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

Program and Abstracts

ICCOPT 2016 Tokyo Organizing Committee

Contents

Dear Participants,

On behalf of the organizing committee and the program committee, it is our pleasure to welcome you to ICCOPT 2016 Tokyo, the Fifth International Conference on Continuous Optimization of the Mathematical Optimization Society. ICCOPT 2016 is co-sponsored by the Operations Research Society of Japan.

ICCOPT 2016 includes a Summer School and a Conference. The Summer School (August 6-7) is being held at the National Olympics Memorial Youth Center (NYC) and it is directed at PhD students and young researchers. The topics are First-order, Splitting and Related Methods for Big Data Optimization and Links between Continuous and Discrete Optimization by 4 lecturers. The Conference (August 8-11) is being held on the campus of the National Graduate Institute for Policy Studies (GRIPS). The conference includes 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 about 550 talks grouped in 15 clusters. We would like to express our gratitude to all of the cluster co-chairs and session organizers. The program also has a session of poster presentations and a session for the Best Paper Prize finalists. The conference could not have happened without the dedicated work of many other people. We are grateful to all the members of the program committee, the organizing committee, and the best paper prize committee. We also thank to the sponsor companies.

Finally, we hope that you will also enjoy our Social Program: the Welcome Reception, the Conference Banquet, the Student Social, and other events.

We wish you a pleasant and productive meeting.

Yinyu Ye
Chair of the program committee

Shinji Mizuno
Chair of the organizing committee

Greetings from the Chair of MOS,

As the chair of the Mathematical Optimization Society I wish to extend a warm welcome to all of the participants of the ICCOPT meeting in Tokyo. This is the fifth ICCOPT meeting; a flagship meeting on continuous optimization of the society.

The meeting starts with a summer school for PhD-students and young researchers and is succeeded by the ICCOPT conference. The program is impressive and includes four plenary and eight semi-plenary talks, and more than 540 invited and contributed presentations. I am impressed by the scope of the meeting covering, among others, linear, non-linear, stochastic, robust, conic, and polynomial optimization. Many important application areas are included as well. I am sure that this meeting will highlight new and exciting developments in our field!

Next to a very exciting scientific program, I want to recommend to everybody to explore the city and surroundings of Tokyo, a city where ancient history and ultramodern inventions meet.

The society wants to thank the organizers of the meeting, and all the students and volunteers who must have been busy for the past three years with preparing and arranging everything that is required to make such a large meeting a rewarding scientific event! Enjoy!

Karen Aardal

Karen Aardal

The Operations Research Society of Japan

Dear Participants,

It is a great pleasure to host the 5th International Conference on Continuous Optimization (ICCOPT) 2016 at the National Graduate Institute for Policy Studies (GRIPS) in Tokyo, Japan from August 8 to 11, 2016. On behalf of the members of the Board of Trustees at GRIPS and also as the President of the Operations Research Society of Japan (ORSJ), I would like to express our great appreciation and sincere thanks for giving GRIPS the opportunity to be the venue for this year's conference. I firmly believe that with more than 500 participants from all over the world, ICCOPT 2016 will be a great success.

Continuous optimization is one of the major academic disciplines within the area of optimization, which itself has been a major research topic in the operations research field. Optimization theory and its applications have allowed a great many researchers and practitioners to challenge solving various types of both theoretical and practical problems, and subsequently, they have contributed on a large scale to both the private and public sector, including industry, business, military, public service and society as well. We can confidently say that continuous optimization occupies a large and conspicuous share in the area of optimization.

We believe that ICCOPT 2016 will surely contribute to further advancing the academic level within the field by providing opportunities for researchers and practitioners to positively and actively communicate and engage in stimulating discussions at the conference.

To all the participants, including both researchers and practitioners, of ICCOPT 2016, please continue to contribute to the field through your efforts in your own discipline after enjoying your participation at the conference and your short stay in Tokyo.

Tatsuo Oyama
President, The Operations Research Society of Japan
Member, Board of Trustees, Professor Emeritus
National Graduate Institute for Policy Studies

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National Graduate Institute for Policy Studies
Gateway to Global Leadership
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Dear Participants in the ICCOPT 2016:

On behalf of the faculty, staff, and students of the National Graduate Institute for Policy Studies (GRIPS), I am pleased to welcome you to the ICCOPT 2016.

Founded in 1997 as a stand-alone graduate institute, GRIPS has been providing interdisciplinary education for future leaders in the public sector and conducting research on contemporary policy issues to generate innovative solutions to challenging policy problems. Today, GRIPS is an international premier school of public policy comprised of world-class academics and distinguished practitioners with expertise in public-sector policy formulation and management. The vast majority of our students are mid-career public officials with strong leadership skills and managerial potential. Of the 400 students currently enrolled, approximately 70 percent are recruited from outside Japan. Our alumni network is a vibrant community of over 4,000 graduates actively shaping policy in more than 100 countries.

The world is faced with new, complex problems, such as terrorism, global migration, environmental pollution, energy shortages, and financial crises. Addressing these problems requires a new type of leader, one who embraces change, who is capable of using the latest knowledge and research tools to meet new challenges, and who can harness innovative collaborations to forge a path to a new age. As a school that aims at training a diverse pool of talented public officials to become such leaders, we are very proud to host the ICCOPT 2016, and we hope that the unique insights stemming from the conference will enhance the teaching and research capabilities not only of scholars working in the field of optimization but also of researchers and professionals working in many other fields.

The ICCOPT 2016 is taking place in Roppongi, the very heart of Tokyo. I am happy to welcome you on our beautiful campus, which was designed by Richard Rogers, a prominent architect known for his work on the Pompidou Centre in Paris. I am confident that you will find our campus a welcoming and enjoyable place and I hope that you will use this opportunity to explore a fascinating mixture of traditional and modern Japan that Roppongi has to offer.

I would like to thank the members of the local organizing committee for their dedicated efforts in organizing the conference and I sincerely wish all of you every success. I hope that you will view this conference not only as a forum for sharing ideas about research and practice in the field of optimization but also as an opportunity to establish and strengthen ties with colleagues from many institutions and countries.

Mikitaka Masuyama
Professor and Dean

GRIPS
政策研究大学院大学
National Graduate Institute for Policy Studies

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Applications in Energy, Science and Engineering
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Asgeir Tomasgard (Norwegian University of Science and Technology, Norway)
Victor Zavala (University of Wisconsin-Madison, USA)

Applications in Finance and Economics
Woo Chang Kim (Korea Advanced Institute of Science and Technology, Korea)
Shushang Zhu (Sun Yat-Sen University, China)

Complementarity and Variational Inequalities
Uday V Shanbhag (Pennsylvania State University, USA)
Jie Sun (Curtin University, Australia)

Conic and Polynomial Optimization
Etienne de Klerk (Tilburg University, Netherlands)
Jean B Lasserre (LAAS-CNRS, France)

Convex and Nonsmooth Optimization
Jalal Fadili (Ecole Nationale Supérieure d'Ingénieurs de Caen, France)
Kim Chuan Toh (National University of Singapore, Singapore)

Derivative-free and Simulation-based Optimization
Francesco Rinaldi (University of Padova, Italy)
Zaikun Zhang (Hong Kong Polytechnic University, Hong Kong)

Global Optimization
Chris Floudas (Texas A&M University, USA)
Nikolaos Sahinidis (Carnegie Mellon University, USA)

Linear Optimization
Antoine Deza (McMaster University, Canada)
Tamás Terlaky (Lehigh University, USA)

Multi-Objective and Vector Optimization
Vladimir Shikhman (Université catholique de Louvain, Belgium)
Tamaki Tanaka (Niigata University, Japan)

Nonlinear Optimization
Serge Gratton (Intitut National Polytechnique de Toulouse, France)
Daniel P Robinson (Johns Hopkins University, USA)

Optimization Implementations and Software
Carl Laird (Purdue University, USA)
John Siirola (Sandia National Laboratories, USA)

PDE-constrained Optimization
Kazufumi Ito (North Carolina State University, USA)
Michael Ulbrich (Technische Universität München, Germany)

Robust Optimization
Timothy Chan (University of Toronto, Canada)
Daniel Kuhn (Ecole Polytechnique Fédérale de Lausanne, Switzerland)

Sparse Optimization and Information Processing
Coralia Cartis (University of Oxford, United Kingdom)
Yuesheng Xu (Syracuse University, USA)

Stochastic Optimization
Andrzej Ruszczyński (Rutgers University, USA)
Huifu Xu (University of Southampton, United Kingdom)

GENERAL INFORMATION

VENUE AND ACCESS

ICCOPT 2016 Tokyo consists of a conference and a summer school. The conference is held at National Graduate Institute for Policy Studies (GRIPS) from August 8 (Mon) to 11 (Thu), 2016. Some sessions are held at the National Art Center, Tokyo, a national art museum next door to GRIPS. The summer school is held at the Seminar Hall 417 of the Central Building of National Olympics Memorial Youth Center (NYC) on August 6 (Sat) and 7 (Sun), 2016. Special accommodation is arranged at NYC by the organizing committee for participants' convenience.

National Graduate Institute for Policy Studies (Conference Venue)
GRIPS is the newest national (graduate) university founded in 1997 and is now located in Roppongi, the core center of entertainment, contemporary culture and art of Japan. About a hundred professors and four hundred international/domestic students are engaged in the study and research of policy sciences.

See pages 121 and 125 for access to GRIPS from NARITA/HANEDA airports. A floor map of the venue is located on pages 122–124.
- Homepage: http://www.grips.ac.jp/en/
- Access: http://www.grips.ac.jp/en/about/access/

National Olympics Memorial Youth Center (Summer School Venue)
NYC is located in Yoyogi, neighboring Meiji Shrine and Yoyogi Park. NYC was redeveloped at the site of the Olympic village of 1964 Tokyo Olympic Games as a public facility for study and training equipped with accommodation. From there, GRIPS is within 7 minutes by metro (25 minutes including walk from/to stations).

See pages 125 and 126 for access to NYC from NARITA/HANEDA airports. The location of the Central Building and how to get to GRIPS from NYC are also explained.
- Homepage: http://nyc.niye.go.jp/en/
- Access: http://nyc.niye.go.jp/category/english/access-english/

Further Information
Please check out http://www.iccopt2016.tokyo/travel/index.html for more detailed information about how to get to GRIPS and NYC from NARITA/HANEDA airports. The page also contains useful travel tips in Japan.

REGISTRATION DESK

The registration desk of the Conference is located at the foyer of Soukairou Hall on the first floor (see the map on page 123), and will be opened during:

August 7	15:00–19:00
August 8	8:15–19:00
August 9	8:30–19:00
August 10	8:30–18:30
August 11	8:30–16:00

The registration desk of the Summer School is located in front of the Seminar Hall 417 at the Central Building of NYC. If you complete registration at the Summer School venue, you do not have to do it again at the conference venue. The desk will be opened during:

August 6	9:00–17:00
August 7	9:00–12:00

Instructions For Presentation

Instructions to Speakers and Chairs (Session Structure and Length of Talk)
Each parallel session is 75-minute long, and has three speaker-spots. To allow attendees to do "session jumping," each speaker is asked to finish his/her talk within 25 minutes including questions and discussion time and follow the order of the presentations, as shown in pages 33 to 44, even if the session has only one or two speakers. Even if the first or second speaker does not show up in the session, the session chairs are requested not to slide the following talks to the empty spot.

Instructions to Speakers (Presentation Device)

1. All session rooms will be equipped with a computer projector and a VGA cable. We ask you to bring your own presentation device (laptop/tablet computer) to your session rooms and connect it to the projector with the VGA cable on your own or pre-arrange to share with others in your sessions. Note that we will not prepare the other type connectors, adapters, or pointers. Especially if your laptop is an Apple product or a tablet, you will need appropriate adapters for the external video output.
   Please bring a power adapter. We recommend that you do not attempt to run your presentation off the laptop battery. If your laptop is not compatible with AC power, please bring an electrical adapter so you can connect to Japanese electricity. Note that the type of the electrical plug in Japan is Type A and the voltage is 100V.
2. We also ask you to bring an electronic copy of your presentation with a USB flash drive as a backup.
3. Please check if you can connect your presentation device without trouble in advance before the session starts. If you have a problem, you can ask for help from staff. (They are wearing yellow vest of ICCOPT 2016 Tokyo and are always around the rooms where the sessions are going on.)

Instructions for Poster Presentation
Please put up your poster on a board placed at the Foyer on the 1st floor by 17:30, Monday August 8, before the poster session starts. The location of your board will be indicated at the site. You can put up your poster from 14:30. Poster boards are 90cm wide and 180cm height. Please use tape to hang your poster. Tape will be provided by us.

Other Practical Information

Internet Connection
Free WiFi GRIPS SPOT is available inside the building of GRIPS. eduroam is also available. Public free WiFi is also available at the National Art Center. On the other hand, wireless connection at the Summer School venue is limited. NYC does not have their own wireless connection for public users. We will set up several mobile WiFi routers at the Seminar hall 417 for convenience of lecturers and participants. SSID and password will be announced at the venue.

Restaurants
There are many nice restaurants around GRIPS. The National Art Center also has a cafeteria (B1), a coffee shop (1F), a tea salon (2F), and a restaurant (3F).

Exhibits
Exhibits take place at the Foyer on the 1st floor of GRIPS.

US Army Facilities
A US army heliport and other army facilities are located just on the west side of GRIPS. You are kindly asked to refrain from taking photos.

Checking in to NYC Accommodation (For guests)
Please receive your room key at the following time and place. More detailed information will be e-mailed to all the guests at NYC accommodation about one week before their arrival.

From August 4th to 8th

16:00 – 22:00	Entrance Hall, Central Building 1st Floor
22:00 –	Lodging Building D

Exhibition of Renoir at the National Art Center, Tokyo
A large exhibition of the famous impressionist Pierre-Auguste Renoir is held at the National Art Center during the conference. You are welcome to visit and enjoy great pictures! (but please don't miss talks and sessions :-))

Scientific Program

Summer School

The Summer School lectures will take place at the Seminar Hall of the National Olympics Memorial Youth Center (*NYC*, for short), Yoyogi, on August 6 and 7. (See pages 125–126 for the access map to NYC.) The attendees at the School are required to make registration and payment of fee online or on site and to check in at the Registration Desk, located in front of the Seminar Hall 417 in the Central Building of NYC, and receive a bag containing several conference materials. The ICCOPT badge, which is contained in the bag, must be worn to the School as well as to all sessions and events of the Conference. (The attendees who will attend only the Conference can check in or make on-site registration at the Registration Desk of GRIPS. See "Registration Desk" on page 15.)

Conference

The Conference will be held on August 8 to 11 at the National Graduate Institute for Policy Studies (*GRIPS*, for short). Roppongi. and the National Art Center, Tokyo (*NACT*, for short), located in front of GRIPS. (See pages 121 and 125 for the access map to GRIPS.) The four-day conference consists of four Plenary and eight Semi-plenary Talks, one Best Paper Prize (BPP) session, twelve Parallel Session slots, one Poster Session, as well as a few social events including Conference Banquet (optional) and Welcome Receptions.

- The Opening, all the Plenary Talks, the BPP Session, and the Closing will take place at Soukairou Hall ("1S" for short), which is on the 1st floor of GRIPS. Those plenary events are going to be simulcast live to several nearby rooms, such as Meeting Rooms 1A, 1B, and 1C, and Cafeteria.
- Poster Session will be carried out in the foyer on the 1st floor of GRIPS. Refreshment will be served to all participants during the Poster Session.
- Semi-plenary Talks will take place either at Soukairou Hall or at the Auditorium of NACT ("m3S" for short), located in front of GRIPS. Meeting Rooms 1A, 1B, and 1C on the 1st floor of GRIPS may also be used for multicasting Semi-plenary Talks at Soukairou Hall.
- All the Parallel Sessions, whether organized or contributed talks, will be in GRIPS or in NACT.

See pages 33–44 for the detailed scheduling and pages 122–124 for the layout of the rooms. See page 30 for the detailed information on the Conference Banquet and the Welcome Reception.

Summer School Schedule

Saturday, August 6th

09:00 School and Conference Registration
09:45 Opening Remarks
10:00 Lectures by Prof. Friedlander
(30 min. break included)
13:00 Lunch
14:30 Lectures by Prof. Toh
(30 min. break included, and end at 17:30)
19:00 Summer School Dinner (ends at 21:00)

Sunday, August 7th

09:00 School and Conference Registration
09:45 Opening Remarks
10:00 Lectures by Prof. Deza
(30 min. break included)
13:00 Lunch
14:30 Lectures by Prof. Murota
(30 min. break included, and end at 17:30)
18:30 (Welcome Reception of ICCOPT at GRIPS, Roppongi)

CONFERENCE SCHEDULE

SUNDAY, AUGUST 7th

15:00 Conference Registration (closes at **19:00**)
18:30 Welcome Reception (ends at **20:30**)

MONDAY, AUGUST 8th

09:00 Opening (1S + nearby rooms)
09:15 Plenary Talk by Prof. Zhang (1S + nearby rooms)
10:15 Coffee Break
10:45 Parallel Sessions Mon.A.xx
12:00 Lunch (on your own)
13:30 Parallel Sessions Mon.B.xx
14:45 Coffee Break
15:15 Semi-plenary Talks by Profs. Dür (1S) and Uhler (m3S)
16:00 Break
16:15 BPP Session (1S + nearby rooms)
17:30 Poster Session and Reception (end at **19:30**; Foyer)

TUESDAY, AUGUST 9th

09:00 Plenary Talk by Prof. Bach (1S + nearby rooms)
10:00 Coffee Break
10:30 Parallel Sessions Tue.A.xx
11:45 Lunch (on your own)
13:15 Parallel Sessions Tue.B.xx
14:30 Break
14:45 Parallel Sessions Tue.C.xx
16:00 Coffee Break
16:30 Parallel Sessions Tue.D.xx (end at **17:45**)
19:00 Conference Banquet (ends at **22:00**)

WEDNESDAY, AUGUST 10th

09:00 Plenary Talk by Prof. Jarre (1S + nearby rooms)
10:00 Coffee Break
10:30 Semi-plenary Talks by Profs. Hazan (1S) and Dai (m3S)
11:30 Semi-plenary Talks by Profs. Fujisawa (1S) and Delage (m3S)
12:15 Lunch (on your own)
13:45 Parallel Sessions Wed.A.xx
15:00 Break
15:15 Parallel Sessions Wed.B.xx
16:30 Coffee Break
17:00 Parallel Sessions Wed.C.xx (ends at **18:15**)
18:30 Student Social (ends at **20:30**; Cafeteria)

THURSDAY, AUGUST 11th

09:00 Parallel Sessions Thu.A.xx
10:15 Coffee Break
10:45 Parallel Sessions Thu.B.xx
12:00 Lunch (on your own)
13:30 Parallel Sessions Thu.C.xx
14:45 Coffee Break
15:15 Semi-plenary Talks by Profs. Kelner (1S) and Ward (m3S)
16:00 Break
16:15 Plenary Talk by Prof. Pang (1S + nearby rooms)
17:15 Closing (ends at **17:30**)

See page 31 for the entire structure of the sessions and pages 33–44 for the detailed schedule of parallel sessions.

Summer School Lectures And Lecturers

Michael Friedlander

University of British Columbia, Canada

Level-Set Methods for Convex Optimization

Saturday, August 6, 10:00–13:00, Seminar Hall 417 (NYC)

Certain classes of convex optimization problems have computationally favorable objectives but complicating constraints that render established algorithms ineffectual for large-scale problems; these often arise in machine learning and signal processing applications. Level-set methods are a group of techniques for transforming a constrained problem into a sequence of simpler subproblems that are amenable to standard algorithms. The theoretical and computational benefits of the approach are many. This tutorial lays out the basic theoretical background needed to understand the approach, including duality and its connection to properties of the optimal-value function, and presents the main algorithmic tools needed to solve the subproblems. Various applications and problem formulations are used throughout to highlight key aspects of the level-set approach. [Based on joint work with A. Aravkin, J. Burke, D. Drusvyatskiy, and S. Roy.]

Michael Friedlander is IBM Professor of Computer Science and Professor of Mathematics at the University of British Columbia. He received his PhD in Operations Research from Stanford University in 2002, and his BA in Physics from Cornell University in 1993. From 2002 to 2004 he was the Wilkinson Fellow in Scientific Computing at Argonne National Laboratory. He has held visiting positions at UCLA's Institute for Pure and Applied Mathematics (2010), and at Berkeley's Simons Institute for the Theory of Computing (2013). His research is primarily in developing numerical methods for large-scale optimization, their software implementation, and applying these to problems in signal processing and machine learning.

Kim-Chuan Toh

National University of Singapore, Singapore

Large Scale Convex Composite Optimization: Duality, Algorithms and Implementations

Saturday, August 6, 14:30–17:30, Seminar Hall 417 (NYC)

Convex composite optimization problems arise frequently in a wide variety of domains including machine learning, statistics, signal processing, semidefinite programming, etc. Typically, the problems are large scale and their underlying structures must be fully exploited in the algorithms designed to solve them. In this tutorial, we will survey some basic tools for designing efficient and robust algorithms for large scale convex composite optimization problems. In particular, we will describe augmented Lagrangian based algorithms which can be designed to solve those problems, and discuss how the subproblems can be solved efficiently by a semismooth Newton-CG method. While it is popularly believed that first-order methods are the most appropriate framework for solving those large scale problems, we shall convincingly demonstrate that for difficult problems, incorporating the second-order information wisely into the algorithmic design is necessary for achieving reasonably good accuracy and computational efficiency. (This talk is based on a paper co-authored by Prof. Defeng Sun (National University of Singapore, Singapore).)

Dr Toh is a Professor at the Department of Mathematics, National University of Singapore (NUS). He obtained his BSc degree in Mathematics from NUS in 1990 and the PhD degree in Applied Mathematics from Cornell University in 1996 under the direction of Nick Trefethen. He is currently an Area Editor for Mathematical Programming Computation, and an Associate Editor for the SIAM Journal on Optimization. He also serves as the secretary of the SIAM Activity Group on Optimization. He has been invited to speak at numerous conferences and workshops, including SIAM Annual Meeting in 2010 and ISMP in 2006. His current research focuses on designing efficient algorithms and software for convex programming, particularly large scale optimization problems arising from data science and large scale matrix optimization problems such as linear semidefinite programming (SDP) and convex quadratic semidefinite programming (QSDP).

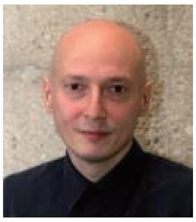
Antoine Deza

McMaster University, Canada

Algorithmic and Geometric Aspects of Combinatorial and Continuous Optimization

Sunday, August 7, 10:00–13:00, Seminar Hall 417 (NYC)

The question of whether a linear optimization problem can be solved in strongly polynomial time - that is, the existence of an algorithm independent from the input data length and polynomial in the number of constrains and the dimension - is listed by Fields medalist Smale as one of the top mathematical problems for the XXI century. The simplex and primal-dual interior point methods are the most computationally successful algorithms for linear optimization. While simplex methods follow an edge path, interior point methods follow the central path. The curvature of a polytope, defined as the largest possible total curvature of the associated central path, can be regarded as a continuous analogue of its diameter. We review results and conjectures dealing with the combinatorial, geometric, and algorithmic aspects of linear optimization. In particular, we highlight links between the edge and central paths, and between the diameter and the curvature. We recall continuous results of Dedieu, Malajovich, and Shub, and discrete results of Holt, Klee, and Walkup, and related conjectures including the Hirsch conjecture that was disproved by Santos. We present results dealing with curvature and diameter of polytopes, such as a counterexample to a continuous analogue of the polynomial Hirsch conjecture by Allamigeon, Benchimol, Gaubert, and Joswig, a strengthening of the Kleinschmidt and Onn upper bound for the diameter of lattice polytopes by Del Pia and Michini, and the strengthening of the Kalai and Kleitman upper bound for the diameter of polytopes by Kitahara, Sukegawa, and Todd.



Since 2004, Antoine Deza has been at McMaster University where he has held a Canada Research Chair in Combinatorial Optimization. Since 2008, he has been the Head of the Advanced Optimization Laboratory. He had previously held a faculty position at the Tokyo Institute of Technology. He has been the Chair of the Fields Institute Industrial Optimization Seminar since 2008, a co-organizer of several conferences including the 2011 Fields Institute Thematic Program on Discrete Geometry and Applications, an Associate Editor for Discrete Applied Mathematics, Optimization Letters, and the Journal of Discrete Algorithms. He was elected a Fields Institute Fellow in the 2014. He has held visiting positions at Ecole Polytechnique Federale de Lausanne, Technion Haifa, Tokyo Institute of Technology, Universite Paris Sud, where he holds a Digiteo Chair in Combinatorics and Optimization, Universite Pierre et Marie Curie, and Ecole Nationale des Ponts et Chaussees, Paris.

Kazuo Murota

Tokyo Metropolitan University, Japan

Convex Analysis Approach to Discrete Optimization

Sunday, August 7, 14:30–17:30, Seminar Hall 417 (NYC)

Discrete convex analysis is a theory that aims at a discrete analogue of convex analysis for nonlinear discrete optimization. We first introduce fundamental classes of discrete convex functions, including submodular functions, integrally convex functions, M-convex functions and L-convex functions. Emphasis is put on the relation between submodularity and convexity/concavity.

Next we explain fundamental properties of discrete convex functions, including:

(i) Operations such as addition, scaling, convolution and transformation by networks,

(ii) Conjugacy relation between L-convexity and M-convexity under Legendre transformation, and

(iii) Duality theorems such as separation theorem and Fenchel-type minimax theorem.

Then we go on to algorithmic aspects of minimization of discrete convex functions, including:

(i) Local optimality criterion for global minimality, which varies with types of discrete convexity,

(ii) Descent algorithms for M-convex and L-convex functions, and

(iii) M-convex intersection algorithm for minimizing the sum of two M-convex functions.

Kazuo Murota is a professor at School of Business Administration, Faculty of Urban Liberal Arts, Tokyo Metropolitan University, where he has been since 2015. He received his Doctor of Engineering from University of Tokyo in 1983 and Doctor of Science from Kyoto University in 2002. Murota's research interests is broad in mathematical engineering, in particular, discrete and continuous optimization (discrete convex analysis), combinatorial matrix theory (mixed matrices), numerical analysis, and economic geography. He is the author of five English books, including "Discrete Convex Analysis" and "Systems Analysis by Graphs and Matroids." He was awarded Inoue Prize for Science in 2004.

Plenary Talks And Speakers

Shuzhong Zhang

University of Minnesota, USA

Variants of the ADMM and Their Convergence Properties

Monday, August 8, 9:15–10:15, Soukairou Hall (1S, GRIPS)

Chair: Tamás Terlaky

The alternating direction method of multipliers (ADMM) proved to be a remarkably stable and effective solution approach to solve many structured convex optimization models. In the past few years, an intensive stream of research effort has been paid to the performance of the ADMM and its many variants designed to accommodate various formulations arising from applications. In this talk, we shall survey several aspects of the afore-mentioned research effort, and present some new results including the convergence of a randomized multi-block ADMM.

Shuzhong Zhang is Professor and Head of Department of Industrial and System Engineering, University of Minnesota. He received a B.Sc. degree in Applied Mathematics from Fudan University in 1984, and a Ph.D degree in Operations Research and Econometrics from the Tinbergen Institute, Erasmus University, in 1991. He had held faculty positions at Department of Econometrics, University of Groningen (1991-1993), and Econometric Institute, Erasmus University (1993-1999), and Department of Systems Engineering & Engineering Management, The Chinese University of Hong Kong (1999-2010). He received the Erasmus University Research Prize in 1999, the CUHK Vice-Chancellor Exemplary Teaching Award in 2001, the SIAM Outstanding Paper Prize in 2003, the IEEE Signal Processing Society Best Paper Award in 2010, and the 2015 SPS Signal Processing Magazine Best Paper Award. Dr. Zhang was an elected Council Member at Large of the MPS (Mathematical Programming Society) (2006-2009), and served as Vice-President of the Operations Research Society of China (ORSC) (2008-2012). He serves on the Editorial Board of several academic journals, including Operations Research, and Management Science.

Francis Bach

INRIA, France

Linearly-convergent Stochastic Gradient Algorithms

Tuesday, August 9, 9:00–10:00, Soukairou Hall (1S, GRIPS)

Chair: Akiko Takeda

Many machine learning and signal processing problems are traditionally cast as convex optimization problems where the objective function is a sum of many simple terms. In this situation, batch algorithms compute gradients of the objective function by summing all individual gradients at every iteration and exhibit a linear convergence rate for strongly-convex problems. Stochastic methods rather select a single function at random at every iteration, classically leading to cheaper iterations but with a convergence rate which decays only as the inverse of the number of iterations. In this talk, I will present the stochastic averaged gradient (SAG) algorithm which is dedicated to minimizing finite sums of smooth functions; it has a linear convergence rate for strongly-convex problems, but with an iteration cost similar to stochastic gradient descent, thus leading to faster convergence for machine learning problems. I will also mention several extensions, in particular to saddle-point problems, showing that this new class of incremental algorithms applies more generally.

Francis Bach is a researcher at Inria, leading since 2011 the Sierra project-team, which is part of the Computer Science Department at Ecole Normale Superieure. He completed his Ph.D. in Computer Science at U.C. Berkeley, working with Professor Michael Jordan, and spent two years in the Mathematical Morphology group at Ecole des Mines de Paris, then he joined the Willow project-team at INRIA/Ecole Normale Superieure from 2007 to 2010. Francis Bach is interested in statistical machine learning, and especially in graphical models, sparse methods, kernel-based learning, convex optimization, vision and signal processing. He obtained in 2009 a Starting Grant from the European Research Council and received in 2012 the INRIA young researcher prize. In 2015, he was program co-chair of the International Conference in Machine Learning (ICML).

Florian Jarre

Heinrich Heine Universität Düsseldorf, Germany

Nonlinear Minimization Techniques without Using Derivatives

Wednesday, August 10, 9:00–10:00, Soukairou Hall (1S, GRIPS)

Chair: Takashi Tsuchiya

It is mostly a matter of laziness — but with important implications: We discuss possible applications of minimization without (explicitly) using derivatives. While automatic differentiation offers an elegant and efficient alternative in many cases, due to its simplicity, the minimization without using derivative information is interesting in several respects: On the one side the applications mentioned above, on the other side a slight change in the use of the tools for minimization. More precisely, we consider the problem of finding a local optimal solution to an optimization problem with a smooth objective function and smooth constraints, but without the availability of derivative informations. There is a wealth of methods tuned to very expensive and/or noisy function evaluations, and there are methods in Matlab/Octave such as fmincon, fminunc, or minFunc that are tailored to situations where the derivative information is provided, and that use finite differences when derivatives are unavailable.We discuss modifications of the latter approach taking into account the fact that finite differences are numerically expensive compared to standard matrix operations. In particular, we consider a new line search based on least squares spline functions, a new finite difference setup, and a Sl_2QP method for constrained minimization. Some numerical examples conclude the talk.

Florian Jarre is Professor of Mathematics at the Heinrich-Heine-Universität Düsseldorf, Germany, and leads the Optimization Group in Düsseldorf. He received his PhD from the University of Würzburg, Germany in 1989. Dr. Jarre's research is concerned with interior point methods for convex optimization, large scale approaches for solving convex conic programs, and applications of semidefinite and completely positive programming. His recent interest are applications of optimization without using derivatives. He is an Associate Editor of Optimization Methods and Software and Optimization and Engineering.

Jong-Shi Pang

University of Southern California, USA

Difference-of-Convex Optimization for Statistic Learning

Thursday, August 11, 9:00–10:00, Soukairou Hall (1S, GRIPS)

Chair: Jie Sun

We address a fundamental bi-criteria optimization problem for variable selection in statistical learning; the two criteria being a loss function which measures the fitness of the model and a penalty function which controls the complexity of the model. Motivated by the increased interest in non-convex surrogates of the step ℓ_0-function that counts the number of nonzero components of the model variables, we show that many well-known sparsity functions existed in the literature admit a unified difference-of-convex (dc) representation that facilitates systematic analysis and algorithmic development. Such a representation involves non-differentiable functions and thus understanding the associated optimization problems require care. Two classes of sparsity functions are considered: exact versus surrogate. Exact sparsity functions are those whose zeros coincide with the sparsity pattern of the model unknowns; surrogate sparsity functions are those that are substitutes for the ℓ_0-function. We derive several theoretical results on the non-convex Lagrangian formulation of the bi-criteria optimization, relating it with a penalty constrained formulation in terms of their prospective computable stationary solutions, and giving conditions under which a directional stationary solution of the Lagrangean problem is a global minimizer. We present computational algorithms for solving these bi-criteria dc optimization problems and present numerical results using data sets existed in the literature. The results demonstrate the superiority of using a non-convex formulation over a convex approach on a variety of compressed sensing and binary classification problems.

Jong-Shi Pang joined the University of Southern California as the Epstein Family Professor of Industrial and Systems Engineering in August 2013. Prior to this position, he was the Caterpillar Professor and Head of the Department of Industrial and Enterprise Systems Engineering for six years between 2007 and 2013. He held the position of the Margaret A. Darrin Distinguished Professor in Applied Mathematics in the Department of Mathematical Sciences and was a Professor of Decision Sciences and Engineering Systems at Rensselaer Polytechnic Institute from 2003 to 2007. He was a Professor in the Department of Mathematical Sciences at the Johns Hopkins University from 1987 to 2003, an Associate Professor and then Professor in the School of Management from 1982 to 1987 at the University of Texas at Dallas, and an Assistant and then an Associate Professor in the Graduate

School of Industrial Administration at Carnegie-Mellon University from 1977 to 1982. During 1999 and 2001 (full time) and 2002 (part-time), he was a Program Director in the Division of Mathematical Sciences at the National Science Foundation. Professor Pang was a winner of the 2003 George B. Dantzig Prize awarded jointly by the Mathematical Programming Society and the Society for Industrial and Applied Mathematics for his work on finite-dimensional variational inequalities, and a co-winner of the 1994 Frederick W. Lanchester Prize awarded by the Institute for Operations Research and Management Science. Several of his publications have received best paper awards in different engineering fields: signal processing, energy and natural resources, computational management science, and robotics and automation. He is an ISI Highly Cited Researcher in the Mathematics Category between 1980–1999; he has published 3 widely cited monographs and more than 100 scholarly journals in top peer reviewed journals. Dr. Pang is a member in the inaugural 2009 class of Fellows of the Society for Industrial and Applied Mathematics. Professor Pang's general research interest is in the mathematical modeling and analysis of a wide range of complex engineering and economics systems with focus in operations research, (single and multi-agent) optimization, equilibrium programming, and constrained dynamical systems.

Semiplenary Talks And Speakers

Mirjam Dür

Universität Trier, Germany

Copositive Optimization

Monday, August 8, 15:15–16:00, Soukairou Hall (1S, GRIPS)

Chair: Etienne de Klerk

A copositive optimization problem is a problem in matrix variables with a constraint which requires that the matrix be in the copositive cone. This means that its quadratic form takes nonnegative values over the nonnegative orthant. By definition, every positive semidefinite matrix is copositive, and so is every entrywise nonnegative matrix, but the copositive cone is significantly larger than both the semidefinite and the nonnegative matrix cones. Many combinatorial problems like for example the maximum clique problem can be equivalently formulated as a copositive problem. Burer (2009) showed that also any nonconvex quadratic problem with linear constraints and binary variables can be reformulated as such a copositive problem. This is remarkable, since by this approach a nonconvex problem is reformulated equivalently as a convex problem. The complexity of the original problem is entirely shifted into the cone constraint. We review recent progress in this copositive approach, concerning both theoretical results and numerical issues.

Mirjam Dür was born in Vienna, Austria, where she received a M.Sc. degree in Mathematics from the University of Vienna in 1996. She received a PhD in applied mathematics from University of Trier (Germany) in 1999. After that, she worked as an assistant professor at Vienna University of Economics and Business Administration, as a junior professor at TU Darmstadt (Germany), and as a Universitair Docent at the University of Groningen (The Netherlands). Since October 2011, she is a professor of Nonlinear Optimization at the University of Trier, Germany. Prof. Dür is a member of the editorial boards of the journals Mathematical Methods of Operations Research, Journal of Global Optimization, and Optimization Methods and Software, and of the book series Springer Briefs in Optimization. In 2010, she was awarded a VICI-grant by the Dutch Organisation for Scientific Research (NWO), and in 2012 a GIF Research grant by the German-Israeli Foundation for Scientific Research and Development. As of 2016, she is one of the principal investigators in the Research Training Group Algorithmic Optimization at the University of Trier.

Caroline Uhler

Institute of Science and Technology, Austria

Brownian Motion Tree Models: Theory and Applications

Monday, August 8, 15:15–16:00, Auditorium (m3S, NACT)

Chair: Masao Fukushima

Brownian motion tree models are heavily used for phylogenetic analysis based on continuous characters and as network tomography models to analyze the connections in the Internet. These models are a special instance of Gaussian models with linear constraints on the covariance matrix. Maximum likelihood estimation in this model class leads to a non-convex optimization problem that typically has many local maxima. Current methods for parameter estimation are based on heuristics with no guarantees. I will present efficient algorithms and explain how to initiate the algorithms in a data-informed way to obtain provable guarantees for finding the global maximum in this model class.

Caroline Uhler is an assistant professor in EECS and IDSS at MIT. She holds an MSc in Mathematics, a BSc in Biology, and an MEd in High School Mathematics Education from the University of Zurich. She obtained her PhD in Statistics from UC Berkeley in 2011. After short postdoctoral positions at the Institute for Mathematics and its Applications at the University of Minnesota and at ETH Zurich, she joined IST Austria as an assistant professor (2012–2015). Her research focuses on mathematical statistics, in particular on graphical models and the use of optimization, algebraic and geometric methods in statistics, and on applications to biology. She is an elected member of the International Statistical Institute and she received a Sofja Kovalevskaja Award from the Humboldt Foundation and a START Award from the Austrian Science Fund.

Elad Hazan

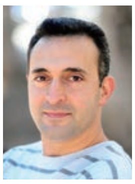
Princeton University, USA

Simulated Annealing with an Efficient Universal Barrier

Wednesday, August 10, 10:30–11:15, Soukairou Hall (1S, GRIPS)

Chair: Robert M Freund

Interior point methods and random walk approaches have been long considered disparate approaches for convex optimization. We show how simulated annealing, one of the most common random walk algorithms, is equivalent, in a certain sense, to the central path interior point algorithm applied to the enhanced entropic universal barrier function. Using this observation we improve the state of the art in polynomial time convex optimization in the membership-oracle model.



Elad Hazan is a professor of computer science at Princeton University. Previously he had been an associate professor of operations research at the Technion. His research focuses on the design and analysis of algorithms for basic problems in machine learning and optimization. Amongst his contributions are the co-development of the AdaGrad algorithm for training learning machines, and the first sublinear-time algorithms for convex optimization. He is the recipient of (twice) the IBM Goldberg best paper award in 2012 for contributions to sublinear time algorithms for machine learning, and in 2008 for decision making under uncertainty, a European

Research Council grant , a Marie Curie fellowship and a Google Research Award (twice). He serves on the steering committee of the Association for Computational Learning and has been program chair for COLT 2015.

Yu-hong Dai

Chinese Academy of Sciences, China

The Steepest Descent and Conjugate Gradient Methods Revisited

Wednesday, August 10, 10:30–11:15,
Auditorium (m3S, NACT)
Chair: Hiroshi Yabe

The steepest descent and conjugate gradient methods are basic first order methods for unconstrained optimization. More efficient variants have been proposed in recent decades by forcing them to approximate Newton's method (or quasi-Newton method). In this talk, I shall review some recent advances on steepest descent method and conjugate gradient method. While significant numerical improvements have been made, the behavior of these more efficient variants are still to be understood and more analysis are obviously required.

