparse greedy optimization techniques based on the Frank-Wolfe algorithm (also known as conditional gradient) have seen a surge of interest recently, driven by many new promising applications in machine learning, signal processing and other fields. For constrained convex optimization problems, an iteration of the Frank-Wolfe algorithm only requires the solution of a linear subproblem over the same domain, and does not need any projection steps. Here we provide stronger and more general primal-dual convergence results for the Frank-Wolfe algorithm for arbitrary domains, enabled by a simple framework of duality gap certicates for constrained optimization. Our analysis also holds if the linear subproblems are only solved approximately (as well as if the gradients are inexact), and is proven to be worst-case optimal in the sparsity of the obtained solutions. On the application side, this allows us to unify a large variety of existing sparse greedy methods, in particular for optimization over convex hulls of an atomic set, even if those sets can only be approximated, including sparse (or structured sparse) vectors or matrices, low-rank matrices, permutation matrices, or max-norm bounded matrices. We also discuss a new general framework for convex optimization over matrix factorizations, where every Frank-Wolfe iteration will consist of a low-rank update, and consider some applications of this approach.

3. **Edge concave quadratic programs**

James Hungerford (freerad@ufl.edu) University of Florida, USA, *William Hager*

An edge concave quadratic program is a quadratic program in which the objective function is concave along the edges of the polyhedral feasible set (here, we assume the objective function is minimized). Examples include linear programs and the continuous formulations of the vertex and edge separator problems in network optimization. We discuss two remarkable properties of these programs: there always exists an extreme point minimizer and local optimality can be checked in polynomial time. In addition, we present a specialized algorithm for obtaining quick local solutions.

The Session of Poster Presentations will take place Monday, July 29, at the Entrance Hall of the Department of Mathematics, from 18:30 to 20:30. The session will be chaired by Sam Burer.

P1. The Manopt toolbox: Making optimization on manifolds easy

Nicolas Boumal (nicolas.boumal@uclouvain.be) Université Catholique de Louvain, Belgium, *Bamdev Mishra*

Optimization on manifolds is a powerful paradigm to address nonlinear optimization problems. It has been successful in solving matrix problems with low-rank or orthogonality constraints for example. The theory for smooth optimization on manifolds is well-understood, with most standard algorithms (steepest descent, conjugate gradients, trust-regions...) available with convergence guarantees matching the standard theory. We propose a new Matlab toolbox called Manopt. Its purpose is to make optimization on manifolds feel as simple as standard nonlinear optimization. We will motivate the importance of this class of optimization problems in applications and illustrate how the toolbox can be used to address them. http://www.manopt.org

P2. Optimization of the charging process of electric vehicles

Xavier Fernandes (xavierdsf@hotmail.com) Department of Mathematics, University of Coimbra, Portugal, *João Gouveia*, *Joana Rebelo*

We study the problem of establishing the charging schedule of electric vehicles (EV's) at a charging station. We assume only a limited number of EV's can charge simultaneously and that each of them has a set value of energy demanded and a maximum amount of time in which it is available for charging. The only control we assume to be available to the charging station is the ability to (at any given time) turn on or off the power supply to any EV. In this work, we propose two distinct approaches to this problem: a discretized time version, based on a greedy-like algorithm, and a continuous time version, based on linear programming. We compare these two approaches, and numerically study the improvement they yield in the efficiency of the charging procedure. Finally we propose several variants to deal with different issues like minimizing wear to the battery or allowing differentiated classes of users. This work was realized as an integrated part of the MobiOS (Mobility Operating System) project.

P3. Optimal control of passive particle under point vortices

Teresa Daniela Grilo (tgrilo@fc.up.pt) Instituto de Sistemas e Robótica do Porto-FEUP/Centro de Matemática da Universidade do Porto-FCUP, Portugal, *Fernando Lobo Pereira*, *Sílvio Gama*

The objective of this work is to develop a mathematical framework for modeling, control and optimization of dynamic control systems whose state variable is driven by interacting ODE's and PDE's. This framework should provide a sound basis for the design and control of new advanced engineering systems arising in many important classes of applications, some of which encompass gliders and mechanical fishes. The research effort has been focused in applying necessary conditions of optimality for some classes of flows driven dynamic control systems, in particular, using the vortex methods. The control problem of moving a particle between two given points driven by this classes of flows have been solved by using the maximum principle.

P4. Interior point methods for a production planning problem

Toshihiro Kosaki (toshihirokosaki@gmail.com) Stera Link Co., Ltd.

We present a practical linear time method for a (one item) production planning problem (PPP) where time horizon is T. The production planning problem is a linear programming (LP) where demand is given and the purpose is determining production plan that minimizes both production cost and inventory cost subject to satisfying the demand. The proposed algorithm is based on a primal-dual infeasible interior point method (IPM). We show that the argumented equation is reduced to a tridiagonal equation and that, at each iteration, the tridiagonal equation is solved in $O(T)$. In practice the number of iterations is from 10 to dozens of, in other words, $O(1)$. Therefore the proposed algorithm is a practical linear time method. The numerical test shows that computational time is linear in T.

P5. On optimisation of strategies in the internet admarket

Natalia Kudryashova (nk375@cam.ac.uk) Cambridge Centre for Analysis, University of Cambridge, UK

Functioning of the internet market involves interactions of players of multiple kinds, who have distinct and often orthogonal objectives, who constantly learn about behaviour of other players and update their strategies accordingly, as well as their immediate goals. We consider simultaneous continuous optimization of multiple strategies on the example of the market of sponsored links, involving large number of advertisers and users, and few competing search platform and discuss the implication in terms of the market dynamics and regulatory challenges.

P6. Calibrating the model parameters using trust region method

Qing-hua Ma (qh.ma@163.com) College of Applied Arts and Science, Beijing Union University, Beitucheng West Road, Haidian District Beijing, China, *Zuo-liang Xu*, *Li-ping Wang*

In this paper, we consider using trust region method for solving the calibration problem in option pricing. Due to limitations of local convergence of gradient descent methods in literature, we consider a global convergent method in this paper. We investigate the problem of calibrating the parameters using trust region method from given price data. It is an ill-posed problem because of at least one of three well-posed conditions violating. We start with a kind of option pricing problem. We formulate the problem by obtaining the integral equation and provide a theory of identifying the parameter, and then we apply trust region method for retrieval problems. Numerical simulations are given to illustrate the feasibility of our method.

P7. Lower bounds and improved relaxations for tensor recovery

Cun Mu (cm3052@columbia.edu) Industrial Engineering and Operations Research, Columbia University, USA, *Bo Huang*, *John Wright*, *Donald Goldfarb*

Recovering a low-rank tensor from incomplete information is a recurring problem in signal processing and machine learning. The most popular convex relaxation of this problem minimizes the sum of the nuclear norms of the unfoldings of the tensor. We show that this approach can be substantially suboptimal: reliably recovering a K-way tensor of length n and Tucker rank r from Gaussian measurements requires $\Omega(rn^{K-1})$ observations. In contrast, a certain (intractable) nonconvex formulation needs only $O(r^K + nrK)$ observations. We introduce a very simple, new convex relaxation, which partially bridges this gap. Our new formulation succeeds with $O(r^{\lfloor K/2 \rfloor} n^{\lceil K/2 \rceil})$ observations. While these results pertain to Gaussian measurements, simulations strongly suggest that the new norm also outperforms the sum of nuclear norms for tensor completion from a random subset of entries. Our lower bounds for the sum-of-nuclear-norm model follow from a new result on simultaneously structured models, which may be of independent interest for matrix and vector recovery problems.

P8. Morphology and batch time optimization of a crystallization process using real time particle shape measurements

David Ochsenbein (ochsenbein@control.ee.ethz.ch) Automatic Control Laboratory, ETH Zürich, Switzerland

Size and shape of organic crystals define important product and downstream processing properties such as filterability and powder flow behavior. Control of these attributes is therefore of vital interest in many industrial fields that employ crystallization. Shape characteristics and batch time of the seeded batch cooling crystallization of an organic compound (β-L-glutamic acid) are optimized offline using a multidimensional population balance model (a hyperbolic partial differential equation) and previously determined growth rate kinetics. The seed mass and a piecewise-linear temperature profile are set as input variables for the constrained nonlinear, nonconvex optimization problem. The resulting optimal trajectory can be cast in different ways, determining the specific control scheme. Two state of the art techniques are known as 'temperature' and 'concentration control'. In the former, the temperature over time profile is used directly whereas in the latter, the optimal path in the phase diagram is followed. Neither method makes use of particle shape information. In this work, different strategies for the calculation of the set temperature are tested and compared to a novel feedback setup which uses online measurements of the multidimensional particle size distribution. The goal of this work is to study the performance of the various controller schemes with respect to uncertainty in the initially supplied parameters, the seed mass and the measurement process itself.

P9. Optimal control and numerical approaches in a problem of management of hydroelectric resources

Ana Filipa Ribeiro (afr@fe.up.pt) University of Porto, FEUP, Portugal, *V. A. Bushenkov*, *M. M. A. Ferreira*, *G. V. Smirnov*

This work focuses on the study of a system of hydroelectric power stations for which the energy production must be optimized. In the systems considered it is possible to reverse the turbines and pump water up from a downstream reservoir to an upstream one. A simplified model for these systems is analysed in the context of optimal control theory with the fluxes of water to turbine or pump on each power station as control variables and the maximization of the profit of energy sale being the objective function. The presence of state constraints and the nonconvexity of the cost function contribute to an increase of complexity of the problem. We obtain a global solution to this problem using a free software of Jieqiu Chen and Samuel Burer (for details, see article "Globally solving nonconvex quadratic programming problems via completely positive programming"). Two different approaches are adopted. In the first, after constructing a discretization of the problem, it is applied the Chen-Burer software (CB). In a second approach a numerical method of constructing projections of convex polyhedral sets (Bushenkov's software) is used to reduce the dimension of the problem. After that the CB is applied and we restore all the variables with help of Simplex method. Results and execution time of the two procedures are compared. Some theoretical analysis of the problem involving the Maximum Principle of Pontryagin is also undertaken.

P10. Positive semidefinite rank of polytopes

Richard Z. Robinson (rzr@math.washington.edu) University of Washington, USA, *João Gouveia*, *Rekha Thomas*

We define the positive semidefinite (psd) rank of a polytope P to be the size of the smallest cone of psd matrices that admits a lift of P. This can be thought of as a measure on how well semidefinite programming may be used to optimize over P. We will present an overview of the subject and several recent results.

P11. Linear-quadratic control problems with L1-cost

Christopher Schneider (Christopher.Schneider@uni-jena.de) Friedrich Schiller University of Jena, Germany, *Walter Alt*

We analyze a class of linear-quadratic optimal control problems with additional L1-control cost depending on a parameter. These are optimization problems with nonsmooth cost functional. To deal with the nonsmooth problem we use an augmentation approach in which the number of control variables is doubled. It is shown that if the optimal control of the augmented problem is bang-bang, the solutions are continuous functions of the parameter. We also show that the optimal controls for two different parameters coincide except on a small set. Since the minimum principles give the same results for both the original problem and the augmented one we use the Euler discretization to solve the augmented problem. Then we can refer to known results for error bounds of the approximation.

P12. Energy optimization of railways by voltage control on substations

Toshihiro Wada (Wada.Toshihiro@bx.MitsubishiElectric.co.jp) Mitsubishi Electric Corporation, Japan, *Kenji Ueda*, *Arvind Raghunathan*, *Satoru Takahashi*

We propose a method for minimizing energy consumption in a direct-current-electrified railway by controlling voltage of substations, with consideration for regenerative brakes. We model substations as one-way voltage sources, accelerating trains as power sinks, regenerating trains as power sources and feeders as resistors mathematically. Regenerative brakes are designed to inhibit regeneration depending on voltage, to prevent overvoltage. Voltage of substations should be kept higher to reduce loss in feeders, whereas it obstructs energy transfers among trains beyond substations because of the voltage limitation of regenerative brakes. Hence there exists an optimal voltage of each substation which achieves minimum energy consumption. The optimization problem includes conditional constraints derived from substations and regenerative brakes. We relax those conditional constraints to complementarity constraints, and the resulting problem forms a Mathematical Program with Equilibrium Constraints (MPEC). We apply a recently developed approach [1] to the problem, and illustrate that our method saves energy with the medium-scale numerical example (which includes 20 trains and 10 substations.) The maximum computation time is 500 milliseconds with a commonly-used computer, which is acceptable for real time control. [1] A.U. Raghunathan, L.T. Biegler, An interior point method for mathematical programs with complementarity constraints (MPCCs), SIAM J. Optim., 15(3), 720/750 (2005)