Yu-Hong Dai received his bachelor degree in applied mathematics from the Beijing Institute of Technology, China, in 1992. Then he studied nonlinear optimization in the Institute of Computational Mathematics, Chinese Academy of Sciences (CAS), and received his doctor degree in 1997. Now he is Feng Kang distinguished professor of Academy of Mathematics and Systems Science (AMSS) of CAS. Currently, he is also assistant president of AMSS and Vice-Director of Center for Optimization and Applications (COA) of AMSS. His research interests mainly lie in nonlinear optimization and various optimization applications. Specifically, he is quite interested in proposing simple but efficient optimization methods (for example, the Dai-Yuan conjugate gradient method) and in providing theoretical properties for existing elegant optimization methods (for example, the perfect example for the failure of the BFGS method and the R-linear convergence of the Barzilai-Borwein gradient method). He has published many papers in various journals, including Mathematical Programming, SIOPT, SIIS, SIMAX, ITSP, Mathematics of Computation, Numerische Mathematics, IMA Journal on Numerical Analysis and Journal of the OR Society of China. Because of his accomplishments, he received the Fifth ZhongJiaQing Mathematics Award (1998), Second Prize of the National Natural Science of China in 2006 (Rank 2), the Tenth Science and Technology Award for Chinese Youth (2007), Best Paper Award of International Conference on Communication (2011), the China National Funds for Distinguished Young Scientists (2011), Feng Kang Prize of Scientific Computing (2015). Dr. Dai is currently the president of Chinese Mathematical Programming Subsociety of ORSC. Meanwhile, he has held editorial positions for several journals, including International Transactions in Operational Research (ITOR), Asia Pacific Journal of Optimization (APJOR) , Science China: Mathematics （SciChina:Math), Journal of the OR Society of China.

Katsuki Fujisawa

Kyushu University, Japan

High-Performance and Power-efficient Computing for Large-Scale Optimization Problem

Wednesday, August 10, 11:30–12:15,
Soukairou Hall (1S, GRIPS)
Chair: Masakazu Kojima

In this talk, we present our ongoing research project. The objective of this project is to develop advanced computing and optimization infrastructures for extremely large-scale graphs on post peta-scale supercomputers. We explain our challenge to Graph 500 and Green Graph 500 benchmarks that are designed to measure the performance of a computer system for applications that require irregular memory and network access patterns. In 2014 and 2015, our project team was a winner of the 8th, 10th, and 11th Graph 500 and the 3rd to 6th Green Graph500 benchmarks, respectively. We present our parallel implementation for large-scale SDP (SemiDefinite Programming) problem. The semidefinite programming (SDP) problem is a predominant problem in mathematical optimization. The primal-dual interior-point method (PDIPM) is one of the most powerful algorithms for solving SDP problems, and many research groups have employed it for developing software packages. We solved the largest SDP problem (which has over 2.33 million constraints), thereby creating a new world record. Our implementation also achieved 1.774 PFlops in double precision for large-scale Cholesky factorization using 2,720 CPUs and 4,080 GPUs on the TSUBAME 2.5 supercomputer. We have also started another research project for developing the Urban OS (Operating System). The Urban OS gathers big data sets of people and transportation movements by utilizing different sensor technologies and storing them to the cloud storage system. The Urban OS employs the graph analysis system developed by our research project above and provides a feedback to a predicting and controlling center to optimize many social systems and services. we briefly explain our ongoing research project for realizing the Urban OS.

Fujisawa has been a Full Professor at the Institute of Mathematics for Industry (IMI) of Kyushu University and a research director of the JST (Japan Science and Technology Agency) CREST (Core Research for Evolutional Science and Technology) post-Peta High Performance Computing. He received his Ph. D. from the Tokyo Institute of Technology in 1998. The objective of the JST CREST project is to develop an advanced computing and optimization infrastructure for extremely large-scale graphs on post peta-scale super-computers. His project team has challenged the Graph 500 and Green Graph 500 benchmarks, which are designed to measure the performance of a computer system for applications that require irregular memory and network access patterns. In 2014 and 2015, his project team was a winner of the 8th, 10th, and 11th Graph500 and the 3rd to 6th Green Graph500 benchmarks, respectively.

Erick Delage

HEC Montrál, Canada

Preference Robust Optimization for Decision Making under Uncertainty

Wednesday, August 10, 11:30–12:15,
Auditorium (m3S, NACT)
Chair: Melvyn Sim

Decisions often need to be made in situations where parameters of the problem that is addressed are considered uncertain. While there are a number of well-established paradigms that can be used to design an optimization model that accounts for risk aversion in such a context (e.g. using expected utility or convex risk measures), such paradigms can often be impracticable since they require a detailed characterization of the decision maker's perception of risk. Indeed, it is often the case that the available information about the DM's preferences is both incomplete, because preference elicitation is time consuming, and imprecise, because subjective evaluations are prone to a number of well-known cognitive biases. In this talk, we introduce preference robust optimization as a way of accounting for ambiguity about the DM's preferences. In a financial environment, an optimal preference robust investment will have the guarantee of being preferred to the largest risk-free return that could be made available. We show how preference robust optimization models are quasiconvex optimization problems of reasonable dimension when parametric uncertainty is described using scenarios and preference information takes the form of pairwise comparisons of discrete lotteries. Finally, we illustrate numerically our findings with a portfolio allocation problem and discuss possible extensions.

Erick Delage completed his Ph.D. at Stanford University in 2009, is currently associate professor in the Department of Decision Sciences at HEC Montreal, and was recently appointed as chairholder of Canada Research Chair in Decision Making Under Uncertainty. He serves on the editorial board of Management Science, Pacific Journal of Optimization, and Computational Management Science where he recently co-edited a special issue on recent advances in the field of robust optimization. His research interests span the areas of robust optimization, stochastic programming, decision theory, artificial intelligence and applied statistics.

Jonathan Kelner

Massachusetts Institute of Technology, USA

Bridging the Continuous and the Combinatorial: Emerging Tools, Techniques, and Design Principles for Graph Algorithms and Convex Optimization

Thursday, August 11, 15:15–16:00,
Soukairou Hall (1S, GRIPS)
Chair: Satoru Iwata

Flow and cut problems on graphs are among the most fundamental and extensively studied problems in Operations Research and Optimization, playing a foundational role in both the theory and practice of algorithm design. While the classical algorithms for these problems were largely based on combinatorial approaches, the past several years have witnessed the emergence of a powerful collection of new approaches rooted in continuous optimization. These have allowed researchers to provide better provable algorithms for a wide range of graph problems, in some cases breaking algorithmic barriers that had stood for several decades. The key to these improvements has been the development of a set of techniques for systematically linking the combinatorial structure of a graph problem to the numerical and geometric properties of the corresponding convex program, and for exploiting this connection to design iterative methods with improved guarantees. This relationship between graph theory and continuous optimization has proven fruitful in the other direction as well, leading to fast algorithms and new insights for solving a variety of problems in convex optimization, computational linear algebra, and the analysis of random processes. In this talk, I will survey some of the main results, recurring themes, and technical tools that arise in this confluence of fields, and I will illustrate these by sketching how they can be used to find approximately maximum flows on undirected graphs in close to linear time. I will then discuss some recent results and highlight several challenges and open problems that I believe are within reach.

Jonathan Kelner is an Associate Professor of Applied Mathematics in the MIT Department of Mathematics and a member of the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL). His research focuses on the application of techniques from pure mathematics to the solution of fundamental problems in algorithms and complexity theory. He was an undergraduate at Harvard University, and he received his Ph.D. in Computer Science from MIT in 2006. Before joining the MIT faculty, he spent a year as a member of the Institute for Advanced Study. He has received a variety of awards for his work, including an NSF CAREER Award, an Alfred P. Sloan Research Fellowship, the Best Paper Awards at STOC 2011, SIGMETRICS 2011, and SODA 2014, the Harold E. Edgerton Faculty Achievement Award, and the MIT School of Science Teaching Prize.

Rachel Ward

University of Texas at Austin, USA

Clustering Subgaussian Mixtures by Semidefinite Programming

Thursday, August 11, 15:15–16:00,
Auditorium (m3S, NACT)
Chair: Pablo A Parrilo

We introduce a model-free relax-and-round algorithm for k-means clustering based on a semidefinite relaxation of the (NP-hard) k-means optimization problem. The algorithm interprets the SDP output as a denoised version of the original data and then rounds this output to a hard clustering. We provide a generic method for proving performance guarantees for this algorithm, and we analyze the algorithm in the context of subgaussian mixture models. We also study the fundamental limits of estimating Gaussian centers by k-means clustering in order to compare our approximation guarantee to the theoretically optimal k-means clustering solution. This is joint work with Dustin Mixon and Soledad Villar.

Rachel Ward received the B.Sc. degree in mathematics from the University of Texas at Austin in 2005 and the Ph.D. degree in applied and computational mathematics in 2009 from Princeton University. After working as a Post-Doctoral Fellow at the Courant Institute, New York University, she joined the University of Texas at Austin in 2011 as an Assistant Professor of mathematics. She received the Alfred P Sloan Research Fellowship, the Donald D. Harrington Faculty Fellowship, and the NSF CAREER Grant. Her research interests include image processing, statistical machine learning, optimization, compressed sensing, and quantization.

Best Paper Prize Finalists

The ICCOPT 2016 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 (Amir Beck, Nick Gould, Kim-Chuan Toh, Akiko Yoshise, chaired by Andrzej Ruszczyński) invited the following contestants to present their work in a dedicated session of the conference. The session will be chaired by Akiko Yoshise.

Peyman Mohajerin Esfahani
EPFL & ETH Zurich
peyman.mohajerin@epfl.ch

Data-driven Distributionally Robust Optimization Using the Wasserstein Metric: Performance Guarantees and Tractable Reformulations

We consider stochastic programs where the distribution of the uncertain parameters is only observable through a finite training dataset. Using the Wasserstein metric, we construct a ball in the space of (multivariate and non-discrete) probability distributions centered at the uniform distribution on the training samples, and we seek decisions that perform best in view of the worst-case distribution within this Wasserstein ball. The state-of-the-art methods for solving the resulting distributionally robust optimization (DRO) problems rely on global optimization techniques, which quickly become computationally excruciating. In this talk we demonstrate that, under mild assumptions, the DRO problems over Wasserstein balls can in fact be reformulated as finite convex programs—in many interesting cases even as tractable linear programs. Leveraging recent measure concentration results, we also show that their solutions enjoy powerful finite-sample performance guarantees. Our theoretical results are exemplified in mean-risk portfolio optimization as well as uncertainty quantification.
The finalist selected based on the paper: P.M. Esfahani and D. Kuhn, Data-driven Distributionally Robust Optimization Using the Wasserstein Metric: Performance Guarantees and Tractable Reformulations, conditionally accepted for publication in Mathematical Programming.

Mingyi Hong
Iowa State University
mingyi@iastate.edu

Convergence Analysis of Alternating Direction Method of Multipliers for a Family of Nonconvex Problems

The alternating direction method of multipliers (ADMM) is widely used to solve large-scale linearly constrained optimization problems, convex or nonconvex, in many engineering fields. However there is a general lack of theoretical understanding of the algorithm when the objective function is nonconvex. In this work we analyze the convergence of the ADMM for solving certain nonconvex consensus and sharing problems. By using a three-step argument, we show that the classical ADMM converges to the set of stationary solutions, provided that the penalty parameter in the augmented Lagrangian is chosen to be sufficiently large. For the sharing problems, we show that the ADMM is convergent regardless of the number of variable blocks. Our analysis does not impose any assumptions on the iterates generated by the algorithm, and is broadly applicable to many ADMM variants involving proximal update rules and various flexible block selection rules. Finally, we discuss a few generalizations of the three-step analysis to a broader class of algorithms, with applications in signal processing and machine learning.
The finalist selected based on the paper: M. Hong, Z.-Q. Luo, and M. Razaviyayn, Convergence Analysis of Alternating Direction Method of Multipliers for a Family of Nonconvex Problems, accepted for publication in SIAM Journal on Optimization.

Mengdi Wang
Princeton University
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Stochastic Composition Optimization: Algorithms and Sample Complexities

Classical stochastic gradient methods are well suited for minimizing expected-value objective functions. However, they do not apply to the minimization of a composition of two expected-value functions, i.e., the stochastic composition optimization problem which involves an outer stochastic function and an inner stochastic function:$\min_x \mathbb{E}_v \left[f_v(\mathbb{E}_w [g_w(x)]) \right]$. Stochastic composition optimization finds wide application in learning, estimation, risk-averse optimization, dynamic programming, etc. In order to solve this problem, we propose a class of stochastic compositional first-order methods that can be viewed as stochastic versions of quasi-gradient method. The algorithms update the solutions based on queries to a sampling oracle and use auxiliary variables to track the unknown inner quantities. We prove that the algorithms converge almost surely to an optimal solution for convex optimization problems (or a stationary point for nonconvex problems), as long as such a solution exists. The convergence involves the interplay of two martingales with different timescales. We obtain rate of convergence results under various assumptions, and show that the algorithms achieve the

optimal sample-error complexity in several important special cases. These results provide the best-known rate benchmarks for stochastic composition optimization. Indeed, stochastic composition optimization is very common in practice. We demonstrate its application to statistical estimation and reinforcement learning.
The finalist selected based on the paper: M. Wang, E.X. Fang, and H. Liu, Stochastic Compositional Gradient Descent: Algorithms for Minimizing Nonlinear Functions of Expected Values, accepted for publication in Mathematical Programming.

Please join us on Monday, August 8th from 16:15 to 17:30 (Soukairou Hall, 1S) as the finalists present their papers. The winner will be announced right before the plenary talk in the morning of Tuesday, August 9th.

Social Program

Welcome Reception
Sunday, August 7, 18:30–20:30
GRIPS Cafeteria (1st Floor)

The Welcome Reception will take place at the Cafeteria located on the 1st floor of GRIPS. Light meals with beer and soft drinks will be served to all participants.

Poster Session And Reception
Monday, August 8, 17:30–19:30
GRIPS Foyer (1st Floor)

Refreshments will be served to all participants during the Poster Presentations Session, which takes place at the Foyer on the 1st floor of GRIPS.

Conference Banquet
Tuesday, August 9, 19:00–22:00
Sushi Izakaya MACCHAN
8,000 yen per person, not included in the registration fee.

The Conference Banquet will be offered in a cozy Japanese Izakaya (Tavern) style. The Izakaya restaurant is located in the heart of Roppongi, within walking distances from GRIPS or Tokyo Metro/Toei Subway Roppongi stations. Our staff will guide you to the restaurant from GRIPS. Enjoy Sushi, Sashimi and other specialties exclusively chosen for the banquet. A limited number of tickets may be available on site. Ask for availability at the Registration Desk if you have not purchased yours online.

Student Social (students only)
Wednesday, August 10, 18:30–20:30
GRIPS Cafeteria (1st Floor)

The Student Social will take place at the Cafeteria located on the 1st floor of GRIPS. Light meal with alcoholic and soft drinks will be served to all student participants.

Coffee Breaks

Coffee, mineral water and light snacks will be served at the Cafeteria on the 1st floor and the Lounge on the 5th floor during 30-minute breaks between sessions.

HOW TO FIND YOUR SESSION

All the rooms for the Parallel Sessions will be on the first, the fourth, or the fifth floor of GRIPS or on the third floor of the National Art Center, Tokyo (NACT). See pages 122–124 for the floor plan.

The session code includes all the information you need to identify your parallel session, whether organized or contributed (take Tue.D.5H as an example):

Tue The day of the week:
- **Mon** Monday
- **Tue** Tuesday
- **Wed** Wednesday
- **Thu** Thursday

D The time of the day:
- **A** 1st slot: 10:45–12:00 (Mon), 10:30–11:45 (Tue), 13:45–15:00 (Wed), 9:00–10:15 (Thu)
- **B** 2nd slot: 13:30–14:45 (Mon), 13:15–14:30 (Tue), 15:15–16:30 (Wed), 10:45–12:00 (Thu)
- **C** 3rd slot: 14:45–16:00 (Tue), 17:00–18:15 (Wed), 13:30–14:45 (Thu),
- **D** 4th slot: 16:30–17:45 (Tue)

5H The room code:
- **1x** Room x on the 1st floor of GRIPS
- **4x** Room x on the 4th floor of GRIPS
- **5x** Room x on the 5th floor of GRIPS
- **m3x** Room x on the 3rd floor of NACT

where x=S stands for the auditorium of GRIPS or that of NACT (namely, ‘1S’ refers to the Soukairou Hall and ‘m3S’ refers to the auditorium of NACT).

The following table summarizes the structure of the scientific program.

building	room	Monday, August 8th						Tuesday, August 9th				
		9:00-10:15	10:45-12:00	13:30-14:45	15:15-16:00	16:15-17:30	17:30-19:30	9:00-10:00	10:30-11:45	13:15-14:30	14:45-16:00	16:30-17:45
		Opening + Plenary	**Mon.A**	**Mon.B**	Semi-Plenary	Best Paper Prize	Poster	Plenary	**Tue.A**	**Tue.B**	**Tue.C**	**Tue.D**
GRIPS	**1S**	Zhang	NO	NO	Dür	finalists	╲	Bach	NO	NO	NO	NO
GRIPS	**1A**		NO	NO	+	╲	plus @ foyer		NO	NO	NO	NO
GRIPS	**1B**		PDE-O	PDE-O	+	╲			PDE-O	PDE-O	PDE-O	PDE-O
GRIPS	**1C**		DSO	DSO	+	╲			DSO	DSO	DSO	DSO
GRIPS	**4A**		AESE	AESE			╲		AESE	AESE	AESE	AESE
GRIPS	**4B**		PDE-O	AESE			╲		AFE	AFE	CVI	CVI
GRIPS	**5A**	╲	╲	╲			╲		M-OVO	M-OVO	M-OVO	M-OVO
GRIPS	**5C**		M-OVO	╲	╲	╲	╲		╲	╲	╲	╲
GRIPS	**5D**		LO	LO			╲		LO	LO	LO	SOIP
GRIPS	**5E**		RO	RO			╲		RO	RO	RO	RO
GRIPS	**5F**		CNO	CNO			╲		SOIP	╲	╲	
GRIPS	**5G**		╲	╲			╲		OIS	OIS	OIS	LO
GRIPS	**5H**		AFE	NO		╲	╲		M-OVO	RO	AFE	AFE
GRIPS	**5I**		CPO	CPO			╲		CPO	CPO	CPO	CPO
GRIPS	**5J**	╲	╲	╲	╲	╲	╲	╲	CNO	CNO	CNO	CNO
GRIPS	**5K**	╲	╲	CPO			╲	╲	╲	╲	╲	*CS*
GRIPS	**5L**	+	CPO	CPO			╲	+	CNO	CNO	CNO	CPO
Nat'l Art Cntr	**m3S**	╲	SOIP	CNO	Uhler		╲	╲	╲	╲	╲	╲
Nat'l Art Cntr	**m3AB**	╲	╲	M-OVO			╲	╲	╲	╲	╲	╲

building	room	Wednesday, August 10th						Thursday, August 11th				
		9:00-10:00	10:30-11:15	11:30-12:15	13:45-15:00	15:15-16:30	17:00-18:15	9:00-10:15	10:45-12:00	13:30-14:45	15:15-16:00	16:15-17:15
		Plenary	Semi-Plenary	Semi-Plenary	**Wed.A**	**Wed.B**	**Wed.C**	**Thu.A**	**Thu.B**	**Thu.C**	Semi-Plenary	Plenary + Closing
GRIPS	**1S**	Jarre	Hazan	Fujisawa	NO	NO	NO	NO	NO	NO	Kelner	Pang
GRIPS	**1A**		+	+	NO	NO	NO	NO	NO	NO	+	
GRIPS	**1B**		+	+	PDE-O	PDE-O	PDE-O	PDE-O	PDE-O	PDE-O	+	
GRIPS	**1C**		+	+	DSO	DSO	DSO	DSO	DSO	*CS*	+	
GRIPS	**4A**				AESE	AESE	AESE	AESE	AESE	AESE		
GRIPS	**4B**				CVI	CVI	CVI	*CS*	*CS*	AESE		
GRIPS	**5A**	╲	╲	╲	╲	M-OVO	M-OVO	*CS*				
GRIPS	**5C**				╲	╲	M-OVO	M-OVO	M-OVO	M-OVO		
GRIPS	**5D**				LO	LO	CNO	LO	LO	LO		
GRIPS	**5E**				RO	RO	RO	RO	RO	RO		
GRIPS	**5F**	╲	╲	╲	M-OVO	SOIP	SOIP	CNO	SOIP	╲		
GRIPS	**5G**				LO	LO	LO	*CS*	*CS*			
GRIPS	**5H**				AFE	AFE	SO	SO	SO	*CS*		
GRIPS	**5I**				*CS*							
GRIPS	**5J**				CPO	CNO	*CS*	*CS*	*CS*	*CS*		
GRIPS	**5K**	╲	╲	╲	╲	CPO	CPO	CPO		*CS*		
GRIPS	**5L**	+			CPO	CPO	CNO	CPO	CPO			+
Nat'l Art Cntr	**m3S**	╲	Dai	Delage	CNO	CNO	╲	╲	CPO	CNO	Ward	
Nat'l Art Cntr	**m3AB**	╲			GO	GO	╲	╲	CNO	CPO		

╲ : ICCOPT participants are NOT allowed to enter
CS : contributed session
\+ : possible use for simulcasting plenary/semiplenary talk

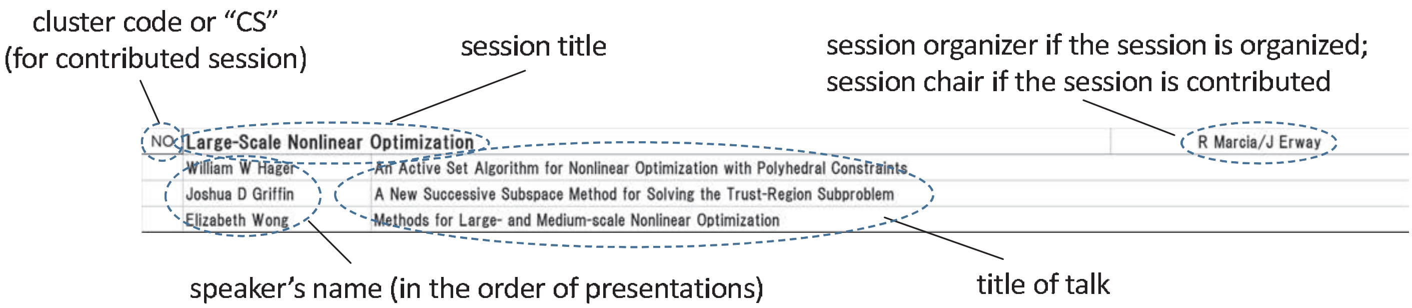
Here, the slots with diagonal line indicate that the room is NOT reserved for the conference and the ICCOPT participants are not allowed to enter.

The cluster code is defined as follows.

Acronym	Cluster
AESE	Applications in Energy, Science and Engineering
AFE	Applications in Finance and Economics
CVI	Complementarity and Variational Inequalities
CPO	Conic and Polynomial Optimization
CNO	Convex and Nonsmooth Optimization
DSO	Derivative-free and Simulation-based Optimization
GO	Global Optimization
LO	Linear Optimization
M-OVO	Multi-Objective and Vector Optimization
NO	Nonlinear Optimization
OIS	Optimization Implementations and Software
PDE-O	PDE-constrained Optimization
RO	Robust Optimization
SOIP	Sparse Optimization and Information Processing
SO	Stochastic Optimization

Detailed Information on Parallel Sessions

The following pages 33–44 summarize the detailed information of the parallel sessions.



fl	room	Mon.A 10:45-12:00 Monday, August 8th			
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Nonlinear Optimization and Its Applications I**		DP Robinson
			Frank E Curtis	Self-correcting Variable-Metric Algorithms for Nonlinear Optimization	
			Lorenz T Biegler	Solving MPCCs with IPOPT	
			Andreas Waechter	A Logical Benders Decomposition Algorithm for Binary-constrained Quadratic Programs with Complementarity Constraints	
	1A (Meeting Room 1A)	NO	**Methods for Large-Scale Problems**		F Rinaldi
			Joe Naoum-Sawaya	Column Generation Approach for the Interceptor Vehicle Routing Problem	
			James T Hungerford	A Partially Aggregated Dantzig Wolfe Decomposition Algorithm for Multi-Commodity Flows	
			Emanuele Frandi	Scalable and Sparse Optimization in Machine Learning via Frank-Wolfe Methods	
	1B (Meeting Room 1B)	PDE-O	**Inverse Problems**		T Takeuchi
			Takaaki Nara	A Direct Reconstruction Formula for the Conductivity and Permittivity from the Measurements of the Time-harmonic Magnetic Field	
			Benny Hon	Finite Integration Method for Inverse Heat Conduction Problems	
			Leevan Ling	Numerical Differentiation by Kernel-based Probability Measures	
	1C (Meeting Room 1C)	DSO	**Derivative-free and Simulation-based Optimization with Surrogate Models**		F Rinaldi/Z Zhang
			Anne-Sophie Crélot	Surrogate Strategies for Mixed-Variable Derivative-free Optimization	
			Giacomo Nannicini	RBFOpt: An Open-Source Library for Surrogate Model Based Optimization	
			Christine A Shoemaker	Efficient Mulit Objective Surrogate Global Optimization in Parallel with MOPLS and pySOT Toolbox	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Role of Optimization in Graphical Models Inference**		A Mittal
			Kei Hirose	Robust Estimation for Gaussian Graphical Modeling and Its Application to Gene Expression Data	
			Muneki Yasuda	Approximate Techniques for Boltzmann Machines	
			Areesh Mittal	Changing Graph Structure for Performing Fast, Approximate Inference in Graphical Models	
	4B (Research Meeting Room 4B)	PDE-O	**Algorithmic Advances in PDE-constrained Optimization**		A Schiela
			Martin Siebenborn	Shape Optimization Algorithms for Inverse Modeling in Extreme Scales	
			Sebastian Goetschel	Non-uniform Adaptive Lossy Trajectory Compression for Optimal Control of Parabolic PDEs	
			Anton Schiela	An Affine Covariant Composite Step Method for Optimization with PDEs as Equality Constraints	
5th floor of GRIPS	5A (Lecture Room A)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5C (Lecture Room C)	M-OVO	**Solutions of Equilibrium Problems: Computation and Stability**		A Schwartz
			Axel Dreves	How to Select a Solution in GNEPs	
			Sonja Steffensen	An Interior Point Algorithm for Equality Constrained GNEPs	
			Michal Cervinka	Stability and Sensitivity Analysis of Stationary Points in Mathematical Programs with Complementarity Constraints	
	5D (Lecture Room D)	LO	**Various Aspects of Conic Optimization and Mathematical Modeling Systems**		L Faybusovich/T Tsuchiya
			Yongdo Lim	Wasserstein Barycenters of Gaussian Measures	
			Kouhei Harada	A DC Programming Approach for Long-Short Multi-Factor Model	
			Keiichi Morikuni	Implementation of Interior-Point Methods for LP using Krylov Subspace Methods Preconditioned by Inner Iterations	
	5E (Lecture Room E)	RO	**Theory and Applications of Robust Optimization**		M Sim
			Zhi Chen	Distributionally Robust Optimization with Semi-infinite Ambiguity Sets	
			Shuming Wang	Tolerance-driven Appointment Scheduling and Sequencing using Perceived Delay Measures	
			Jianzhe Zhen	Solving Distributionally Robust Multistage Optimization Problems via Fourier-Motzkin Elimination	
	5F (Lecture Room F)	CNO	**Recent Advances on Convergence Rates of First-Order Methods: Part I**		Q Tran-Dinh/I Necoara
			Ion Necoara	Linear Convergence of First-Order Methods for Non-strongly Convex Optimization	
			Alp Yurtsever	A Universal Primal-Dual Convex Optimization Framework	
			Adrien B Taylor	Exact Worst-Case Performance of First-Order Methods for Composite Convex Minimization	
	5G (Lecture Room G)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5H (Lecture Room H)	AFE	**Financial Optimization and Robo Advisors 1**		C Lin
			Frank Wang	Robo-Advisor in China's Market	
			Changle Lin	Personalized Asset & Liability System: Goal-based Investing	
	5I (Lecture Room I)	CPO	**Interior-Point Methods and Applications for Conic Optimization**		Y Xia
			Sena Safarina	An Efficient Second-Order Cone Programming Approach for Optimal Selection in Tree Breeding	
			Kei Takemura	A Numerically Stable Primal-Dual Interior-Point Method for SDP	
	5J (Lecture Room J)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5K (Lecture Room K)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5L (Lecture Room L)	CPO	**Moments, Positive Polynomials & Optimization: Part I**		J Nie/JB Lasserre
			Etienne de Klerk	Improved Convergence Rates for Lasserre-Type Hierarchies of Upper Bounds for Box-constrained Polynomial Optimization	
			Xinzhen Zhang	Real Eigenvalues of Nonsymmetric Tensors	
			Panos Parpas	A Multilevel Method for Semidefinite Programming Relaxations of Polynomial Optimization Problems with Structured Sparsity	
3rd floor of NACT	m3S (Auditorium)	SOIP	**Sparse Optimization and Applications**		C Cartis
			Francis Bach	Submodular Functions: From Discrete to Continous Domains	
			Caroline Uhler	Learning Directed Acyclic Graphs Based on Sparsest Permutations	
			Katsuya Tono	A Link between DC Algorithms and Proximal Gradient Methods	
	m3AB (Lecture Rooms A&B)			Another event will be in progress: ICCOPT participants are not allowed to enter.	

fl	room	Mon.B 13:30-14:45 Monday, August 8th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Nonlinear Optimization and Its Applications II**	FE Curtis
		Daniel P Robinson	An Evolving Subspace Method for Low Rank Minimization	
		Katya Scheinberg	Convergence Rate of a Trust Region Method for Stochastic Nonconvex Optimization	
		Hao Wang	A Dynamic Penalty Parameter Updating Strategy for Matrix-free Sequential Quadratic Optimization Methods	
	1A (Meeting Room 1A)	NO	**Nonlinear Optimization Solvers**	Y Ye/O Hinder
		Oliver H Hinder	A One Phase Interior Point Method for Non-convex Optimization	
		Yu Watanabe	Inexact Sequential Quadratically Constrained Quadratic Programming Method of Feasible Directions with Global and Superlinear Convergence Properties	
		Roummel Marcia	Shape-changing L-SR1 Trust-Region Methods	
	1B (Meeting Room 1B)	PDE-O	**Advances in PDE-constrained Optimization I**	K Ito/M Ulbrich
		John A Burns	Optimization for Design and Control of Composite Thermal Fluid Systems	
		Constantin Christof	Sensitivity Analysis for Elliptic Variational Inequalities of the Second Kind: A Model Problem and Applications in Optimal Control	
		Johann M Schmitt	Optimal Control of Hyperbolic Balance Laws with State Constraints	
	1C (Meeting Room 1C)	DSO	**Computational and Algorithmic Aspects of Derivative-free Optimization**	F Rinaldi/Z Zhang
		Simon Wessing	Improved Sampling for Two-Stage Methods	
		Dimo Brockhoff	Benchmarking Bi-Objective Derivative-free Optimizers with COCO	
		Sébastien Le Digabel	The Mesh Adaptive Direct Search Algorithm for Discrete Blackbox Optimization	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Energy Systems and Markets**	A Tomasgard
		Yan Gao	Nonsmooth Equations Approach to the Real-Time Pricing for Smart Grid	
		Somayeh Moazeni	An Energy Storage Deployment Program under Random Discharge Permissions	
		Chiara Bordin	Smart Charging of Electric Vehicles through Indirect Control and Smart Price Signals	
	4B (Research Meeting Room 4B)	AESE	**Optimization in Healthcare**	N Dimitrov
		Murat Karatas	Cyber Defense Based on Network Structure	
		Felix Jost	Personalized Measurement Time Points by Optimum Experimental Design for Mathematical Leukopenia Models	
		Xi Chen	Texas Arbovirus Risk Maps and Uncertainty Analysis	
5th floor of GRIPS	5A (Lecture Room A)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5C (Lecture Room C)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5D (Lecture Room D)	LO	**Optimization over Symmetric Cones and Related Topics**	L Faybusovich
		Thanasak Mouktonglang	Primal-Dual Algorithms for Infinite-dimensional Second-Order Cone Programming Problems and LQ-Problem with Time Dependent Linear Term in the Cost Function	
		Sangho Kum	Incremental Gradient Method for Karcher Mean on Symmetric Cones	
		Bruno F Lourenço	FRA-Poly: Partial Polyhedrality and Facial Reduction	
	5E (Lecture Room E)	RO	**Robust Optimization in Data and Signal Processing**	AMC So
		Karthik Natarajan	On Reduced Semidefinite Programs for Second Order Moment Bounds with Applications	
		Wing Kin Ma	Semidefinite Relaxation of a Class of Robust QCQPs: A Verifiable Sufficient Condition for Rank-One Solutions	
		Man-Chung Yue	Epsilon-Net Techniques for a Class of Uncertain Quadratic Programming and Its Applications in Robust Beamforming with Cognitive Radio Constraints	
	5F (Lecture Room F)	CNO	**Recent Advances on Convergence Rates of First-Order Methods: Part II**	Q Tran-Dinh/I Necoara
		Lasith Adhikari	Limited-Memory Trust-Region Methods for Sparse Reconstruction	
		Cesar A Uribe	Non-asymptotic Convergence Rate for Distributed Learning in Graphs	
		Quoc Tran-Dinh	Adaptive Smoothing Fast Gradient Methods for Fully Nonsmooth Composite Convex Optimization	
	5G (Lecture Room G)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5H (Lecture Room H)	NO	**Optimization in Finance**	M Takac
		Michel Baes	Continuous Selections of Optimal Portfolios	
		Norbert Trautmann	A Hybrid Approach for Tracking the 1/N Portfolio	
		YiKuan Jong	On the Dependency among Asian Currency Exchange Rates under the Influence of Financial Tsunami	
	5I (Lecture Room I)	CPO	**Theoretical and Computational Aspects of Conic Programs**	M Yamashita/M Fukuda
		Ellen H Fukuda	Second-Order Conditions for Nonlinear Semidefinite Optimization Problems via Slack Variables Approach	
		Akihiro Tanaka	Some Tractable Subcones for Testing Copositivity	
		Makoto Yamashita	An Iterative Method using Boundary Distance for Box-constrained Nonlinear Semidefinite Programs	
	5J (Lecture Room J)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5K (Lecture Room K)	CPO	**Conic and Integer Conic Optimization**	T Terlaky/M Anjos/JC Góez
		Nathan Krislock	BiqCrunch: Solving Binary Quadratic Problems Efficiently using Semidefinite Optimization	
		Hongbo Dong	On a Semidefinite Relaxation for the Sparse Linear Regression Problem	
		Julio C Goez	Disjunctive Conic Cuts for Mixed Integer Second Order Cone Optimization	
	5L (Lecture Room L)	CPO	**Moments, Positive Polynomials & Optimization: Part II**	J Nie/JB Lasserre
		Gonzalo Munoz	LP Approximations to Polynomial Optimization Problems with Small Tree-Width	
		Amir A Ahmadi	Robust to Dynamics Optimization (RDO)	
		Guoyin Li	Error Bounds for Parametric Polynomial Systems with Applications to Higher-Order Stability Analysis and Convergence Rate	
3rd floor of NACT	m3S (Auditorium)	CNO	**Stochastic Optimization**	F Bach
		Elad Hazan	Second-Order Optimization for Machine Learning in Linear Time	
		Julien Mairal	Proximal Minimization by Incremental Surrogate Optimization (MISO)	
		Guanghui Lan	An Optimal Randomized Incremental Gradient Method	
	m3AB (Lecture Rooms A&B)	M-OVO	**Set Optimization: Advances and Applications**	AH Hamel
		Carola Schrage	Set-valued Variational Inequalities in Vector Optimization	
		Giovanni P Crespi	Introducing Well-Posedness to Set-Optimization	
		Andreas H Hamel	The Fundamental Duality Formula in Convex Set Optimization	

fl	room	Tue.A 10:30-11:45 Tuesday, August 9th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Nonlinear Optimization Algorithms and Their Complexity II**	P Toint
			Mohammadreza Samadi	A Trust Region Algorithm with a Worst-Case Iteration Complexity of $O(\varepsilon^{-3/2})$ for Nonconvex Optimization
			Philippe Toint	Second-Order Optimality and (Sometimes) Beyond
	1A (Meeting Room 1A)	NO	**Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 1**	YF Liu
			Simon Foucart	Sparse Recovery via Nonconvex Optimization, with Application in Metagenomics
			Xiaojun Chen	Penalty Methods for a Class of Non-Lipschitz Optimization Problems
			Takayuki Okuno	A Continuous DC Programming Approach to Nonlinear Mixed Integer Programs
	1B (Meeting Room 1B)	PDE-O	**Advances in PDE-constrained Optimization II**	M Ulbrich/K Ito
			Ariana Pitea	A Geometric Approach of Some Multitime Multiobjective Variational Problems
			Livia Susu	Optimal Control of Nonsmooth Semilinear Parabolic Equations
			Sven Leyffer	Mixed-Integer PDE-constrained Optimization
	1C (Meeting Room 1C)	DSO	**Derivative-free Optimization Methods for Structured Problems**	F Rinaldi/Z Zhang
			Laurent Dumas	A New DFO Algorithm for the Optimization of Partially Separable Functions
			John P Eason	A Trust Region Method for Glass Box/Black Box Optimization
			Stefan M Wild	Model-based Methods for Composite Blackbox Optimization
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Dynamics and Optimal Control**	JA Gomez
			Bulat Khusainov	Multi-Objective Co-Design for Embedded Optimization-based Control
			Anil V Rao	Novel Computational Framework for the Numerical Solution of Constrained Optimal Control Problems
			Jose A Gomez	Optimization of Dynamic Systems with Linear Programs Embedded and Its Application to Sustainable Biofuels Production
	4B (Research Meeting Room 4B)	AFE	**Financial Optimization and Robo Advisors 2**	G Jun
			Yongjae Lee	Goal Based Investment via Multi-Stage Stochastic Programming for Robo-Advisor Service — Part I: Modeling Issues
			Do-gyun Kwon	Goal Based Investment via Multi-Stage Stochastic Programming for Robo-Advisor Service — Part II: Implementation Issues
			Gyun Jeon	Asian Perspective on 'Robo-Advisor': Case of Korean Market
5th floor of GRIPS	5A (Lecture Room A)	M-OVO	**Robust Multi-Objective Optimization Problems**	GM Lee
			Chuong Thai Doan	Necessary Optimality Conditions for Nonsmooth Multiobjective Bilevel Optimization Problems
			Satoshi Suzuki	Surrogate Duality for Quasiconvex Vector Optimization with Data Uncertainty
			Sangwoon Yun	A Coordinate Descent Homotopy Method for Bi-Level Problem and Linearly Constrained Minimization
	5C (Lecture Room C)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5D (Lecture Room D)	LO	**Theoretical Advances in Linear Optimization — Barrier Methods**	AD Sidford/YT Lee
			Yin Tat Lee	A Faster Algorithm for Linear Programming and the Maximum Flow Problem
			Aaron D Sidford	A Faster Algorithm for Linear Programming and the Maximum Flow Problem
			Jakub Pachocki	Geometric Median
	5E (Lecture Room E)	RO	**On the Interplay of Choice, Robustness and Optimization**	K Natarajan
			Zhenzhen Yan	Multi-Product Pricing Optimization with Robust Choice Model
			Xiaobo Li	Analysis of Discrete Choice Models: A Welfare-based Approach
			Selin D Ahipasaoglu	Distributionally Robust Project Crashing with Full, Partial or No Correlation Information
	5F (Lecture Room F)	SOIP	**Sparse Solution Reconstruction in Inverse Problems**	E Resmerita
			Thomas Möllenhoff	Precise Relaxation of Nonconvex Energies via Structured Sparsity
			Daniel Gerth	On Convergence of Sparsity-promoting Regularization for Non-sparse Solutions
			Elena Resmerita	Variable Exponent Penalties for Sparse Solution Reconstruction
	5G (Lecture Room G)	OIS	**Advances in Optimization Modeling Languages**	J Siirola
			Bethany Nicholson	Modeling Abstractions and Automatic Discretization Frameworks for Optimization Problems with Differential Equations in Pyomo
			John D Siirola	New Developments in Pyomo
	5H (Lecture Room H)	M-OVO	**Vector Optimization**	A Loehne
			Andreas Loehne	A Set-valued Approach to Matrix Games with Vector Payoffs
			Benjamin Weissing	Duality in Polyhedral Projection Problems
			Shashi K Mishra	Optimality and Duality for Mathematical Programmes with Equilibrium Constraints
	5I (Lecture Room I)	CPO	**Geometry and Algorithms for Conic Programming**	M Muramatsu
			Henrik A Friberg	Facial Reduction in MOSEK
			Leonid Faybusovich	Primal-Dual Potentiai-Reduction Algorithm for Symmetric Programming Problem with Nonlinear Objective Function
			Gabor Pataki	Exact Duals and Short Certificates of Infeasibility and Weak Infeasibility in Conic Linear Programming: Part 1
	5J (Lecture Room J)	CNO	**Recent Advances in Splitting Methods for Large-Scale Convex Programming: Part I**	X Yuan/C Chen
			Wenxing Zhang	Lattice-based Patterned Fabric Inspection by Sparse and Low-Rank Representation
			Xingju Cai	A Proximal Point Algorithm with Asymmetric Linear Term
			Yuan Shen	An Alternating Minimization Algorithm for Robust Principal Component Analysis
	5K (Lecture Room K)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5L (Lecture Room L)	CNO	**Notions of Robustness and Dynamics in Convex Optimization: Part I**	B Recht/PA Parrilo
			Maryam Fazel	An Optimal First Order Method based on Optimal Quadratic Averaging
			Francois Glineur	Convergence of First-Order Algorithms for Convex Optimization using Inexact Information
			Alexander Rakhlin	On Equivalence between Deterministic First-Order Optimization Algorithms and Martingale Inequalities
3rd floor of NACT	m3S (Auditorium)		The National Art Center, Tokyo will be closed on Tuesday.	
	m3AB (Lecture Rooms A&B)		The National Art Center, Tokyo will be closed on Tuesday.	