P13. Fused binary compressive sensing using hard thresholding and (modified) total variation projection

Xiangrong Zeng (zengxrong@gmail.com) Instituto de Telecomunicações, Instituto Superior Técnico, Portugal, *Mário A. T. Figueiredo*

We propose a new approach, fused binary compressive sensing (FBCS), to recover sparse piece-wise smooth signals from 1-bit compressive measurements. We also propose a modified total variation (MTV) having the properties of sparsity-persevering and smoothness-promoting, against the sparsity-breaking tendency of total variation (TV). The proposed approach is a modification of the previous binary iterative hard thresholding (BIHT) algorithm, in which, the objective function consists of a one-sided L_1 (or L_2) function and an indicator function of K-sparsity and an indicator function of TV or MTV constraint. The subgradient of one-sided L_1 (or L_2) function and the projection onto the K-sparsity and TV or MTV constraint set are easy to compute, such that the forward-backward splitting can be applied in FBCS efficiently. Experiments on the recovery of sparse piece-wise smooth signals show that the proposed FBCS is able to take advantage of the piece-wise smoothness of the original signal, achieving more accurate recovery than BIHT. Especially, the FBCS with the MTV and the L_1 objective allows for much more robust and accurate recovery from fewer 1-bit measurements than other algorithms.

Sessions where the person is a speaker are listed in **bold**. Sessions where the person is an organizer are listed in regular text.

A

Acary, Vincent **Mon.C.14**
Adam, Lukas **Tue.A.25**
Adly, Samir Mon.A.25, **Wed.A.14**
Agra, Agostinho **Thu.B.16**
Ahipasaoglu, Selin Damla **Wed.B.16**
Ahmadi, Amir Ali Mon.A.21, **Thu.A.16**
Ahookhosh, Masoud **Wed.B.13**
Akimoto, Youhei **Wed.A.15**
Albrecht, Sebastian **Mon.B.14**
Ali, M. Montaz **Tue.C.17**
Alizadeh, Farid **Thu.A.21**
Alvarado, Alberth **Tue.C.14**
Amelunxen, Dennis **Wed.D.14**
An, Phan Thanh **Wed.C.17**, Wed.C.17
Anava, Oren **Wed.C.21**
Andersen, Erling D. Wed.D.23
Andersen, Martin S. **Wed.D.23**
Andreani, Roberto **Wed.C.13**
Anitescu, Mihai **Mon.A.17**, Mon.B.17, Tue.A.17
Anjos, Miguel F. **Wed.A.11**
Antil, Harbir **Thu.A.24**
Aravkin, Aleksandr Y. **Thu.A.12**, Thu.A.12
Arias, Luis M. Briceño **Tue.C.25**
Arima, Naohiko **Thu.B.11**
Arnold, Dirk **Wed.A.15**
Arrondo, Aránzazu G. **Wed.B.17**
Assellaou, Mohamed **Mon.B.23**
Auger, Anne Wed.A.15
Aybat, Necdet Serhat Wed.C.22, **Thu.A.22**
Azmi, Behzad **Mon.A.13**

B

Baes, Michel **Wed.B.16**
Bai, Yanqin Wed.D.21
Bandeira, Afonso S. **Tue.C.15**, Tue.C.15
Barton, Paul I. Tue.A.16, **Wed.P.AA**
Bayen, Térence Mon.B.25, **Wed.B.24**
Beck, Amir **Mon.B.22**, **Tue.S.AA**
Becker, Stephen **Thu.B.22**
Behling, Roger **Thu.B.14**
Belenky, Alexander S. **Mon.B.23**
Benson, Hande Y. **Wed.C.23**, Wed.C.23
Berchesan, Livia-Mihaela **Wed.A.25**
Betz, Thomas **Wed.C.24**
Bhattacharyya, Chiranjib **Wed.A.18**
Biegler, Lorenz T. **Mon.C.17**
Birge, John **Wed.D.18**
Birgin, Ernesto G. Tue.C.AB, Wed.C.13, **Thu.A.13**, Thu.A.13
Bomze, Immanuel **Wed.C.16**, Wed.C.16
Bonnel, Henri **Thu.B.25**, Thu.B.25
Bottou, Leon **Wed.D.22**
Bott, Stefanie **Mon.A.24**
Boumal, Nicolas **Poster**
Brás, Carmo P. **Wed.C.14**
Brezhneva, Olga **Tue.A.13**
Brito, Rui Pedro **Thu.B.18**
Buchheim, Christoph Mon.C.16, **Tue.C.16**
Bueno, Luís Felipe **Tue.C.AB**
Burachik, Regina **Mon.S.AB**, **Mon.C.25**
Burai, Pál **Tue.A.13**
Burer, Sam **Mon.S.AA**, Thu.B.11
Burgdorf, Sabine **Wed.D.11**
Burke, James V. **Thu.B.21**

C

Cafieri, Sonia **Wed.A.16**
Carlini, Elisabetta **Wed.D.25**
Carlisle, Michael **Mon.A.18**
Carrasco, Miguel **Wed.C.25**
Cartis, Coralia Wed.A.AB, Wed.B.AB, Wed.D.13,**Thu.S.AB**
Casado, Leocadio G. **Wed.C.17**
Casas, Eduardo Wed.A.24, Thu.B.24
Castaño, Fernando García **Wed.A.25**
Castro, Jordi **Wed.A.17**, Wed.A.17
Cervinka, Michal **Tue.A.25**
Chachuat, Benoit **Tue.A.16**
Chandrasekaran, Venkat **Tue.B.AA**
Chen, Bilian **Wed.D.21**
Chen, Ruobing **Mon.A.15**
Chen, Xiaojun **Wed.A.AB**
Choi, Sou-Cheng (Terrya) **Mon.C.14**
Chua, Chek Beng **Wed.B.11**
Cibulka, Radek **Mon.A.25**
Clason, Christian Wed.A.24, **Thu.B.24**, Thu.B.24
Cojocaru, Monica Gabriela **Wed.B.14**
Crespi, Giovanni Paolo **Wed.B.14**
Csizmadia, Zsolt **Wed.B.23**
Curtis, Frank E. **Mon.C.AB**
Custódio, Ana Luísa **Wed.B.15**

D

Dahl, Joachim **Wed.D.23**, Wed.D.23
Dai, Yu-Hong **Thu.A.AB**
Dalkiran, Evrim **Thu.A.16**, Thu.A.16
Daniele, Patrizia **Wed.A.14**, Wed.A.14, Wed.B.14
de Castro, Yohan **Wed.D.12**
De Lara, Michel **Thu.S.AA**

De los Reyes, Juan Carlos **Wed.B.24**, Wed.C.24, Wed.D.24
Delbos, Frédéric **Thu.B.15**
Dempe, Stephan **Mon.B.21**, Mon.B.21
DeMiguel, Victor **Tue.S.AB**
Diedam, Holger **Tue.A.16**
Dinh, Quoc Tran **Tue.A.22**, Thu.B.22
Diniz-Ehrhardt, Maria A. **Tue.A.15**
Diouane, Youssef **Wed.B.15**
Doan, Xuan Vinh **Wed.B.18**, Wed.B.18
Dobre, Cristian **Thu.A.11**
Domínguez-Bravo, Carmen-Ana **Wed.D.17**
Dong, Hongbo **Wed.C.16**
Dorsch, Dominik **Tue.C.21**
Dreves, Axel **Thu.B.14**
Drori, Yoel **Mon.C.22**
Drusvyatskiy, Dmitriy **Wed.A.21**, Wed.A.21
Dupuis, Xavier **Mon.B.25**

E

Eckstein, Jonathan **Tue.C.13**, Tue.C.13
Eichfelder, Gabriele **Tue.C.11**
Erway, Jennifer B. **Tue.A.AB**
Escudero, Laureano F. **Wed.A.16**, Wed.A.16

F

Facchinei, Francisco **Tue.C.14**, Thu.A.14
Fan, Jinyan **Thu.A.AB**
Fang, Sheng **Wed.A.13**
Farshbaf-Shaker, M. Hassan **Wed.C.24**
Fawzi, Hamza **Mon.C.11**
Fercoq, Olivier **Tue.C.22**, Tue.C.22
Fernandes, Luís Merca **Thu.A.16**
Fernandes, Xavier **Poster**
Fernandez-Granda, Carlos **Wed.D.12**
Ferreira, Orizon P. **Wed.B.25**
Ferris, Michael C. **Mon.P.AA**, **Thu.A.23**
Figueiredo, Mário A. T. **Summer School**
Fischer, Andreas **Thu.A.14**, Thu.B.14
Fliege, Joerg **Thu.B.25**
Flores, Salvador **Thu.B.23**
Forsgren, Anders **Wed.D.13**
Fountoulakis, Kimon **Tue.A.17**
Fourer, Robert **Thu.A.23**, Thu.A.23
Fowkes, Jaroslav M. **Wed.B.AB**
Frandi, Emanuele **Thu.B.15**
Frasch, Janick **Mon.A.17**
Freund, Robert M. **Wed.C.21**, Wed.C.21
Friedlander, Ana **Thu.B.14**
Friedlander, Michael P. **Wed.C.22**
Fukuda, Ellen H. **Tue.C.13**

G

Gajardo, Pedro **Thu.A.25**
Garatti, Simone **Tue.C.18**
Garber, Dan **Wed.D.22**
Garmanjani, Rohollah **Wed.B.13**
Giang, Dinh T. **Wed.C.17**
Gijben, Luuk **Tue.C.11**
Gill, Philip E. Mon.A.AB, **Mon.B.AB**, Mon.B.AB, Mon.C.AB, Tue.A.AB
Gillis, Nicolas **Wed.C.11**
Giuffrè, Sofia **Wed.B.14**
Glineur, François Wed.D.14, **Thu.A.21**
Göllner, Thea **Thu.A.17**
Gondzio, Jacek **Mon.B.AB**
Gonzaga, Clovis **Wed.B.13**
González-Brevis, Pablo **Wed.C.23**
Gotoh, Jun-Ya **Thu.B.18**
Gould, Nick **Mon.A.AB**, Mon.A.AB, Mon.B.AB, Mon.C.AB, Tue.A.AB
Gouveia, João Mon.A.11, Mon.B.11, **Tue.A.11**, Wed.C.11
Gower, Robert **Wed.B.23**
Graber, Jameson **Wed.B.24**
Gray, Genetha **Mon.B.15**
Grigas, Paul **Wed.C.21**
Grilo, Teresa Daniela **Poster**
Grothey, Andreas **Mon.B.17**
Guerrero, Vanesa **Wed.D.16**
Gurol, Selime **Tue.A.17**
Guzman, Cristobal **Wed.B.12**

H

Hadjiliadis, Olympia Mon.A.18
Haeser, Gabriel **Wed.C.13**
Hager, William **Tue.A.AB**
Hall, Julian **Thu.B.12**, Thu.B.12
Hansen, Nikolaus **Wed.A.15**
Hantoute, Abderrahim **Mon.C.25**
Harchaoui, Zaid **Wed.B.21**
Hare, Warren **Wed.D.15**, Wed.D.15
Hatz, Kathrin Mon.B.14, Mon.C.14, **Tue.A.14**, Tue.A.14
Haugland, Dag **Tue.C.17**
Hecht, Claudia **Wed.D.24**
Hendrix, Eligius M. T. **Wed.B.17**
Hermosilla, Cristopher **Tue.C.23**
Hernandez-del-Valle, Gerardo **Mon.A.18**
Herrera, Juan F. R. **Wed.A.17**
Hesse, Robert **Wed.A.21**
Hildebrand, Roland **Wed.B.21**, Wed.B.21
Hintermüller, Michael **Wed.S.AA**, **Thu.A.24**
Hoheisel, Tim **Thu.B.21**, Thu.B.21
Homann, Carolin **Mon.C.24**

Hoppe, Ronald Thu.A.24
Houska, Boris **Tue.B.AA**
Hübner, Ruth **Mon.C.16**
Hungerford, James **Thu.B.AB**

I

Ito, Masaru **Mon.C.22**

J

Jaggi, Martin **Thu.B.AB**
Jakovetic, Dusan **Tue.A.22**
Jargalsaikhan, Bolor **Tue.A.11**
Júdice, Pedro **Wed.D.18**, Wed.D.18
Jerez, Juan L. **Mon.C.17**
Jofré, Alejandro Mon.C.25, **Tue.C.25**, Tue.C.25
Jordan-Squire, Christopher **Thu.B.21**
Jourani, Abderrahim **Thu.A.25**