fl	room	Tue.B	13:15-14:30 Tuesday, August 9th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Nonlinear Optimization Algorithms and Their Complexity I**		P Toint
			Sandra A Santos	Evaluation Complexity for Nonlinear Constrained Optimization using Unscaled KKT Conditions and High-Order Models	
			Oleg Burdakov	Limited Memory Algorithms with Cubic Regularization	
			Zaikun Zhang	A Space Transformation Framework for Nonlinear Optimization	
	1A (Meeting Room 1A)	NO	**Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 2**		YF Liu
			Feng Min Xu	Theory and Algorithms for Sparse Finance Optimization	
			Wei Bian	Optimality and Some Numerical Analysis for Constrained Optimization Problems with Nonconvex Regularization	
	1B (Meeting Room 1B)	PDE-O	**Numerical Methods for PDE-constrained Optimization under Uncertainty**		M Ulbrich
			Reinhold Schneider	Hierarchical Tensor Approximation for Optimal Control with Uncertain Coefficients	
			Oliver Lass	A Second Order Approximation Technique for Robust Optimization in Parametrized Shape Optimization	
			Michael Ulbrich	Constrained Optimization with Low-Rank Tensors and Applications to Problems with PDEs under Uncertainty	
	1C (Meeting Room 1C)	DSO	**Advances in Derivative-free and Simulation-based Optimization I**		F Rinaldi/Z Zhang
			Geovani N Grapiglia	Nonmonotone Derivative-free Trust-Region Algorithms for Composite Nonsmooth Optimization	
			Ubaldo M García-Palomares	An Approach for Solving Mixed Integer Nonlinear Optimization Problems via Derivative Free Optimization Techniques	
			Dmitri E Kvasov	On Numerical Comparison of Deterministic and Stochastic Derivative-free Global Optimization Algorithms	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Energy Systems I**		AW Dowling
			Claudia D'Ambrosio	Strong Valid Inequalities for the Standard Pooling Problem	
			Rui Huang	Challenges and Opportunities for Optimization-based Workflow in Industry	
			Alexander W Dowling	A Stochastic Programming Framework for Multi-Stakeholder Decision-Making and Conflict Resolution	
	4B (Research Meeting Room 4B)	AFE	**Asset-Liability Management**		WC Kim
			Woong Bee Choi	Extending the Scope of ALM to Social Investment — Investing in Population Growth to Enhance Sustainability of Korea National Pension Service	
			Chong H Won	The Peculiarity of Liability of National Pension in Korea and the Way to Sustain Pension Scheme	
			Woo Chang Kim	Personalized Asset-Liability Management Service: Products, Markets, Regulations and Technologies	
5th floor of GRIPS	5A (Lecture Room A)	M-OVO	**Bilevel Optimization: Theory and Solution Methods**		A Zemkoho
			Stephan Dempe	Solution Algorithm for Optimistic Bilevel Optimization Problems	
			Alain Zemkoho	Newton Method for Bilevel Optimization	
			Patrick Mehlitz	Stationarity Concepts for Bilevel Optimization Problems with Lower Level Constraints in Lebesgue Spaces	
	5C (Lecture Room C)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5D (Lecture Room D)	LO	**Theoretical Advances in Linear Optimization — Sampling Methods**		AD Sidford/YT Lee
			Hariharan Narayanan	Randomized Interior Point Methods for Sampling and Optimization	
			Santosh S Vempala	Geodesic Gliding and Polytope Sampling	
			Jacob Abernethy	Faster Convex Optimization: Simulated Annealing with an Efficient Universal Barrier	
	5E (Lecture Room E)	RO	**Robust Optimization: Theory and Applications**		V Goyal
			Phebe Vayanos	Robust Wait Time Estimation in Resource Allocation Systems with an Application to Kidney Allocation	
			Melvyn Sim	Satisficing Awakens: Models to Mitigate Uncertainty	
			Vineet Goyal	Piecewise Affine Policies for Two-Stage Robust Optimization under Demand Uncertainty	
	5F (Lecture Room F)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5G (Lecture Room G)	OIS	**Parallel Implementations and Algorithms for Continuous Optimization**		C Laird
			Jose S Rodriguez	A Parallel Nonlinear Interior-Point Approach for Dynamic Optimization Problems	
			Jean-Paul Watson	Parallel Scenario-based Decomposition Methods for Solving the Contingency-constrained AC Optimal Power Flow Problem	
			Ai Kagawa	The Rectangular Maximum Agreement Problem	
	5H (Lecture Room H)	RO	**Robust Optimization and Applied Probability**		Y Guan
			Matthew D Norton	Buffered Probability of Exceedance, A New Characterization of Uncertainty and Application to Support Vector Machines and Robust Optimization	
			Ye Wang	Applications of the Earth Mover's Distance in Optimization	
	5I (Lecture Room I)	CPO	**Geometry, Duality and Complexity in Conic Linear Programming I**		G Pataki
			Minghui Liu	Exact Duals and Short Certificates of Infeasibility and Weak Infeasibility in Conic Linear Programming: Part 2	
			Preston E Faulk	Preprocessing Semidefinite Programs	
			Takashi Tsuchiya	Solving SDP Completely with an Interior-Point Oracle	
	5J (Lecture Room J)	CNO	**Recent Advances in Splitting Methods for Large-Scale Convex Programming: Part II**		X Yuan/C Chen
			WenYi Tian	Faster Alternating Direction Method of Multipliers with an $O(1/n^2)$ Convergence Rate	
	5K (Lecture Room K)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5L (Lecture Room L)	CNO	**Notions of Robustness and Dynamics in Convex Optimization: Part II**		B Recht/PA Parrilo
			Laurent Lessard	Automating the Analysis and Design of Large-Scale Optimization Algorithms	
			Nathan Srebro	Stability as the Master Force Behind Stochastic Gradient Descent	
			Benjamin Recht	Stochastic Robustness of Gradient Methods	
3rd floor of NACT	m3S (Auditorium)			The National Art Center, Tokyo will be closed on Tuesday.	
	m3AB (Lecture Rooms A&B)			The National Art Center, Tokyo will be closed on Tuesday.	

fl	room		**Tue.C** 14:45-16:00 Tuesday, August 9th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Optimization in Machine Learning I**		J Griffin/W Zhou
			Scott R Pope	Combining Information from Second-Order Solvers and SGD	
			Wenwen Zhou	A Modified Conjugate Gradient Method with Warm-Starts for Large-Scale Nonconvex Optimization Problems	
	1A (Meeting Room 1A)	NO	**Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 3**		YF Liu
			Bo Jiang	Structured Nonconvex Optimization Models: Algorithms and Iteration Complexity Analysis	
			Yun Shi	Numerical Algorithms for PDE-constrained Optimization with Non-convex Non-smooth Objectives	
			Ya-Feng Liu	Composite L_q (0<q<1) Minimization over Polyhedron	
	1B (Meeting Room 1B)	PDE-O	**Optimal Control of Coupled Systems**		R Herzog
			Sven-Joachim Kimmerle	Optimal Control of a Coupled System of a Vehicle Transporting a Fluid Subject to Shallow Water Equations	
			Ailyn Stötzner	Optimal Control of Thermoviscoplasticity	
			Cedric Sehrt	Optimal Control of Scalar Transport in Incompressible Fluid Flow	
	1C (Meeting Room 1C)	DSO	**Randomized Methods and Stochastic Problems**		F Rinaldi/Z Zhang
			Enlu Zhou	Gradient-based Stochastic Search for Simulation Optimization	
			Hiva Ghanbari	AUC Maximization and Tuning Parameters of Cost Sensitive Logistic Regression via Derivative Free Optimization	
			Raghu Pasupathy	Adaptive Sampling Recursions for Simulation Optimization	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Energy Systems II**		F Gilbert
			Morteza Ashraphijuo	A Strong Semidefinite Programming Relaxation of the Unit Commitment Problem	
			Mouhacine Benosman	Data-driven Optimal Reduced Order Model Tuning for Partial Differential Equations: Application to the 3D Boussinesq Equation	
			Francois Gilbert	Handling Dynamic Constraints in Power System Optimization	
	4B (Research Meeting Room 4B)	CVI	**Applications of Complementarity Models: Sparsity and Games**		S Cui
			Alexandra Schwartz	A Reformulation of Sparse Optimization Problems using Complementarity-Type Constraints	
			Andrew Lu Liu	Distributed Algorithms for Potential Generalized Nash Equilibrium Problems (GNEPs) and Nonseparable Optimization Problems	
			Tatsuya Hirano	Multi-Leader Single-Follower Game between Suppliers with a Manufacturer	
5th floor of GRIPS	5A (Lecture Room A)	M-OVO	**Convex Optimization for Learning and Data Sciences**		S Villa
			Hongzhou Lin	A Universal Catalyst for First-Order Optimization	
			Lorenzo A Rosasco	Less is More: Optimal Learning with Stochastic Projection Regularization	
			Silvia Villa	Computational Regularization in Learning and Inverse Problems	
	5C (Lecture Room C)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.		
	5D (Lecture Room D)	LO	**Theoretical Advances in Linear Optimization — New Perspectives**		AD Sidford/YT Lee
			Di Wang	Faster Approximation for Packing and Covering LPs	
			Damian Straszak	Slime Molds and Sparse Recovery	
			Daniel N Dadush	Solving Linear Programs via Rescalable Geometry	
	5E (Lecture Room E)	RO	**Ambiguity-aware Decision Making under Uncertainty**		R Jiang
			Yongpei Guan	Risk-averse Stochastic Unit Commitment with Incomplete Information	
			Ruiwei Jiang	Two-Stage Stochastic Program with Distributional Ambiguity	
			Siqian Shen	Distributionally Robust Chance-constrained Bin Packing Problem	
	5F (Lecture Room F)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.		
	5G (Lecture Room G)	OIS	**Numerical Methods for Large Scale Nonlinear Optimisation**		C Bueskens
			Sören Geffken	Parametric Sensitivity Analysis within Sequential Quadratic Programming — Post Optimality Analysis of Subproblems	
			Renke Schäfer	Implementation of a Penalty-Interior-Point Algorithm within WORHP	
			Christian Kirches	SQP Methods and QP Hot-starting for Nonlinear Model Predictive Control	
	5H (Lecture Room H)	AFE	**Financial Decision Making under Distress**		J Chen
			Chanaka Edirisinghe	To Track or Not to Track: Can Economic and Financial Indicators Help Smart-Beta Funds?	
			Shushang Zhu	Optimally Manage Crash Risk	
			Jingnan Chen	Optimal Portfolio Deleveraging under Cross-Asset Price Pressure	
	5I (Lecture Room I)	CPO	**Geometry, Duality and Complexity in Conic Linear Programming II**		G Pataki
			Frank N Permenter	A Reduction Method for SDP Based on Projection Lattices and Jordan Algebras	
			Shota Yamanaka	Duality of a Generalized Absolute Value Optimization Problem	
			Masakazu Muramatsu	Weak Infeasibility, Facial Reduction, and Geometry in Second-Order Cone Programming	
	5J (Lecture Room J)	CNO	**Fast Inertial Proximal-Gradient Methods for Structured Optimization: $O(1/k^2)$ and Beyond**		H Attouch
			Hedy Attouch	The Rate of Convergence of Nesterov's Accelerated Forward-Backward Method is Actually Faster Than $1/k^2$	
			Juan Peypouquet	A Fast Convergent First-Order Method bearing Second-Order Information	
			Garrigos Guillaume	Convergence Rates in Convex Optimization: Going beyond the Worst-Case Analysis	
	5K (Lecture Room K)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.		
	5L (Lecture Room L)	CNO	**Notions of Robustness and Dynamics in Convex Optimization: Part III**		B Recht/PA Parrilo
			Venkat Chandrasekaran	Fitting Convex Sets to Data via Matrix Factorization	
			Pablo A Parrilo	Switched System Analysis via Dual/Sum-of-Squares Techniques	
3rd floor of NACT	m3S (Auditorium)		The National Art Center, Tokyo will be closed on Tuesday.		
	m3AB (Lecture Rooms A&B)		The National Art Center, Tokyo will be closed on Tuesday.		

fl	room	Tue.D 16:30-17:45 Tuesday, August 9th			
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Large-Scale Nonlinear Optimization**		R Marcia/J Erway
			William W Hager	An Active Set Algorithm for Nonlinear Optimization with Polyhedral Constraints	
			Joshua D Griffin	A New Successive Subspace Method for Solving the Trust-Region Subproblem	
			Elizabeth Wong	Methods for Large- and Medium-Scale Nonlinear Optimization	
	1A (Meeting Room 1A)	NO	**Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 4**		YF Liu
			Dong Kang	New Strategies of Stochastic RBF Method for Expensive Black-Box Global Optimization	
			Cheng Chen	A Subspace Multilevel Method for Nonlinear Optimization	
			Zhilong Dong	A General Proximal Quasi-Newton Method for Large Scale l_1 Penalized Optimization Problem	
	1B (Meeting Room 1B)	PDE-O	**PDE Optimization and Applications I**		T Takeuchi
			Tomoaki Hashimoto	Receding Horizon Control for Spatiotemporal Dynamic Systems	
			Kentaro Yaji	Topology Optimization for Fluid Dynamics Problems and Its Applications in Flow Channel Design	
			Masato Kimura	Shape Optimization Approach to Free Boundary Problems by Traction Method	
	1C (Meeting Room 1C)	DSO	**Advances in Derivative-free and Simulation-based Optimization II**		F Rinaldi/Z Zhang
			Alessandra Papini	An Implicit Filtering-based Algorithm for Derivative Free Multiobjective Optimization	
			Margherita Porcelli	Global Derivative-free Quasi-Newton Methods for Bound-constrained Nonlinear Systems	
			Warren L Hare	Using Inexact Subgradients to Compute Proximal Points of Convex Functions	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Optimization Models in Energy**		J Lavaei
			Marc D Vuffray	Monotonicity Properties in Dissipative Flow Networks	
			Abdulrahman Kalbat	Optimal Distributed Control of Power Systems with a High Level of Renewable Energy	
			Javad Lavaei	Power System State Estimation with a Limited Number of Measurements	
	4B (Research Meeting Room 4B)	CVI	**Stochastic Optimization and Variational Inequality Problems**		M Wang/S Cui
			Shisheng Cui	On the Analysis of Three Stochastic Extragradient Variants for Monotone Stochastic Variational Inequality Problems	
			Yue Xie	On the Resolution of Complementarity Formulations of the L_0-Norm Minimization Problem via ADMM Schemes	
			Sun Jie	A Distributionally Robust Model for Three Stage Stochastic Linear Optimization	
5th floor of GRIPS	5A (Lecture Room A)	M-OVO	**Generalized Convexity and Set Optimization**		D Kuroiwa
			Matteo Rocca	Robust Vector Optimization: Well-Posedness, Sensitivity to Uncertainty and Generalized Convexity of Set-valued Maps	
			Daishi Kuroiwa	Unified Approach in Set Optimization and Generalized Convexity for Set-valued Maps	
			Kazuki Seto	Generalized Convexity for Set-valued Maps and Its Applications	
	5C (Lecture Room C)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5D (Lecture Room D)	SOIP	**Sparse and Low Rank Approximation**		C Cartis
			John Wright	Nonconvex Recovery of Low Complexity Models	
			Mahdi Soltanolkotabi	Breaking Sample Complexity Barriers via Nonconvex Optimization?	
			Rachel Ward	A Semidefinite Relaxation for Computing Distances between Metric Spaces	
	5E (Lecture Room E)	RO	**Recent Advances in Data-driven Optimization**		V Gupta
			Adam Elmachtoub	Smart "Predict, Then Optimize"	
			Paul Grigas	An Extended Frank-Wolfe Method with "In-Face" Directions, and Its Application to Low-Rank Matrix Completion	
			Vishal Gupta	Empirical Bayes and Optimization in the Small-Data Regime	
	5F (Lecture Room F)			No session	
	5G (Lecture Room G)	LO	**Linear Optimization and Computation**		SD Ahipasaoglu/G Nannicini
			Roland Wunderling	Improving the CPLEX LP Solver	
			Matthias Miltenberger	LP Solution Polishing to Improve MIP Performance	
			Soomin Lee	Primal-Dual Method for Decentralized Online Optimization	
	5H (Lecture Room H)	AFE	**Optimization in Portfolio Selection and Risk Management**		D Li
			Moris S Strub	Portfolio Optimization with Non-recursive Reference Point Updating	
			Jianjun Gao	On Multiperiod Mean-CVaR Portfolio Optimization	
			Duan Li	Quadratic Convex Reformulations for Semi-continuous Quadratic Programming and Its Application in Cardinality Constrained Mean-Variance Portfolio Selection	
	5I (Lecture Room I)	CPO	**Barriers in Conic Optimization**		R Hildebrand
			Cristobal Guzman	New Upper Bounds for the Density of Translative Packings of Three-dimensional Convex Bodies with Tetrahedral Symmetry	
			Ronen Eldan	The Entropic Barrier: A Universal and Optimal Self Concordant Barrier	
			Roland Hildebrand	Barriers on Symmetric Cones	
	5J (Lecture Room J)	CNO	**Primal-Dual Algorithm for Convex Optimization**		Q Lin
			Peter Richtarik	Stochastic Dual Ascent for Solving Linear Systems	
			Antonin Chambolle	Remarks on Acceleration for Primal-Dual Algorithms	
			Lin Xiao	A Randomized Asynchronous Algorithm for Distributed Optimization with Parameter Servers	
	5K (Lecture Room K)	CS	**First Order Methods and Applications**		CHJ Pang
			Masaru Ito	An Adaptive Restarting for Universal Gradient Method of Minimizing Strongly Convex Functions	
			Naoki Ito	Fast Accelerated Proximal Gradient Method and Its Application to Unified Classification Algorithm	
			CH Jeffrey Pang	The Supporting Halfspace-quadratic Programming Strategy for the Dual of the Best Approximation Problem	
	5L (Lecture Room L)	CPO	**Algebraic Methods in Polynomial Optimization**		AA Ahmadi
			Greg Blekherman	Spectrahedral Cones with Rank 1 Extreme Rays, Sums of Squares and Matrix Completion	
			Ahmadreza Marandi	The Bounded SOS Hierarchy for Bilinear Programming	
			Jiawang Nie	Positive Maps and Separable Matrices	
3rd floor of NACT	m3S (Auditorium)			The National Art Center, Tokyo will be closed on Tuesday.	
	m3AB (Lecture Rooms A&B)			The National Art Center, Tokyo will be closed on Tuesday.	

fl	room		Wed.A 13:45-15:00 Wednesday, August 10th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**MIP + NLP**		O Gunluk
			Sanjeeb Dash	Optimization over Structured Subsets of Positive Semidefinite Matrices via Column Generation	
			Andy Sun	Cutting Planes to Strengthen Second Order Conic Relaxation of the OPF Problem	
			Oktay Gunluk	Solving Box-constrained Nonconvex QPs	
	1A (Meeting Room 1A)	NO	**Optimization Methods for Inverse Problems 1**		X Liu/Y Wang
			Yanfei Wang	Seismic Diffraction Extraction for Discontinuous Geologies using Sparse Regularization	
			Cong Sun	On a Special Structured Matrix Problem	
			Ran Gu	Semidefinite Penalty Method for Quadratically Constrained Quadratic Programming	
	1B (Meeting Room 1B)	PDE-O	**PDE Optimization and Applications II**		T Takeuchi
			Yikan Liu	Iterative Thresholding Algorithm for Inverse Source Problems for Hyperbolic-Type Equations	
			Genta Kawahara	Optimization of Heat Transfer in Plane Couette Flow	
			Takeshi Ohtsuka	Optimal Control Problem for Allen-Cahn Type Equation Associated with Total Variation Energy	
	1C (Meeting Room 1C)	DSO	**Theoretical Aspects of Derivative-free Optimization**		F Rinaldi/Z Zhang
			Anne Auger	On the Linear Convergence of Comparison-based Step-size Adaptive Randomized Search	
			Serge Gratton	Direct Search Based on Inaccurate Function Values	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Data and Networks I**		AU Raghunathan
			Ermin Wei	Parallel Multi-splitting Proximal Method	
			Arvind U Raghunathan	Dual Decomposition and Nonsmooth Equations	
	4B (Research Meeting Room 4B)	CVI	**Vector Variational Inequalities and Applications**		SK Mishra
			Jein-Shan Chen	On New Discrete-Type Complementarity Functions	
			Balendu B Upadhyay	On Relations between Vector Variational-like Inequalities and Vector Optimization Problems in Asplund Spaces	
			Mengdi Wang	Online Markovian Decision Problems as a Stochastic Minimax Problem	
5th floor of GRIPS	5A (Lecture Room A)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.		
	5C (Lecture Room C)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.		
	5D (Lecture Room D)	LO	**Computational and Complexity Challenges for Linear Conic Optimization**		M Anjos
			Leo S Liberti	A Random Projection Method for Solving Linear Programs	
			Tamás Terlaky	A Polynomial Column-wise Rescaling von Neumann Algorithm	
			Miguel Anjos	Computational Study of Some Valid Inequalities for k-Way Graph Partitioning	
	5E (Lecture Room E)	RO	**Advances in Robust Optimization I**		O Nohadani
			Anil Aswani	Numerical Solution of Bilevel Programs using a Duality-based Approach	
			Edwin Romeijn	Accounting for the Tongue-and-Groove Effect in IMRT Treatment Planning using a Robust Direct Aperture Optimization Approach	
			Omid Nohadani	Robust Maximum Likelihood Estimation with Application to Radiation Therapy	
	5F (Lecture Room F)	M-OVO	**Mathematical Programming and Economic Equilibria**		J Garg
			Vladimir Shikhman	Computation of Fisher-Gale Equilibrium by Auction	
			Jugal Garg	Polynomial-Time Complementary Pivot Algorithms for Market Equilibria	
			Joseph M Ostroy	Price-taking Equilibrium in Games	
	5G (Lecture Room G)	LO	**Algorithmic and Geometric Aspects of Linear Optimization**		A Deza
			Noriyoshi Sukegawa	Improving Bounds on the Diameter of a Polyhedron in High Dimensions	
			George O Manoussakis	On the Diameter of Lattice Polytopes	
			Domingos M Cardoso	Star Sets/Star Complements of Graph Eigenvalues and Simplex Like Techniques in Combinatorial Problems	
	5H (Lecture Room H)	AFE	**Robust Portfolio Optimization**		J Gotoh
			Alba V Olivares-Nadal	A Robust Perspective on Transaction Costs in Portfolio Optimization	
			Jang Ho Kim	Higher Factor Dependency of Robust Portfolios for Achieving Robustness	
			Andrew Lim	Robust Empirical Optimization	
	5I (Lecture Room I)	CS	**Stochastic Optimization: Theory and Algorithms**		M Michta
			Hiroyuki Kasai	Riemannian Stochastic Variance Reduced Gradient on Grassmann Manifold	
			Kai A Spürkel	Strong Convexity in Two-Stage Linear Stochastic Programs with Partially Random Right-Hand Side	
			Mariusz Michta	Properties of Weak Solutions to Stochastic Inclusions and Their Applications in Optimization Problems	
	5J (Lecture Room J)	CPO	**Matrix Optimization Problems: Recent Advances in Convergence Rate Analysis and Recovery Guarantees**		AMC So
			Chao Ding	Convex Optimization Learning of Faithful Euclidean Distance Representations in Nonlinear Dimensionality Reduction	
			Huikang Liu	Quadratic Optimization with Orthogonality Constraints: Explicit Lojasiewicz Exponent and Linear Convergence of Line-Search Methods	
			Zirui Zhou	A Unified Approach to Error Bounds for Structured Convex Optimization	
	5K (Lecture Room K)		A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.		
	5L (Lecture Room L)	CPO	**Moments, Positive Polynomials & Optimization: Part III**		J Nie/JB Lasserre
			Gue Myung Lee	On Stability and Genericity Results for Polynomial Optimization Problems	
			Jeya Jeyakumar	Globally Solving Polynomial Mathematical Programs with Equilibrium Constraints	
			Victor L Magron	Convergent Robust SDP Approximations for Semialgebraic Optimization	
3rd floor of NACT	m3S (Auditorium)	CNO	**Recent Advances in First-Order Methods: Part I**		M Teboulle/S Sabach
			Edouard Pauwels	Sequential Convex Programming, Value Function and Convergence	
			Nadav Hallak	On Computing the Proximal Mapping Associated with the l_0-Norm over Symmetric Sets	
			Marc Teboulle	Beyond Lipschitz Gradient Continuity: A Novel Path for First Order Methods	
	m3AB (Lecture Rooms A&B)	GO	**Advances in Deterministic Global Optimization I**		R Misener
			Rohit Kannan	Convergence-Order Analysis of Lower Bounding Schemes for Constrained Global Optimization Problems	
			Remigijus Paulavicius	Enhancing the Performance of BASBL: Branch-And-Sandwich BiLevel Solver with the Adaptive Branching, Domain Reduction and Parallel Computing Schemes	
			Radu Baltean-Lugojan	A Parametric Approach to Solving the Pooling Problem	

fl	room	Wed.B 15:15-16:30 Wednesday, August 10th			
1st floor of GRIPS	1S (Soukairou Hall)	NO	Optimization Methods and Its Applications		C Sun
			Xin Liu	Column-wise Block Coordinate Descent Approach for Orthogonal Constrained Optimization Problems	
			Bo Jiang	L_p-Norm Regularization Algorithms for Optimization over Permutation Matrices	
			Qingna Li	A Quadratically Convergent Regularized Semismooth Newton Method for Nonlinear Equations under Error Bound Conditions	
	1A (Meeting Room 1A)	NO	Optimization Methods for Inverse Problems 2		X Liu/Y Wang
			Xiucui Guan	Inverse Max+Sum Spanning Tree Problem under Hamming Distance by Modifying the Sum-Cost Vector	
			Bo Wen	Linear Convergence of Proximal Gradient Algorithm with Extrapolation for a Class of Nonconvex Nonsmooth Minimization Problems	
	1B (Meeting Room 1B)	PDE-O	PDE-constrained Optimization in Electromagnetism		F Tröltzsch/I Yousept
			Irwin Yousept	Optimization of Non-smooth Hyperbolic Evolution Maxwell's Equations in Type-II Superconductivity	
			Peter Gangl	Sensitivity-based Topology and Shape Optimization of an Electric Motor	
			Fredi Tröltzsch	Optimal Control of Some Quasilinear Parabolic Maxwell Equations	
	1C (Meeting Room 1C)	DSO	Derivative-free Optimization Algorithms for Stochastic Problems		F Rinaldi/Z Zhang
			Matt Menickelly	Probabilistically Fully Linear Models in STORM	
			Satyajith Amaran	On the Implementation of a Trust Region-based Algorithm for Derivative-free Optimization over Stochastic Simulations	
			Youssef M Marzouk	A Gaussian Process Trust-Region Method for Derivative-free Nonlinear Constrained Stochastic Optimization	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	Data and Networks II		NY Chiang
			Hassan Mansour	Online Blind Deconvolution in Through-the-Wall Radar Imaging	
			Ruth Misener	Using Functional Programming to Recognize Named Structure in an Optimization Problem: Application to Pooling	
			Nai-Yuan Chiang	A Regularized Augmented Lagrangian Filter Method for Nonlinear Building MPC Problems	
	4B (Research Meeting Room 4B)	CVI	Algorithms for Complementarity and Equilibrium Problems		U Shanbhag
			Todd Munson	Lexicographic Pivoting for Mixed Linear Complementarity Problems	
			Yura Malitsky	New Projection Methods for Monotone Variational Inequalities	
			Tianyu Hao	Value Function Based Non-cooperative Games	
5th floor of GRIPS	5A (Lecture Room A)	M-OVO	Optimality and Algorithm for Convex and Multiple-Objective Optimization		R Wangkeeree/N Petrot
			Rabian Wangkeeree	On Optimality Theorems for Multiobjective Optimization Problems over Feasible Set Defined by Tangentially Convex Inequalities	
			Narin Petrot	Methods for Finding Solutions of Convex Optimization and Feasibility Problem without Convex Representation	
	5C (Lecture Room C)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5D (Lecture Room D)	LO	Recent Advances in Linear Optimization		T Terlaky
			Lukas Schork	Inexact Directions in Interior Point Methods	
			Antoine Deza	Euler Polytopes and Convex Matroid Optimization	
			Pascal Benchimol	Long and Winding Central Paths	
	5E (Lecture Room E)	RO	Advances in Robust Optimization II		V Doan
			Xuan Vinh Doan	Fréchet Bounds and Distributionally Robust Optimization	
			Varun Gupta	Tight Moments-based Bounds for Queueing Systems	
			Henry Lam	The Empirical Divergence-based Distributionally Robust Optimization	
	5F (Lecture Room F)	SOIP	Low Complexity Models and Applications		M Lotz
			Ke Wei	A Provable Nonconvex Algorithm for Spectrally Sparse Signal Reconstruction	
			Raphael A Hauser	Tomography with Nonlinear Compressed Sensing	
			Axel Flinth	Compressed Sensing Stability through High-dimensional Geometry	
	5G (Lecture Room G)	LO	Perspectives on Simplex Algorithms		TD Hansen
			Yann Disser	The Simplex Algorithm is NP-mighty	
			Thomas D Hansen	An Improved Version of the Random-Facet Pivoting Rule for the Simplex Algorithm	
			Walter Morris	A Directed Steinitz Theorem for Oriented Matroid Programming	
	5H (Lecture Room H)	AFE	Optimization Approaches for Derivative Pricing and Risk Management		C Yiu
			Jingtang Ma	Hybrid Laplace Transform and Finite Difference Methods for Pricing American Options	
			Cedric Yiu	Optimal Portfolio and Insurance Problems with Risk Constraint	
	5I (Lecture Room I)			No session	
	5J (Lecture Room J)	CNO	Sparse Optimization: Algorithms and Applications		M Friedlander
			Cho-Jui Hsieh	Inexact Proximal Newton Methods for Composite Minimization	
			Madeleine Udell	Making Sketchy Decisions: Semidefinite Programming with Optimal Storage	
			Rene Vidal	Global Optimality in Matrix and Tensor Factorization, Deep Learning, and Beyond	
	5K (Lecture Room K)	CPO	Some New Results on Conic Optimization and Its Applications to Machine Learning		A Yoshise
			Daigo Narushima	Inner and Outer Approximations of the Semidefinite Cone using SD Bases and Their Applications to Some NP-hard Problems	
			Mirai Tanaka	Diversity Extraction via Condition Number Constrained Matrix Factorization	
			Akiko Yoshise	Rank Minimization Approach to Collaborative Filtering Based on the Nuclear Norm Minimization	
	5L (Lecture Room L)	CPO	Moments, Positive Polynomials & Optimization: Part IV		J Nie/JB Lasserre
			Jean B Lasserre	BSOS: A Bounded-Degree SOS Hierarchy for Polynomial Optimization	
			Jinyan Fan	Computing the Distance between the Linear Matrix Pencil and the Completely Positive Cone	
			Georgina Hall	DC Decomposition of Nonconvex Polynomials with Algebraic Techniques	
3rd floor of NACT	m3S (Auditorium)	CNO	Recent Advances in First-Order Methods: Part II		M Teboulle/S Sabach
			Yoel Drori	The Exact Information-based Complexity of Smooth Convex Minimization	
			Shoham Sabach	A First Order Method for Solving Convex Bi-Level Optimization Problems	
			Amir Beck	Primal and Dual Predicted Decrease Approximation Methods	
	m3AB (Lecture Rooms A&B)	GO	Advances in Deterministic Global Optimization II		CA Floudas/NV Sahinidis
			Syuuji Yamada	A Branch and Bound Procedure for a Quadratic Reverse Convex Programming Problem by Listing FJ Points	
			Monica G Cojocaru	Generalized Nash Games and Cap and Trade Environmental Models	
			Pietro Belotti	Solving Hard Mixed Integer Quadratic and Conic Optimization Problems	

fl	room	Wed.C 17:00-18:15 Wednesday, August 10th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Advances in Large-Scale Optimization**	M De Santis
		Bissan Ghaddar	A Global Optimization Approach for the Valve Setting Problem	
		Yufei Yang	Worst-Case and Sparse Portfolio Selection: Insights and Alternatives	
		Marianna De Santis	An Active Set Strategy for Nonlinear Programming Problems with Box Constraints	
	1A (Meeting Room 1A)	NO	**Optimization Methods for Inverse Problems 3**	X Liu/Y Wang
		Tingting Wu	Solving Constrained TV2L1-L2 MRI Signal Reconstruction via an Efficient Alternating Direction Method of Multipliers	
		Deren Han	Asymmetric Proximal Point Algorithms with Moving Proximal Centers	
		Lingling Xu	A Proximal Alternating Direction Method for Multi-Block Coupled Convex Minimization	
	1B (Meeting Room 1B)	PDE-O	**Recent Developments in PDE-constrained Optimization I**	S Ulbrich
		Michael Hintermüller	Optimal Control of Multiphase Fluids and Droplets	
		Christian Clason	A Nonlinear Primal-Dual Extragradient Method for Nonsmooth PDE-constrained Optimization	
		Stefan Ulbrich	Preconditioners for Time-dependent PDE-constrained Optimization and an Implementation Based on Parareal Time-Domain Decomposition	
	1C (Meeting Room 1C)	DSO	**Advances in Derivative-free and Simulation-based Optimization III**	F Rinaldi/Z Zhang
		Francesco Rinaldi	A New Derivative-free Method for Integer Programming Problems	
		Jeffrey Larson	Asynchronously Parallel Optimization Solver for Finding Multiple Minima	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Data and Networks III**	G Scutari
		Mingyi Hong	Decomposing Linearly Constrained Nonconvex Problems by a Proximal Primal-Dual Approach	
		Konstantinos Slavakis	Accelerated Hybrid Steepest Descent Method for Solving Affinely Constrained Composite Convex Optimization Problems	
		Gesualdo Scutari	In-Network Nonconvex Large-Scale Optimization	
	4B (Research Meeting Room 4B)	CVI	**Algorithms for Variational Inequality and Optimization Problems**	U Shanbhag
		Thanyarat Jitpeera	Convergence Analysis of Fixed Point Optimization Algorithm for the Triple-hierarchical Constrained Optimization Problem	
		Gabriel Haeser	On the Global Convergence of Nonlinear Optimization Algorithms under Weak Assumptions	
		Yina Liu	Characterization of Weakly Sharp Solutions of a Variational Inequality by Its Primal Gap Function	
5th floor of GRIPS	5A (Lecture Room A)	M-OVO	**Set-valued Analysis and Nonlinear Scalarization**	T Tanaka
		Yutaka Saito	On Generalization of a Fixed Point Theorem for Set-valued Maps	
		Yuto Ogata	Generalized Alternative Theorems Based on Set-Relations and an Application to Semidefinite Programming Problems	
		Issei Kuwano	A Scalar Characterization of Set-valued Optimization Problems	
	5C (Lecture Room C)	M-OVO	**Set-valued and Vector Optimization**	T Bajbar
		Jerzy Motyl	Order Convex Selections of Set-valued Functions and Their Applications to Convex Optimization	
		Yousuke Araya	Existence of Set Equilibrium Problem via Ekeland's Variational Principle	
		Tomas Bajbar	On the Real Jacobian Conjecture and Newton Polytopes	
	5D (Lecture Room D)	CNO	**Nonconvex Splitting Methods and Applications**	W Yin
		Lei Yang	Alternating Direction Method of Multipliers for a Class of Nonconvex and Nonsmooth Problems with Applications to Background/Foreground Extraction	
		Jinshan Zeng	ExtraPush for Convex Decentralized Optimization over Directed Networks with Extensions	
	5E (Lecture Room E)	RO	**Advances in Robust Optimization III**	B Van Parys
		Rahul Mazumder	A New Perspective on Boosting in Linear Regression via Subgradient Optimization and Relatives	
		Bart Van Parys	Stochastic Optimization with Data: Large Deviation Limits	
	5F (Lecture Room F)	SOIP	**Novel Perspectives on Nonlinear Optimization**	C Cartis
		Yuji Nakatsukasa	Global Optimization via Eigenvalues	
		Michal Kocvara	On Multigrid Methods in Convex Optimization	
		Robert M Gower	Randomized Quasi-Newton Updates are Linearly Convergent Matrix Inversion Algorithms	
	5G (Lecture Room G)	LO	**Theoretical and Algorithmic Developments of Linear Optimization and Semi-infinite Linear Optimization**	S Ma
		Amitabh Basu	Projection: A Unified Approach to Semi-infinite Linear Programs and Duality in Convex Programming	
		Christopher T Ryan	Strong Duality and Sensitivity Analysis in Semi-infinite Linear Programming	
		Sam Wong	Faster Algorithms for Convex and Submodular Function Minimization	
	5H (Lecture Room H)	SO	**Stability Analysis in Stochastic Programming**	M Claus
		Huifu Xu	Stability Analysis for Mathematical Programs with Distributionally Robust Chance Constraint	
		Johanna Burtscheidt	On Stability of Risk Averse Complementarity Problems under Uncertainty	
		Matthias Claus	On Stability of Stochastic Bilevel Programs with Risk Aversion	
	5I (Lecture Room I)		No session	
	5J (Lecture Room J)	CS	**Advances in Nonlinear Optimization I**	YS Niu
		Bilian Chen	On New Classes of Nonnegative Symmetric Tensors and Applications	
		Ryuta Tamura	A Mixed Integer Semidefinite Programming Approach for Variable Selection avoiding Multicollinearity	
		Yi-Shuai Niu	On Global Optimization of Mixed-01 Nonlinear Program via DC Algorithms	
	5K (Lecture Room K)	CPO	**SDP and DNN Relaxations of Discrete Polynomial Optimization Problems**	S Kim/M Kojima
		Shinsaku Sakaue	Exact SDP Relaxations with Truncated Moment Matrix for Binary Polynomial Optimization Problems	
		Sunyoung Kim	A Robust Lagrangian-DNN Method for a Class of Quadratic Optimization Problems	
		Masakazu Kojima	A Lagrangian and Doubly Nonnegative Relaxation for Polynomial Optimization Problems in Binary Variables	
	5L (Lecture Room L)	CNO	**Advances in First-Order Methods and Handling Uncertainty**	F Kilinc-Karzan
		Nam Ho-Nguyen	First-Order Methods for Robust Convex Optimization	
		Mert Gurbuzbalaban	Incremental Methods for Additive Convex Cost Optimization	
		Fatma Kilinc-Karzan	A Second-Order Cone Based Approach for Solving the Trust Region Subproblem and Its Variants	
3rd floor of NACT	m3S (Auditorium)		Another event will be in progress: ICCOPT participants are not allowed to enter.	
	m3AB (Lecture Rooms A&B)		Another event will be in progress: ICCOPT participants are not allowed to enter.	