K

Kalise, Dante **Wed.D.25**
Kasimbeyli, Refail **Tue.A.13**
Kassay, Gabor **Wed.A.25**
Kaya, C. Yalcin **Thu.B.25**
Kilinc-Karzan, Fatma **Wed.A.22**
Kim, Sunyoung **Thu.B.11**
Kirches, Christian **Mon.B.14**
Kirst, Peter **Tue.C.16**
Kleinert, Jan **Thu.A.17**
Klep, Igor **Wed.D.11**
Kolehmainen, Ville **Tue.A.24**
Koller, Daniela **Mon.B.24**
Kosaki, Toshihiro **Poster**
Kouri, Drew **Mon.A.24**, Mon.A.24
Kovacec, Alexander **Tue.A.11**
Krejic, Natasa **Thu.A.13**
Kroener, Axel **Thu.B.24**
Kudryashova, Natalia **Poster**
Kuhn, Daniel **Tue.C.18**, Tue.C.18
Kungurtsev, Vyacheslav **Mon.C.13**
Kurennoy, Alexey S. **Thu.B.13**
Kvasov, Dmitri **Mon.B.15**

L

Lacoste-Julien, Simon **Wed.B.12**, Wed.D.22
Lan, Guanghui (George) **Wed.A.22**, Wed.A.22
Larson, Jeffrey **Mon.A.15**, Mon.A.15
Laurain, Antoine Mon.C.24, **Tue.A.24**, Tue.A.24
Lavor, Carlile Thu.B.16
Le Digabel, Sébastien Mon.C.15, **Wed.D.15**
Leclere, Vincent **Mon.B.17**
Lee, Soomin **Tue.A.22**
Lejeune, Miguel **Mon.C.18**, Mon.C.18
Leyffer, Sven Mon.A.24, Mon.B.14, **Mon.C.13**, Mon.C.14, Tue.A.14
Li, QingNa **Thu.A.22**
Li, Zhening **Wed.D.21**, Wed.D.21
Lieder, Felix **Thu.B.11**
Lim, Lek-Heng Mon.C.11, Tue.A.11, Tue.C.11
Liu, Xin **Mon.B.12**
Liu, Ya-Feng **Wed.D.AB**
Liuzzi, Giampaolo **Wed.C.15**, Wed.C.15
Lizon, Claire **Mon.C.16**
López, Julio **Wed.C.25**
Lorenz, Dirk **Tue.A.12**, Tue.A.12, Wed.D.12
Lotz, Martin **Wed.A.AB**
Lu, Shu **Mon.A.14**, Mon.A.14
Lu, Zhaosong Wed.A.22
Lucet, Yves **Mon.C.15**
Luss, Ronny **Wed.C.22**

M

Ma, Qing-hua **Poster**
Ma, Shiqian **Wed.B.22**, Thu.A.22
Maggioni, Francesca **Tue.A.18**
Manapova, Aygul **Mon.B.24**
Mansour, Hassan **Thu.A.12**
Marcia, Roummel F. **Wed.C.AB**
Marechal, Matthieu **Wed.C.14**
Maringer, Dietmar **Wed.D.16**
Martin-Campo, F. Javier **Wed.A.16**
Martin-Utrera, Alberto **Thu.A.18**
Martínez, José Mario Tue.A.15, **Thu.A.13**
Martins, Joaquim R. R. A. **Wed.B.23**
Mei, Xiaoling **Thu.A.18**
Meinlschmidt, Hannes **Tue.C.23**
Messine, Frédéric **Tue.C.17**, Tue.C.17
Mészáros, Alpár Richárd **Wed.D.25**
Meyer, Christian **Summer School**, **Wed.A.24**, Wed.C.24, Wed.D.24
Meza, Juan C. **Mon.B.15**
Miltenberger, Matthias **Thu.B.12**
Misener, Ruth **Mon.A.16**
Mitchell, Tim **Mon.C.AB**
Mitra, Gautam **Wed.D.18**
Mitsos, Alexander Mon.A.16, **Tue.A.21**
Möller, Michael **Tue.A.12**
Monniaux, David **Mon.A.21**
Monteiro, Renato D. C. **Wed.B.22**, Wed.B.22
Morgan, Jacqueline **Mon.C.14**
Morini, Benedetta **Wed.B.AB**
Mu, Cun **Poster**
Mucherino, Antonio **Thu.B.16**, Thu.B.16
Munson, Todd S. **Tue.C.14**

Muramatsu, Masakazu **Wed.A.11**, Wed.A.11
Myklebust, Tor **Mon.A.11**

N

Nagy, Adrienn **Mon.B.13**
Nannicini, Giacomo Wed.B.16
Necoara, Ion **Mon.C.21**, Tue.A.22
Nedich, Angelia **Tue.A.14**
Neitzel, Ira **Wed.A.24**
Nesterov, Yurii **Mon.C.21**, **Tue.P.AA**
Nocedal, Jorge **Mon.A.AB**
Nogales, Javier Thu.A.18
Noll, Dominikus **Tue.C.21**
Noyan, Nilay **Tue.A.18**, Tue.A.18
Nutini, Julie **Wed.C.15**

O

Ochsenbein, David **Poster**
Odland, Tove **Wed.A.13**
Oliveira, Paulo Roberto **Wed.B.25**
Olsson, Per-Magnus **Thu.A.15**
Omheni, Riadh **Mon.C.13**
Orban, Dominique **Tue.A.AB**
Ortigosa, Pilar M. **Wed.B.17**, Wed.B.17
Ortiz, Camilo Wed.B.22
Outrata, Jiri Tue.A.25

P

Pang, C. H. Jeffrey **Wed.A.21**
Pang, Jong-Shi **Mon.A.14**, Tue.C.14
Parpas, Panos **Wed.D.16**, Wed.D.16
Parrilo, Pablo **Tue.C.11**
Pataki, Gabor **Mon.B.11**
Patrascu, Andrei **Thu.B.22**
Pearson, John **Tue.C.24**
Pedroso, Lucas Garcia **Tue.A.15**
Perkkiö, Ari-Pekka **Tue.C.25**
Petra, Noemi **Mon.C.24**, Mon.C.24, Tue.A.24
Pfaff, Sebastian **Tue.C.23**
Pfeiffer, Laurent **Mon.B.25**
Philipp, Anne **Wed.D.17**
Picarelli, Athena **Mon.B.25**
Piccialli, Veronica **Thu.A.14**
Pieper, Konstantin **Wed.D.12**
Pierucci, Federico **Tue.C.22**
Pinar, Mustafa C. **Wed.C.18**
Plaumann, Daniel **Mon.B.11**
Pokutta, Sebastian **Wed.C.11**
Pólik, Imre **Tue.C.12**, Tue.C.12
Potschka, Andreas **Tue.C.24**, Tue.C.24
Povh, Janez **Wed.D.11**, Wed.D.11
Powell, M. J. D. **Mon.C.15**
Prudente, Leandro F. **Wed.C.13**

Q

Qiang, Feng **Thu.A.23**

R

Raghunathan, Arvind U. **Mon.B.17**
Ralph, Daniel **Mon.A.14**
Ramirez, Héctor **Wed.C.25**, Wed.C.25
Ravikumar, Pradeep **Mon.B.22**
Razaviyayn, Meisam **Tue.B.AA**
Ribeiro, Ana Filipa **Poster**
Riccardi, Rossana **Wed.A.14**
Richtarik, Peter **Mon.A.22**, Wed.D.14
Riener, Cordian **Mon.C.11**, Mon.C.11, Tue.A.11, Tue.C.11
Rinaldi, Francesco **Wed.C.15**, Thu.B.AB
Robinson, Daniel P. **Mon.A.AB**, Mon.B.AB, Mon.C.AB, Tue.A.AB
Robinson, Richard Z. **Poster**
Rocha, Ana Maria A. C. **Wed.A.17**
Rodosthenous, Neofytos **Mon.A.18**
Royer, Clément W. **Thu.A.15**
Ruiz, Natalia **Mon.C.22**
Rupprecht, Christoph **Wed.D.24**

S

Sabach, Shoham **Wed.A.12**
Sachs, Ekkehard **Mon.B.24**
Sadoghi, Amirhossein **Wed.C.18**
Sager, Sebastian **Mon.C.17**
Salzo, Saverio **Wed.B.25**
Sampaio, Phillipe R. **Wed.B.15**
Sanogo, Satafa **Thu.A.17**
Santos, Sandra A. **Tue.C.AB**
Santos, Telma J. **Wed.B.21**
Sartenaer, Annick **Wed.A.13**
Saunderson, James **Mon.A.11**
Schäfer, Carsten **Mon.C.24**
Scheinberg, Katya **Tue.C.15**
Schiela, Anton **Mon.A.24**
Schmidt, Mark Wed.B.12, **Wed.D.22**
Schmutzer, Andreas **Mon.C.16**
Schneider, Christopher **Poster**
Schöpfer, Frank **Tue.A.12**
Schultz, Ruediger **Tue.A.18**
Schwartz, Alexandra **Mon.B.21**
Scott, Joseph K. **Tue.A.16**
Shefi, Ron **Wed.A.12**
Sheng, Zhenli **Wed.D.AB**
Shikhman, Vladimir **Mon.A.16**, Tue.A.21, Tue.C.21
Sichau, Adrian **Wed.C.14**
Signoretto, Marco **Thu.B.22**
Silva, Francisco J. **Mon.A.25**, Wed.B.24, Wed.D.25
Silva, Paulo J. S. **Tue.C.13**, Tue.C.13

Simons, Stephen **Mon.C.25**
Sinoquet, Delphine **Thu.A.15**
Solntsev, Stefan **Wed.D.13**
Stadler, Georg **Tue.A.24**
Stein, Oliver **Tue.A.21**
Stoll, Martin Tue.C.24, **Thu.A.24**
Sun, Defeng **Mon.A.12**
Sun, Yuekai **Wed.B.12**
Sun, Zhao **Mon.B.11**
Surowiec, Thomas **Tue.C.21**

T

Takac, Martin Mon.B.22, **Mon.C.21**, Mon.C.21
Tanaka, Akihiro **Wed.A.11**
Tanaka, Mirai **Wed.B.11**
Tanner, Jared **Wed.A.AB**
Tappenden, Rachael **Wed.D.14**
Teboulle, Marc **Wed.A.12**, Wed.A.12
Terlaky, Tamás **Tue.C.12**
Tews, Benjamin **Wed.C.24**
Theis, Dirk Oliver **Wed.C.11**
Thomas, Rekha Mon.A.11, Mon.B.11, **Mon.C.11**, Wed.C.11
Toh, Kim-Chuan **Mon.A.12**, Mon.A.12
Toint, Philippe **Wed.B.AB**
Towhidi, Mehdi **Wed.C.23**
Trang, Le Hong **Mon.B.13**
Traversi, Emiliano **Wed.B.16**
Tröltzsch, Anke Wed.B.15, **Wed.D.15**
Truetsch, Uwe **Thu.A.11**
Tsuchiya, Takashi **Wed.D.14**

U

Uhler, Caroline **Mon.A.21**
Ulbrich, Michael **Summer School**
Ulbrich, Stefan **Tue.A.14**
Uschmajew, Andre **Wed.D.21**
Uskov, Evgeny I. **Thu.B.13**

V

Vahn, Gah-Yi **Thu.A.18**, Thu.B.18
Vallentin, Frank **Mon.A.11**
Vallerio, Mattia **Mon.A.17**
van den Berg, Ewout **Wed.C.22**
Van Parys, Bart Paul Gerard **Tue.C.18**
Vandenberghe, Lieven **Wed.D.23**
Varvitsiotis, Antonios **Mon.A.21**
Vaz, A. Ismael F. **Mon.A.13**
Vera, Jorge R. **Wed.C.18**
Vera, Juan C. **Thu.A.11**, Thu.A.11
Vicente, Luis Nunes **Tue.C.15**
Villa, Silvia **Thu.B.AB**
von Heusinger, Anna **Wed.D.17**