fl	room			Thu.A 9:00-10:15 Thursday, August 11th	
1st floor of GRIPS	1S (Soukairou Hall)	NO	**ADMM-like Methods for Convex Optimization and Monotone Inclusions**		J Eckstein
			Necdet S Aybat	Distributed Proximal Gradient Methods for Cooperative Multi-Agent Consensus Optimization	
			Wotao Yin	ARock: Asynchronous Parallel Coordinate Update Framework and Its Application to ADMM	
			Jonathan Eckstein	Asynchronous Projective Monotone Operator Splitting Algorithms	
	1A (Meeting Room 1A)	NO	**Optimization Methods for Inverse Problems 4**		X Liu/Y Wang
			Qian Dong	A Parallel Line Search Subspace Correction Method for Convex Optimization Problems	
			Yong Xia	Generalized Newton Method for Globally Solving the Total Least Squares with Tikhonov Regularization	
			Hongying Liu	Conditional Gradient Algorithms for Rank-k Matrix Approximations with a Sparsity Constraint	
	1B (Meeting Room 1B)	PDE-O	**Recent Developments in PDE-constrained Optimization II**		S Ulbrich
			Winnifried Wollner	PDE Constrained Optimization with Pointwise Gradient Constraints	
			Hannes Meinlschmidt	Optimal Control of the Thermistor Problem in Three Spatial Dimensions	
			Roland Herzog	Controlling Feasibility and Optimality in Iterative Solvers for Optimality Systems	
	1C (Meeting Room 1C)	DSO	**Derivative-free Optimization Algorithms for Large-Scale Problems**		F Rinaldi/Z Zhang
			Sebastian Stich	Efficiency of Random Search on Structured Problems	
			Nacer E Soualmi	An Indicator for the Switch from Derivative-free to Derivative-based Optimization	
			Youhei Akimoto	Comparison-based Stochastic Algorithm with Adaptive Gaussian Model for Large-Scale Continuous Optimization	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Optimization in Energy Management Systems with Integrated Economic/Physical Models**		T Ohtsuka
			Toru Namerikawa	Distributed Optimal Power Management Based on Dynamic Pricing in Multi-Period Electricity Market	
			Kenji Hirata	Real-Time Pricing Leading to Optimal Operation and Applications to Energy Management Systems	
			Yusuke Okajima	A Study on Modeling and Optimization of an Energy Demand Network with Strategic Aggregators	
	4B (Research Meeting Room 4B)	CS	**Applications to Practical Problems**		RS Maglasang
			Shogo Kishimoto	A Successive LP Approach with C-VaR Type Constraints for IMRT Optimization	
			Gu Yan	A Tri-Level Optimization Model for Private Road Competition Problem with Traffic Equilibrium Constraints	
			Renan S Maglasang	The Shelf Space Allocation Problem under Carbon Tax and Emission Trading Policies	
5th floor of GRIPS	5A (Lecture Room A)	CS	**Applications in Production and Energy Economics**		P Krokhmal
			Takako Hoshiyama	To Predict the Bottleneck Node by Queueing Network Modeling of a Production Model with Long Lead Time and Large Variety of Small Quantity Production	
			Benjamin M Horn	Shape Optimization for Contact Problems Based on Isogeometric Analysis and Nonconvex Bundle Methods	
			Pavlo Krokhmal	A Semidefinite Programming Approach to Computing Bounds on the Overall Properties of Composite Materials with Randomly Oriented Fibers	
	5C (Lecture Room C)	M-OVO	**Non-convex Vector Optimization and Applications**		C Günther/M Hillmann
			Marius Durea	Minimal Time Function with Respect to a Set of Directions and Applications	
			Marcus Hillmann	Necessary Optimality Conditions for Some Nonconvex Facility Location Problems	
	5D (Lecture Room D)	LO	**Extended Formulations and Related Topics**		D Bremner
			Sebastian Pokutta	Strong Reductions for Linear and Semidefinite Programs	
			Hidefumi Hiraishi	A Note on Extended Formulations of Lower-truncated Transversal Polymatroids	
			David Bremner	Small Linear Programs for Decision Problems	
	5E (Lecture Room E)	RO	**Advances in Robust Optimization IV**		W Wiesemann
			Frans de Ruiter	Duality in Two-Stage Adaptive Linear Optimization: Faster Computation and Stronger Bounds	
			Daniel Kuhn	Regularization via Mass Transportation	
			Wolfram Wiesemann	Ambiguous Joint Chance Constraints under Mean and Dispersion Information	
	5F (Lecture Room F)	CNO	**Low-Order Algorithms for Nonlinear Optimization**		S Zhang
			Shiqian Ma	Barzilai-Borwein Step Size for Stochastic Gradient Descent	
			Qihang Lin	Distributed Stochastic Variance Reduced Gradient Methods and a Lower Bound for Communication Complexity	
			Simai He	Distributional Robust Optimization for IFR Distributions	
	5G (Lecture Room G)	CS	**Advanced Topics of Linear Optimization**		A Oliveira
			Toshihiro Kosaki	Weak Duality Theorems for Two Families of Complex Optimization Problems	
			Lucie Schaynová	A Client's Health from the Point of View of the Nutrition Adviser using Operational Research	
			Aurelio Oliveira	Reducing Interior Point Method Iterations via Continued Directions	
	5H (Lecture Room H)	SO	**Stochastic Complementarity Problems and Sample Average Approximation**		H Sun/D Zhang
			Shaojian Qu	Distributionally Robust Games with an Application to Environmental Problem	
			Dali Zhang	Computation of Stochastic Nash Equilibrium via Variable Sample	
			Hailin Sun	SAA-Regularized Methods for Multiproduct Price Optimization under the Pure Characteristics Demand Model	
	5I (Lecture Room I)			No session	
	5J (Lecture Room J)	CS	**Advances in Conic Optimization**		A Varvitsiotis
			Tang Peipei	A Two-Phase Algorithm for Large-Scale QPLogdet Optimization Problem	
			Anja Kuttich	Robust Topology Design of Mechanical Systems under Uncertain Dynamic Loads via Nonlinear Semidefinite Programming	
			Antonios Varvitsiotis	Completely Positive Semidefinite Rank	
	5K (Lecture Room K)	CPO	**Algorithms and Applications for Conic and Related Optimization Problems**		Y Xia
			Patrick Groetzner	Finding Decompositions for Completely Positive Matrices using Orthogonal Transformations	
			Shinji Yamada	A Fast Approximation Method for Nonconvex Quadratic Optimizations with Few Constraints	
			Ting Kei Pong	Explicit Estimation of KL Exponent and Linear Convergence of 1st-Order Methods	
	5L (Lecture Room L)	CPO	**Polynomial Optimization: Theory and Applications I**		LF Zuluaga
			Ramtin Madani	Penalized Semidefinite Programming Relaxation for Polynominal Optimization Problems	
			Jamie Haddock	A Sampling Kaczmarz-Motzkin Algorithm for Linear Feasibility	
			Juan C Vera	Positive Polynomials on Unbounded Domains	
3rd floor of NACT	m3S (Auditorium)			Another event will be in progress: ICCOPT participants are not allowed to enter.	
	m3AB (Lecture Rooms A&B)			Another event will be in progress: ICCOPT participants are not allowed to enter.	

fl	room	Thu.B 10:45-12:00 Thursday, August 11th			
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Optimization in Machine Learning II**		M Takac
			Reza B Harikandeh	Stop Wasting My Gradients: Practical SVRG	
			Niao He	Fast Optimization for Non-Lipschitz Poisson Regression	
			Martin Takac	Primal-Dual Rates and Certificates	
	1A (Meeting Room 1A)	NO	**Numerical Linear Algebra and Optimization I**		A Sartenaer/D Orban
			Jacek Gondzio	Preconditioning KKT Systems in Interior Point Methods	
			Michael Saunders	The DQQ Procedure for Multiscale Optimization	
			Dominique Orban	A Tridiagonalization Method for Saddle-Point and Quasi-definite Systems	
	1B (Meeting Room 1B)	PDE-O	**Risk-averse Optimization with PDE Constraints I**		D Ridzal/DP Kouri/B van Bloemen Waanders
			Thomas M Surowiec	Risk Averse PDE-constrained Optimization using Coherent Measures of Risk	
			Denis Ridzal	Trust-Region Algorithms for Large-Scale Stochastic Optimization with PDE Constraints	
			Bart van Bloemen Waanders	The Rapid Optimization Library: A PDE-constrained Optimization under Uncertainty Framework	
	1C (Meeting Room 1C)	DSO	**Applications of Derivative-free and Simulation-based Optimization**		F Rinaldi/Z Zhang
			Patrick Koch	Derivative Free Optimization for Automated, Efficient Tuning of Predictive Models	
			Matteo Diez	A Hybrid Global/Local Multi-Objective Approach to Simulation-based Design Optimization: Deterministic Particle Swarm with Derivative-free Local Searches	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Applications of Optimal Control**		MR de Pinho
			Thomas A Weber	Multiattribute Pricing	
			Ellina V Grigorieva	Optimally Control Treatment of Psoriasis Skin Disease	
			Maria dR de Pinho	Optimal Control for Path Planning of AUV using Simplified Models	
	4B (Research Meeting Room 4B)	CS	**Informatics and Geometric Problems**		DO Theis
			Luis F Bueno	Sequential Equality Programming for Topology Optimization	
			Naoshi Shiono	Location Problem of Supply Facilities in Gas Distribution Networks	
			Dirk O Theis	Computing Unique Information	
5th floor of GRIPS	5A (Lecture Room A)			No session	
	5C (Lecture Room C)	M-OVO	**Variational Analysis, Optimization, and Applications**		LM Briceño-Arias
			Hector Ramirez	New Advances in Sensitivity Analysis of Solution Maps to Parameterized Equilibria with Conic Constraints	
			Nghia TA Tran	On the Linear Convergence of Forward-Backward Splitting Methods	
			Luis M Briceño-Arias	Projected Chambolle-Pock Splitting for Solving Monotone Inclusions	
	5D (Lecture Room D)	LO	**Discrete and Computational Geometry**		Y Okamoto
			May K Szedlák	Redundancy Detection for Linear Programs with Two Variables per Inequality	
			Hiroyuki Miyata	On Classes of Oriented Matroids That Admit 2-dimensional Topological (Geometric) Representations	
			Sonoko Moriyama	Geometric Optimization Related with an LCP with SPD-Matrices	
	5E (Lecture Room E)	RO	**Advances in Robust Optimization V**		I Yanıkoğlu
			Boris Houska	Robust Optimal Control using Generalized Higher Order Moment Expansions	
			Krzysztof Postek	Robust Optimization with Ambiguous Stochastic Constraints under Mean and Dispersion Information	
			Ihsan Yanıkoğlu	Decision Rule Bounds for Stochastic Bilevel Programs	
	5F (Lecture Room F)	SOIP	**Sparsity and Semidefinite Programming Connections**		C Cartis
			Somayeh Sojoudi	Large-Scale Graphical Lasso Problems	
			Raphael Louca	Bounds on the Rank of Solutions to Sparse Semidefinite Programs	
	5G (Lecture Room G)	CS	**Routing and Related Problems**		K Kobayashi
			Achmad Maulidin	A Meta-Heuristic for the Location Routing Problem with Time-dependent Travel Times	
			Chulin Likasiri	A Capacitated Vehicle Routing Problem Approach for Solving Clustering Problem: A Case Study from Chiang Mai, Thailand	
			Kazuhiro Kobayashi	MISOCP Formulation for the Optimal Fuel Routing Problem and the Route Generation Algorithm	
	5H (Lecture Room H)	SO	**Applications of Stochastic Programming in Finance and Economics**		H Sun/D Zhang
			Qiyu Wang	Sparse Portfolio Selection via Linear Complementarity Approach	
			Zhaolin Hu	Convex Risk Measures: Efficient Computations via Monte Carlo	
			Bintong Chen	Dynamic Pricing and Return Pricing for Airline Industry	
	5I (Lecture Room I)			No session	
	5J (Lecture Room J)	CS	**Advances in Nonlinear Optimization II**		FACC Fontes
			Nimit Nimana	A Hybrid Algorithm for Split Hierarchical Optimization Problems with Fixed Point Constraints in Hilbert Spaces	
			Ning Zheng	Modulus Methods for Box Constrained Least Squares Problems	
			Fernando ACC Fontes	Optimal Control of Constrained Nonlinear Systems: An Adaptive Time-Grid Refinement Algorithm Guided by the Adjoint Multipliers	
	5K (Lecture Room K)			No session	
	5L (Lecture Room L)	CPO	**Polynomial Optimization: Theory and Applications II**		LF Zuluaga
			Janez Povh	A New Approximation Hierarchy for Polynomial Conic Optimization	
			Olga Kuryatnikova	New Bounds for Scheduling on Two Unrelated Selfish Machines	
			Cedric Josz	Moment/Sum-of-Squares Hierarchy for Complex Polynomial Optimization	
3rd floor of NACT	m3S (Auditorium)	CPO	**First-Order Methods for Convex Optimization: New Complexity/Convergence Theory**		RM Freund
			Defeng Sun	Linear Rate Convergence of the Alternating Direction Method of Multipliers for Convex Composite Quadratic and Semi-definite Programming	
			Simon Lacoste-Julien	On the Global Linear Convergence of Frank-Wolfe Optimization Variants	
			Robert M Freund	New Computational Guarantees for Solving Convex Optimization Problems with First Order Methods, via a Function Growth Condition Measure	
	m3AB (Lecture Rooms A&B)	CNO	**Advances in Large-Scale Nonsmooth Optimization**		S Becker
			Joseph Salmon	GAP Safe Screening Rule for Sparsity Enforcing Penalties	
			Jessica Gronski	Nuclear Norms for Collaborative Filtering	
			Bang Cong Vu	Stochastic Numerical Methods for Monotone Inclusions in Hilbert Spaces	

fl	room		Thu.C 13:30-14:45 Thursday, August 11th		
1st floor of GRIPS	1S (Soukairou Hall)	NO	**Recent Advances in Coordinate Descent Algorithms**		M Takac
			Julie Nutini	Is Greedy Coordinate Descent a Terrible Algorithm?	
			Rachael Tappenden	Flexible Coordinate Descent	
			Zheng Qu	Coordinate Descent with Arbitrary Sampling: Algorithms and Complexity	
	1A (Meeting Room 1A)	NO	**Numerical Linear Algebra and Optimization II**		A Sartenaer/D Orban
			Anders Forsgren	On Solving an Unconstrained Quadratic Program by the Method of Conjugate Gradients and Quasi-Newton Methods	
			Daniela di Serafino	BFGS-like Updates of Constraint Preconditioners for Sequences of KKT Linear Systems	
			Daniel Ruiz	Refining the Bounds from Rusten-Winther with Insights on the Interaction between the Blocks (Hessian vs Constraints) in KKT Systems	
	1B (Meeting Room 1B)	PDE-O	**Risk-averse Optimization with PDE Constraints II**		D Ridzal/DP Kouri/B van Bloemen Waanders
			Drew P Kouri	A Data-driven Approach to PDE-constrained Optimization under Uncertainty	
			Harbir Antil	Optimizing the Kelvin Force in a Moving Target Subdomain	
			Philip Kolvenbach	Nonlinear Robust Optimization using Second-Order Approximations and an Application to the Shape Optimization of Hyperelastic Load-carrying Structures	
	1C (Meeting Room 1C)	CS	**Nonlinear Optimization: Algorithms and Implementations**		PJS Silva
			Hiroshige Dan	Implementation of NLP Solver with Multiple Precision Arithmetic and Numerical Behavior Analysis of SQP Method for Ill-posed NLPs	
			Shummin Nakayama	A Memoryless Sized Symmetric Rank-One Method with Sufficient Descent Property for Unconstrained Optimization	
			Paulo JS Silva	Strict Constraint Qualifications and Sequential Optimality Conditions for Constrained Optimization	
4th floor of GRIPS	4A (Research Meeting Room 4A)	AESE	**Engineering Applications for Large Scale Nonlinear Optimization**		C Büskens/M Echim
			Mitja Echim	Large-Scale Trajectory Optimization for Autonomous Deep Space Missions	
			Matthias Knauer	Optimization of Large Scale Characteristics for the Automotive Industry	
			Clemens Zeile	Mixed-Integer Optimal Control Problems with Indicator Constraints in Automotive Applications	
	4B (Research Meeting Room 4B)	AESE	**Newton-Krylov Methods in Real-Time Optimization for Nonlinear Model Predictive Control**		T Ohtsuka
			Andrew Knyazev	Recent Advances in Newton-Krylov Methods for NMPC	
			Koji Inoue	Manycore Execution of Model Predictive Control	
			Mike Huang	Velocity Form Nonlinear Model Predictive Control of a Diesel Engine Air Path	
5th floor of GRIPS	5A (Lecture Room A)			No session	
	5C (Lecture Room C)	M-OVO	**Vector Equilibrium Problems and Vector Optimization**		DT Luc
			Gábor Kassay	Vector Quasi-Equilibrium Problems for the Sum of Two Multivalued Mappings	
			Radu Strugariu	A New Type of Directional Regularity for Multifunctions with Applications to Optimization	
			Dinh T Luc	On Equilibrium in Multi-Criteria Transportation Networks	
	5D (Lecture Room D)	LO	**Linear Optimization in the Context of Solving NP-hard Problems**		S Chubanov
			Austin Buchanan	Extended Formulations for Vertex Cover	
			Petra R Takács	New Search Direction-based Interior-Point Algorithm for P*(K) Horizontal Linear Complementarity Problems over Cartesian Product of Symmetric Cones	
			Sergei Chubanov	A Polynomial Projection Algorithm and Its Applications in Integer Linear Programming and Combinatorial Optimization	
	5E (Lecture Room E)	RO	**Advances in Robust Optimization VI**		H Xu
			William B Haskell	Simulation-based Algorithms for Robust Markov Decision Processes	
			Huan Xu	Learning the Uncertainty in Robust Markov Decision Processes	
	5F (Lecture Room F)			A lecture of GRIPS will be in progress: ICCOPT participants are not allowed to enter.	
	5G (Lecture Room G)			No session	
	5H (Lecture Room H)	CS	**Stochastic Optimization: Theory and Applications**		A Gaivoronski
			Nobusumi Sagara	Subdifferentials of Nonconvex Integral Functionals in Banach Spaces with Applications to Stochastic Dynamic Programming	
			Jorge R Vera	Achieving Consistency in Intertemporal Decisions via Stochastic and Robust Approaches	
			Alexei A Gaivoronski	Design of Reconfigurable Networks under Uncertainty by Concurrent Stochastic Optimization and Simulation	
	5I (Lecture Room I)			No session	
	5J (Lecture Room J)	CS	**Advances in Nonlinear Optimization III**		P Kirst
			Hassan S Nor	A Method of Multipliers with Alternating Constraints for Nonlinear Optimization Problems	
			Pakeeta Sukprasert	The Common Limit in the Range of Property for Two Nonlinear Mappings	
			Peter Kirst	Solving Disjunctive Optimization Problems by Generalized Semi-infinite Optimization Techniques	
	5K (Lecture Room K)	CS	**Algorithms for Nonsmooth Optimization**		A Uschmajew
			Chengjing Wang	A Primal Majorized Semismooth Newton-CG Augmented Lagrangian Method for Large-Scale Linearly Constrained Convex Programming	
			Martin Knossalla	Bundle Trust-Region Method for Marginal Functions using Outer Subdifferentials	
			André Uschmajew	A Riemannian Gradient Sampling Algorithm for Nonsmooth Optimization on Manifolds	
	5L (Lecture Room L)			No session	
3rd floor of NACT	m3S (Auditorium)	CNO	**Augmented Lagrangian-based Algorithms for Large-Scale Conic Programming**		KC Toh
			Xudong Li	Fast Algorithm for Lasso	
			Ying Cui	Semidefinite Inverse Quadratic Eigenvalue Problem with Prescribed Entries and Partial Eigendata	
			Kim-Chuan Toh	SDPNAL+: A Matlab Software for Semidefinite Programming with Bound Constraints	
	m3AB (Lecture Rooms A&B)	CPO	**Conic and Polynomial Optimization: Copositive Optimization**		LF Zuluaga
			E Alper Yildirim	Inner Approximations of Completely Positive Reformulations of Mixed Binary Quadratic Programs	
			Van Nguyen	On Completely Positive Modeling of Quadratic Problems	
			Luis F Zuluaga	Copositive Certificates of Non-negativity	

Abstracts Of Talks In Parallel Sessions

■ Mon.A.1S

Monday, 10:45-12:00, Room 1S

Nonlinear Optimization and Its Applications I

Cluster: Nonlinear Optimization
Session organized by: *Daniel P Robinson*

1. **Self-correcting Variable-Metric Algorithms for Nonlinear Optimization**

   Frank Edward Curtis (frank.e.curtis@gmail.com) Lehigh University, USA

From both geometric and algebraic viewpoints, the self-correcting properties of BFGS updating are discussed. These properties, expressed in terms of the sequence of BFGS Hessian approximations, lead to useful properties of the corresponding inverse Hessian approximations. These latter properties are exploited in two proposed algorithms, one for stochastic (nonconvex) optimization and one for deterministic convex (nonsmooth) optimization. As opposed to popular approaches that employ BFGS updating, neither of the proposed algorithms employ line searches.

2. **Solving MPCCs with IPOPT**

   Lorenz T Biegler (lb01@andrew.cmu.edu) Carnegie Mellon University, USA, *Wei Wan*

Mathematical Programs with Complementarity Constraints pose well-known difficulties, particularly because they violate constraint qualifications at their solution. Nevertheless, strongly stationary MPCC solutions, which are characterized by solutions to relaxed nonlinear programming (RNLP) problems that satisfy LICQ, can be found through NLP reformulations of the MPCC problem. Such reformulations include i) inequality relaxations of the complementarity constraints, ii) replacing complementarity constraints by smoothed NCP functions and iii) embedding complementarity terms as exact penalties. This talk discusses our experiences in extending the well-known primal-dual barrier solver, IPOPT to deal with the solution of MPCCs. Our hybrid approach combines the penalty parameter adjustment from Leyffer, Lopez-Calva and Nocedal (2007) along with a recent structured regularization approach in IPOPT that effectively deletes degenerate constraints. The combined strategy leads to a workable algorithm with modified Newton steps that depend on the local behavior of the complementarity constraints. We evaluate this approach on problems from the MacMPEC library, examples that do not have strongly stationary solutions, and larger MPCCs based on engineering systems. In addition, we compare with NLP strategies derived from the above classes of problem reformulations.

3. **A Logical Benders Decomposition Algorithm for Binary-constrained Quadratic Programs with Complementarity Constraints**

   Andreas Waechter (waechter@iems.northwestern.edu) Northwestern University, USA, *Francisco Jara-Moroni, John E Mitchell, Jong-Shi Pang*

We present an algorithm for solving convex quadratic programs with complementarity constraints and continuous and binary variables to global optimality. Following a Benders decomposition approach, LP and QP subproblems compute feasibility cuts that are added to a satisfiability master problem. To enhance performance of the method, the cuts are sparsified using an l_1-norm or l_0-norm approach, and approximate optimality cuts are generated to steer the master problem towards trial points with good objective values. Numerical results are presented.

■ Mon.A.1A

Monday, 10:45-12:00, Room 1A

Methods for Large-Scale Problems

Cluster: Nonlinear Optimization
Session organized by: *Francesco Rinaldi*

1. **Column Generation Approach for the Interceptor Vehicle Routing Problem**

   Joe Naoum-Sawaya (jnaoumsa@uwaterloo.ca) Ivey Business School, Canada, *Claudio Gambella, Bissan Ghaddar*

We address a generalization of the vehicle routing problem that seeks to minimize the vehicles travel time given moving pick-up locations and a common destination. The problem is formulated as a mixed integer second order cone program and a branch-and-price approach is proposed as a solution methodology. Strengthening inequalities are proposed and computational results on instances of varying sizes are presented.

2. **A Partially Aggregated Dantzig Wolfe Decomposition Algorithm for Multi-Commodity Flows**

   James T Hungerford (jamesthungerford@gmail.com) M.A.I.O.R., Srl., USA, *Alberto Caprara, Antonio Frangioni, Tiziano Parriani*

We consider the standard multi-commodity network flow problem, in which several commodities must be routed through a network while sharing resources along the network arcs and while optimizing a linear objective function. The celebrated Dantzig Wolfe Decomposition Algorithm solves the continuous relaxation of the problem by alternating between solving a Lagrangian subproblem, in which the arc mutual capacity constraints are relaxed, and a master problem, which computes an optimal convex combination over a small collection of hand-picked flows. Historically, two versions of this approach have been employed: an aggregated version, in which each Lagrangian subproblem solution is assigned a single convex multiplier in the master problem; and a disaggregated version, in which convex combinations are taken with respect to each commodity. In this talk, we investigate the effect on performance of employing a partial aggregation strategy, in which commodities are aggregated either arbitrarily or according to their similarities, and each aggregate is represented in the master problem by a different convex multiplier. A quadratic stabilization term is used to speed up convergence. We present preliminary computational results which indicate that the optimal level of aggregation often lies somewhere in between complete aggregation and complete disaggregation.

3. **Scalable and Sparse Optimization in Machine Learning via Frank-Wolfe Methods**

   Emanuele Frandi (emanuele.frandi@gmail.com) ESAT-STADIUS, KU Leuven, Belgium, *Ricardo Nanculef, Marcelo Aliquintuy, Stefano Lodi, Claudio Sartori, Johan A K Suykens*

Machine Learning problems involving large-scale datasets arise in a wide variety of domains and applications. As such, there is a constant demand for high-performance optimization tools with strong theoretical guarantees which can (1) handle the scalability challenges posed by large-scale datasets and (2) provide sparse solutions while preserving the accuracy of the underlying models. In this context, a helpful tool is provided by the class of Frank-Wolfe (FW, a.k.a. Conditional Gradient) methods. We present an overview of our recent work on the topic, focusing in particular on the role played by FW optimization in the context of two classical Machine Learning problems, SVM training and Lasso regression. We first consider both problems on their own, and later show how they can be effectively combined to obtain sparse approximations of general SVM classifiers. We provide experimental results on a variety of benchmark large-scale problems, illustrating how carefully implementing FW methods leads to efficient and fast algorithms which can compute accurate models while at the same time controlling or enforcing the sparsity of the solution.

■ Mon.A.1B

Monday, 10:45-12:00, Room 1B

Inverse Problems

Cluster: PDE-constrained Optimization
Session organized by: *Tomoya Takeuchi*

1. **A Direct Reconstruction Formula for the Conductivity and Permittivity from the Measurements of the Time-harmonic Magnetic Field**

   Takaaki Nara (nara@alab.t.u-tokyo.ac.jp) The University of Tokyo, Japan, *Tetsuya Furuichi, Motofumi Fushimi, Shigeru Ando*

Estimation of the electric conductivity and permittivity inside the human body gives precious information for tumor diagnosis. Recently, magnetic resonance (MR)-based electrical property tomography attracts considerable attention. The problem is to estimate the electric conductivity and permittivity in the time-harmonic Maxwell equation from the transverse magnetic field component of the applied RF field at the Larmor frequency measured with an MRI scanner. Conventional methods assume that these electrical properties are homogeneous inside the human body, which leads to a reconstruction error. Recently, a linear PDE for the inverse of admittivity is derived and a method by using FEM is proposed. However, the problem is that it requires the Laplacian of the magnetic field, which leads to a severe numerical error. In this paper, we propose a stable reconstruction formula for the admittivity.

2. **Finite Integration Method for Inverse Heat Conduction Problems**

Benny Hon (Benny.Hon@cityu.edu.hk) City University of Hong Kong, Hong Kong

In this talk we will present the application of a recently developed Finite integration method (FIM) for solving inverse heat conduction problems (IHCPs). The use of the Laplace transform technique for temporal discretization and Lagrange quadrature formula for spatial integration is shown to be effective and efficient for solving IHCPs under regular domains. For problems defined on irregular domains, the meshless radial basis function (RBF) is combined with the FIM to give a highly accurate spatial approximation to the IHCPs. Numerical stability analysis indicates that the convergence of the FIM-RBF is less sensitive to the chosen value of the shape parameter contained in the multiquadric radial basis functions. The optimal choice for this shape parameter is still an open problem, whose value is critical to the accuracy of the approximation. For tackling the ill-conditioned linear system of algebraic equations, the standard regularization methods of singular value decomposition and Tikhonov regularization technique are both adopted for solving IHCPs with data measurement errors. Keywords: Finite integration method, inverse heat condition problem, Laplace transform, Lagrange formula, radial basis function, singular value decomposition, Tikhonov regularization technique

3. **Numerical Differentiation by Kernel-based Probability Measures**

Leevan Ling (lling@hkbu.edu.hk) Hong Kong Baptist University, Hong Kong, *Qi Ye*

We combine techniques in meshfree methods and stochastic regressions to construct kernel-based approximants for numerical derivatives from noisy data. We construct Bayesian estimators from normal random variables defined on some SPD kernel-based probability measures, in which a Tikhonov regularization naturally arise in the formulation and the kernel's shape parameter also plays the role of the regularization parameter. Our analysis provides two important features to this novel approach. First, we show that the conditional mean squared error of any approximant is computable without knowing the exact derivative and can be used as an a posteriori error bound. This allows user to evaluate the approximation quality of any given kernel-based approximant to the derivative, and hence, select the best one (in the sense of kernel-based probability) out of many resulted from some brute-force approaches.

■ Mon.A.1C

Monday, 10:45-12:00, Room 1C

Derivative-free and Simulation-based Optimization with Surrogate Models

Cluster: Derivative-free and Simulation-based Optimization

Session organized by: *Francesco Rinaldi, Zaikun Zhang*

Session chair: *Christine A Shoemaker*

1. **Surrogate Strategies for Mixed-Variable Derivative-free Optimization**

Anne-Sophie Crélot (anne-sophie.crelot@unamur.be) University of Namur, Belgium, *Charlotte Beauthier, Dominique Orban, Caroline Sainvitu, Annick Sartenaer*

We propose a surrogate management framework for challenging derivative-free problems in mixed continuous, integer, discrete and categorical variables. Our framework employs the globally convergent mesh-adaptive direct search method implemented in the NOMAD library. A radial basis function-based surrogate is used to guide the optimization during both the local poll and global search steps. The surrogate is minimized by way of an evolutionary algorithm implemented in the MINAMO package. Our numerical results compare several surrogate variants.

2. **RBFOpt: An Open-Source Library for Surrogate Model Based Optimization**

Giacomo Nannicini (nannicini@us.ibm.com) IBM Research, USA

COIN-OR RBFOpt is an open-source library for expensive derivative-free optimization, that implements variations of Gutmann's RBF method and of Regis and Shoemaker's Metric Stochastic Response Surface Method. This talk will discuss the general framework for the two methods, and the specific contributions of RBFOpt: an approach to handle noisy but fast objective function evaluations; a fast automatic model selection phase; and a methodology to allow parallel asynchronous objective function evaluations. Numerical results will be presented.

3. **Efficient Mulit Objective Surrogate Global Optimization in Parallel with MOPLS and pySOT Toolbox**

Christine Annette Shoemaker (ceesca@nus.edu.sg) National University of Singapore, Singapore, *Taimoor Akhtar*

We present a new method MOPLS for Multi objective optimization of multimodal functions using surrogates. We show in numerical results that MOPLS greatly outperforms NSGA-II and also outperforms PAREGO, AMALGUM, and GOMORS. Here MOPLS is used with a radial basis function surrogate, but as part of the python toolbox pySOT, both single and multi objective problems can be.solved with different surrogates and ensembles of surrogates..

■ Mon.A.4A

Monday, 10:45-12:00, Room 4A

Role of Optimization in Graphical Models Inference

Cluster: Applications in Energy, Science and Engineering

Session organized by: *Areesh Mittal*

1. **Robust Estimation for Gaussian Graphical Modeling and Its Application to Gene Expression Data**

Kei Hirose (hirose@imi.kyushu-u.ac.jp) Kyushu University, Japan, *Hironori Fujisawa*

In Gaussian graphical model, a penalized maximum likelihood approach with the L_1 penalty is often used. However, the penalized maximum likelihood procedure is sensitive to outliers. To overcome this problem, we introduce a robust estimation procedure based on the gamma-divergence. The proposed method has a redescending property, which is known as a desirable property in robust statistics. The parameter estimation procedure is constructed using the Majorize-Minimization algorithm, which guarantees that the objective function monotonically decreases at each iteration. Extensive simulation studies showed that our procedure performed much better than the existing methods, in particular, when the contamination rate was large. A real data analysis was carried out to illustrate the usefulness of our proposed procedure.

2. **Approximate Techniques for Boltzmann Machines**

Muneki Yasuda (muneki@yz.yamagata-u.ac.jp) Yamagata University, Japan

Boltzmann machine is a type of graphical model based on a Markov random field, and is a fundamental model in the field of deep learning, for example, restricted Boltzmann machine and deep Boltzmann machine. Unfortunately, we cannot perform inference and learning on Boltzmann machines without an approximation, because they require a summation over all configurations of variables, namely, the combinatorial explosion problem. Various approximate techniques for Boltzmann machines have been developed, such as advanced mean-field approximation, contrastive divergence, maximum pseudo-likelihood method, maximum composite likelihood method, and so on. In the first part of this talk, we overview Boltzmann machines and some practical learning algorithms for Boltzmann machines. In the second part, we tough on some recent developments of learning and inference algorithms for Boltzmann machines including restricted Boltzmann machines and deep Boltzmann machines.

3. **Changing Graph Structure for Performing Fast, Approximate Inference in Graphical Models**

Areesh Mittal (areeshmittal@utexas.edu) University of Texas at Austin, USA, *Nedialko Dimitrov*

Complexity of exact marginal inference algorithms in probabilistic graphical models is exponential in the treewidth of the underlying graph. We develop a method to perform approximate inference on discrete graphical models by modifying the graph to another graph with a desirable edge structure. If the new graph structure has low treewidth, then performing exact inference on it becomes tractable. Performing exact inference on the new graph gives an approximate solution to the inference on original graph. We derive error bounds on the approximate inference solution as compared to the exact inference solution. We show that the problem of finding parameters of the new graph which gives the tightest error bounds can be formulated as a linear program (LP). The number of constraints in the LP grow exponentially with the number of nodes in the graph. To solve this issue, we develop a row generation algorithm to solve the LP.

■ Mon.A.4B

Monday, 10:45-12:00, Room 4B

Algorithmic Advances in PDE-constrained Optimization

Cluster: PDE-constrained Optimization

Session organized by: *Anton Schiela*

1. **Shape Optimization Algorithms for Inverse Modeling in Extreme Scales**

Martin Siebenborn (siebenborn@uni-trier.de) Trier University, Germany, *Volker Schulz*

In many applications, modeled by partial differential equations, there is a small number of spatially distributed materials or parameters distinguished by interfaces forming complex contours. We present an algorithm that utilizes multigrid strategies and quasi Newton updates in order to achieve scalability on very large shape optimization problems. We show how this can be implemented into an augmented Lagrangian method such that geometric constraints on the shape can be incorporated additionally. In this context optimizing shapes automatically means to deform finite element meshes iteratively. This usually deteriorates the quality of the discretization and thus affects the performance of the solver. We therefore introduce novel shape metrics that show good performance in retaining aspect ratios of discretization elements. The presented algorithm is shown to perform on two applications. A standard test case is to identify the shape that minimizes energy dissipation in a Stokes flow. Here we demonstrate that the proposed algorithm retains good mesh quality. Furthermore, it is shown how geometric constraints are incorporated. The second application is the identification of the shape of human skin cells. It is demonstrated how the distribution of permeability coefficients in a computational model for the human skin are fitted to measurements.

2. **Non-uniform Adaptive Lossy Trajectory Compression for Optimal Control of Parabolic PDEs**

Sebastian Goetschel (goetschel@zib.de) Zuse Institute Berlin, Germany

For the solution of optimal control problems governed by parabolic PDEs, methods working on the reduced objective functional are often employed to avoid a full spatio-temporal discretization of the problem. The evaluation of the reduced gradient requires one solve of the state equation forward in time, and one backward solve of the adjoint equation. As the state enters into the adjoint equation, the storage of a 4D data set is needed. To get accurate numerical results, in many cases very fine discretizations are necessary, leading to a huge amount of data to be stored. Methods for lossy compression of such trajectories were developed as a means to reduce these high demands of storage capacity and bandwidth, without a significant loss of accuracy or increase of computational complexity. For carefully chosen quantization tolerances, convergence of optimization algorithms is not impeded. To extend this approach, in this talk we consider the sensitivity of the reduced gradient with respect to the reconstruction error of the compressed state. It indicates that the finite element solution trajectory should be stored at higher precision in some parts of the space-time cylinder, while it can be compressed more severely in other parts. We investigate the choice of such non-uniform quantization tolerances, their influence on the optimization progress, and present application examples.

3. **An Affine Covariant Composite Step Method for Optimization with PDEs as Equality Constraints**

Anton Schiela (anton.schiela@uni-bayreuth.de) Universität Bayreuth, Germany, *Lars Lubkoll, Martin Weiser*

We propose a composite step method, designed for equality constrained optimization with partial differential equations. Focus is laid on the construction of a globalization scheme, which is based on cubic regularization of the objective and an affine covariant damped Newton method for feasibility. Numerical results are shown for optimal control problems subject to nonlinear elastic equations arising from an implant design problem in craniofacial surgery.

■ Mon.A.5C

Monday, 10:45-12:00, Room 5C

Solutions of Equilibrium Problems: Computation and Stability

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Alexandra Schwartz*

1. **How to Select a Solution in GNEPs**

Axel Dreves (axel.dreves@unibw.de) Universität der Bundeswehr Munich, Germany

We propose a new solution concept for generalized Nash equilibrium problems (GNEPs). This concept leads under suitable assumptions to unique solutions, which are generalized Nash equilibria and the result of a mathematical procedure modeling the process of finding a compromise. We first compute the best possible strategy for each player, if he could dictate the game, and use the best response on the others best possible strategies as starting point. Then we perform a tracing procedure, where we solve parametrized GNEPs, in which the players reduce the weight on the best possible and increase the weight on the current strategies of the others. Finally, we define the limiting points of this tracing procedure as solutions. Under our assumptions the new concept selects one reasonable out of typically infinitely many generalized Nash equilibria. Moreover, we present a Semismooth Tracing Algorithm as an algorithmic realization of the solution concept together with its convergence theory and some numerical results on diverse problems from literature.

2. **An Interior Point Algorithm for Equality Constrained GNEPs**

Sonja Steffensen (steffensen@igpm.rwth-aachen.de) RWTH Aachen, Germany, *Michael Herty*

We present an interior point algorithm that is based on a potential reduction Newton method and applied to the KKT-system associated with the equality constrained GNEP. Furthermore, we discuss the theoretical properties of such problems and analyse the global convergence of the interior point method. Finally we will report about some computational results of the implementation of our algorithm.

3. **Stability and Sensitivity Analysis of Stationary Points in Mathematical Programs with Complementarity Constraints**

Michal Cervinka (cervinka@utia.cas.cz) Czech Academy of Sciences, Czech Republic, *Jiri V Outrata, Lukas Adam, Miroslav Pistek*

We consider parameter-dependent mathematical programs with constraints governed by the generalized nonlinear complementarity problem and with additional non-equilibrial constraints. We study a local behavior of stationarity maps that assign the respective stationarity points (in particular C- or M-stationarity points) of the problem to the parameter. Using recent advances of generalized differential calculus we provide various criteria for the isolated calmness property and the Aubin property of stationarity maps considered. To this end, we derive new effective technique of computation of tangent and normal cones to unions of convex polyhedral sets and derive formulas of some particular objects of the third-order variational analysis useful for our sensitivity analysis.