W

Wachsmuth, Daniel **Thu.B.24**
Wada, Toshihiro **Poster**
Waechter, Andreas **Mon.C.AB**
Wang, Hao **Thu.A.12**
Wang, Xiao **Thu.A.AB**
Wang, Yanfei **Wed.D.AB**
Wang, Zizhuo **Thu.B.23**
Wen, Zaiwen **Mon.B.12**, Mon.B.12
Wild, Stefan M. **Mon.C.15**
Wittmann-Hohlbein, Martina **Mon.A.16**
Wollner, Winnifried **Wed.A.24**
Wong, Elizabeth **Mon.B.AB**
Word, Daniel P. **Tue.A.17**
Wright, John **Wed.A.18**
Wright, Margaret H. Mon.B.15
Wright, Stephen J. **Summer School**, **Mon.A.22**, Mon.A.22

X

Xia, Yu **Wed.B.11**, Thu.A.21
Xu, Huan Wed.A.18, **Wed.B.18**

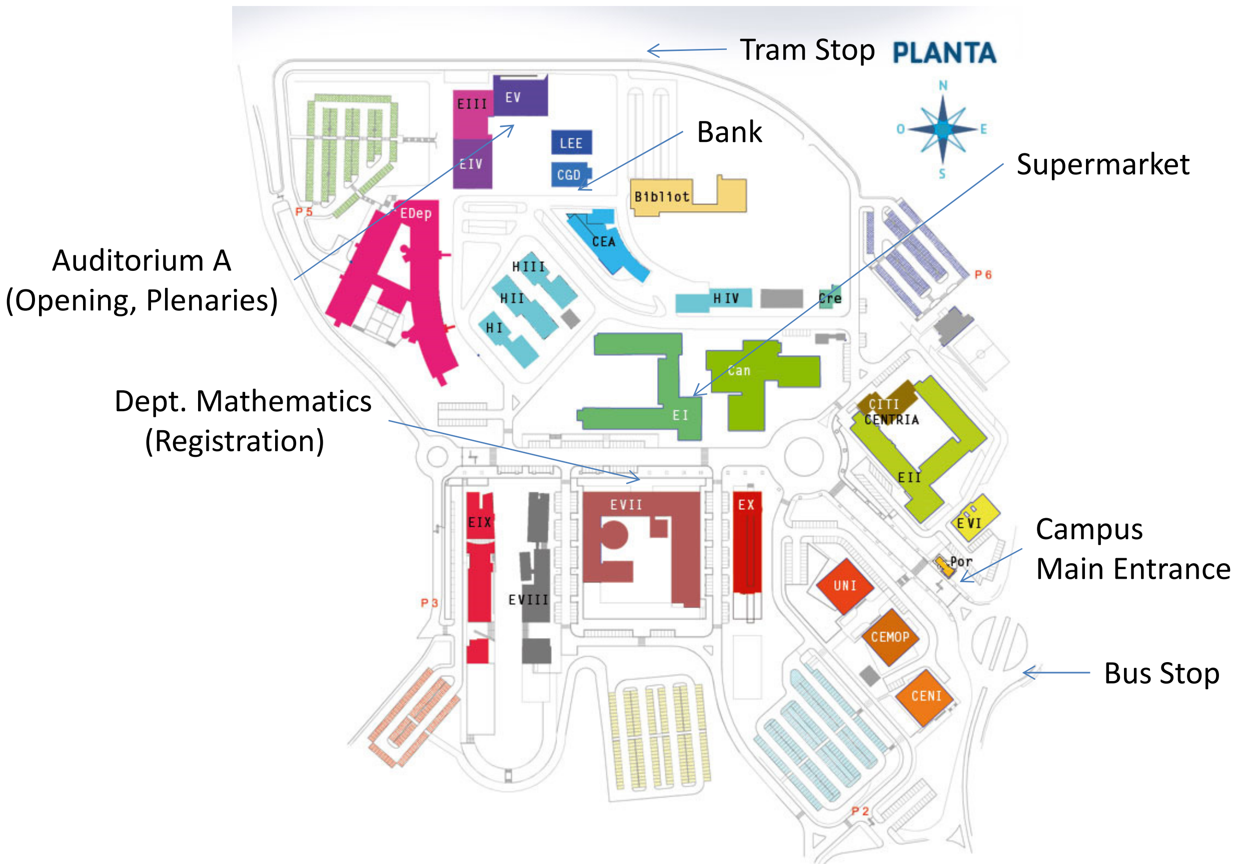
Y

Yan, Yiming **Wed.D.13**
Yang, Chao **Mon.B.12**
Yanikoglu, Ihsan **Wed.B.18**
Ye, Yinyu **Thu.P.AA**
Yildirim, E. Alper **Wed.C.16**
Yin, Wotao **Thu.A.22**
Yoshise, Akiko Wed.B.11
Yousept, Irwin **Wed.D.24**
Yu, Jia Yuan **Wed.A.18**
Yuan, Xiaoming **Mon.A.12**
Yuan, Ya-xiang **Wed.S.AB**, Wed.C.AB, Wed.D.AB, Thu.A.AB
Yun, Sangwoon **Tue.C.22**

Z

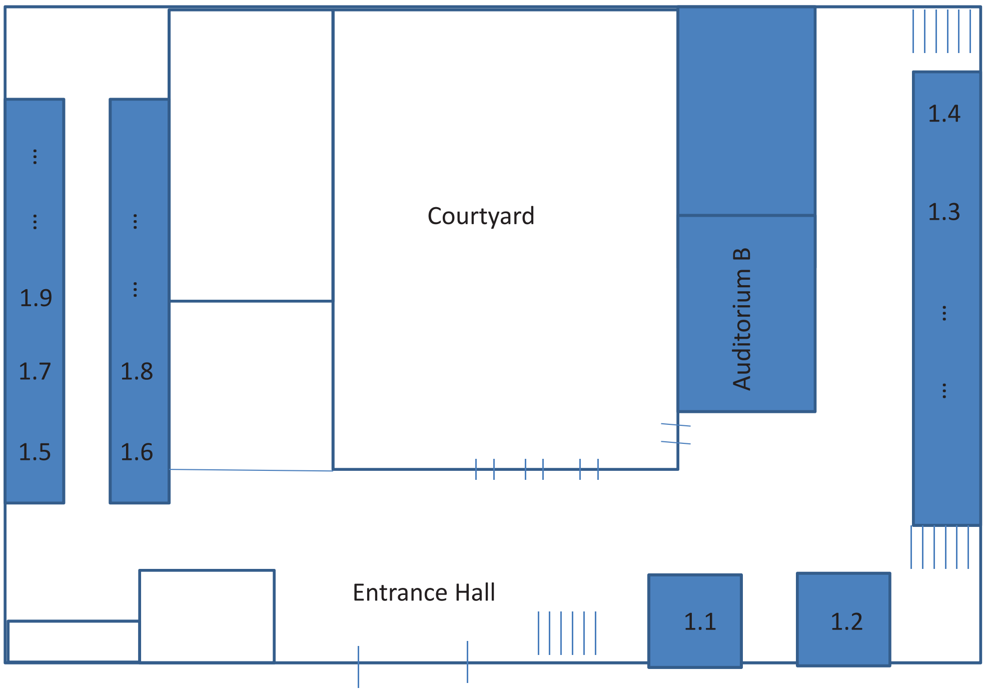
Zagrodny, Dariusz **Thu.A.25**, Thu.A.25
Zalas, Rafał **Thu.A.14**
Zavala, Victor M. Mon.A.17, Mon.C.17, **Mon.C.18**
Zemkoho, Alain B. **Mon.B.21**, Mon.B.21
Zeng, Xiangrong **Poster**
Zhang, Hongchao **Wed.C.AB**
Zhang, Zaikun **Mon.A.15**
Zikrin, Spartak **Wed.C.AB**
Zuluaga, Luis F. **Thu.B.18**