■ Mon.A.5D

Monday, 10:45-12:00, Room 5D

Various Aspects of Conic Optimization and Mathematical Modeling Systems

Cluster: Linear Optimization

Session organized by: *Leonid Faybusovich, Takashi Tsuchiya*

1. **Wasserstein Barycenters of Gaussian Measures**

Yongdo Lim (ylim@skku.edu) Sungkyunkwan University, Korea

We show that the Wasserstein least squares problem of Gaussian measures can be equivalently transformed to a convex optimization problem on the convex cone of positive definite matrices by establishing the strict convexity of the Wasserstein distance.

2. **A DC programming Approach for Long-Short Multi-Factor Model**

Kouhei Harada (harada@msi.co.jp) NTT DATA Mathematical Systems Inc., Japan, *Kensuke Otsuki, Takahito Tanabe*

In this talk, we introduce a new application of DC (difference of convex) programming to a financial problem. DC programming approach is a well-known framework to handle non-convex intractable problems. Recently, some financial problems, such as long-short MAD (Mean-Absolute Deviation) model, has been efficiently solved by this framework. We applied the technique to long-short multi-factor model, and confirmed its superior performance as well as long-short MAD model. Although the solution is not globally optimal, some favorable features, which is not achieved by applying mere heuristics, are observed. We also talk about modeling language SIMPLE. Applying DC algorithms, one might have some difficulty with implementation since it is necessary to solve similar convex programming problems repeatedly. However, it is shown that we can handle them easily by using SIMPLE.

3. **Implementation of Interior-Point Methods for LP using Krylov Subspace Methods Preconditioned by Inner Iterations**

Keiichi Morikuni (morikuni@cs.tsukuba.ac.jp) University of Tsukuba, Japan, *Yiran Cui, Takashi Tsuchiya, Ken Hayami*

We apply inner-iteration preconditioned Krylov subspace methods to underdetermined systems of linear equations arising in the interior-point algorithm for solving linear programming (LP) problems. The inner-iteration preconditioners require small amount of memory compared to previous preconditioners, and enable us to overcome the severe ill-conditioning of the linear systems in the final phase of interior-point iterations. These Krylov subspace methods do not break down for LP problems with rank deficient constraint matrices even when previous direct methods fail. Numerical experiments on 125 instances from Netlib, QAPLIB and Mittelmann's LP benchmarks show that our implementation is more stable and robust than the standard direct methods SeDuMi and SDPT3. As far as we know, this is the first result that an interior-point method entirely based on iterative methods succeed in solving a fairly large number of standard LP instances under the standard stopping criteria. Moreover, the proposed method outperforms the interior-point solver of the state-of-the-art commercial code MOSEK for LP problems with random dense rank-deficient ill-conditioned constraint matrices.

■ Mon.A.5E

Monday, 10:45-12:00, Room 5E

Theory and Applications of Robust Optimization

Cluster: Robust Optimization
Session organized by: *Melvyn Sim*

1. **Distributionally Robust Optimization with Semi-infinite Ambiguity Sets**

   Zhi Chen (chenzhi@u.nus.edu) National University of Singapore, Singapore, *Melvyn Sim, Huan Xu*

In distributionally robust optimization (DRO), the distribution of uncertainty is only known to belong to an ambiguity set. Recent studies lead to significant progress on computationally tractable reformulations of DRO over several classes of ambiguity sets. With probability and expectation constraints, these ambiguity sets provide support, moments, other statistical information and even structural properties of uncertainty. However, their modelling power is limited by the allowance of only a finite number of constraints. Motivated from commonly used moment ambiguity sets and our new approximation of independence among uncertain components, we investigate a class of semi-infinite ambiguity sets that involve infinite expectation constraints. Thought DRO over this class of ambiguity set is generally intractable, we approach the intractability by first considering relaxed ambiguity sets with finite expectation constraints. We then demonstrate an algorithm based on the worst-case distribution that could tractably and gradually tighten the relaxation. We present expressive examples of this class of ambiguity sets and show cases where the worst-case distribution is relatively easy to verify, thus the algorithm could be efficient. We are also inspired by the performance of our new approximation of independence.

2. **Tolerance-driven Appointment Scheduling and Sequencing using Perceived Delay Measures**

   Shuming Wang (wangshuming@ucas.ac.cn) University of Chinese Academy of Sciences, China, *Teck Meng Marcus Ang, Tsan Sheng Adam Ng*

In this paper, we study the problem of appointment scheduling and sequencing in the healthcare service setting with uncertain service times and the patients's no-show information. We propose a Perceived Delay Measure (PDM) which focuses on the patients' tolerance-to-delay with respect to the waiting time, which by illustrative examples shows its advantage in capturing the effect of tolerance-to-delay compared with some other measures. Using the PDM measure, we develop a design model with known service time distributions or samples that incorporates the patients' tolerance-to-delay levels into the scheduling and sequencing optimization. Furthermore, we extend the model by considering the distributional ambiguity of the service time distribution. The PDM design model with known distributions can be formulated into a mixed integer linear program, while the PDM model with distributional ambiguity can be transformed into a mixed integer second-order conic program, and both can be handled by the off-the-shelf MIP solvers. The numerical experiments demonstrate the sound performance and some insights of using the proposed PDM models in the appointment scheduling and sequencing design.

3. **Solving Distributionally Robust Multistage Optimization Problems via Fourier-Motzkin Elimination**

   Jianzhe Zhen (j.zhen@uvt.nl) Tilburg University, Netherlands, *Melvyn Sim*

This paper demonstrates how distributionally robust multistage optimization (DRMO) problems can be casted as (single period) distributionally robust optimization problems. A scheme based on a blending of classical Fourier-Motzkin elimination and a simple Linear Programming technique, that can efficiently remove redundant constraints, is used to reformulate this general class of DRMO problems. This reformulation technique, contrasts with the classical approximation scheme via dynamic programming, enables us to solve DRMO problems to optimality. We show via numerical experiments that, given limited computational resources, for small-size multistage problems, our novel approach finds the optimal solutions, and for moderate or large-size instances, we successively improve the known approximated solutions.

■ Mon.A.5F

Monday, 10:45-12:00, Room 5F

Recent Advances on Convergence Rates of First-Order Methods: Part I

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Quoc Tran-Dinh, Ion Necoara*

1. **Linear Convergence of First-Order Methods for Non-strongly Convex Optimization**

   Ion Necoara (ion.necoara@acse.pub.ro) University Politehnica Bucharest, Romania, *Yurii Nesterov, Francois Glineur*

Usually, in order to show linear convergence of first-order methods for smooth convex optimization, we need to require strong convexity of objective function, an assumption which does not hold in many applications. In this paper we derive linear convergence rates of several first-order methods for solving smooth non-strongly convex constrained optimization problems, i.e. objective function has Lipschitz continuous gradient and satisfies some relaxed strong convexity relation. In particular, for smooth constrained convex programming, we prove that some relaxations of strong convexity of objective function are sufficient for getting linear convergence for many first-order methods. The most general relaxation we introduce is a second order growth condition, which shows that objective function grows quicker than a quadratic function along the secant between any feasible point and its projection on optimal set. We also propose other non-strongly convex relaxations, which are more conservative than the second order growth condition, and establish relations between them. Moreover, we prove that the class of first-order methods achieving linear convergence under these strongly convex relaxations is broad. Finally, we show that the proposed relaxed non-degeneracy conditions cover important applications: e.g. linear systems, linear programming and dual formulations of convex programs.

2. **A Universal Primal-Dual Convex Optimization Framework**

   Alp Yurtsever (alp.yurtsever@epfl.ch) École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, *Quoc Tran-Dinh, Volkan Cevher*

We propose a new primal-dual algorithmic framework for a prototypical constrained convex optimization template. The algorithmic instances of our framework are universal since they can automatically adapt to the unknown Holder continuity degree and constant within the dual formulation. They are also guaranteed to have optimal convergence rates in the objective residual and the feasibility gap for each Holder smoothness degree. In contrast to existing primal-dual algorithms, our framework avoids the proximity operator of the objective function. We instead leverage computationally cheaper, Fenchel-type operators, which are the main workhorses of the generalized conditional gradient (GCG)-type methods. In contrast to the GCG-type methods, our framework does not require the objective function to be differentiable, and can also process additional general linear inclusion constraints, while guarantees the convergence rate on the primal problem.

3. **Exact Worst-Case Performance of First-Order Methods for Composite Convex Minimization**

   Adrien B Taylor (adrien.taylor@uclouvain.be) Université catholique de Louvain, Belgium, *Francois Glineur, Julien M Hendrickx*

We introduce the performance estimation approach. This methodology aims at automatically analyzing the convergence properties of first-order algorithms for solving (composite) convex optimization problems. In particular, it allows obtaining tight guarantees for fixed-step first-order methods involving a variety of different oracles — namely explicit, projected, proximal, conditional and inexact (sub)gradient steps — and a variety of convergence measures. During the presentation, links with other methodologies for automatic algorithmic analysis will be emphasized, and we will illustrate how they can be used to further develop new algorithmic schemes, i.e., for obtaining better-performing first-order methods.

■ Mon.A.5H

Monday, 10:45-12:00, Room 5H

Financial Optimization and Robo Advisors 1

Cluster: Applications in Finance and Economics
Session organized by: *Changle Lin*

1. **Robo-Advisor in China's Market**

   Frank Wang (frankwang@creditease.cn) CreditEase, China

The talk will present CreditEase's thoughts about how to develop a robo-advisor in China.

2. **Personalized Asset & Liability System: Goal-based Investing**

   Changle Lin (changlelin1@gmail.com) Princeton University, USA, *Woo Chang Kim*

Modern wealth management industry has been transforming itself from a product-driven and sales-driven industry to a more client-centric industry. Goal-based investing is gaining popularity and becoming a mainstream approach adopted by large wealth management institutions to better serve their clients. Existing literature mostly model and optimize each goal in a client's holistic financial planning separately. This approach, though capturing the behavior tendency of private client's "mental accounting" behavior, will inevitably yield suboptimal results if taking all goals into account altogether. In this paper, we utilize the techniques and methodology used in asset liability management for institutions and adapt this financial technology, which has been only available for institutional investors, for personal investors.

■ Mon.A.5I

Monday, 10:45-12:00, Room 5I

Interior-Point Methods and Applications for Conic Optimization

Cluster: Conic and Polynomial Optimization
Session organized by: *Yu Xia*
Session chair: *Makoto Yamashita*

1. **An Efficient Second-Order Cone Programming Approach for Optimal Selection in Tree Breeding**

   Sena Safarina (safarina.s.aa@m.titech.ac.jp) Tokyo Institute of Technology, Japan, *Tim J Mullin, Makoto Yamashita*

An important issue in tree breeding is an optimal selection to determine the contribution of candidate pedigree members and to produce the highest performance of seed orchard while keeping genetic diversity. To address this problem from the viewpoint of mathematical optimization, Pong-Wong and Wolliams proposed semidefinite programming (SDP) formulation. Ahlinder et al. implemented the SDP formulation using SDPA and compared it with GENCONT. They reported that SDP approach attained a better optimal value than GENCONT, but its formulation consumed much longer computation than GENCONT. Our research is focused on second-order cone programming (SOCP) formulations for the optimal selection problem to reduce the heavy computation time of SDP. Though SOCP is a special case of SDP, simple SOCP formulation is not more efficient compared to SDP formulation. Therefore, we aggressively exploit a structural sparsity of the Wright numerator matrix and employ the Henderson algorithm to accelerate the computation. Numerical results show that the proposed SOCP approach reduced computation time from 39,200 seconds under the SDP approach to less than 2 seconds.

2. **A Numerically Stable Primal-Dual Interior-Point Method for SDP**

   Kei Takemura (takemura.k.ac@m.titech.ac.jp) Tokyo Institute of Technology, Japan, *Makoto Yamashita*

We present a new numerical stable interior-point method for semidefinite programming (SDP). Some SDP problems are very hard for interior-point methods due to numerical errors. One of the reasons for the numerical errors comes from the computation of inverse matrix. Since the matrix variables become ill-conditioned as they approach the optimal solution, the inverse matrix computation gets less reliable. We utlize an eigenvalue decomposition form of symmetric matricies as variable matrices instead of treating the matrix variables directly. We propose a path-following interior-point method by classifying the introduced variables into two groups. One group has eigenvalues and central path parameter. The other group has other variables including eigenvectors. A similar study called Q method (Alizadeh, Haeberly and Overton (1994)) did not achieve global convergence. In contrast, we give numerical results to show that the proposed method achieves numerical stability and global convergence.

■ Mon.A.5L

Monday, 10:45-12:00, Room 5L

Moments, Positive Polynomials & Optimization: Part I

Cluster: Conic and Polynomial Optimization
Session organized by: *Jiawang Nie, Jean B Lasserre*

1. **Improved Convergence Rates for Lasserre-Type Hierarchies of Upper Bounds for Box-constrained Polynomial Optimization**

   Etienne de Klerk (e.deklerk@uvt.nl) Tilburg University, Netherlands *Roxana Hess, Monique Laurent*

We consider the problem of minimizing a given mulltivariate polynomial over the hypercube. An idea introduced by Lasserre, is to find a probability distribution on the hypercube with polynomial density function of fixed degree, say r, so that the expected value of the polynomial is minimized. The expected value then gives an upper bound on the minimum value, depending on the value of r. We will show a convergence rate for these upper bounds of $O(1/r^2)$. The convergence rate analysis relies on the theory of polynomial kernels, and in particular on Jackson kernels. We also show that the resulting upper bounds may be computed as generalized eigenvalue problems.

2. **Real Eigenvalues of Nonsymmetric Tensors**

   Xinzhen Zhang (xzzhang@tju.edu.cn) Tianjin University, China, *Jiawang Nie*

This talk discusses the computation of real Z-eigenvalues of nonsymmetric tensors. A general nonsymmetric tensor has finitely many Z-eigenvalues, while there may be infinitely many ones for special tensors. We propose Lasserre type semidefinite relaxation methods for computing such eigenvalues. For every nonsymmetric tensor that has finitely many real Z-eigenvalues, we can compute all of them; each of them can be computed by solving a finite sequence of semidefinite relaxations. Various examples are presented.

3. **A Multilevel Method for Semidefinite Programming Relaxations of Polynomial Optimization Problems with Structured Sparsity**

   Panos Parpas (p.parpas@imperial.ac.uk) Imperial College London, United Kingdom

We propose a multilevel paradigm for the global optimisation of polynomials with sparse support. Such polynomials arise through the discretisation of PDEs, optimal control problems and in global optimization applications in general. We construct projection operators to relate the primal and dual variables of the SDP relaxation between lower and higher levels in the hierarchy, and theoretical results are proven to confirm their usefulness. Numerical results are presented for polynomial problems that show how these operators can be used in a hierarchical fashion to solve large scale problems with high accuracy.

■ Mon.A.m3S

Monday, 10:45-12:00, Room m3S

Sparse Optimization and Applications

Cluster: Sparse Optimization and Information Processing
Session organized by: *Coralia Cartis*
Session chair: *Raphael A Hauser*

1. **Submodular Functions: From Discrete to Continous Domains**

   Francis Bach (francis.bach@ens.fr) INRIA - Ecole Normale Supérieure, France

Submodular set-functions have many applications in combinatorial optimization, as they can be minimized and approximately maximized in polynomial time. A key element in many of the algorithms and analyses is the possibility of extending the submodular set-function to a convex function, which opens up tools from convex optimization. Submodularity goes beyond set-functions and has naturally been considered for problems with multiple labels or for functions defined on continuous domains, where it corresponds essentially to cross second-derivatives being nonpositive. In this talk, we show that most results relating submodularity and convexity for set-functions can be extended to all submodular functions. In particular, we naturally define a continuous extension in a set of probability measures, show that the extension is convex if and only if the original function is submodular, and prove that the problem of minimizing a submodular function is equivalent to a typically non-smooth convex optimization problem. Most of these extensions from the set-function situation are obtained by drawing links with the theory of multi-marginal optimal transport, which provides also a new interpretation of existing results for set-functions. Applications to sparse proximal operators will be presented. (available at https://hal.archives-ouvertes.fr/hal-01222319v2/document)

2. **Learning Directed Acyclic Graphs Based on Sparsest Permutations**

   Caroline Uhler (cuhler@mit.edu) Massachusetts Institute of Technology, USA

We consider the problem of learning a Bayesian network or directed acyclic graph (DAG) model from observational data. We propose the sparsest permutation algorithm, a nonparametric approach based on finding the ordering of the variables that yields the sparsest DAG. We prove consistency of this method under strictly weaker conditions than usually required. We discuss how to find the sparsest ordering by introducing the DAG associahedron and a simplex-type algorithm on this convex polytope.

3. **A Link between DC Algorithms and Proximal Gradient Methods**

Katsuya Tono (katsuya_tono@mist.i.u-tokyo.ac.jp) The University of Tokyo, Japan, *Akiko Takeda, Jun-ya Gotoh*

Several nonconvex sparsity-inducing regularizers have been recently proposed in the context of sparse learning. Accordingly, nonconvex and nonsmooth optimization problems have appeared in many application areas. In this talk, we provide an efficient algorithm to deal with such optimization problems where the objective function is the sum of a smooth nonconvex function and a nonsmooth DC (Difference of Convex) function. While the DC algorithm has been widely used for this type of problems, it often requires a large computation time to solve a sequence of convex subproblems. Our algorithm, which we call the proximal DC algorithm (PDCA), overcomes this issue of the ordinary DC algorithm by employing a special DC decomposition of the objective function. In PDCA, closed-form solutions can be obtained for the convex subproblems, leading to efficient performance in numerical experiments. We also discuss the theoretical aspects: PDCA can be viewed as a nonconvex variant of the proximal gradient methods (PGM), which provides an insight on the relation between PGM and DC algorithms.

■ Mon.B.1S

Monday, 13:30-14:45, Room 1S

Nonlinear Optimization and Its Applications II

Cluster: Nonlinear Optimization
Session organized by: *Frank E Curtis*

1. **An Evolving Subspace Method for Low Rank Minimization**

Daniel P Robinson (daniel.p.robinson@gmail.com) Johns Hopkins University, USA

I present a method for solving low rank minimization problems that combines subspace minimization techniques, inexact subspace conditions to terminate exploration of the subspace, and inexact singular value decompositions. Taking together, these features allow the algorithm to scale well, and in fact be competitive with nonconvex approaches that are often used. Convergence results are discussed and preliminary numerical experiments are provided.

2. **Convergence Rate of a Trust Region Method for Stochastic Nonconvex Optimization**

Katya Scheinberg (katyascheinberg@gmail.com) Lehigh University, USA, *Jose Blanchet, Coralia Cartis, Matt Menickelly*

We will discuss a classical variance reducing trust region method applied to the stochastic nonconvex smooth problems. We will present a convergence rate analysis which shows that canonical convergence rates can be achieved. The analysis is based on properties of a stopping time of supermartingales. We will discuss the conditions on the rate of variance reduction and its effect on the final result. We will also present some applications from machine learning.

3. **A Dynamic Penalty Parameter Updating Strategy for Matrix-free Sequential Quadratic Optimization Methods**

Hao Wang (wanghao1@shanghaitech.edu.cn) Shanghai Tech University, China, *James V Burke, Frank E Curtis, Jiashan Wang*

This talk focuses on the issue of updating the penalty parameter within a penalty Sequential Quadratic Optimization (SQO) algorithm for solving nonlinear optimization problems. In contemporary penalty SQO methods, the common strategy is to update the penalty parameter after a subproblem (or a sequence of them) has been solved. This may lead to inefficiency if the parameter is slow to adapt to the problem scaling or structure. By contrast, we propose an approach to update a penalty parameter during the optimization process for each subproblem, where the goal is to produce a search direction that simultaneously predicts progress towards feasibility and optimality. We prove that our approach yields reasonable (i.e., not excessively small) values of the penalty parameter and illustrate the behavior of our approach via numerical experiments.

■ Mon.B.1A

Monday, 13:30-14:45, Room 1A

Nonlinear Optimization Solvers

Cluster: Nonlinear Optimization
Session organized by: *Yinyu Ye, Oliver Hinder*

1. **A One Phase Interior Point Method for Non-convex Optimization**

Oliver H Hinder (ohinder@gmail.com) Stanford University, USA, *Yinyu Ye*

Interior point methods in convex optimization, such as the homogeneous algorithm or infeasible start algorithm, can efficiently find an optimal solution or prove infeasibility in one phase. However, in non-convex optimization these algorithms will not converge to a local minimizer of infeasibility. To date, there are two main approaches to solving this issue: a feasibility restoration phase (i.e. IPOPT) or a penalty method. We introduce a new one phase interior point method that is guaranteed to converge to either a local optimum or a local minimizer of the L_1 norm of the constraint violation. The basic idea of the algorithm is to add dummy variables and one constraint to precisely control the rate of L_1 constraint violation. Depending on the state of progress, the algorithm takes either an aggressive step, which simultaneously searches for optimality and feasibility, or a stabilization step, which searches for optimality (without reducing the constraint violation). We present early empirical testing on CUTEst and compare our performance with IPOPT and KNITRO.

2. **Inexact Sequential Quadratically Constrained Quadratic Programming Method of Feasible Directions with Global and Superlinear Convergence Properties**

Yu Watanabe (1415702@ed.tus.ac.jp) Tokyo University of Science, Japan, *Satoshi Nakatani, Hiroshi Yabe*

We consider the sequential quadratically constrained quadratic programming (SQCQP) method for nonlinear inequality constrained optimization problems. The sequential quadratic programing (SQP) method is one of effective numerical methods for solving these problems. However it is known that the Maratos effect may occur in the SQP method. This phenomenon is that a unit step size can not be always accepted near an optimal solution. In order to overcome this defect, the SQCQP method was focused on. The SQCQP method solves the quadratically constrained quadratic programming (QCQP) subproblem at each iteration. The QCQP subproblem can not always have optimal solutions. Jian gave the SQCQP method of feasible directions in which subproblem was always solvable. Based on the idea of Jian, we propose an inexact SQCQP method that solves the QCQP subproblem inexactly at each iteration. Since QCQP subproblem is usually solved by iterative methods, they are not solved exactly. Therefore, it is significant to consider the inexact SQCQP method. In this study, we prove its global and superlinear convergence properties.

3. **Shape-changing L-SR1 Trust-Region Methods**

Roummel Marcia (rmarcia@ucmerced.edu) University of California, Merced, USA, *Johannes Brust, Oleg Burdakov, Jennifer Erway, Ya-xing Yuan*

In this talk, we discuss methods for solving the trust-region subproblem when a limited-memory symmetric rank-one matrix is used in place of the true Hessian matrix. In particular, we propose methods that exploits two shape-changing norms to decompose the trust-region subproblem into two separate problems. The proposed solver makes use of the structure of limited-memory symmetric rank-one matrices to find solutions that satisfy these optimality conditions.

■ Mon.B.1B

Monday, 13:30-14:45, Room 1B

Advances in PDE-constrained Optimization I

Cluster: PDE-constrained Optimization
Session organized by: *Kazufumi Ito, Michael Ulbrich*

1. **Optimization for Design and Control of Composite Thermal Fluid Systems**

John Allen Burns (jaburns@vt.edu) Virginia Tech, USA

In this paper we consider optimization problems for design and control of composite infinite dimensional systems. These systems arise naturally when the problem is multidisciplinary (e.g., aero-elasticity, thermal-fluids) but also occur when actuator dynamics are included in the control design problem. We present examples to highlight some technical issues that occur when dealing with interconnected systems and then focus on a special class of composite systems that occur when actuator dynamics are included as part of the model. Numerical examples are presented to illustrate the theoretical results. Finally, we suggest some new application areas that offer enormous opportunities for researchers interested in distributed parameter control.

2. **Sensitivity Analysis for Elliptic Variational Inequalities of the Second Kind: A Model Problem and Applications in Optimal Control**

Constantin Christof (constantin.christof@tu-dortmund.de) TU Dortmund, Germany, *Christian Meyer*

This talk is concerned with the sensitivity analysis that is needed for the study of optimal control problems governed by elliptic variational inequalities of the second kind. We demonstrate by means of a prototypical example how to prove directional differentiability for the solution map of a variational inequality of the second kind, how to compute directional derivatives of the solution operator and how to identify points where the Gâteaux derivative exists. Our findings are compared with classical results of F. Mignot and A. Shapiro. The talk concludes with a discussion of the consequences that our analysis has for the derivation of stationarity conditions and the numerical treatment of optimal control problems governed by variational inequalities of the second kind.

3. **Optimal Control of Hyperbolic Balance Laws with State Constraints**

Johann Michael Schmitt (jschmitt@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

This talk deals with the treatment of pointwise state constraints in the context of optimal control of hyperbolic nonlinear scalar balance laws. We study an optimal control problem governed by balance laws with an off/on switching device that allows to interrupt the flux, where the switching times between on- and off-modes are the control variables. Such a problem arises, for example, when considering the optimal control of the traffic density on a one-way street with a traffic light in the middle. The appearance of state constraints presents a special challenge, since solutions of nonlinear hyperbolic balance laws develop discontinuities after finite time. In this talk, we will therefore mainly focus on their treatment and use the recently developed sensitivity- and adjoint calculus by Pfaff and Ulbrich to derive necessary optimality conditions. In addition, we will use Moreau-Yosida regularization for the algorithmic treatment of the pointwise state constraints. Hereby, we will prove convergence of the optimal controls and weak convergence of the corresponding Lagrange multiplier estimates of the regularized problems.

■ Mon.B.1C

Monday, 13:30-14:45, Room 1C

Computational and Algorithmic Aspects of Derivative-free Optimization

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Sebastien Le Digabel*

1. **Improved Sampling for Two-Stage Methods**

Simon Wessing (simon.wessing@tu-dortmund.de) Technische Universität Dortmund, Germany

In this work, we apply two-stage optimization algorithms, which consist of alternating global and local searches, to essentially unconstrained global optimization problems. These algorithms are attractive because of their simplicity and their demonstrated performance on multimodal problems. The main focus is on improving the global stages, as local search is already a thoroughly investigated topic. This is done by considering previously sampled points and found optima in the global sampling, thus obtaining a super-uniform distribution. The approach is based on maximizing the minimal distance in a point set, while boundary effects of the box-constrained search space are avoided by correction methods. Experiments confirm the superiority of this algorithm over random uniform sampling and other methods on benchmark problems.

2. **Benchmarking Bi-Objective Derivative-free Optimizers with COCO**

Dimo Brockhoff (dimo.brockhoff@inria.fr) INRIA, France

Numerical optimization problems are at the core of many industrial design and development tasks. Often, multiple (conflicting) objective functions (such as cost and energy consumption) have to be optimized and the functions are non-differentiable, non-convex, multimodal, noisy, or not mathematically tractable. Multi-objective black-box optimizers, also called derivative-free vector optimization algorithms, are the methods of choice in such cases because they interpret problems as black-boxes and only use the function value vectors of some query points. Algorithm benchmarking is the mandatory but also a tedious (because repetitive) path when designing and recommending efficient and robust algorithms. The Comparing Continuous Optimizers platform (COCO) aims at automatizing this benchmarking in the case of numerical black-box problems—freeing the time of algorithm designers and practitioners alike. In 2016, the first bi-objective test suite became available within COCO which now allows to automatically benchmark optimizers for problems with two objectives for the first time. In this talk, we will see, in a tutorial-like style, how to use the COCO software and how to interpret its main plots when comparing algorithm performance. We will also present benchmarking results that have been collected for the first Bi-objective Black-box Optimization Benchmarking workshop (BBOB-2016)

3. **The Mesh Adaptive Direct Search Algorithm for Discrete Blackbox Optimization**

Sébastien Le Digabel (sebastien.le.digabel@gerad.ca) École Polytechnique de Montréal, Canada, *Charles Audet, Christophe Tribes*

The Mesh Adaptive Direct Search (MADS) algorithm is designed for blackbox optimization problems where the functions defining the objective and the constraints are typically the outputs of a simulation. It is a derivative-free method designed for continuous variables and which is supported by a convergence analysis based on the Clarke calculus. This talk introduces a modification of the MADS algorithm for the handling of variables with a controlled number of decimals. A corollary of this approach is the ability to treat discrete variables. Computational results are presented using the NOMAD software, the free C++ distribution of the MADS algorithm.

■ Mon.B.4A

Monday, 13:30-14:45, Room 4A

Energy Systems and Markets

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Asgeir Tomasgard*
Session chair: *Chiara Bordin*

1. **Nonsmooth Equations Approach to the Real-Time Pricing for Smart Grid**

Yan Gao (gaoyan@usst.edu.cn) University of Shanghai for Science and Technology, China, *Hongjie Wang*

Smart grid is an electricity delivery system enhanced with communication facilities and information technologies. According to the real-time price, the users can improve the insulation conditions and try to shift the energy consumption schedule of their high-load household appliances to off-peak hours to achieving optimal allocation of resources. In this paper, we mainly research the real-time pricing under the social utility maximization in smart grid. We adopt the utility function to reflect consumer's preferences and spending power, and set up the social utility model. We discuss the properties of the social utility model and adopt the shadow price as real-time price. In existing researches, dual method are used to solving this problem. But this method usually need to solve a series of unconstrained minimization problem, so the amount of computation is huge. According to KKT conditions, we set up a nonsmooth equations based on social utility model firstly. Then, we propose a new smooth approximating function based on the complementary theory which is more suitable to real-time pricing problem. The nonsmooth equations are shifted to smooth ones. The smooth equations is solved by quasi-Newton method. It is showed that the present is effective by the simulation.

2. **An Energy Storage Deployment Program under Random Discharge Permissions**

Somayeh Moazeni (smoazeni@stevens.edu) Stevens Institute of Technology, USA, *Boris Defourny*

Recent developments in energy storage technology and the greater use of renewables have increased interest in energy storage. This interest has created the need to design and study efficient energy storage deployment programs, with the goal of providing attractive flexibility to storage owners while still indirectly supervising their operations. We envision a framework that defines random times at which a particular participating storage unit is allowed to discharge. In this flexible energy storage deployment program, a participating storage unit receives permissions at random to discharge during peak hours in real time. Should discharge permission be issued, the storage owner has the option to discharge and be paid at a time-dependent reward that is specified contractually, or can wait for future permissions. A Poisson process models the discharge permission times. We study the problem of optimizing discharge operations from the perspective of the storage resource owner.

3. **Smart Charging of Electric Vehicles through Indirect Control and Smart Price Signals**

Chiara Bordin (chiara.bordin@iot.ntnu.no) Norwegian University of Science and Technology, Norway, *Stig Ødegaard Ottesen, Asgeir*

Tomasgard, Siri Bruskeland Ager-Hanssen, Siri Olimb Myhre

The increasing demand for Electric Vehicles (EV) charging puts pressure on the power grids and highlights the necessity to level out the load curve in order to avoid that the power consumption exceeds the grid capacity. We propose a linear programming model for the indirect control of EV charging that finds an optimal set of price signals to be sent to the drivers according to their flexibility. The objective is to satisfy the demand when there is a capacity lack by minimizing the curtailment of loads and prioritizing the loads shifting. The key contribution is the use of elasticity matrices through which it is possible to forecast the drivers reactions to the price signals. As real world data on relating the elasticity values to the EV drivers behaviour are currently inexistent, we concentrate on investigating the sensitivity of elasticity patterns to the optimal price structure. In particular, we study how different combinations of drivers with different elasticity may affect the ability of the operator to both handle a capacity problem and properly satisfy the charging needs. When a capacity problem arises we investigate in which conditions load shifting is not enough and curtailment becomes a necessity.

■ Mon.B.4B

Monday, 13:30-14:45, Room 4B

Optimization in Healthcare

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Nedialko Dimitrov*

1. **Cyber Defense Based on Network Structure**

Murat Karatas (mkaratas@utexas.edu) The University of Texas at Austin, USA, *Nedialko Dimitrov*

Infrastructures, such as university nuclear reactors, are controlled through cyber-physical systems. Recent attacks on government offices and foreign consulates showed that assessing the vulnerability of these systems is key in directing defensive investment. We present an MDP to compute an optimal attack policy. The MDP has an exponential number of states, and is based on tracking the set of available attacks for each link in the network. We show that it is possible to compute values for each MDP state, and optimal attack policies using s-t reliability. We also show that finding an optimal defensive investment strategy is a network interdiction model. Such a policy can be calculated using a direct and a simulation approach. The example we use includes a company network with 20 nodes and 25 edges.

2. **Personalized Measurement Time Points by Optimum Experimental Design for Mathematical Leukopenia Models**

Felix Jost (felix.jost@ovgu.de) Otto-von-Guericke University Magdeburg, Germany, *Kristine Rinke, Thomas Fischer, Enrico Schalk, Sebastian Sager*

In this talk we present and discuss the optimization of measurement time points by optimal experimental design for patient specific parameter estimation. The standard deviations of the parameter estimates depend strongly on the timing of the measurements. The underlying mathematical model describes the dynamics of leukocytes of patients having acute myeloid leukemia. The model is used to investigate Leukopenia which is a clinically important side effect arising from the treatment with chemotherapy. The dynamics of leukocytes are modelled by ordinary differential equations and the chemotherapy with cytarabin is described by a pharmacokinetics/pharmacodynamics model consisting of two compartments and a log-linear function representing the drug effect. The disease progression differs for each patient, so that the mathematical model is fitted individually to experimental data which results in patient-specific sets of parameters. The different dynamics of the leukocytes also result in personalized measurement time points which provide maximal information about the model parameters. Consequently, the individually optimized designs are superior to the usual designs chosen by the physician's experience. We discuss integer and relaxed solutions of the mathematical optimization problems providing optimal experimental designs and analyze their relation.

3. **Texas Arbovirus Risk Maps and Uncertainty Analysis**

Xi Chen (carol.chen@utexas.edu) University of Texas at Austin, USA, *Nedialko Dimitrov*

Arbovirus diseases are a major public health concern in Texas. Two viruses that have not yet established local transmission but may pose a threat are dengue virus and chikungunya. Both of these viruses are consistently imported into Texas and have seen an increase in the number of cases over the past few years. We introduce a county-level risk assessment framework for identifying areas that may be at high risk for importation of these arboviruses. Human importation risk is estimated using a maximum entropy algorithm, based on historical dengue case data, socioeconomic, demographic, and bio-climatic data. A significant reason for the popularity of the maximum entropy methodology is its applicability to presence-only data. To address the uncertainty quantification in the point estimation of maximum entropy model, we analytically deriving an expression of the variance of the target species distribution probabilities and comparing the results with bootstrap methods.

■ Mon.B.5D

Monday, 13:30-14:45, Room 5D

Optimization over Symmetric Cones and Related Topics

Cluster: Linear Optimization
Session organized by: *Leonid Faybusovich*

1. **Primal-Dual Algorithms for Infinite-dimensional Second-Order Cone Programming Problems and LQ-Problem with Time Dependent Linear Term in the Cost Function**

Thanasak Mouktonglang (mouktonglang.thanasak@gmail.com) Chiang Mai University, Thailand, *Leonid Faybusovich*

In this paper, we consider a tracking problem in a general Hilbert space. It is shown that the problem can be rewritten as an infinite dimension second order cone programming problem which can be solved by a primal-dual algorithm of infinite-dimensional second-order cone problem. We then consider Muti-Criteria Linear-Quadratic Control problem (MCLQP). The problem consists of a minimization of several maximum quadratic functions. For a decent direction, it turns out that solving a number of Linear-Quadratic problems (LQ-problem) with time dependent linear term in the cost function is required. We prove the existence and uniqueness of the solution of the LQ-problem with time dependent linear term the cost function and describe the solution explicitly. We consider applications to deterministic version of Kalman filtering and multi-target LQ control problem on semi-infinite interval.

2. **Incremental Gradient Method for Karcher Mean on Symmetric Cones**

Sangho Kum (shkum@cbnu.ac.kr) Chungbuk National University, Korea, *Sangwoon Yun*

In this talk, we deal with the minimization problem for computing Karcher mean on a symmetric cone. The objective of this minimization problem consists of the sum of the Riemannian metric distances with many given points in a symmetric cone. Moreover, the problem can be reduced to a bound constrained minimization problem. These motivate us to adapt an incremental gradient method. So we propose an incremental gradient method and establish its global convergence properties exploiting the Lipschitz continuity of the gradient of the Riemannian metric distance function.

3. **FRA-Poly: Partial Polyhedrality and Facial Reduction**

Bruno Figueira Lourenço (lourenco@st.seikei.ac.jp) Seikei University, Japan, *Masakazu Muramatsu, Takashi Tsuchiya*

Facial reduction is a procedure that aims at restoring Slater's condition in conic linear programs. Each step consists of obtaining a supporting hyperplane that contains the feasible region of the problem, in hopes of confining the problem to a smaller face of the underlying cone. Then, it is of paramount importance to bound the number of steps necessary to finish the procedure, since each step is very costly. In this talk, we discuss FRA-poly, a facial reduction algorithm that explores polyhedrality in the lattice of faces of the cone. Under mild assumptions, the worst case number of steps is smaller than the amount predicted by the classical facial reduction analysis. In particular, a significant improvement is obtained for the case of the doubly nonnegative cone, where the complexity decreases from quadratic to linear. We will also examine the performance of FRA-Poly in the symmetric cone case.

■ Mon.B.5E

Monday, 13:30-14:45, Room 5E

Robust Optimization in Data and Signal Processing

Cluster: Robust Optimization
Session organized by: *Anthony Man-Cho So*

1. **On Reduced Semidefinite Programs for Second Order Moment Bounds with Applications**

Karthik Natarajan (karthik_natarajan@sutd.edu.sg) Singapore University of Technology and Design, Singapore, *Chung Piaw Teo*

We show that the complexity of computing the second order moment bound on the expected optimal value of a mixed integer linear program with a random objective coecient vector is closely related to the complexity of characterizing the convex hull of the points $(1\ x)(1\ x)'$ for x in X where X is the feasible region. As an application of the result, we identify a new polynomial time solvable semidefinite relaxation of the distributionally robust multi-item newsvendor problem by exploiting results from the Boolean quadric polytope. We illustrate the usefulness of the reduced semide nite programming bounds in estimating the expected range of random variables with two applications arising in random walks and best-worst choice models.

2. **Semidefinite Relaxation of a Class of Robust QCQPs: A Verifiable Sufficient Condition for Rank-One Solutions**

   Wing Kin Ma (wkma@ee.cuhk.edu.hk) The Chinese University of Hong Kong, Hong Kong, *Anthony Man-Cho So*

This talk will concentrate on a specific robust quadratically-constrained quadratic program (QCQP) that arises in the context of signal processing and communications, namely, quality-of-service constrained optimization for multiuser downlink transmit beamforming. The problem takes a separable QCQP form where we have worst-case robust quadratic constraints under spherically bounded uncertainties. In previous work, this problem was tackled by semidefinite relaxation (SDR). Curiously, simulation results have suggested that the SDR problem admits rank-one solutions—or exactly solves the robust QCQP—in most instances. This gives rise to an important question, namely, whether we can identify sufficient conditions under which SDR admits a rank-one solution. This talk will present one such condition, proven by the speaker and his collaborators recently. Simply speaking, the condition indicates that if the uncertainty sphere radii are not too large and the nominal multiuser channel is not too poorly conditioned, then any solution to the SDR problem must have rank one. The aforementioned condition appears as a simple verifiable expression with respect to the problem instance. As will be further described in the talk, the key insight lies in establishing a duality framework through which an equivalence relationship between SDR and a related maximin semidefinite program is revealed.

3. **Epsilon-Net Techniques for a Class of Uncertain Quadratic Programming and Its Applications in Robust Beamforming with Cognitive Radio Constraints**

   Man-Chung Yue (mcyue214@gmail.com) The Chinese University of Hong Kong, Hong Kong, *Xiaoxiao Wu, Wing-Kin Ma, Anthony Man-Cho So*

We consider quadratic optimization subject to multiple uncertain quadratic constraints, where the positive semidefinite matrices defining the constraints are of rank-one and each of them is the outer product of some unknown vector lying a ball. Problems of this form often arise in field of wireless communication. A standard approach to this class of quadratic programming is the semidefinite relaxation followed a Gaussian randomization. In this work, we study the relative accuracy of this approximation scheme. In particular, we establish probabilistic bounds on the relative accuracy using the epsilon-net arguments, a technique from geometric functional analysis. We also discuss an application of the result to the problem of robust beamforming with cognitive radio constraint.

■ Mon.B.5F

Monday, 13:30-14:45, Room 5F

Recent Advances on Convergence Rates of First-Order Methods: Part II

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Quoc Tran-Dinh, Ion Necoara*

1. **Limited-Memory Trust-Region Methods for Sparse Reconstruction**

   Lasith Adhikari (ladhikari@ucmerced.edu) University of California, Merced, USA, *Jennifer Erway, Shelby Lockhart, Roummel Marcia*

In this talk, we solve the L_2-L_1 sparse reconstruction problem using trust-region methods. Specifically, we transform the minimization problem into an unconstrained differentiable problem and use a limited-memory BFGS approximation to the Hessian to define a sequence of trust-region subproblems. We perform numerical experiments to show that the proposed approach accurately recovers the true signal and eliminates spurious solutions more effectively and efficiently than competing gradient projection-type methods.

2. **Non-asymptotic Convergence Rate for Distributed Learning in Graphs**

   Cesar A Uribe (cauribe2@illinois.edu) University of Illinois at Urbana-Champaign, USA, *Alexander Olshevsky, Cesar M Uribe*

We will consider the problem of distributed cooperative learning in a network of agents, where the agents are repeatedly gaining partial information about an unknown random variable whose distribution is to be jointly estimated. The learning is based on Bayesian update adapted to distributed information structure inherited from the network. Our results establish consistency and a non-asymptotic, explicit, geometric convergence rate for the learning dynamics.

3. **Adaptive Smoothing Fast Gradient Methods for Fully Nonsmooth Composite Convex Optimization**

   Quoc Tran-Dinh (quoctd@email.unc.edu) University of North Carolina at Chapel Hill, USA

We propose an adaptive smoothing fast-gradient algorithm based on Nesterov's smoothing technique for solving fully nonsmooth composite convex optimization problems. Our method combines both Nesterov's accelerated proximal gradient scheme and a new homotopy strategy for smoothness parameter. By an appropriate choice of smoothing functions, we develop new algorithms that have up to the $O(1/k)$-convergence rate while allow one to automatically update the smoothness parameter at each iteration. Then, we further exploit the structure of problems to select smoothing functions and develop suitable algorithmic variants that reduce the complexity-per-iteration. We also specify our algorithm to solve constrained convex problems and show its convergence guarantee on a primal sequence of iterates. We demonstrate our algorithm through three numerical examples and compare it with other algorithms.

■ Mon.B.5H

Monday, 13:30-14:45, Room 5H

Optimization in Finance

Cluster: Nonlinear Optimization

Session organized by: *Martin Takac*

1. **Continuous Selections of Optimal Portfolios**

   Michel Baes (michel.baes@math.uzh.ch) University of Zurich, Switzerland, *Pablo Koch, Cosimo Munari*

Financial institutions are required by regulators to hold an adequate capital buffer (e.g. cash money) to protect policyholders from default risk. Often the theory of risk measures implicitly assumes that this capital is invested in a single eligible asset. However, this is too restrictive and will typically not be efficient, particularly if an institution has assets and liabilities in several currencies. In the context of multiple eligible assets, we are confronted with several questions that are critical from an operational perspective. Three of them are: 1. What is the set of optimal portfolios? 2. Is there a unique optimal portfolio? 3. If several optimal portfolios exist, how robust is the choice of a specific portfolio? I particular, can we select one that is continuous with respect to the capital position of the institution? We present complete answers for these questions for convex risk measures, polyhedral risk measures, and for Value-at-Risk. Since these three classes of problems are structurally very different, we had to develop for each of them a proper set of mathematical tools and techniques.

2. **A Hybrid Approach for Tracking the $1/N$ Portfolio**

   Norbert Trautmann (norbert.trautmann@pqm.unibe.ch) University of Bern, Switzerland, *Oliver Strub*

The $1/N$ portfolio represents a naïve diversification strategy which is applied in practice and has been widely discussed in the literature. An investor who follows this strategy should invest in all N assets from a given investment universe, which, in general, incorporates substantial portfolio-management costs due to the large number of assets. We consider the problem of constructing a tracking portfolio, i.e., a portfolio consisting of far less than N assets, to track the returns of the $1/N$ portfolio. This problem can be formulated as a mixed-integer quadratic program, which, however, gets computationally expensive when N grows large. Therefore, we propose a hybrid approach that combines an iterated greedy heuristic for selecting the assets to be included in the tracking portfolio and a quadratic program for determining the weights of these assets. In an experimental performance analysis, we defined the constituents of various stock market indices as investment universes. We applied a commercial standard solver to the mixed-integer quadratic programming formulation, and compared the results obtained to those obtained by the novel hybrid approach. It turns out that the hybrid approach performs advantageously in terms of tracking accuracy and of CPU time.

3. **On the Dependency among Asian Currency Exchange Rates under the Influence of Financial Tsunami**

   YiKuan Jong (ykjong@mail.sju.edu.tw) St. John's University, Taiwan

Due to the development of internet, the information of currency exchange rates update almost instantly. Modeling the dependence between currency exchange rates is a way to understand the change of relation between them. For financial time series, linear structure is often not sufficient to model the dependency between the log returns of two exchange rates. Therefore, we try use the t-distribution to model the marginal distributions of log-returns and the Clayton Copula to model the dependency between log-returns of exchange rates The pair dependent structure between Taiwan Dollar (TWD) and other Asian currency exchange rates against US. dollars before and after the Financial Tsunami has been studied. Evidence shows that dependency of different pairs of log-return for currency exchange rates varies. Dependence of currency exchange rates showed more correlated after the Financial Tsunami.

■ Mon.B.5I

Monday, 13:30-14:45, Room 5I

Theoretical and Computational Aspects of Conic Programs

Cluster: Conic and Polynomial Optimization

Session organized by: *Makoto Yamashita, Mituhiro Fukuda*

1. **Second-Order Conditions for Nonlinear Semidefinite Optimization Problems via Slack Variables Approach**

   Ellen Hidemi Fukuda (ellen@i.kyoto-u.ac.jp) Kyoto University, Japan, *Bruno Figueira Lourenço, Masao Fukushima*

Comparing to the usual nonlinear optimization case, the second-order optimality conditions for nonlinear semidefinite optimization problems are more complex, because they involve extra terms associated to the curvature of the cone. As an alternative way for obtaining such optimality conditions, we propose the use of squared slack variables, which reformulate the original conic problem into an ordinary nonlinear programming problem. Although the original and the reformulated problems are equivalent in terms of optimal points, the relation between their stationary or Karush-Kuhn-Tucker points is less clear. In order to derive the second-order conditions, we first analyze such relation. Then, we will show that the second-order conditions of these problems are essentially the same, under appropriate regularity conditions.

2. **Some Tractable Subcones for Testing Copositivity**

   Akihiro Tanaka (tanaka.akihiro@sk.tsukuba.ac.jp) University of Tsukuba, Japan, *Akiko Yoshise*

The authors in previous papers devised certain subcones of the copositive cone and showed that one can detect whether a given matrix belongs to each of them by solving linear optimization problems. They also devised LP-based algorithms for testing copositivity using the subcones. Among others, they introduced a semidefinite basis that is a basis of the space of symmetric matrices consisting of rank-1 semidefinite matrices. In this talk, we will show that how the semidefinite basis can be used for constructing tractable subcones and examine the efficiency of those subcones for testing copositivity.

3. **An Iterative Method using Boundary Distance for Box-constrained Nonlinear Semidefinite Programs**

   Makoto Yamashita (Makoto.Yamashita@is.titech.ac.jp) Tokyo Institute of Technology, Japan, *Akihiko Komatsu*

In this talk, we propose an iterative method to minimize a nonlinear objective function on a symmetric matrix over a box-type constraint in which the eigenvalues of the variable matrix are restricted to the interval [0, 1]. Though this optimization problem is one of simple nonlinear semidefinite programming problems, the size of the variable matrix that can be solved with a penalty barrier method is at most only 500. The proposed method uses a quadratic approximation function to obtain a search direction, then computes a step length determined by a radius in a similar way to the trust-region methods. The separation of the computation of the search direction and that of the step length enables us to handle large variable matrices whose sizes are more than 5000. We also give a global convergence of the proposed method to a first-order optimality point. In addition. We verified through numerical tests that the computation time of the proposed method is faster than a feasible direction method and the penalty barrier method.

■ Mon.B.5K

Monday, 13:30-14:45, Room 5K

Conic and Integer Conic Optimization

Cluster: Conic and Polynomial Optimization

Session organized by: *Tamás Terlaky, Miguel Anjos, Julio César Góez*

1. **BiqCrunch: Solving Binary Quadratic Problems Efficiently using Semidefinite Optimization**

   Nathan Krislock (nkrislock@niu.edu) Northern Illinois University, USA, *Jérôme Malick, Frédéric Roupin*

BiqCrunch is a branch-and-bound solver that uses semidefinite optimization to compute high-quality bounds to many difficult (in fact, NP-hard) combinatorial optimization problems that can be modeled as binary quadratic problems, such as MaxCut, Max-*k*-Cluster, Maximum-Independent-Set, the Exact Quadratic Knapsack Problem, and the Quadratic Assignment Problem. BiqCrunch does not use an interior-point method for computing its bounds. Instead, an eigenvalue solver and a quasi-Newton method are used to efficiently compute tight bounds. We will discuss our bounding procedure and give an update on the new features and performance enhancements of the latest version of BiqCrunch.

2. **On a Semidefinite Relaxation for the Sparse Linear Regression Problem**

   Hongbo Dong (hongbo.dong@wsu.edu) Washington State University, USA

We consider stronger convex relaxations for the sparse linear regression problem. In a recent work it has been shown that some piecewise quadratic concave penalty functions, including the minimax concave penalty (MCP) used in statistical community for variable selection, can be derived by using perspective relaxations. A related minimax problem providing tightest relaxation (in terms of lower bounds for the L_2-L_0 problem) can be solved by a semidefinite relaxation. In this subsequent work we derive sufficient conditions on the signal-noise ratio that guarantee high-probability exact support recovery of sparse signals. We compare our new condition with similar ones that were derived for the convex case of MCP, and show that our sufficient condition can be arbitrarily weaker. We further consider the heuristics by solving low-rank approximations for the semidefinite relaxation and report our numerical findings.

3. **Disjunctive Conic Cuts for Mixed Integer Second Order Cone Optimization**

   Julio Cesar Goez (julio.goez@nhh.no) Norwegian School of Economics, Norway, *Pietro Belotti, Imre Polik, Ted Ralphs, Tamás Terlaky*

We investigate the derivation of disjunctive conic cuts for mixed integer second order cone optimization (MISOCO). These conic cuts characterize the convex hull of the intersection of a disjunctive set and the feasible set of a MISOCO problem. We present a full characterization of these inequalities when the disjunctive set considered is definned by parallel hyperplanes.

■ Mon.B.5L

Monday, 13:30-14:45, Room 5L

Moments, Positive Polynomials & Optimization: Part II

Cluster: Conic and Polynomial Optimization

Session organized by: *Jiawang Nie, Jean B Lasserre*

1. **LP Approximations to Polynomial Optimization Problems with Small Tree-Width**

   Gonzalo Munoz (gonzalo@ieor.columbia.edu) Columbia University, USA, *Daniel Bienstock*

We present a class of linear programming approximations for mixed-integer polynomial optimization problems that take advantage of structured sparsity in the constraints. In particular, we show that if the intersection graph of the constraints (obtained by creating a node per variable and an edge whenever two variables appear in a common constraint) has tree-width bounded by a constant, then for any arbitrary tolerance there is a linear programming formulation of polynomial size that approximates the problem. Via an additional reduction, we obtain a polynomial-time approximation scheme for the “AC-OPF” problem on graphs with bounded tree-width. This improves on a number of results in the literature, both from the perspective of formulation size and generality.

2. **Robust to Dynamics Optimization (RDO)**

   Amir A Ahmadi (a_a_a@princeton.edu) Princeton University, USA, *Oktay Gunluk*

We introduce a new type of robust optimization problems that we call “robust to dynamics optimization” (RDO). The input to an RDO problem is twofold: (i) a mathematical program (e.g., an LP, SDP, IP), and (ii) a dynamical system (e.g., a linear, nonlinear, discrete, or continuous dynamics). The objective is to maximize over the set of initial conditions that forever remain feasible under the dynamics. We initiate an algorithmic study of RDO and demonstrate tractability of some important cases.

3. **Error Bounds for Parametric Polynomial Systems with Applications to Higher-Order Stability Analysis and Convergence Rate**

Guoyin Li (g.li@unsw.edu.au) University of New South Wales, Australia, *B S Mordukhovich, T TA Nghia, T S Pham*

In this talk, we consider parametric inequality systems described by polynomial functions in finite dimensions, where state-dependent infinite parameter sets are given by finitely many polynomial inequalities and equalities. Such systems can be viewed, in particular, as solution sets to problems of generalized semi-infinite programming with polynomial data. Exploiting the imposed polynomial structure together with powerful tools of variational analysis and semialgebraic geometry, we establish an extension of the Lojasiewicz gradient inequality to the general nonsmooth class of supremum marginal functions as well as higher-order (Holder type) local error bounds results with explicitly calculated exponents. The obtained results are applied to higher-order quantitative stability analysis for various classes of optimization problems including generalized semi-infinite programming with polynomial data, optimization of real polynomials under polynomial matrix inequality constraints, and polynomial second-order cone programming. Other applications provide explicit convergence rate estimates for the cyclic projection algorithm to find common points of convex sets described by matrix polynomial inequalities and for the asymptotic convergence of trajectories of sub-gradient dynamical systems in semi-algebraic settings.

■ Mon.B.m3S

Monday, 13:30-14:45, Room m3S

Stochastic Optimization

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Francis Bach*

1. **Second-Order Optimization for Machine Learning in Linear Time**

Elad Hazan (ehazan@cs.princeton.edu) Princeton University, USA, *Naman Agarwal, Brian Bullins*

First-order stochastic methods are the state-of-the-art in large-scale machine learning optimization due to their extremely efficient per-iteration computational cost. Second-order methods, while able to provide faster convergence, have been much less explored due to the high cost of computing the second-order information. We will present a second-order stochastic method for optimization problems arising in machine learning that match the per-iteration cost of gradient descent, yet enjoy convergence properties of second-order optimization.

2. **Proximal Minimization by Incremental Surrogate Optimization (MISO)**

Julien Mairal (julien.mairal@inria.fr) INRIA, France, *Hongzhou Lin, Zaid Harchaoui*

We present an incremental algorithm for solving a large finite sum of strongly-convex smooth functions with a possibly non-smooth convex regularization term. The method achieves a linear convergence rate, which may be independent of the condition number of the problem when the sum is large enough, making it particularly well suited to big data problems arising in machine learning. This strategy can be interpreted as a duality-free variant of stochastic dual coordinate ascent (SDCA), with a different step-size and simpler optimality certificate. The construction is indeed purely primal and does not rely on duality. Last but not least, the algorithm may be accelerated in the sense of Nesterov, providing significant improvements when the problem is ill-conditioned. We illustrate the effectiveness of our approach on large-scale classification problems, where the method achieves competitive results with state-of-the-art solvers for support vector machines.

3. **An Optimal Randomized Incremental Gradient Method**

Guanghui Lan (george.lan@isye.gatech.edu) Georgia Institute of Technology, USA, *Yi Zhou*

We present a randomized incremental gradient method and show that this algorithm possesses unimprovable rate of convergence for convex optimization by deriving a lower complexity bound for a general class of randomized methods. We provide a natural game theoretic interpretation for this method as well as for the related Nesterov's optimal method. We also point out the situations when this randomized algorithm can outperform the deterministic optimal method.

■ Mon.B.m3AB

Monday, 13:30-14:45, Room m3AB

Set Optimization: Advances and Applications

Cluster: Multi-Objective and Vector Optimization
Session organized by: *Andreas H Hamel*

1. **Set-valued Variational Inequalities in Vector Optimization**

Carola Schrage (Carola.Schrage@unibz.it) Free University of Bozen, Italy, *Giovanni P Crespi, Andreas H Hamel, Matteo Rocca*

Variational inequalities of directional derivatives are widely used to solve vector optimization problems. Since the ordering in vector spaces generally lacks completeness, the introduced methods typically turn out to be somewhat awkward; Either, the derivatives attain ℓ_∞ values' which are defined in some way or other, or derivatives are defined as set-valued functions, thus the type of function under consideration is changed. We propose to follow a different approach by introducing the set-valued extension of a vector-valued function. Applying the Complete Lattice Approach to set-valued functions, we develop a coherent system of variational inequalities characterizing solutions to the set optimization problem, containing the vector optimization problem as a special case.

2. **Introducing Well-Posedness to Set-Optimization**

Giovanni Paolo Crespi (giovanni.crespi@uninsubria.it) Università degli studi dell'Insubria, Italy, *Andreas Hamel, Matteo Rocca, Carola Schrage*

Set-optimization provides a new look at Optimization problems involving set-valued objective functions. The approach allows to handle sets as elements in a (con-)linear space and to act mostly as with single-valued functions. Among other topics, well-posedness of an optimization problem can be addressed through these tools. In the process, we need to provide a suitable notion of approximate solution to a set-optimization problem that allows unveiling a new notion of well-posed set-optimization.

3. **The Fundamental Duality Formula in Convex Set Optimization**

Andreas H Hamel (andreas.hamel@unibz.it) Free University Bozen, Italy

To an enormous extend, convex duality is responsible for the success and applicability of (scalar) optimization theory. It even serves as blueprint for non-convex theories such as dc-programming and duality in combinatorial optimization. A similar success is foreseen for duality in set optimization based on the complete lattice approach which uses the so-called set relations as a tool for the construction of appropriate image spaces (of sets). The Fenchel-Moreau theorem along with a new version of the fundamental duality formula for set optimization will be presented along with applications in finance and economics. Moreover, the decades-old problem with duality in vector optimization will shown to be completely resolvable using the new approach.

■ Tue.A.1S

Tuesday, 10:30-11:45, Room 1S

Nonlinear Optimization Algorithms and Their Complexity II

Cluster: Nonlinear Optimization
Session organized by: *Philippe Toint*

1. **A Trust Region Algorithm with a Worst-Case Iteration Complexity of $O(\varepsilon^{-3/2})$ for Nonconvex Optimization**

Mohammadreza Samadi (mos213@lehigh.edu) Lehigh University, USA, *Frank E Curtis, Daniel P Robinson*

We present a trust region method for unconstrained nonconvex optimization that, in the worst-case, is able to drive the norm of the gradient of the objective below a prescribed threshold $\varepsilon > 0$ after at most $O(\varepsilon^{-3/2})$ iterations. Our work is inspired by the recently proposed Adaptive Regularisation framework using Cubics (i.e., the ARC algorithm), which attains the same worst-case complexity bound. Our algorithm is modeled after a traditional trust region algorithm, but employs modified step acceptance criteria and a novel trust region updating mechanism that allows it to achieve this desirable property. Importantly, our method also maintains standard global and fast local convergence guarantees. Numerical results are presented.

2. **Second-Order Optimality and (Sometimes) Beyond**

Philippe Toint (philippe.toint@unamur.be) University of Namur, Belgium, *Coralia Cartis, Nick Gould*

The talk will discuss optimality conditions for high-order criticality and consider algorithms whose purpose is to obtain approximate high-order critical points. The unconstrained, convexly-constrained and nonlinear equality constrained cases will be considered and worst-case complexity estimates presented for these cases. These estimates recover known results for the first- and second-order unconstrained cases. Limitations of the present approach(es) to numerical optimization will also be discussed in view of the presented results.

■ Tue.A.1A

Tuesday, 10:30-11:45, Room 1A

Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 1

Cluster: Nonlinear Optimization

Session organized by: *Ya-Feng Liu*

1. **Sparse Recovery via Nonconvex Optimization, with Application in Metagenomics**

   Simon Foucart (foucart@tamu.edu) Texas A&M University, USA

After reviewing some fundamental results on sparse recovery via ℓ_q-minimization with $q \leq 1$, we introduce the metagenomics problem of "community profiling". Using k-mer information, it essentially boils down to a sparse recovery problem with added nonnegativity constraints. We describe the ℓ_1-regularization that we selected and solved as a nonnegative least square problem when creating the software Quikr. Next, we discuss the corresponding ℓ_q-regularization with $q < 1$. We conclude by refining the optimization program with the replacement of the ℓ_q-quasinorm by the more meaningful notion of q-biodiversity.

2. **Penalty Methods for a Class of Non-Lipschitz Optimization Problems**

   Xiaojun Chen (maxjchen@polyu.edu.hk) The Hong Kong Polytechnic University, Hong Kong, *Zhaosong Lu, Ting Kei Pong*

We consider a class of constrained optimization problems with a possibly nonconvex non-Lipschitz objective and a convex feasible set being the intersection of a polyhedron and a possibly degenerated ellipsoid. Such a problem has a wide range of applications in data science, where the objective is used for inducing sparsity in the solutions while the constraint set models the noise tolerance and incorporates other prior information for data fitting. To solve this kind of constrained optimization problems, a common approach is the penalty method. However, there is little theory on exact penalization for problems with nonconvex and non-Lipschitz objective functions. In this paper, we study the existence of exact penalty parameters regarding local minimizers, stationary points and ε-minimizers under suitable assumptions. Moreover, we discuss a penalty method whose subproblems are solved via a nonmonotone proximal gradient method with a suitable update scheme for the penalty parameters, and prove the convergence of the algorithm to a KKT point of the constrained problem. Preliminary numerical results demonstrate the efficiency of the penalty method for finding sparse solutions of underdetermined linear systems.

3. **A Continuous DC Programming Approach to Nonlinear Mixed Integer Programs**

   Takayuki Okuno (t_okuno@rs.tus.ac.jp) Tokyo University of Science, Japan, *Yoshiko Ikebe*

In this talk, we consider a mixed integer nonconvex program (MINP). In particular, we restrict ourselves to the MINP whose objective function is a DC function. Based on a new technique proposed by T. Maehara, et al.(2015), we transform the MINP to a certain equivalent continuous DC program. For solving it, we propose a proximal point type DC algorithm. Under several mild assumptions, we prove that the sequence generated by the proposed method converges to some stationary point of the MINP.

■ Tue.A.1B

Tuesday, 10:30-11:45, Room 1B

Advances in PDE-constrained Optimization II

Cluster: PDE-constrained Optimization

Session organized by: *Michael Ulbrich, Kazufumi Ito*

1. **A Geometric Approach of Some Multitime Multiobjective Variational Problems**

   Ariana Pitea (arianapitea@yahoo.com) University Politehnica of Bucharest, Romania

In a geometric framework, some multitime multiobjective fractional variational problems of minimizing a vector of quotients of functionals subject to certain partial differential equations and/or inequations are studied by means of the parametric approach. Necessary and sufficient optimality conditions are established, by using generalized types of convexity. Also, multiobjective variational dual problems are introduced, and various types of duality results are stated.

2. **Optimal Control of Nonsmooth Semilinear Parabolic Equations**

   Livia Susu (liviasusu@yahoo.com) TU Dortmund, Germany, *Christian Meyer*

This talk is concerned with an optimal control problem governed by a semilinear, nonsmooth operator differential equation. The nonlinearity is locally Lipschitz-continuous and directionally differentiable, but not Gâteaux-differentiable. Two types of necessary optimality conditions are derived, the first one by means of regularization, the second one by using the directional differentiability of the control-to-state mapping. The talk ends with the application of the general results to a semilinear heat equation involving a general Lipschitz-continuous function.

3. **Mixed-Integer PDE-constrained Optimization**

   Sven Leyffer (leyffer@anl.gov) Argonne National Laboratory, USA, *Bart van Bloemen Waanders Pelin Cay Drew Kouri Anna Thuenen*

Many complex applications can be formulated as optimization problems constrained by partial differential equations (PDEs) with integer decision variables. Examples include the remediation of contaminated sites and the maximization of oil recovery; the design of next generation solar cells; the layout design of wind-farms; the design and control of gas networks; disaster recovery; and topology optimization. We will present emerging applications of mixed-integer PDE-constrained optimization, review existing approaches to solve these problems, and highlight the computational and mathematical challenges of this new class of challenging problems. We introduce a new set of benchmark problems for this class of problems, and present some early numerical experience using both mixed-integer nonlinear solvers and heuristic techniques.

■ Tue.A.1C

Tuesday, 10:30-11:45, Room 1C

Derivative-free Optimization Methods for Structured Problems

Cluster: Derivative-free and Simulation-based Optimization

Session organized by: *Francesco Rinaldi, Zaikun Zhang*

Session chair: *Stefan M Wild*

1. **A New DFO Algorithm for the Optimization of Partially Separable Functions**

   Laurent Dumas (laurent.dumas@uvsq.fr) Versailles University, France, *Didier Ding, Benjamin Marteau*

Many industrial problems involve optimizing a function without any knowledge of its derivative. To reduce the number of evaluations of this function, we can try to identify and exploit its particular structure. We present a derivative free algorithm adapted to partially separable functions. At each iteration of the algorithm, a quadratic interpolation model is computed in a dynamic trust region. Both the cost of the model update step and the cost of the interpolation set improvement step are designed to minimize the number of evaluations of the objective function. By exploiting a self-correcting property of the interpolation sets, we are able to propose a proof of the global convergence of our algorithm. To further validate our method, we performed some numerical tests that give some promising results.

2. **A Trust Region Method for Glass Box/Black Box Optimization**

   John Patrick Eason (jeason@andrew.cmu.edu) Carnegie Mellon University, USA, *Lorenz T Biegler*

Modern nonlinear programming solvers can efficiently handle very large scale optimization problems when accurate derivative information is available. However, black box or derivative free modeling components are often unavoidable in practice when the modeled phenomena may cross length and time scales. Here we consider the problem of hybrid glass box/black box optimization, where part of the system is described by black-box (simulation) models without derivative information, and the rest is described by equation oriented constraints. We propose an algorithm that combines ideas from SQP filter methods and derivative free trust region methods to solve this class of problems. The black box portion of the model is replaced by a sequence of reduced models in trust region subproblems. By carefully managing reduced model construction, the algorithm reduces the number of function calls to the (often expensive) black box; global convergence is also proved under mild assumptions. We further investigate methods to take advantage of the equation oriented information of the system to propagate optimality error from reduced model error. This information leads to more efficient control of reduced model construction and effective termination criteria.

3. **Model-based Methods for Composite Blackbox Optimization**

Stefan M Wild (wild@anl.gov) Argonne National Laboratory, USA, *Kamil Khan, Jeffrey Larson, Matt Menickelly*

We discuss model-based methods for solving nonlinear optimization problems where the objective function and/or some constraints depend on blackbox outputs from a numerical or physical simulation. We provide real applications where the composite function is nonsmooth, or even discontinuous, but using smooth models of the blackbox components can accelerate convergence to stationary points. Numerical results will identify benefits of the approach and opportunities for further development.

■ Tue.A.4A

Tuesday, 10:30-11:45, Room 4A

Dynamics and Optimal Control

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Jose Alberto Gomez*

1. **Multi-Objective Co-Design for Embedded Optimization-based Control**

Bulat Khusainov (b.khusainov@imperial.ac.uk) Imperial College London, United Kingdom, *Eric Colin Kerrigan, George Anthony Constantinides*

Model Predictive Controller (MPC) relies on solving an optimization problem at every sampling instant in order to derive the optimal input sequence based on a plant model. An MPC design problem often involves a number of tunable parameters that affect different design objectives. Conventional design approaches propose manual tuning of design parameters in order to improve the closed-loop cost function, while considering computational resources as a fixed constraint. We introduce a multi-objective formulation of an MPC design problem, which aims to identify Pareto optimal designs with the best performance-resources trade-offs. Our approach is based on Bayesian optimization and uses a hypervolume expected improvement measure which was recently proposed in the multi-objective optimization literature. The key features of our algorithm are: (1) simultaneous optimization of high-level algorithmic parameters (e.g. prediction horizon length) and low-level hardware design variables (e.g. data representation); (2) parallel evaluation of objective functions; (3) building separate feasibility model to eliminate infeasible designs on the early stages of design flow. A numerical example is presented for a field-programmable gate array implementation of a model predictive controller.

2. **Novel Computational Framework for the Numerical Solution of Constrained Optimal Control Problems**

Anil V Rao (anilvrao@gmail.com) University of Florida, USA

A novel computational framework is described for solving complex constrained nonlinear optimal control problems. The framework has a wide variety of applications in mechanical and aerospace engineering. The basis of the framework is the new class of hp-adaptive Gaussian quadrature methods that transcribe the continuous optimal control problem to a finite-dimensional nonlinear optimization problem. The hp-adaptive methods have the feature that high accuracy can be obtained with a significantly smaller mesh when compared with traditional fixed-order methods while accurately capturing nonsmoothness or rapidly changing behavior. The hp-adaptive methods employed using advanced sparse nonlinear programming (NLP) solvers. The derivatives required by the NLP solvers are obtained using a new approach to algorithmic differentiation where efficient derivative source code is produced through a method that combines operator overloading with source transformation. The mathematical foundation of the framework is provided and examples are given that demonstrate the improvement over previously developed approaches.

3. **Optimization of Dynamic Systems with Linear Programs Embedded and Its Application to Sustainable Biofuels Production**

Jose Alberto Gomez (jagomezr@mit.edu) Massachusetts Institute of Technology, USA, *Kai Höffner, Kamil A Khan, Paul I Barton*

Bioprocesses are challenging to model. With genome-scale metabolic network reconstructions of the microorganisms, reliable and predictive bioprocess models can be constructed using dynamic flux balance analysis. Dynamic flux balance analysis results in dynamic systems with linear programs embedded, which are nonsmooth. With lexicographic differentiation, sensitivities of dynamic flux balance analysis systems can be computed. Therefore, their optimization is possible using nonsmooth optimization algorithms. These ideas have been applied to a raceway pond system for biomass cultivation. Cellulosic sugars are fed to raceway ponds where heterotrophic and autotrophic microorganisms interact to convert the sugars and solar energy into lipids. This raceway pond system has been modeled using dynamic flux balance analysis, and has been optimized to maximize lipids production. This optimization problem yields an optimal design and operation of the raceway pond system. This framework can be used to discover cost-competitive biodiesel processes.

■ Tue.A.4B

Tuesday, 10:30-11:45, Room 4B

Financial Optimization and Robo Advisors 2

Cluster: Applications in Finance and Economics
Session organized by: *Gyun Jun*

1. **Goal Based Investment via Multi-Stage Stochastic Programming for Robo-Advisor Service — Part I: Modeling Issues**

Yongjae Lee (yongjae.lee@kaist.ac.kr) KAIST, Korea, *Woo Chang Kim, Do-gyun Kwon, Jang Ho Kim*

Robo-advisors, which denote recently developed online investment management or advisory services, aim to attract non high-net-worth individual investors by significantly lowering the entry barrier to professional wealth management industry. Unfortunately, existing schemes of robo-advisors have not been sophisticated enough to provide fully personalized investment advices, as these services make decisions based only on the online questionnaire on the user's risk appetite and high-level investment goals. However, it surely is challenging to ask clients, who might lack financial literacy, to provide their detailed financial situation through online platform. Therefore, we propose a goal-based investment model that only requires the input of wealth, income, and consumption goals with priorities. Note that all the inputs are non-arbitrary numbers that users can easily provide. The model employs multi-stage stochastic programming approach, while maintaining its linear programming problem structure. With its simplicity, flexibility, and computational efficiency, it could suggest a new paradigm change in the robo-advisor industry. Part I discusses the detailed problem structure of the proposed model, and Part II provides extensive numerical analyses to demonstrate its practical advantages.

2. **Goal Based Investment via Multi-Stage Stochastic Programming for Robo-Advisor Service — Part II: Implementation Issues**

Do-gyun Kwon (dogyun@kaist.ac.kr) KAIST, Korea, *Woo Chang Kim, Yongjae Lee, Jang Ho Kim*

In Part I, we proposed a goal-based investment model for robo-advisor service, which employs multi-stage stochastic programming approach. In order for an investment model to be actually implemented to provide automated financial advisory service, it should exhibit two important features. First, the input parameters for the model should be user-friendly, or equivalently, specific. As noted in Part I, our model does not require any arbitrary inputs; it only requires specific and intuitive inputs that users can easily figure out. Second, the model should at least support quasi-real-time interaction, as users should be able to see how their investment changes with respect to their inputs to the model. In Part II, therefore, we provide extensive numerical analyses on the model to demonstrate its computational efficiency. The analyses would further reveal its advantages from a practical standpoint, such as flexibility and expandability.

3. **Asian Perspective on 'Robo-Advisor': Case of Korean Market**

Gyun Jeon (jgrats@hotmail.com) Samsung Securities Co., Ltd., Korea

There is not an unified definition about robo-advisor but some common characters in robo-advisor; 1) structuring portfolio with several assets class, 2) managing portfolio based investing engine without human manager's judgment, 3) rebalancing portfolio timely corresponding market conditions 4) providing on-line advisory service. Robo-advisor used to choose ETFs for low cost and public advisory services. The expense cost of ETFs are lower than common mutual funds and ETFs listed in U.S. exchanges covers equity and fixed income including domestic and other countries, even commodities and REITs. The abundant ETF is one of success conditions for robo-advisor. Leading robo-advisor firms applied some financial theories like as Markowitz' Portfolio theory, Black-Litterman model, behavior finance, etc. Goal-based investment strategy based investor's risk budget has to take dynamic rebalancing its portfolio. Since the risk-return profile of assets has change continuously, robo-advisor needs the big data analysis techniques about asset's profiles and automatic rebalancing algorithm of catching regime switching. Several robo-advisors utilize machine learning technic into analyzing the financial time series and economic data. I analyzed the effects of robo-advisor on asset management industry and found the rich potential of robo-advisor in Asia, especially Korea.

■ Tue.A.5A

Tuesday, 10:30-11:45, Room 5A

Robust Multi-Objective Optimization Problems

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Gue Myung Lee*

1. **Necessary Optimality Conditions for Nonsmooth Multiobjective Bilevel Optimization Problems**

   Chuong Thai Doan (chuongthaidoan@gmail.com) University of New South Wales, Australia

This talk is devoted to the study of a nonsmooth multiobjective bilevel optimization problem, which involves the vector-valued objective functions in both levels of the considered program. We first formulate a relaxation problem for the multiobjective bilevel problem and examine the relationships of solutions between them. We then establish Fritz John (FJ) and Karush-Kuhn-Tucker (KKT) necessary conditions for the nonsmooth multiobjective bilevel optimization problem via its relaxation. This is done by studying a related multiobjective optimization problem with operator constraints.

2. **Surrogate Duality for Quasiconvex Vector Optimization with Data Uncertainty**

   Satoshi Suzuki (suzuki@math.shimane-u.ac.jp) Shimane University, Japan, *Daishi Kuroiwa*

In this talk, we study surrogate duality for quasiconvex vector optimization with data uncertainty. We investigate surrogate strong duality for robust quasiconvex vector optimization with its necessary and sufficient constraint qualification. In addition, we compare a solution of our robust counterpart with a solution in set optimization.

3. **A Coordinate Descent Homotopy Method for Bi-Level Problem and Linearly Constrained Minimization**

   Sangwoon Yun (yswmathedu@skku.edu) Sungkyunkwan University, Korea, *Yoon Mo Jung*

We consider the bi-level problem which minimizes a convex function over the set of stationary points of a certain smooth function. If the smooth function is a linear least square function, then the bi-level problem is a linearly constrained convex minimization problem which includes the L_1-minimization problem arising in compressed sensing. The proposed method solves the bi-level problem by applying a coordinate gradient descent method to a sequence of the regularized subproblems. We prove that any cluster point of the generated iterates is a solution of the bi-level problem. We compare our proposed method with Bregman iterative algorithm and linearized Bregman iterative algorithm for solving large-scale L_1-minimization problems.

■ Tue.A.5D

Tuesday, 10:30-11:45, Room 5D

Theoretical Advances in Linear Optimization — Barrier Methods

Cluster: Linear Optimization

Session organized by: *Aaron Daniel Sidford, Yin Tat Lee*

1. **A Faster Algorithm for Linear Programming and the Maximum Flow Problem**

   Yin Tat Lee (YinTatLee@gmail.com) Massachusetts Institute of Technology, USA, *Aaron Daniel Sidford*

In this talk, we will present a new algorithm for solving linear programs. Given a linear program with n variables, $m > n$ constraints, and bit complexity L, our algorithm runs in $\tilde{O}(\sqrt{n}L)$ iterations each consisting of solving $\tilde{O}(1)$ linear systems and additional nearly linear time computation. Our method improves upon the convergence rate of previous state-of-the-art linear programming methods which required solving either $\tilde{O}(\sqrt{m}L)$ linear systems [R88] or consisted of $\tilde{O}((mn)^{\frac{1}{4}})$ steps of more expensive linear algebra [VA93]. Interestingly, our algorithm not only nearly matches the convergence rate of the universal barrier of Nesterov and Nemirovskii [NN94], but in the special case of the linear programming formulation of various flow problems our methods converge at a rate faster than that predicted by any self-concordant barrier. In particular, we achieve a running time of $\tilde{O}(|E|\sqrt{|V|}\log^2 U)$ for solving the maximum flow problem on a directed graph with $|E|$ edges, $|V|$ vertices, and capacity ratio U, thereby improving upon the previous fastest running time for solving this problem when $|E| > \Omega(|V|^{(1+\epsilon)})$ for any constant epsilon. This talk will be split into two parts given by Yin Tat Lee and Aaron Sidford.

2. **A Faster Algorithm for Linear Programming and the Maximum Flow Problem**

   Aaron Daniel Sidford (aaron.sidford@gmail.com) Stanford University, USA, *Yin Tat Lee*

In this talk, we will present a new algorithm for solving linear programs. Given a linear program with n variables, $m > n$ constraints, and bit complexity L, our algorithm runs in $\tilde{O}(\sqrt{n}L)$ iterations each consisting of solving $\tilde{O}(1)$ linear systems and additional nearly linear time computation. Our method improves upon the convergence rate of previous state-of-the-art linear programming methods which required solving either $\tilde{O}(\sqrt{m}L)$ linear systems [R88] or consisted of $\tilde{O}((mn)^{\frac{1}{4}})$ steps of more expensive linear algebra [VA93]. Interestingly, our algorithm not only nearly matches the convergence rate of the universal barrier of Nesterov and Nemirovskii [NN94], but in the special case of the linear programming formulation of various flow problems our methods converge at a rate faster than that predicted by any self-concordant barrier. In particular, we achieve a running time of $\tilde{O}(|E|\sqrt{|V|}\log^2 U)$ for solving the maximum flow problem on a directed graph with $|E|$ edges, $|V|$ vertices, and capacity ratio U, thereby improving upon the previous fastest running time for solving this problem when $|E| > \Omega(|V|^{(1+\epsilon)})$ for any constant epsilon. This talk will be split into two parts given by Yin Tat Lee and Aaron Sidford.

3. **Geometric Median**

   Jakub Pachocki (merettm@gmail.com) Harvard University, USA, *Michael Cohen, Yin Tat Lee, Gary Miller, Aaron Sidford*

The geometric median of a set of points is the point minimizing the sum of distances to the points. The problem of finding an efficient algorithm to compute the median, known as the Fermat-Weber problem, has remained an active area of research for many years. In this talk we present the first nearly linear time algorithm for computing the median.