A map of the campus is given below.



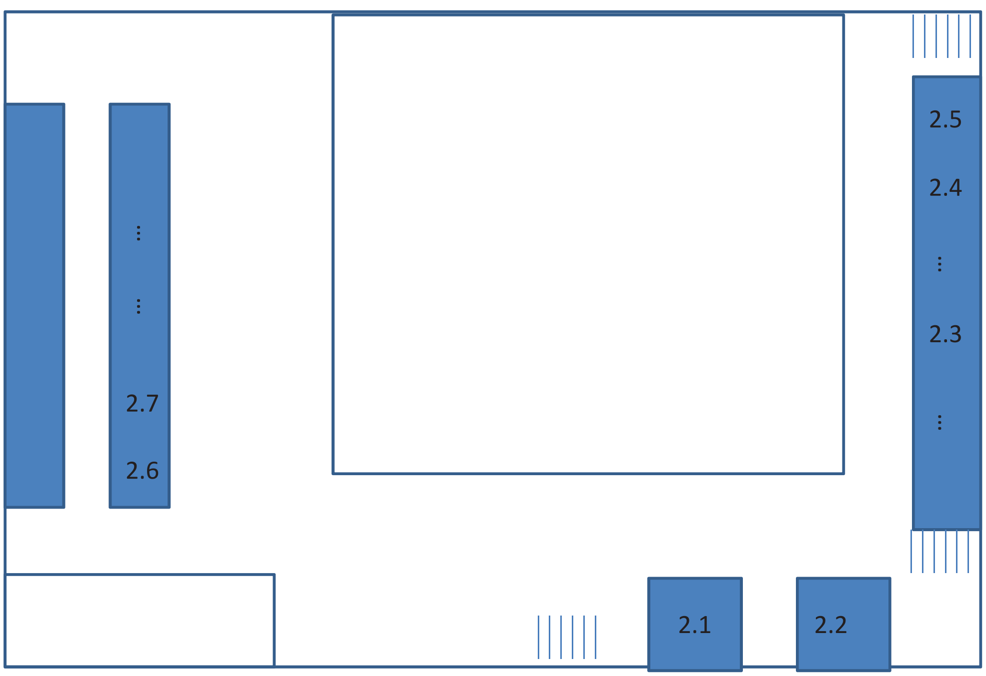
Below are the plans of the floors of the Department of Mathematics where the Summer School and most of the Conference will take place.

Floor 1



Room 1.9 is the First Aid Room (a professional nurse will always be present).

Floor 2



Rooms 2.6 and 2.7 are the Computer Rooms (for computer terminals with internet access).

The campus is served by a tram line that connects “Universidade” (the campus stop) to

- “Pragal” (the stop for trains to Lisbon),
- “Almada” (the stop for Lisboa Almada Hotel), and
- “Cacilhas” (the stop for ferries to Lisbon).

See the following map.

ICCOPT 2013 Program Overview

	Summer School		Conference				
	Saturday July 27	Sunday July 28	Monday July 29	Tuesday July 30	Wednesday July 31	Thursday August 1	
08:45 09:00			Opening				08:45 09:00
09:00 09:50	School and Conference Registration	School and Conference Registration	Plenary Michael C. Ferris	Plenary Yurii Nesterov	Plenary Paul I. Barton	Parallel Sessions Thu.A	09:00 10:30
09:50 10:00	Opening Remarks 1	Opening Remarks 2					
10:00 10:30	PDE-Constrained Optimization (30 min. break included)	Sparse Optimization and Applications to Information Processing (30 min. break included)	Coffee Break	Coffee Break	Coffee Break		
10:30 11:15			Semi-plenaries Regina Burachik Sam Burer	Semi-plenaries Amir Beck Victor DeMiguel	Semi-plenaries Michael Hintermüller Ya-xiang Yuan	Coffee Break	10:30 11:00
						Parallel Sessions Thu.B	11:00 12:30
11:30 13:00			Parallel Sessions Mon.A	Parallel Sessions Tue.A	Parallel Sessions Wed.A	Lunch	12:30 14:00
13:00 14:30	Lunch	Lunch	Lunch	Lunch	Lunch	Semi-plenaries Coralia Cartis Michel De Lara	14:00 14:45
14:30 17:30	PDE-Constrained Optimization (30 min. break included)	Sparse Optimization and Applications to Information Processing (30 min. break included)	Parallel Sessions Mon.B	Best Paper Prize Session	Parallel Sessions Wed.B	Plenary Yinyu Ye	15:00 16:00
		Conference Registration	Coffee Break	Coffee Break	Coffee Break	Closing	16:00 16:15
			Parallel Sessions Mon.C	Parallel Sessions Tue.C	Parallel Sessions Wed.C	Conference Tour	16:30 18:00
17:30 18:00							
18:00 18:30				Conference Banquet (18:15-22:45)	Parallel Sessions Wed.D		18:00 19:30
18:30 19:00		MOS Welcome Reception (18:30-20:30)	Poster Presentations and Reception				
19:00 20:30	Summer School Dinner (19:00-22:00)				Student Social		20:00 22:00