■ Tue.A.5E

Tuesday, 10:30-11:45, Room 5E

On the Interplay of Choice, Robustness and Optimization

Cluster: Robust Optimization

Session organized by: *Karthik Natarajan*

1. **Multi-Product Pricing Optimization with Robust Choice Model**

   Zhenzhen Yan (a0109727@u.nus.edu) National University of Singapore, Singapore, *Cong Cheng, Karthik Natarajan, Chung Piaw Teo*

We study the multi-product pricing problem with robust choice model using pricing experiments. In particular, we develop a data driven approach to this problem using the theory of marginal distribution. We show that the pricing problem is convex for a large class of discrete choice models, including the classical logit and nested logit model. In fact, our model remains convex as long as the marginal distribution is log-concave. More importantly, by fitting data to optimize the selection of choice model, we develop an LP based approach to the semi-parametric version of the pricing problem. Preliminary tests using a set of automobile data show that this approach provides near optimal solution, even with random coefficient logit model.

2. **Analysis of Discrete Choice Models: A Welfare-based Approach**

   Xiaobo Li (lixx3195@umn.edu) University of Minnesota, USA, *Zizhuo Wang, Guiyun Feng*

Based on the observation that many existing discrete choice models admit a welfare function of utilities whose gradient gives the choice probability vector, we propose a new perspective to view choice models by treating the welfare function as the primitive. We call the resulting choice model the welfare-based choice model. The welfare-based choice model is meaningful on its own by providing an alternative way of constructing choice models. We prove that the welfare-based choice model is equivalent to the representative agent choice model and the semi-parametric choice model, establishing the equivalence of the latter two. We show that these three models are all strictly more general than the random utility model, while when there are only two alternatives, those four models are equivalent. Moreover, the welfare-based choice model subsumes the nested logit model with positive dissimilarity parameters. We then define a new concept in choice models: substitutability/complementarity between alternatives. We show that the random utility model only allows substitutability between different alternatives; while the welfare-based choice model allows more flexible substitutability/complementarity patterns. We argue that such flexibility could be desirable in capturing certain practical choice patterns, such as the halo effects. We present ways of constructing new choice mode.

3. **Distributionally Robust Project Crashing with Full, Partial or No Correlation Information**

Selin Damla Ahipasaoglu (ahipasaoglu@sutd.edu.sg) Singapore University of Technology and Design, Singapore, *Karthik Natarajan, Dongjian Shi*

Project crashing is a method for optimally shortening the project makespan by reducing the time of one or more activities in a project network to less than its normal activity time at the expense of additional costs. The traditional project crashing problem assumes that the activity durations are deterministic. However, in reality activity durations are uncertain. We propose a distributionally robust project crashing problem to minimize the worst-case expected makespan where the distributions of the activity durations are specified only up to the first two moments. Given mean and variance, we consider three moments models with full, partial or no correlation information on the activity durations. The complexity results known for the worst-case expected makespan is extended to the crashing problems under the three moment models, and second order cone program (SOCP) and semidefinite program (SDP) reformulations are provided. Furthermore, we show that the distributionally robust project crashing problem can be formulated as a saddle point problem with a convex-concave objective function. Based on a characterization of the gradients, the problem can be solved by a globally convergent projection and contraction algorithm in a short time. The numerical results show that the decisions obtained by the distributionally robust project crashing models are quite reasonable.

■ Tue.A.5F

Tuesday, 10:30-11:45, Room 5F

Sparse Solution Reconstruction in Inverse Problems

Cluster: Sparse Optimization and Information Processing

Session organized by: *Elena Resmerita*

1. **Precise Relaxation of Nonconvex Energies via Structured Sparsity**

Thomas Möllenhoff (thomas.moellenhoff@in.tum.de) Technical University of Munich, Germany, *Emanuel Laude, Michael Moeller, Jan Lellmann, Daniel Cremers*

Many inverse problems in computer vision such as depth from stereo, depth from focus, optical flow or robust image denoising are inherently ill-posed and require regularization. Due to the nonconvexity of the data fidelity term, global optimization of corresponding energies is challenging. Functional lifting methods find a convex representation of such energies by reformulating the original problem in a higher dimensional space. By considering a novel structured k-sparsity constraint, we propose a precise piecewise convex approximation. We derive a tight convex relaxation of the nonconvex k-sparsity constraint and show how the resulting optimization problem can be solved using a first-order primal-dual algorithm and efficient epigraphical projections.

2. **On Convergence of Sparsity-promoting Regularization for Non-sparse Solutions**

Daniel Gerth (daniel.gerth@dk-compmath.jku.at) TU Chemnitz, Germany, *Bernd Hofmann*

In recent years, sparsity promoting regularization has gained a lot of attention in the Inverse Problems community. It has been shown by various authors that, assuming the true solution is indeed sparse with respect to some prescribed basis and certain smoothness conditions are imposed, this method of regularization may render the problem of finding the solution to the Inverse Problem from noisy data essentially well-posed. It may, however, be of interest to find a sparse approximation to a non-sparse true solution of the Inverse Problem, for example to extract certain features of the solution. This is a special case of oversmoothing regularization, where it is known a-priori that the sought-after solution does not fulfill the smoothness properties implied by the regularization method. In this case, not much is known about its convergence properties. In this talk we give a short historical overview about the convergence theory for sparsity-promoting regularization methods. We focus on theory based on so called variational inequalities, an abstract smoothness condition which can often be shown in sparsity-promoting regularization. We then review how the case of non-sparse solutions is covered in the literature so far. In the main part of the talk we discuss further extensions of the existing theory to this situation; to problems, challenges and limitations.

3. **Variable Exponent Penalties for Sparse Solution Reconstruction**

Elena Resmerita (elena.resmerita@aau.at) Alps-Adria University of Klagenfurt, Austria, *Kristian Bredies, Barbara Kaltenbacher*

The seminal paper of Daubechies, Defrise, DeMol made clear that ℓ^p spaces with $p \in [1,2)$ and p-powers of the corresponding norms are appropriate settings for dealing with reconstruction of sparse solutions of ill-posed problems by regularization. The case $p = 1$ provides the best results in most of the situations as compared to the cases $p \in (1,2)$. An extensive literature gives great credit also to using ℓ^p spaces with $p \in (0,1)$ together with the corresponding quasinorms. In any of these settings, the question of how to choose the exponent p has been not only a numerical issue, but also a philosophical one. In this work, we introduce a more flexible way of sparse regularization by varying exponents. We present the corresponding functional analytic framework, that leaves the setting of normed spaces but works with so-called F-norms. We collect some known results about these F-norms, provide some new results that are of interest in the context of sparse regularization and investigate regularization properties of these penalties.

■ Tue.A.5G

Tuesday, 10:30-11:45, Room 5G

Advances in Optimization Modeling Languages

Cluster: Optimization Implementations and Software

Session organized by: *John Siirola*

1. **Modeling Abstractions and Automatic Discretization Frameworks for Optimization Problems with Differential Equations in Pyomo**

Bethany Nicholson (bethanylnicholson@gmail.com) Sandia National Laboratories, USA, *Victor M Zavala, John Siirola, Jean-Paul Watson, Lorenz T Biegler*

This talk presents pyomo.dae, an open-source tool for abstracting and discretizing optimization problems constrained by differential equations. Our framework does not require differential equations to have a particular form and is able to represent high-order differential equations as well as partial differential equations on bounded rectangular domains. This provides users a new level of modeling flexibility that is not found in most algebraic modeling languages and optimization frameworks. Furthermore, pyomo.dae provides several automatic discretization methods for converting models containing differential equations to finite-dimensional algebraic models that can be solved with standard optimization solvers. In this talk we present several illustrative examples showing how pyomo.dae can be used to tackle a variety of dynamic optimization problems. We then describe the finite difference and collocation discretization schemes that have been implemented and demonstrate how simple it is to combine such schemes to create new non-intuitive solution strategies. Finally, we discuss the next steps for this tool towards developing a modeling framework for more advanced dynamic optimization techniques as well as exploring new modeling paradigms by combining pyomo.dae with other packages in Pyomo for stochastic or disjunctive programming.

2. **New Developments in Pyomo**

John D Siirola (jdsiiro@sandia.gov) Sandia National Laboratories, USA, *William E Hart, Carl D Laird, Bethany L Nicholson, Jean-Paul Watson, David L Woodruff*

Computational tools for modeling mathematical programs are widely used within both academia and industry. Available commercial and open-source modeling packages support generic modeling by separating modeling constructs from instance data through concepts like sets, parameters, and parameterized constraints. However, limiting models to "flat" algebraic representation forces the modeler to explicitly convert or relax high-level constructs, which can obscure much of the structure in the model. In this presentation, we will provide an overview of recent developments in Pyomo, an open-source library for modeling general algebraic optimization problems in Python. We will focus on the application of high-level non-algebraic modeling constructs coupled with automated model interrogation and transformation to improve model clarity, abstraction, and model validation.

■ Tue.A.5H

Tuesday, 10:30-11:45, Room 5H

Vector Optimization

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Andreas Loehne*

1. **A Set-valued Approach to Matrix Games with Vector Payoffs**

Andreas Loehne (andreas.loehne@uni-jena.de) FSU Jena, Germany, *Andreas H Hamel*

Based on set relations, a new solution concept for matrix games with zero sum vector payoffs is introduced. It is compared with notions from the literature such as Pareto optimal security strategies (POSS) as well as with Shapley equilibria. We demonstrate by examples how to choose optimal strategies in practice and we present an algorithm to compute optimal strategies.

2. **Duality in Polyhedral Projection Problems**

Benjamin Weissing (benjamin.weissing@unibz.it) Friedrich Schiller Universität, Germany

A 'Polyhedral Projection Problem' (pp) is concerned with computing a representation of a polyhedron which is defined as the projection of another, high-dimensional polyhedron onto a low-dimensional real vector space. This problem class occurs quite naturally when 'Vector Linear Problems' (vlp), i.e. linear problems with vector-valued objective, are considered. A solution to (vlp) involves a representation of all minimal points (with respect to a partial order induced by an 'order cone') in the image space. Such a representation can be obtained by considering the 'extended image' of the (vlp). This is a polyhedron whose vertices are all minimal and whose extremal directions are either minimal or belong to the order cone. The computation of the extended image can be interpreted as (pp). The aim of the talk is to define the class of Polyhedral Projection Problems as well as an accompanying solution concept. Furthermore, two different kinds of dual problems will be presented. One is based on the usual understanding of duality in optimisation, while the second one is based on duality between polyhedra (also known as polarity). A further topic will be the relationship between (pp) and (vlp) and their respective solution concepts.

3. **Optimality and Duality for Mathematical Programmes with Equilibrium Constraints**

Shashi Kant Mishra (bhu.skmishra@gmail.com) Banaras Hindu University, Varanasi, India, *Yogendra Pandey*

We present some new results on Strong Kuhn-Tucker Optimality conditions and Duality results for nonsmooth Mathematical Programmes with equilibrium Constraints under generalized convexity assumptions.

■ Tue.A.5I

Tuesday, 10:30-11:45, Room 5I

Geometry and Algorithms for Conic Programming

Cluster: Conic and Polynomial Optimization
Session organized by: *Masakazu Muramatsu*

1. **Facial Reduction in MOSEK**

Henrik Alsing Friberg (haf@mosek.com) MOSEK ApS, Denmark

An introduction to interleaved regularization and optimization via self-dual embeddings and a discussion on the relevance and practical concerns of facial reduction in commercial optimization software.

2. **Primal-Dual Potentiai-Reduction Algorithm for Symmetric Programming Problem with Nonlinear Objective Function**

Leonid Faybusovich (lfaybuso@gmail.com) University of Notre Dame, USA

We introduce a generalized Nesterov-Todd direction for the symmetric programming problem with a nonlinear convex objective function. We prove a global convergence for such an algorithm provided a certain degree of accuracy is attained in calculating this direction. Some applications are considered.

3. **Exact Duals and Short Certificates of Infeasibility and Weak Infeasibility in Conic Linear Programming: Part 1**

Gabor Pataki (gabor@unc.edu) University of North Carolina at Chapel Hill, USA, *Minghui Liu*

In conic linear programming – in contrast to linear programming – the Lagrange dual may not be a strong dual, and the corresponding Farkas' lemma may fail to prove infeasibility. Here we describe exact duals, and certificates of infeasibility and weak infeasibility for conic LPs which retain most of the simplicity of the Lagrange dual, but do not rely on any constraint qualification. Some of our exact duals generalize the SDP duals of Ramana, Klep and Schweighofer to the context of general conic LPs. Some of our infeasibility certificates generalize the row echelon form of a linear system of equations: they consist of a small, trivially infeasible subsystem obtained by elementary row operations. We prove analogous results for weakly infeasible systems. We obtain some fundamental geometric corollaries: an exact characterization of when the linear image of a closed convex cone is closed, and an exact characterization of nice cones. Our infeasibility certificates provide algorithms to generate *all* infeasible conic LPs over several important classes of cones; and *all* weakly infeasible SDPs in a natural class. Using these algorithms we generate a public domain library of infeasible and weakly infeasible SDPs. The status of our instances is easy to verify by inspection in exact arithmetic, but they turn out to be challenging for commercial and research codes.

■ Tue.A.5J

Tuesday, 10:30-11:45, Room 5J

Recent Advances in Splitting Methods for Large-Scale Convex Programming: Part I

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Xiaoming Yuan, Caihua Chen*

1. **Lattice-based Patterned Fabric Inspection by Sparse and Low-Rank Representation**

Wenxing Zhang (wxzh1984@126.com) University of Electronic Science and Technology of China, China, *Michael Ng, Henry Ngan, Xiaoming Yuan*

This talk presents a lattice-based patterned fabric inspection based on a constrained sparse and low-rank approach. Previously, an image decomposition based approach was attempted to tackle the problem of fabric inspection by decomposing patterned texture as a combination of cartoon and texture. However, the ID model was weak at detecting multi-color or nearly piecewise constant patterned fabrics. In short, it has neglected the geometric and regularity properties of a patterned texture. Therefore, a modified ID model proposed in this paper applies the classification of 17 wallpaper groups in geometry, for which each patterned texture can be generated by a specified lattice. This lattice is composed by the most fundamental unit, motif, by pre-defined symmetry rules. This allows every patterned texture possessing a regularity property via the texture generation as well as a sparse and low-rank representation in matrix operation. Incorporating these nice properties, fabric inspection can be accomplished in a decent convex optimization model using the CSL approach. In performance evaluation, the CSL method achieves 99.19% average accuracy on star- and 99.07% average accuracy on box-patterned fabrics of a total of 50 images.

2. **A Proximal Point Algorithm with Asymmetric Linear Term**

Xingju Cai (caixingju@njnu.edu.cn) Nanjing Normal University, China

In this paper, we propose an asymmetric proximal point algorithm (APPA) for solving variatioal inequality problems. The algorithm is "asymmetric" in the sense that the matrix in the linear proximal term is not required to be a symmetric matrix, which makes the method more flexible, especially in dealing with problems with separable structures. Under some suitable conditions, we prove the global linear convergence of the algorithm. To make the method more practical, we allow the subproblem to be solved in an approximate manner and an inaccuracy criterion with constant parameter is adopted. Finally, we report some preliminary Numerical results.

3. **An Alternating Minimization Algorithm for Robust Principal Component Analysis**

Yuan Shen (ocsiban@126.com) Nanjing University of Finance and Economics, China, *Xin Liu, Zaiwen Wen, Yin Zhang*

We focus on solving the problem of Robust Principal Component Analysis (RPCA) arising from various applications in the fields of information theory, statistics, engineering, and etc. Convex optimization with nuclear norm is effective for small-scale RPCA problem, and the resulting algorithm can guarantee convergence to optimal solution. However, the nuclear norm minimization algorithm involves the Singular Value Decomposition (SVD), hence its efficiency and scalability are limited by the computational complexity of SVD as both matrix size and rank increase. Aftermath, nonconvex optimization without nuclear norm was then proposed, the resulting algorithm provides accelerations of computing speed up to multiple orders of magnitude for large-scale problem, compared with the algorithms based on nuclear norm minimization. However, these algorithm can only guarantee convergence to a stationary point. We propose a new efficient algorithm. It utilizes a nonconvex model without nuclear norm, hence avoids the SVD. Its framework is relatively simple, and is almost parameter-free. Without imposing assumptions, we derive the global convergence to strict local optimizer. This is a great improvement compared with those which can only converge to stationary point. Additionally, the new algorithm shows satisfactory numerical performance in experiments with both synthetic and real data.

■ Tue.A.5L

Tuesday, 10:30-11:45, Room 5L

Notions of Robustness and Dynamics in Convex

Optimization: Part I

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Benjamin Recht, Pablo A Parrilo*

1. **An Optimal First Order Method based on Optimal Quadratic Averaging**

Maryam Fazel (mfazel@uw.edu) University of Washington, USA, *Dmitriy Drusvyatskiy, Scott Roy*

In a recent paper, Bubeck, Lee, and Singh introduced a new first order method for minimizing smooth strongly convex functions. Their geometric descent algorithm, largely inspired by the ellipsoid method, enjoys the optimal linear rate of convergence. Motivated by their work, we propose a close variant that iteratively maintains a quadratic global under-estimator of the objective function, whose minimal value approaches the true minimum at an optimal rate. The resulting intuitive scheme comes equipped with a natural stopping criterion and can be numerically accelerated by using accumulated information.

2. **Convergence of First-Order Algorithms for Convex Optimization using Inexact Information**

Francois Glineur (francois.glineur@uclouvain.be) Université Catholique de Louvain, Belgium, *Yurii Nesterov, Olivier Devolder*

Analysis of first-order methods for convex optimization typically assume availability of the objective function and its gradient at every iterate. However, in many cases, only approximate information can be computed. In particular, this happens when the objective function itself is the optimal value of another auxiliary problem. We define a class of inexact oracles that extends the classical notion of epsilon-subgradient to the smooth (strongly) convex case. Such an oracle is naturally available in many situations involving inexact computations, including approaches involving an auxiliary problem (useful for smoothing or solving dual problems). We study the behavior of first-order methods using such an oracle. Convergence of the classical gradient method is mostly unchanged: it converges to a solution whose accuracy is comparable to that of the oracle. In contrast, the fast gradient method suffers from error accumulation, and the best accuracy it can reach is much worse than that of the oracle. We then propose a way to remedy this unsatisfactory situation: we introduce a new hybrid method that, given a certain oracle accuracy and a target objective accuracy unattainable by the fast gradient method, requires a number of steps that is much smaller that the classical gradient method.

3. **On Equivalence between Deterministic First-Order Optimization Algorithms and Martingale Inequalities**

Alexander Rakhlin (rakhlin@wharton.upenn.edu) University of Pennsylvania, USA

In this talk, we will argue that existence of deterministic first-order optimization algorithms can be certified via certain probabilistic inequalities. Conversely, mirror descent style algorithms yield probabilistic inequalities that are otherwise difficult to prove. This connection between the two disparate fields facilitates the development of novel online learning algorithms for such problems as ranking, collaborative filtering, and online shortest path, to name a few.

■ Tue.B.1S

Tuesday, 13:15-14:30, Room 1S

Nonlinear Optimization Algorithms and Their Complexity I

Cluster: Nonlinear Optimization
Session organized by: *Philippe Toint*

1. **Evaluation Complexity for Nonlinear Constrained Optimization using Unscaled KKT Conditions and High-Order Models**

Sandra Augusta Santos (sandra@ime.unicamp.br) University of Campinas, Brazil, *Ernesto G Birgin, John L Gardenghi, Jose M Martinez, Philippe Toint*

In this work, the evaluation complexity of general nonlinear, possibly nonconvex, constrained optimization is analysed. Under suitable smoothness conditions, it is shown that an epsilon-approximate first-order critical point of the problem can be computed in order $O(\varepsilon^{1-2(p+1)/p})$ evaluations of the problem's function and their first p derivatives. This is achieved by using a two-phase algorithm inspired by previous works of Cartis, Gould, and Toint (2011, 2013). It is also shown that strong guarantees (in terms of handling degeneracies) on the possible limit points of the sequence of iterates generated by this algorithm can be obtained at the cost of increased complexity. At variance with previous results, the ε-approximate first-order criticality is defined by satisfying a version of the KKT conditions with an accuracy that does not depend on the size of the Lagrange multipliers.

2. **Limited Memory Algorithms with Cubic Regularization**

Oleg Burdakov (oleg.burdakov@liu.se) Linkoping University, Sweden, *Ya-xiang Yuan, Liang Zhao*

We consider a model with a cubic regularization where the cubic term is determined by the eigendecomposition of a limited memory Hessian approximation. Although the model function may potentially have an exponential number of distinct local minima, its global minimizer can be obtained in closed form. The required eigenvalue decomposition is produced using an efficient approach introduced recently for limited memory Hessian approximations. Convergence results are presented for a standard cubic regularization framework. The efficiency of our algorithms is demonstrated by results of numerical experiments.

3. **A Space Transformation Framework for Nonlinear Optimization**

Zaikun Zhang (zaikunzhang@gmail.com) Hong Kong Polytechnic University, Hong Kong, *Serge Gratton, Luis Nunes Vicente*

We present a space transformation framework for nonlinear optimization. Instead of tackling the problem in the original space, each iteration of this framework seeks for a trial step by modelling and approximately solving the optimization problem in another space. We establish the global convergence and worst case iteration complexity of the framework. Then we show that the framework can be specialized to a parallel space decomposition framework for nonlinear optimization, which can be regarded as an extension of the domain decomposition method for PDEs. A feature of the decomposition framework is that it incorporates the restricted additive Schwarz methodology into the synchronization phase of the method. We will illustrate how this decomposition framework can be applied to design parallel algorithms for optimization problems with or without derivatives.

■ Tue.B.1A

Tuesday, 13:15-14:30, Room 1A

Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 2

Cluster: Nonlinear Optimization
Session organized by: *Ya-Feng Liu*

1. **Theory and Algorithms for Sparse Finance Optimization**

Feng Min Xu (fengminxu@mail.xjtu.edu.cn) Xi'an Jiaotong University, China

In the practical business environment, portfolio managers often face business-driven requirements that limit the number of constituents in their optimal portfolio. A natural sparse finance optimization model is thus to minimize a given objective function while enforcing an upper bound on the number of assets in the portfolio. In this talk we consider three kinds of sparse finance optimization problem, including sparse portfolio selection, sparse index tracking and sparse portfolio rebalancing. In particular, we propose an efficient method for solving these problem. Under some suitable assumptions, we establish that any accumulation point of the sequence generated by our method is a local minimizer of these sparse finance optimization problems. We also conduct empirical tests to demonstrate that our approach generally produces sparse portfolios with higher out-of-sample performance.

2. **Optimality and Some Numerical Analysis for Constrained Optimization Problems with Nonconvex Regularization**

Wei Bian (bianweilvse520@163.com) Harbin Institute of Technology, China, *Xiaojun Chen*

In this paper, we consider a class of constrained optimization problems where the feasible set is a general closed convex set and the objective function has a nonsmooth, nonconvex regularizer. Such regularizer includes widely used SCAD, MCP, logistic, fraction, hard thresholding and non-Lipschitz L_p penalties as special cases. Using the theory of the generalized directional derivative and the tangent cone, we derive a first order necessary optimality condition for local minimizers of the problem, and define the generalized stationary point of it. The new defined generalized stationary point provides a uniform definition for the stationary points of this kind of problem, since it is the Clarke stationary point when the objective function is Lipschitz continuous at this point, and equivalent to the existing stationary points defined for some special models when the objective function is not Lipschitz continuous at this point. We prove the consistency between the generalized directional derivative and the limit of the classic directional derivatives associated with the smoothing function. Moreover, when the regularizer is nonconvex, we study the numerical properties of this problem from the bound property of its local minimizers and its computational complexity.

■ Tue.B.1B

Tuesday, 13:15-14:30, Room 1B

Numerical Methods for PDE-constrained Optimization under Uncertainty

Cluster: PDE-constrained Optimization
Session organized by: *Michael Ulbrich*

1. **Hierarchical Tensor Approximation for Optimal Control with Uncertain Coefficients**

   Reinhold Schneider (schneidr@math.tu-berlin.de) TU Berlin, Germany, *Benjamin Huber*

Hierarchical Tucker tensor format (HT-Hackbusch tensors) and Tensor Trains (TT-Tyrtyshnikov tensors, I. Oseledets) have been introduced recently for low rank tensor product approximation. Hierarchical tensor decompositions are based on sub space approximation by extending the Tucker decomposition into a multi-level framework. Therefore they inherit favorable properties of Tucker tensors, e.g they offer a stable and robust approximation, but still enabling low order scaling with respect to the dimensions. This approach extend the reduced basis model order reduction to high dimensional problems. For many high dimensional problems, this approach offers a novel strategy to circumvent the course of dimensionality. For uncertainty quantification the optimal problem, with uncertain data problem is reformulated as a high dimensional parametric optimal control problem The optimization problems can be constraint further by the restriction to tensors of prescribed ranks r. This problem could be solved by optimization on manifolds or with the help of hierarchical SVD (HSVD).

2. **A Second Order Approximation Technique for Robust Optimization in Parametrized Shape Optimization**

   Oliver Lass (lass@mathematik.tu-darmstadt.de) Technische Universität Darmstadt, Germany, *Stefan Ulbrich*

We consider a nonlinear constrained optimization problem with uncertain parameters. It is addressed by a robust worst-case formulation. The resulting optimization problem is of bi-level structure and is difficult to treat numerically. We propose an approximate robust formulation that employs a quadratic approximation. For an efficient realization in application problems we will mix the introduced framework with a linear approximation when appropriate. The strategy is then applied to the optimal placement of a permanent magnet in the rotor of a synchronous machine. The goal is to optimize the volume and position while maintaining a desired performance level. These quantities are computed from the magnetic vector potentials obtained by the magnetostatic approximation of Maxwell's equation with transient movement. We arrive at an optimization problem governed by a set of elliptic partial differential equations, where one PDE has to be solved for every rotor position. The uncertainty is introduced through uncertainties in material and production precision. The problem formulation as well as the robustification of the optimization lead to high computational cost that requires to investigate methods for efficient realization. To speed up the computation reduced order models are developed. Numerical results are presented to validate the presented approach.

3. **Constrained Optimization with Low-Rank Tensors and Applications to Problems with PDEs under Uncertainty**

   Michael Ulbrich (mulbrich@ma.tum.de) Technical University of Munich, Germany, *Sebastian Garreis*

We present Newton-type methods for inequality constrained nonlinear optimization using low-rank tensors and apply them to variational inequalities with several uncertain parameters and to optimal control problems with PDEs under uncertainty. The developed methods are tailored to the usage of low-rank tensor arithmetics, which only offer a limited set of operations and require truncation (rounding) in between. We show that they can solve huge-scale optimization problems with trillions of unknowns to a good accuracy.

■ Tue.B.1C

Tuesday, 13:15-14:30, Room 1C

Advances in Derivative-free and Simulation-based Optimization I

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Dmitri E Kvasov*

1. **Nonmonotone Derivative-free Trust-Region Algorithms for Composite Nonsmooth Optimization**

   Geovani Nunes Grapiglia (geovani_mat@hotmail.com) Universidade Federal do Paraná, Brazil

Non-monotone derivative-free trust-region algorithms are considered for minimizing a composite function $\Phi(x) = f(x)+h(c(x))$, where f and c are smooth and h is convex but may be non-smooth. Global convergence results and worst-case complexity bounds are discussed. Moreover, numerical results on L1 and minimax problems are also presented.

2. **An approach for solving Mixed Integer Nonlinear Optimization Problems via Derivative Free Optimization Techniques**

   Ubaldo M García-Palomares (ubaldo@gti.uvigo.es) Universidade de Vigo, Spain

In this talk we show how to adapt non monotone derivative free optimization techniques to the solution of the same constrained model subjected to integer values for some or all variables involved. Under the same well known convergence conditions for continuous variables, it is proved that a sequence of discrete quasi minimal points converges to a stationary point of a discrete optimization problem subjected to linear constraints, including finite or infinite bounds on the variables. A minor variation forces the function evaluations on discrete points and has the nice property that if the discretization of variables is somehow relinquished, the procedure may continue without disruption and it converges to a stationary point of the model with continuous variables. Convergence is preserved if nonlinear equalities and inequalities are incorporated as a penalty to the objective function. A variable separation technique is suggested for optimization problems with mixed continuous and discrete variables, but we emphasize that, although theoretically it is not necessary, a space decomposition in general improve the performance of the procedure. Numerical results will be reported in this talk to support this latter statement.

3. **On Numerical Comparison of Deterministic and Stochastic Derivative-free Global Optimization Algorithms**

   Dmitri E Kvasov (kvadim@dimes.unical.it) University of Calabria, Italy, *Yaroslav D Sergeyev, Marat S Mukhametzhanov*

In many simulation-based applications requiring global optimization techniques, the objective function can be multiextremal and non-differentiable thus precluding the use of descending schemes with derivatives. Moreover, the function is often given as a black-box and, therefore, each function evaluation has a high cost with respect to the available computational resources. Derivative-free methods can be particularly suitable to tackle these challenging global optimization problems and can be either of deterministic or stochastic nature. A numerical comparison of these two groups of methods is interesting for several reasons and has a practical importance since stochastic (and particularly, metaheuristic) and deterministic algorithms are used by two mostly disjoint communities. Some difficulties, however, arise when these methods are compared because of their different structure. A new methodology called operational zones is proposed for a reliable comparison and an intuitive visualization of numerical results obtained by stochastic and deterministic global optimization algorithms. This technique is inspired by Grishagin's approach of operational characteristics, known also as data profiles. Several widely used metaheuristic global optimization methods (as genetic, differential evolution, particle swarm optimization, artificial bee colony, and firefly algorithms) are thus compared with Lipschitz-based deterministic methods by using operational zones.

■ Tue.B.4A

Tuesday, 13:15-14:30, Room 4A

Energy Systems I

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Alexander W Dowling*

1. **Strong Valid Inequalities for the Standard Pooling Problem**

   Claudia D'Ambrosio (dambrosio@lix.polytechnique.fr) CNRS & LIX, Ecole Polytechnique, France, *Jeff Linderoth, James Luedtke, Jonas Schweiger*

The focus of this talk will be on the standard pooling problem, i.e., a continuous, non-convex optimization problem arising in the chemical engineering context. The problem consists of finding the optimal composition of final products obtained by blending in pools different percentages of raw materials. Bilinear terms arise from the requirements on the quality of certain attributes of the final products. The quality is a linear combination of the attributes of the raw materials and intermediate products that compose the final product. Three different classical formulations have been proposed in the literature. We start from the strongest of the three, i.e., the one providing a standard linear relaxation closer to the original problem, and propose to strengthen that linear relaxation. In particular, we studied a structured non-convex subset of some special cases to derive valid nonlinear convex inequalities that we proved to define the convex hull of the non-convex subset. Preliminary computational results on instances from the literature are reported and demonstrate the utility of the inequalities when used in a global optimization solver.

2. **Challenges and Opportunities for Optimization-based Workflow in Industry**

Rui Huang (huangr@utrc.utc.com) United Technologies Research Center, USA

Currently buildings consume about 40% of the total US energy and it is the only energy end-use sector showing growth in the energy intensity through 2025. Moreover, 30% of energy in the building area is used inefficiently or unnecessarily. Under the current market condition, United Technologies Corporation, which is the world largest building supplier, is investing in model based system engineering. This talk provides an overview of the new developments in this area and presents the challenges and opportunities in the area of robust design and uncertainty analysis. This talk first shows the applications of system engineering that lead to economic and environment benefit. Then the new optimization-based workflows for system design and operation with additional capabilities are discussed. Moreover, challenges and opportunities of robust design, uncertainty quantification and the associated computational problems will be presented.

3. **A Stochastic Programming Framework for Multi-Stakeholder Decision-making and Conflict Resolution**

Alexander W Dowling (adowling2@wisc.edu) University of Wisconsin-Madison, USA, *Victor M Zavala*

Engineering decision-making is inherently multiobjective and involves multiple stakeholders. As such, it suffers from ambiguity and dimensionality. We propose a decision-making framework to compute compromise solutions that balance conflicting priorities of multiple stakeholders. In our setting, we shape the stakeholder dissatisfaction distribution by solving a conditional-value-at-risk (CVaR) minimization problem. The CVaR problem is parameterized by a probability level that shapes the tail of the dissatisfaction distribution. The proposed approach allows us to compute a family of compromise solutions and generalizes multi-stakeholder settings previously proposed in the literature. We use the concept of the CVaR norm to give a geometric interpretation to this problem and use the properties of this norm to prove that the CVaR minimization problem yields Pareto optimal solutions for any choice of the probability level. We discuss a broad range of potential applications that involve complex decision-making processes. We demonstrate the developments by balancing stakeholder priorities on transportation, safety, water quality, and capital costs in a biowaste facility location case study. We also discuss extensions to energy system design and operation, such as combined cooling, heat and power systems, and solar power generators with energy storage.

■ Tue.B.4B

Tuesday, 13:15-14:30, Room 4B

Asset-Liability Management

Cluster: Applications in Finance and Economics

Session organized by: *Woo Chang Kim*

1. **Extending the Scope of ALM to Social Investment — Investing in Population Growth to Enhance Sustainability of Korea National Pension Service**

Woong Bee Choi (cwbee@kaist.ac.kr) KAIST, Korea, *Min Jeong Kim, Woo Chang Kim*

Currently, Korea's National Pension Plan has been hugely accumulated; in particular, it is the third largest public pension in the world. According to its financial projection from 2013, the accumulated amount of the National Pension is expected to reach the highest amount as much as 50% of the nation's GDP by 2043. However, many predict that this immense fund will become exhausted by 2060 due to the aging population and the low fertility rate. In this research, we develop an optimization model to calculate the effect of the investment for raising the fertility rate. In addition, by using the asset-liability management model, we examine whether the investment for raising the fertility rate improves the sustainability of the National Pension Fund. As a result, under some specific conditions, it is shown that the investment for raising the fertility rate enhances the sustainability of the Nation Pension Fund and postpones its exhaustion. Thus, we show that socially driven investment can also be a good investment asset in which the National Pension Fund should consider to invest.

2. **The Peculiarity of Liability of National Pension in Korea and the Way to Sustain Pension Scheme**

Chong Hyun Won (moimoi1@empal.com) Korea National Assembly Research Service, Korea

The Korea national pension service investment management(NPSIM) has evolved with reserve of 512 trillion KRW. In Korea national pension fund scheme, funding ratio is below 0.5. This fund shall be exhausted around 2060 subject to not change pension scheme. As a public fund for old-age income security, the national pension is belong to both funded scheme and also PAYG scheme. It means that the liability of the pension is not same that of other private pension. Because existence of national pension system is to guarantee stable pension benefit for planholder, the target of the national pension fund should be to improve stability of system, which helps support the generational contract. That's why the purpose of the public pension fund is not to raise the profit rate of management. It is needed to accept that the national pension system can not be preserved in that property and profits applying now in national pension. It is required the management of pension fund which emphasizes the stability and appropriate profits rather than that of pursuit of high rate risky asset weight strongly. Therefore, It is needed to discussion about pension fund management policy, which is different from government pension fund management policy.

3. **Personalized Asset-Liability Management Service: Products, Markets, Regulations and Technologies**

Woo Chang Kim (wkim@kaist.ac.kr) KAIST, Korea

ALM has been employed almost exclusively for institutional investors. Recently, however, with the rise of automated investment management service, called robo advisors, personalized ALM services for individuals are getting available especially for retirement planning. In this talk, I will discuss various issues including products, markets, regulations, and financial optimization technologies required for this service.

■ Tue.B.5A

Tuesday, 13:15-14:30, Room 5A

Bilevel Optimization: Theory and Solution Methods

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Alain Zemkoho*

1. **Solution Algorithm for Optimistic Bilevel Optimization Problems**

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

In bilevel optimization, an objective function is minimized subject to the graph of the solution set mapping of a second, parametric optimization problem. If this second or lower level problem is replaced using the Karush-Kuhn-Tucker conditions a mathematical program with complementarity constraints (MPCC) arises. Both problems are equivalent if global optima are considered. Algorithms solving MPCCs compute stationary solutions in general. For computing local optimal solutions of the bilevel optimization problem we need to consider all Largrange multipliers of the lower level problem or to use carefully adapted algorithms. In the talk one such algorithm is presented, its convergence to a global or a local optimal solution of the bilevel optimization problem is investigated.

2. **Newton Method for Bilevel Optimization**

Alain Zemkoho (a.b.zemkoho@soton.ac.uk) University of Southampton, United Kingdom

We consider a bilevel optimization problem where the lower level problem admits more than one optimal solution for some parameters from the upper level. Considering the lower level value function (LLVF) reformulation, there are two specific classes of stationarity conditions based on the expression of the subdifferential of the LLVF. In this talk, we discuss an auxiliary system of equations based on some vector-valued map, which allows us to compute the aforementioned stationary points by means of a semismooth Newton method. Convergence properties of the method and preliminary numerical experience will also be discussed.

3. **Stationarity Concepts for Bilevel Optimization Problems with Lower Level Constraints in Lebesgue Spaces**

Patrick Mehlitz (mehlitz@mailserver.tu-freiberg.de) Technical University Bergakademie Freiberg, Germany, *Gerd Wachsmuth*

We derive necessary optimality conditions for a bilevel programming problem whose lower level possesses constraints comprising the cone of nonnegative functions in a Lebesgue space. This formulation covers bilevel optimal control problems with lower level inequality constraints on the control function. Using lower level optimality conditions, we transfer the bilevel programming problem into a complementarity constrained single level program. Afterwards, recently introduced stationarity notions and constraint qualifications for MPCCs in Banach spaces are applied to the surrogate problem. A surprising observation regarding Mordukhovich's stationarity concept is discussed in more detail. The talk is based on a joint work with Gerd Wachsmuth.

■ Tue.B.5D

Tuesday, 13:15-14:30, Room 5D

Theoretical Advances in Linear Optimization — Sampling Methods

Cluster: Linear Optimization

Session organized by: *Aaron Daniel Sidford, Yin Tat Lee*

1. **Randomized Interior Point Methods for Sampling and Optimization**

   Hariharan Narayanan (harin@uw.edu) University of Washington, USA, *Ravi Kannan*

We present a Markov Chain, "Dikin walk", for sampling from a convex body equipped with a self-concordant barrier. This Markov Chain corresponds to a natural random walk with respect to a Riemannian metric defined using the Hessian of the barrier function. For every convex set of dimension n, there exists a self-concordant barrier whose self-concordance parameter is $O(n)$. Consequently, a rapidly mixing Markov Chain of the kind we describe can be defined (but not always be efficiently implemented) on any convex set. We use these results to design an algorithm consisting of a single random walk for optimizing a linear function on a convex set. This talk includes joint work with Ravi Kannan.

2. **Geodesic Gliding and Polytope Sampling**

   Santosh S Vempala (vempala@gatech.edu) Georgia Institute of Technology, USA, *Yin Tat Lee*

We analyze a random walk on a Riemannian manifold defined by following geodesics (shortest path curves) of the manifold. We prove its convergence for Riemannian metrics induced by Hessians of convex functions. As a consequence, we obtain the first sampling process with sub-quadratic mixing time for sampling polytopes in R^n. Our process can be viewed as a discrete-time simulation of a stochastic differential equation with a drift term. Its implementation is based on the efficient solution of first-order ordinary differential equations. Our results demonstrate that polytope sampling is more natural (and more efficient) in a non-Euclidean space. The proofs draw on Riemannian geometry, stochastic calculus, complex analysis and linear algebra. This is joint work with Yin Tat Lee (MIT).

3. **Faster Convex Optimization: Simulated Annealing with an Efficient Universal Barrier**

   Jacob Abernethy (jabernet@umich.edu) University of Michigan, USA, *Elad Hazan*

This paper explores a surprising equivalence between two seemingly-distinct convex optimization methods. We show that simulated annealing, a well-studied random walk algorithms, is directly equivalent, in a certain sense, to the central path interior point algorithm for the the entropic universal barrier function. This connection exhibits several benefits. First, we are able improve the state of the art time complexity for convex optimization under the membership oracle model. We improve the analysis of the randomized algorithm of Kalai and Vempala by utilizing tools developed by Nesterov and Nemirovskii that underly the central path following interior point algorithm. We are able to tighten the temperature schedule for simulated annealing which gives an improved running time, reducing by square root of the dimension in certain instances. Second, we get an efficient randomized interior point method with an efficiently computable universal barrier for any convex set described by a membership oracle. Previously, efficiently computable barriers were known only for particular convex sets.

■ Tue.B.5E

Tuesday, 13:15-14:30, Room 5E

Robust Optimization: Theory and Applications

Cluster: Robust Optimization

Session organized by: *Vineet Goyal*

1. **Robust Wait Time Estimation in Resource Allocation Systems with an Application to Kidney Allocation**

   Phebe Vayanos (phebe.vayanos@usc.edu) University of Southern California, USA, *Chaithanya Bandi, Nikolaos Trichakis*

In this paper we study systems that allocate different types of scarce resources to heterogeneous allocatees based on pre-determined priority rules. We tackle the problem of estimating the wait time of an allocatee who possesses incomplete system information, for example, with regard to his relative priority, other allocatees' preferences, and resource availability. We model the system as a multiclass, multiserver queuing system that is potentially unstable or in transient regime. We propose a novel robust optimization solution methodology that builds on the assignment problem. For first-come, first-served systems, our approach yields a mixed-integer programming formulation. For the important case where there is a hierarchy in the resource types, we strengthen our formulation through a drastic variable reduction and also propose a highly scalable heuristic, involving only the solution of a convex optimization problem. We back the heuristic with a tight approximation guarantee. We illustrate the generalizability of our approach by studying systems that operate under different priority rules. We showcase how our methodology can be applied to assist patients in the U.S. deceased-donor kidney waitlist. We calibrate our model using detailed historical data to estimate patient wait times based on their preferences and characteristics.

2. **Satisficing Awakens: Models to Mitigate Uncertainty**

   Melvyn Sim (melvynsim@nus.edu.sg) National University of Singapore, Singapore

Satisficing, as an approach to decision-making under uncertainty, aims at achieving solutions that satisfy the problem's constraints as well as possible. We then study the key features of satisficing decision making that are associated with these problems and provide the complete functional characterization of a satisficing decision criterion. As a consequence, we are able to provide the most general framework of a satisficing model, termed the S-model, which seeks to maximize a satisficing decision criterion in its objective, and the corresponding satisficing-constrained optimization problem that generalizes robust optimization and chance-constrained optimization problems. Next, we focus on a tractable probabilistic S-model, termed the T-model whose objective is a lower bound of the P-model. We show that when probability densities of the uncertainties are log-concave, the T-model can admit a tractable concave objective function. In the case of discrete probability distributions, the T-model is a linear mixed integer program of moderate dimensions. We also show how the T-model can be extended to multi-stage decision-making and present the conditions under which the problem is computationally tractable.

3. **Piecewise Affine Policies for Two-Stage Robust Optimization under Demand Uncertainty**

   Vineet Goyal (vg2277@columbia.edu) Columbia University, USA, *Aharon Ben-Tal, Omar El Housni, Brian Lu*

We consider the problem of designing good piecewise affine policies for two-stage adjustable robust linear optimization problems under right hand side uncertainty. Such problems arise in many applications where we need to satisfy an uncertain demand with minimum possible cost. It is well known that a piecewise affine policy is optimal although the number of pieces can be exponentially many. One of the significant challenges in designing a piecewise affine policy arises from constructing good pieces of the uncertainty set. We introduce a new framework for constructing piecewise affine policies where we "approximate" the uncertainty set by a simplex and construct a piecewise affine policy based on the map from the uncertainty set to the simplex. Our piecewise affine policy has exponentially many pieces but can be computed efficiently and in many cases, even more efficiently than computing the optimal affine policy. Furthermore, the performance of our piecewise affine policy is significantly better than the affine policy.

■ Tue.B.5G

Tuesday, 13:15-14:30, Room 5G

Parallel Implementations and Algorithms for Continuous Optimization

Cluster: Optimization Implementations and Software

Session organized by: *Carl Laird*

1. **A Parallel Nonlinear Interior-Point Approach for Dynamic Optimization Problems**

   Jose Santiago Rodriguez (rodri324@purdue.edu) Purdue University, Colombia, *Carl Laird*

Large-scale optimization plays an important role in a variety of areas, including process design, operation and control. Dynamic optimization problems that commonly arise in these areas need to be solved efficiently. These problems are characterized by having a large number of equations and variables and can become computationally prohibited. However, due to the nature of the problems, these problems have a structure that can be exploited using parallel computing capabilities offered by modern computers. We present a parallel interior-point solver that can exploit the structure of dynamic optimization problems and enable efficient solution in parallel. Interior-point methods have proven to be effective for large-scale nonlinear programming problems. The dominant computational costs are the solution of the KKT system in every iteration of the interior-point algorithm, and computation of NLP functions and derivatives. The simultaneous discretization approach for dynamic optimization problems induces structure in the optimization problem, and our implementation exploits this structure with a Schur-complement decomposition strategy to enable efficient solution of the KKT system in parallel. In the algorithm, all scale-dependent operations are parallelized, including model evaluation. We demonstrate the performance of this algorithm using an online estimation case study.

2. **Parallel Scenario-based Decomposition Methods for Solving the Contingency-constrained AC Optimal Power Flow Problem**

   Jean-Paul Watson (jwatson@sandia.gov) Sandia National Laboratories, USA, *Carl Laird, David Woodruff*

We analyze the performance of scenario-based decomposition methods for solving the contingency-constrained AC optimal power flow problem, specifically progressive hedging, and analyze performance on a number of IEEE benchmark systems.

3. **The Rectangular Maximum Agreement Problem**

   Ai Kagawa (ai.kagawa@gmail.com) Rutgers University, USA, *Jonathan Eckstein, Noam Goldberg*

The NP-hard rectangular maximum agreement (RMA) problem finds a "box" that best discriminates between two weighted datasets. Its data analysis applications include boosting classification methods and boosted regularized regression. We describe a specialized parallel branch-and-bound method for RMA.

■ Tue.B.5H

Tuesday, 13:15-14:30, Room 5H

Robust Optimization and Applied Probability

Cluster: Robust Optimization

Session organized by: *Yongpei Guan*

1. **Buffered Probability of Exceedance, A New Characterization of Uncertainty and Application to Support Vector Machines and Robust Optimization**

   Matthew David Norton (mdnorton@ufl.edu) University of Florida, USA, *Alexander Mafusalov, Stan Uryasev*

We first present a recently developed characterization of uncertainty called Buffered Probability of Exceedance (bPOE) and discuss its benefits as a tool to tackle optimization problems involving a probabilistic objective function with convex and sometimes even linear programming. We then demonstrate the benefits of utilizing bPOE by applying it to machine learning tasks. We show that bPOE is intimately connected to the popular Support Vector Machine classification algorithm. Specifically, we show that the SVM algorithm is equivalent to simple bPOE minimization. Furthermore, we furnish this equivalence with new Robust Optimization formulations having both a non-convex risk seeking and convex risk averse case. Overall, we show that Robust bPOE minimization provides a fruitful approach to the classification task.

2. **Applications of the Earth Mover's Distance in Optimization**

   Ye Wang (wang141@usc.edu) University of Southern California, USA, *Medhi Behroozi, John Gunnar Carlsson*

Earth mover's distance (also known as the Wasserstein or Kantorovich metric) is a statistical metric that describes a distance function between two probability distributions. In our research, we consider the Entropy maximization problem and Highest Posterior Density optimization problem in which we will search through all distributions whose earth mover's distance to the empirical distribution of a given set of data points is sufficiently small. We also show how to use the Earth Mover's Distance to study the distributionally robust travelling salesman problem in the Euclidean plane.

■ Tue.B.5I

Tuesday, 13:15-14:30, Room 5I

Geometry, Duality and Complexity in Conic Linear Programming I

Cluster: Conic and Polynomial Optimization

Session organized by: *Gabor Pataki*

1. **Exact Duals and Short Certificates of Infeasibility and Weak Infeasibility in Conic Linear Programming: Part 2**

   Minghui Liu (liu.m.h2010@gmail.com) University of North Carolina at Chapel Hill, USA, *Gabor Pataki*

In conic linear programming – in contrast to linear programming – the Lagrange dual may not be a strong dual, and the corresponding Farkas' lemma may fail to prove infeasibility. Here we describe exact duals, and certificates of infeasibility and weak infeasibility for conic LPs which retain most of the simplicity of the Lagrange dual, but do not rely on any constraint qualification. Some of our exact duals generalize the SDP duals of Ramana, Klep and Schweighofer to the context of general conic LPs. Some of our infeasibility certificates generalize the row echelon form of a linear system of equations: they consist of a small, trivially infeasible subsystem obtained by elementary row operations. We prove analogous results for weakly infeasible systems. We obtain some fundamental geometric corollaries: an exact characterization of when the linear image of a closed convex cone is closed, and an exact characterization of nice cones. Our infeasibility certificates provide algorithms to generate *all* infeasible conic LPs over several important classes of cones; and *all* weakly infeasible SDPs in a natural class. Using these algorithms we generate a public domain library of infeasible and weakly infeasible SDPs. The status of our instances is easy to verify by inspection in exact arithmetic, but they turn out to be challenging for commercial and research codes.

2. **Preprocessing Semidefinite Programs**

   Preston Elliott Faulk (preston.faulk@unc.edu) University of North Carolina at Chapel Hill, USA, *Gabor Pataki, Quoc Tran Dinh*

We present a simple preprocessing algorithm for SDPs, and present numerical results.

3. **Solving SDP Completely with an Interior-Point Oracle**

   Takashi Tsuchiya (tsuchiya@grips.ac.jp) National Graduate Institute for Policy Studies, Japan, *Bruno Figueria Lourenço, Masakazu Muramatsu*

Consider an oracle capable of solving any semidefinite program (SDP) which is interior-feasible on both primal and dual sides. This oracle is an idealization of primal-dual interior-point algorithm. In this talk, we show how one can use such an oracle to "completely solve" an arbitrary SDP. Here we use the term "completely solve" an SDP to mean a scheme which works in the following way; given an SDP, the scheme determines whether it is feasible or not, and whenever feasible, computes its optimal value, and if the optimal value is attained, obtains a maximal rank optimal solution. If the original SDP is infeasible, the scheme distinguishes strong and weak infeasibility. In the case of unattained optimal value and weak infeasibility, a set of generating matrices can be obtained from which we can compute an approximate optimal solution of arbitrary precision (unattained optimal value case) and an almost feasible solution of arbitrary precision (weakly infeasible case), respectively, just with a polynomially bounded number of arithmetic operations in n without further solving SDPs, where n is the size of the matrix in SDP. We show that the number of oracle calls in this scheme is $O(n)$.

■ Tue.B.5J

Tuesday, 13:15-14:30, Room 5J

Recent Advances in Splitting Methods for Large-Scale Convex Programming: Part II

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Xiaoming Yuan, Caihua Chen*

Session chair: *WenYi Tian*

1. **Faster Alternating Direction Method of Multipliers with an $O(1/n^2)$ Convergence Rate**

   WenYi Tian (wenyi.tian@tju.edu.cn) Tianjin University, China, *Xiaoming Yuan*

The alternating direction method of multipliers (ADMM) has found many applications for solving convex programming models with separable structures. ADMM's worst-case $O(1/n)$ convergence rate measured by the iteration complexity has been established in both the ergodic and nonergodic senses, where n is the iteration counter. However, its faster $O(1/n^2)$ convergence rate can only be established for some very special cases such as when both function components in the objective of the model are strongly convex. The $O(1/n^2)$ convergence rate of ADMM for the general situation remains open. Inspired by a recent work of Chambolle and Pock, we propose a rule for iteratively choosing the penalty parameter and show that ADMM using this rule has an $O(1/n^2)$ worst-case convergence rate for the general scenario under mild assumptions without strong convexity assumption on the objective function.

■ Tue.B.5L

Tuesday, 13:15-14:30, Room 5L

Notions of Robustness and Dynamics in Convex Optimization: Part II

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Benjamin Recht, Pablo A Parrilo*

1. **Automating the Analysis and Design of Large-Scale Optimization Algorithms**

   Laurent Lessard (laurent.lessard@wisc.edu) University of Wisconsin-Madison, USA, *Benjamin Recht, Andrew Packard*

First-order iterative algorithms such as gradient descent, fast/accelerated methods, and operator-splitting methods such as ADMM can be viewed as discrete-time dynamical systems. We will show that if the function being optimized is strongly convex, for example, computing the worst-case performance of a particular algorithm is equivalent to solving a robust control problem. This amounts to establishing feasibility of a small semidefinite program whose size is independent of the dimension of the function's domain. Our unified approach allows for the efficient and automatic evaluation of worst-case performance bounds for a wide variety of popular algorithms. The bounds derived in this manner either match or improve upon the best known bounds from the literature. Finally, our framework can be used to search for algorithms that meet desired performance specifications, thus establishing a new and principled methodology for designing new algorithms.

2. **Stability as the Master Force Behind Stochastic Gradient Descent**

   Nathan Srebro (nati@ttic.edu) Toyota Technological Institute at Chicago, USA

We will show how stability can be used to derive convergence guarantees for stochastic optimization. In particular, we will motivate and derive stochastic gradient descent and stochastic mirror descent as stability-inducing methods, and show how to obtain their familiar convergence guarantees using stability. We will also discuss more aggressive variants that can be derived in a similar fashion.

3. **Stochastic Robustness of Gradient Methods**

   Benjamin Recht (brecht@berkeley.edu) University of California, Berkeley, USA

This talk will explore the stability and robustness admitted by the gradient method. I will first discuss how the gradient method is robust to perturbations of the model and the updates. From a computing systems perspective, this robustness enables parallel implementations. I will also show how the gradient method is robust to perturbations of the loss function itself, and discuss implications for machine learning. I will conclude with a discussion of other notions from robust control theory may yield new insights into the design and analysis of optimization algorithms.

■ Tue.C.1S

Tuesday, 14:45-16:00, Room 1S

Optimization in Machine Learning I

Cluster: Nonlinear Optimization

Session organized by: *Joshua Griffin, Wenwen Zhou*

1. **Combining Information from Second-Order Solvers and SGD**

   Scott R Pope (scott.pope@sas.com) SAS Institute Inc., USA

In this talk, we explore ways to combine information from second order solvers and SGD to increase the performance of either when training weights in artificial neural networks. We look at ways to share information between solvers and various strategies to avoid false convergence from poorly chosen hyper-parameters. This is done in parallel computing environments with both shared and distributed memory.

2. **A Modified Conjugate Gradient Method with Warm-Starts for Large-Scale Nonconvex Optimization Problems**

   Wenwen Zhou (Wenwen.Zhou@sas.com) SAS Institute Inc., USA, *Joshua Griffin*

This talk will focus on solving large-scale nonconvex unconstrained optimization problems with Krylov-based iterative methods when effective preconditioning matrices are unknown or unavailable. For such problems, convergence of the outer iterations can degrade when the iterative solver repeatedly exits on maximum Hessian-vector products rather than relative residual error . To address this issue, a new warm start strategy is proposed to accelerate an existing modified conjugate gradient approach while maintain important convergence properties. Numerical experience for real-life applications and addition to convergence results will be provided.

■ Tue.C.1A

Tuesday, 14:45-16:00, Room 1A

Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 3

Cluster: Nonlinear Optimization

Session organized by: *Ya-Feng Liu*

1. **Structured Nonconvex Optimization Models: Algorithms and Iteration Complexity Analysis**

   Bo Jiang (isyebojiang@163.com) Shanghai University of Finance and Economics, China, *Tianyi Lin, Shiqian Ma, Shuzhong Zhang*

In this paper, we propose several first-order algorithms for computing an ε-stationary point for some structured nonconvex problems. When there is no linear coupled constraints, we propose a generalized conditional gradient (GCG) which can find an ε-stationary point in $O(\varepsilon^{-q})$ iterations under certain conditions, where q is a parameter in the Holderian condition that characterizes the degree of smoothness of the objective function. Moreover, when the smooth part in the objective is concave, the iteration complexity can be improved to $O(\varepsilon^{-1})$. For the more generic problem with affine constraints, we propose two algorithms (named as GADM and LADM) that both can be viewed as variants of the alternating direction method of multipliers (ADMM). We prove the $O(\varepsilon^{-2})$ iteration complexity of the proposed GADM and LADM under some mild conditions, and we do not need to assume the Kurdyka-Lojasiewicz property.

2. **Numerical Algorithms for PDE-constrained Optimization with Non-convex Non-smooth Objectives**

   Yun Shi (15900164r@connect.polyu.hk) The Hong Kong Polytechnic University, Hong Kong, *Yun Shi*

We consider a PDE-constrained optimization problem with non-Lipschitz objective. We perform a specially designed discretization on the problem before examining the optimality conditions and then apply the optimization algorithms with smoothing techniques. The convergence results of the algorithm is investigated and the influences of the discrtization and smoothing is discussed. Variational discretization with a Petrov-Galerkin scheme and Crank-Nicolson time stepping is used, which was proved optimal a priori error bounds under certain Ansatz, and the smoothing quadratic regularization method is the choice of optimization algorithm.

3. **Composite $L_q(0 < q < 1)$ Minimization over Polyhedron**

   Ya-Feng Liu (yafliu@lsec.cc.ac.cn) Academy of Mathematics and Systems Science/Chinese Academy of Sciences, China, *Shiqian Ma, Yu-Hong Dai, Shuzhong Zhang*

The composite $L_q(0 < q < 1)$ minimization problem over a general polyhedron has received various applications in machine learning, wireless communications, image restoration, signal reconstruction, etc. In this talk, we shall present a theoretical study on this problem. Firstly, we show that for any fixed $0 < q < 1$, finding the global minimizer of the problem, even its unconstrained counterpart, is strongly NP-hard. Secondly, we derive Karush-Kuhn-Tucker (KKT) optimality conditions for local minimizers of the problem. Thirdly, we propose a smoothing sequential quadratic programming framework for solving this problem. The framework requires a (approximate) solution of a convex quadratic program at each iteration. Finally, we analyze the worst-case iteration complexity of the framework for returning an ε-KKT point; i.e., a feasible point that satisfies a perturbed version of the derived KKT optimality conditions. To the best of our knowledge, the proposed framework is the first one with a worst-case iteration complexity guarantee for solving composite L_q minimization over a general polyhedron.

■ Tue.C.1B

Tuesday, 14:45-16:00, Room 1B

Optimal Control of Coupled Systems

Cluster: PDE-constrained Optimization
Session organized by: *Roland Herzog*

1. **Optimal Control of a Coupled System of a Vehicle Transporting a Fluid Subject to Shallow Water Equations**

Sven-Joachim Kimmerle (sven-joachim.kimmerle@unibw.de) Universitaet der Bundeswehr Muenchen, Germany, *Matthias Gerdts*

We consider the optimal control of a vehicle transporting an open fluid basin as load. The motion of the fluid is modelled by the non-linear hyperbolic shallow water (Saint-Venant) equations while the vehicle dynamics are described by Newton's equations of motion. The fluid basin is mounted to the vehicle by a spring-damper element. The system may be controlled by the acceleration of the vehicle. This leads to an optimal control problem with a coupled system of partial differential equations (PDEs) and ordinary differential equations (ODEs). The PDEs and ODEs are fully coupled by boundary conditions and force terms. We derive necessary optimality conditions rigorously and solve by a first-optimize-then-discretize approach, using a globalized semi-smooth Newton method in Hilbert spaces. As well we consider a first-discretize-then-optimize approach for the particular case of time optimal control. The Saint-Venant equations are discretized by means of a Lax-Friedrich scheme, involving an artificial viscosity. Finally, we discuss further examples for fully coupled systems of PDEs and ODEs and their particular features and classify our problem within this context.

2. **Optimal Control of Thermoviscoplasticity**

Ailyn Stötzner (ailyn.stoetzner@mathematik.tu-chemnitz.de) Technische Universität Chemnitz, Germany, *Roland Herzog, Christian Meyer*

Elastoplastic deformations play a tremendous role in industrial forming. Many of these processes happen at non-isothermal conditions. Therefore, the optimization of such problems is of interest not only mathematically but also for applications. In this talk we will present the analysis of the existence of a global solution of an optimal control problem governed by a thermovisco(elasto)plastic model. We will point out the difficulties arising from the nonlinear coupling of the heat equation with the mechanical part of the model. Finally, we will discuss first steps to develop an efficient optimization method based on the directional differentiability of the control-to-state mapping.

3. **Optimal Control of Scalar Transport in Incompressible Fluid Flow**

Cedric Sehrt (sehrt@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

We consider an optimal control problem given by the instationary incompressible Navier-Stokes equations and two coupled non-autonomous scalar advection-diffusion equations, which are driven by the bulk motion of the fluid. This kind of PDE system arises in modeling combustion processes with Flamelet Generated Manifolds, where a small number of scalar quantities, following advection-diffusion equations, are used to describe combustion processes. Typically, one scalar quantity represents the mixture of fuel and oxidizer and a second scalar quantity represents the progress of the combustion. The transport equation for the progress variable includes a nonlinear source term depending on the scalar quantities. The considered class of objective functionals includes in particular tracking-type functionals. The control acts on a subset of the domain. The optimal control problem is complemented with control constraints. We will show that the objective functional is Frechét-differentiable with respect to the control. Moreover, we will derive optimality conditions using the adjoint state.

■ Tue.C.1C

Tuesday, 14:45-16:00, Room 1C

Randomized Methods and Stochastic Problems

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Raghu Pasupathy*

1. **Gradient-based Stochastic Search for Simulation Optimization**

Enlu Zhou (enlu.zhou@isye.gatech.edu) Georgia Institute of technology, USA, *Shalabh Bhartnagar*

A variety of systems arising in finance, engineering design, and manufacturing require the use of optimization techniques to improve their performance. Due to the complexity and stochastic dynamics of such systems, their performance evaluation frequently requires computer simulation, which however often lacks structure needed by classical optimization methods. We developed a gradient-based stochastic search approach, based on the idea of converting the original (structure-lacking) problem to a differentiable optimization problem on the parameter space of a sampling distribution that guides the search. A two-timescale updating scheme is further studied and incorporated to improve the algorithm efficiency. Convergence properties of our approach are established through techniques from stochastic approximation, and the performance of our algorithms is illustrated in comparison with some state-of-the-art simulation optimization methods.

2. **AUC Maximization and Tuning Parameters of Cost Sensitive Logistic Regression via Derivative Free Optimization**

Hiva Ghanbari (hig213@lehigh.edu) Lehigh University, USA, *Katya Scheinberg*

Conventional classification problems in machine learning suffer from imbalanced data sets. In order to prevent the dominating effect of the majority class, AUC maximization rather than error rate minimization is preferred. In this work, we have used trust region based derivative free optimization to directly optimize the AUC function. We also propose a rigorous optimization scheme to maximize the AUC function over the class weights and the regularization term in cost sensitive logistic regression.

3. **Adaptive Sampling Recursions for Simulation Optimization**

Raghu Pasupathy (pasupath@purdue.edu) Purdue University, USA

For roughly six decades since the seminal paper of Robbins and Monro (1951), Stochastic Approximation has dominated the landscape of algorithms for solving root finding and optimization problems with Monte Carlo observable functions. Recently, however, inspired by the rise in parallel computing and advances in nonlinear programming methods, there has been increasing interest in alternative sampling-based frameworks. Such frameworks are convenient in that they (could) use an existing recursive method, e.g., line-search or trust-region, with embedded Monte Carlo estimators of objects appearing within the recursion. In this talk, after reviewing existing results on optimal sampling rates, we consider the question of how to adaptively sample within stochastic recursions. Specifically, we will demonstrate that a simple adaptive scheme that has deep connections to proportional-width sequential confidence intervals endows stochastic recursions with convergence rates that are arbitrarily close to being optimal, while remaining practical enough for good finite-time implementation. Two illustrative recursions that embed line-search and a fixed step size will be presented. The adaptive sampling schemes we advertise were independently discovered by Byrd, Chin and Nocedal, but from the viewpoint of the need to estimate descent directions within such algorithms.

■ Tue.C.4A

Tuesday, 14:45-16:00, Room 4A

Energy Systems II

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Francois Gilbert*

1. **A Strong Semidefinite Programming Relaxation of the Unit Commitment Problem**

Morteza Ashraphijuo (ashraphijuo@berkeley.edu) University of California, Berkeley, USA, *Javad Lavaei, Alper Atamturk*

The unit commitment (UC) problem aims to find an optimal schedule of generating units subject to the demand and operating constraints for an electricity grid. The majority of existing algorithms for the UC problem rely on solving a series of convex relaxations by means of branch-and-bound or cutting planning methods. In this work, we develop a strengthened semidefinite program (SDP). This approach is based on first deriving certain valid quadratic constraints and then relaxing them to linear matrix inequalities. These valid inequalities are obtained by the multiplication of the linear constraints of the UC problem. The performance of the proposed convex relaxation is evaluated on several hard instances of the UC problem. For most of the instances, globally optimal integer solutions are obtained by solving a single convex problem. Since the proposed technique leads to a large number of valid quadratic inequalities, an iterative procedure is devised to impose a small number of such valid inequalities. For the cases where the strengthened SDP does give a global integer solution, we incorporate other valid inequalities, including a set of Boolean quadric polytope constraints. The proposed relaxations are extensively tested on various IEEE power systems in simulations.

2. **Data-driven Optimal Reduced Order Model Tuning for Partial Differential Equations: Application to the 3D Boussinesq Equation**

Mouhacine Benosman (benosman@merl.com) Mitsubishi Electric Research Laboratories, USA

The problem of reducing a partial differential equation (PDE) model to a system of finite dimensional ordinary differential equations (ODE), is of paramount importance in engineering and physics where solving such PDE models is too time consuming. The idea of being able to reduce the PDE model to a simple model, without loosing the main characteristics of the original model, such as stability and prediction precision, is appealing for any real-time model-based computations. However, this problem remains challenging, since model reduction can introduce stability loss and prediction degradation. To remedy these problems, many methods have been developed aiming at what is known as stable model reduction. In this talk, we focus on the so-called closure models and their application in reduced order model (ROM) stabilization. More specifically, we introduce few closure-models and propose to auto-tune them online based a data-driven optimization algorithms known as 'extremum-seeking' to tune the closure models' parameters for optimal ROM stabilization. We discuss the convergence of the proposed extremum-seekers and the corresponding tuning performance. The 3D Boussinesq equation is employed as a room's airflow test-bed for the proposed stabilization method.

3. **Handling Dynamic Constraints in Power System Optimization**

   Francois Gilbert (fgilbert@anl.gov) Argonne National Laboratory, USA, *Shrirang Abhyankar, Mihai Anitescu, Zhang Hong*

The inclusion of dynamic stability constraints is the nominal objective of many optimization-based power systems analyses. In current practice, this is typically done off-line. We present an approach for the on-line inclusion of dynamic constraints in power grid optimization problems. The approach is based on an encapsulation that allows for a loose coupling between the optimization and the numerical simulations. We demonstrate the benefits of the approach on a IEEE 118-Bus Systems, for which we solve an economic dispatch with transient constraints.

■ Tue.C.4B

Tuesday, 14:45-16:00, Room 4B

Applications of Complementarity Models: Sparsity and Games

Cluster: Complementarity and Variational Inequalities

Session organized by: *Shisheng Cui*

1. **A Reformulation of Sparse Optimization Problems using Complementarity-Type Constraints**

   Alexandra Schwartz (schwartz@gsc.tu-darmstadt.de) TU Darmstadt, Germany, *Christian Kanzow, Oleg Burdakov*

We consider sparse optimization problems, i.e. mathematical programs where the objective is not only to minimize a given function but also the number of nonzero elements in the solution vector. Possible applications are compressed sensing, portfolio optimization and feature selection. In this talk, we present a continuous reformulation of the noncontinuous sparsity term in the objective function using a complementarity-type constraint. We discuss the relation between the original and the reformulated problem, provide suitable optimality conditions and provide preliminary numerical results.

2. **Distributed Algorithms for Potential Generalized Nash Equilibrium Problems (GNEPs) and Nonseparable Optimization Problems**

   Andrew Lu Liu (andrewliu@purdue.edu) Purdue University, USA, *Run Chen*

We present a unified algorithmic framework to parallelly compute a (local) solution of an optimization problem and an equilibrium for a subclass of GNEPs. The key of the framework is to explore the relationship between potential games and optimization problems. Potential games are a subclass of games in which a single potential function (similar to a merit function) exists that can reflect individual player's payoff changes with different actions, when other players' actions are fixed. Under player-wise convexity, the stationary point from optimizing the potential function is a Nash equilibrium of the corresponding game. On the other hand, any multivariate optimization problem can be viewed as a potential game, with each player (who controls a subset of the variables) having an identical payoff function. We show that the potential function optimization problem can be solved with parallel computing, using the classic method of multipliers, but without requiring separability or convexity of either the objective or constraint functions. The parallel algorithm is exactly a Guass-Jacobian-type algorithm applied to solving the game associated with the potential function optimization, whose convergence can be established based on recent development. Preliminary numerical results will be presented to demonstrate the overall framework's efficiency.

3. **Multi-Leader Single-Follower Game between Suppliers with a Manufacturer**

   Tatsuya Hirano (hirano-tatsuya-fj@ynu.jp) Yokohama National University, Japan, *Yasushi Narushima*

In this talk, we consider a competition occurring in a supply chain. Extending the research of Ang et al. (Journal of Global Optimization, 2012), we analyze the competition. Ang et al. constructed a model about a bi-level non-cooperative game model in a supply chain. In this model, some suppliers (leaders) try to maximize their profits by deciding products' delivery frequencies at the upper level and one manufacturer (follower) tries to minimize his cost by deciding a demand allocation to each supplier at the lower level. This game can be regarded as a multi-leader single-follower game. In the model of Ang et al., the variable of suppliers is delivery frequency only. On the other hand, we regard not only delivery frequency but also products' price as the variables of suppliers. Then, the game is formulated as a generalized Nash equilibrium problem (GNEP). Moreover, we reformulate this problem as a quasi-variational inequalities (QVI) and show the existence of its solution. Finally, we give some numerical results.

■ Tue.C.5A

Tuesday, 14:45-16:00, Room 5A

Convex Optimization for Learning and Data Sciences

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Silvia Villa*

1. **A Universal Catalyst for First-Order Optimization**

   Hongzhou Lin (hongzhou.lin@inria.fr) INRIA, France, *Julien Mairal, Zaid Harchaoui*

We introduce a generic scheme for accelerating first-order optimization methods in the sense of Nesterov, which builds upon a new analysis of the accelerated proximal point algorithm. Our approach consists of minimizing a convex objective by approximately solving a sequence of well-chosen auxiliary problems, leading to faster convergence. This strategy applies to a large class of algorithms, including gradient descent, block coordinate descent, SAG, SAGA, SDCA, SVRG, Finito/MISO, and their proximal variants. For all of these methods, we provide acceleration and explicit support for non-strongly convex objectives. In addition to theoretical speed-up, we also show that acceleration is useful in practice, especially for ill-conditioned problems where we measure significant improvements.

2. **Less is More: Optimal Learning with Stochastic Projection Regularization**

   Lorenzo Andrea Rosasco (lrosasco@mit.edu) DIBRIS, Univ. of Genoa, and LCSL, Istituto Italiano di Tecnologia and Massachusetts Institute of Technology, Italy, *Alessandro Rudi, Raffaello Camoriano*

In this talk, we will discuss the generalization properies of commonly used techniques to scale up kernel methods and Gaussian processes. In particular, we will focus on data dependent and independent sub-sampling methods, namely Nystrom and random features, and study their generalization properties within a statistical learning theory framework. On the one hand we show that these methods can achieve optimal learning errors while being computational efficient. On the other hand, we show that subsampling can be seen as a form of stochastic projection regularization, rather than only a way to speed up computations.

3. **Computational Regularization in Learning and Inverse Problems**

   Silvia Villa (asilviavilla@gmail.com) Istituto Italiano di Tecnologia, Italy, *Lorenzo Rosasco*

Modern high dimensional estimation problems from random noisy data require the development of ever more efficient algorithms. A key observation towards this goal is that the numerical precision in the computations should be taylored to the estimation accuracy allowed by the data rather than only their raw amount. Indeed, this suggests that efficient methods can be derived investigating the interplay and trade-offs between estimation and computational requirements. With this goal in mind in this talk we focus on iterative regularization methods where regularization is achieved by early stopping an iteration defined by the data. Recent results in the context machine learning and inverse problems will be discussed.

■ Tue.C.5D

Tuesday, 14:45-16:00, Room 5D

Theoretical Advances in Linear Optimization — New Perspectives
Cluster: Linear Optimization
Session organized by: *Aaron Daniel Sidford, Yin Tat Lee*

1. **Faster Approximation for Packing and Covering LPs**

Di Wang (wangd@eecs.berkeley.edu) Uniersity of California, Berkeley, USA, *Michael Mahoney, Satish Rao*

In a series of recent breakthroughs, Allen-Zhu and Orecchia leveraged the insights from the first-order optimization methods to provide improved algorithms for packing and covering linear programs [AO STOC'15, AO SODA'15]. The first result is particularly interesting, as the algorithm for packing LP achieves both width-independence and Nesterov-like acceleration, which was not known to be possible before. Somewhat surprisingly, however, their result on covering LP doesn't achieve the same Nesterov-like acceleration. This discrepancy is surprising, and it leaves open the question of the exact role that the optimization scheme is playing in coordinating the complementary gradient and mirror descent step of the algorithm. We clarify these issues for linear coupling algorithms for packing and covering LPs, illustrating that the linear coupling method can lead to improved $O(1/\varepsilon)$ dependence for both packing and covering problems in a unified manner. Our main technical result is a novel dimension lifting method that reduces the coordinate-wise diameters of the feasible region for covering LPs, which is the key structural property to enable the same Nesterov-like acceleration as in the case of packing LPs. The technique is of independent interest and may be useful in applying the accelerated linear coupling method to other combinatorial problems.

2. **Slime Molds and Sparse Recovery**

Damian Straszak (damian.straszak@epfl.ch) École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, *Nisheeth K Vishnoi*

We present a connection between two dynamical systems arising in entirely different contexts: one in sparse recovery and the other in biology. The first is the famous Iteratively Reweighted Least Squares (IRLS) algorithm used in sparse recovery while the second is the dynamics of a slime mold. Both of these dynamics are geared towards finding a minimum ℓ_1-norm solution in an affine subspace. Despite its simplicity the convergence of the IRLS method has been shown only for a certain regularization of it and remains an important open problem. We show that the two dynamics are projections of the same dynamical system in higher dimensions. Subsequently, we show convergence and obtain complexity bounds for a damped version of the IRLS algorithm.

3. **Solving Linear Programs via Rescalable Geometry**

Daniel N Dadush (dndadush@gmail.com) CWI, Netherlands

In 1979, Khachiyan used a "numerical trick" to show that linear programming (LP) is polynomially solvable using the ellipsoid method. Since that time, far more powerful algorithms for LP have been developed, e.g. interior point methods, with faster and faster convergence rates. Despite the steady progress in running times, a deeper understanding of the geometry behind the "numerical trickery" has proved elusive. In this work, we provide a new fine grained view of the relevant geometry for solving linear programs exactly. More precisely, we define a combination of three geometric potentials (which can be bounded by the size of the numbers), that together control the complexity of finding a point in the relative interior of any linear system together with a certificate of this fact. For this purpose, we provide a novel polynomial time "rescaled" interior point method for LP. Conversely, we show that given any such solution together with the certificate, one can define a simple scaling of the rows of the linear system such that all the aforementioned potentials become strongly polynomial.

■ Tue.C.5E
Tuesday, 14:45-16:00, Room 5E
Ambiguity-aware Decision Making under Uncertainty
Cluster: Robust Optimization
Session organized by: *Ruiwei Jiang*

1. **Risk-averse Stochastic Unit Commitment with Incomplete Information**

Yongpei Guan (guan@ise.ufl.edu) University of Florida, USA, *Ruiwei Jiang, Jean-Paul Watson*

In this paper, we study two risk-averse stochastic unit commitment models with incomplete information, with the first to be a chance-constrained unit commitment model and the second to be a two-stage stochastic unit commitment model with recourse. Based on historical data of renewable energy, we construct a confidence set for the probability distribution of the renewable energy and propose data-driven stochastic unit commitment models to hedge against the information incompleteness. Our models also ensure that, with a high probability, a large portion of renewable energy is utilized. Furthermore, we develop solution approaches to solve the models based on deriving strong valid inequalities and Benders' decomposition algorithms. We show that the risk-averseness of both models decreases as more data samples are collected and eventually vanishes as the sample size goes to infinity. Finally, our case studies verify the effectiveness of our proposed models and solution approaches.

2. **Two-Stage Stochastic Program with Distributional Ambiguity**

Ruiwei Jiang (ruiwei@umich.edu) University of Michigan, USA, *Yongpei Guan*

We develop a two-stage stochastic program that takes into account the distributional ambiguity. We derive an equivalent reformulation for this model that applies to both discrete and continuous distributions. Also, the reformulation reflects its linkage with a full spectrum of coherent risk measures under varying data availability.

3. **Distributionally Robust Chance-constrained Bin Packing Problem**

Siqian Shen (siqian@umich.edu) University of Michigan, USA, *Yiling Zhang, Ruiwei Jiang, Saadet Ayca Erdogan*

This paper considers a distributionally robust bin packing problem with random item sizes. We minimize the number of bins to pack all the items, while requiring not exceeding each bin's capacity limit with high probability. This paper considers a distributionally robust bin packing problem with random item sizes. We minimize the number of bins to pack all the items, while requiring not exceeding each bin's capacity limit with high probability. We use moment-based ambiguity sets and build two relaxations as a 0-1 SDP and a 0-1 SOCP. We also derive an exact 0-1 SOCP reformulation of the DR model and exploit submodularity to improve the computational efficiency, via a cutting-plane algorithm with polynomial-time separation subroutines. We demonstrate the computational efficacy and results of different approaches by testing instances of server allocation under random service durations, from an outpatient treatment application.

■ Tue.C.5G
Tuesday, 14:45-16:00, Room 5G
Numerical Methods for Large Scale Nonlinear Optimisation
Cluster: Optimization Implementations and Software
Session organized by: *Christof Bueskens*

1. **Parametric Sensitivity Analysis within Sequential Quadratic Programming — Post Optimality Analysis of Subproblems**

Sören Geffken (sgeffken@math.uni-bremen.de) Universität Bremen, Germany, *Christof Büskens*

Various tasks like parameter identification and discretised optimal control problems require the solution of typically large scale nonlinear optimisation problems. The parametric sensitivity analysis helps to understand the properties of optimisation problems. Parametric sensitivity derivatives quantify the effect of parametric perturbations to the solution of the problem. Within an SQP method quadratic subproblems with linearised constraints must be solved. Parametric sensitivity analysis on the subproblems in the SQP method allows to study the effect of different internal parameters on the subproblems. During the solution of the subproblems using our NLP solver WORHP several factorisations of the KKT matrix must be computed and can later be exploited to obtain parametric sensitivity derivatives at low computational cost. Multiple interesting parametric perturbations with large effect on the subproblems are analysed. Of special interest are perturbations within special strategies like Hessian regularisation and constraint relaxation. Furthermore, a specially structured parametric perturbation of the constraints can be introduced to overcome the deficiencies in the search direction due to the linearisation of the constraints in the sub problems. Different algorithmic extensions and numerical results are presented using the NLP solver WORHP.

2. **Implementation of a Penalty-Interior-Point Algorithm within WORHP**

Renke Schäfer (renke.schaefer@math.uni-bremen.de) University of Bremen, Germany, *Christof Büskens*

Interior-point methods have been shown to be very efficient for large-scale nonlinear programming (NLP) and, thus, form the basis for most of the state-of-the-art NLP solvers. Within our solver WORHP an interior-point method is used to solve the quadratic problems for its sequential quadratic programming (SQP) algorithm. Penalty-interior-point methods include the natural regularization of the constraints of penalty methods, which aims to increase the robustness of the algorithm, in particular for degenerate problems. Different attempts have been studied within the last decades, among them ℓ_1, ℓ_2 and augmented Lagrangian penalty approaches. We implemented an augmented Lagrangian based penalty-interior-point algorithm within WORHP as an alternative to its SQP option. In this presentation we give insights in our implementation and show a numerical study based on the CUTEst test set. The results of our new algorithm are compared with the SQP method of WORHP.

3. **SQP Methods and QP Hot-starting for Nonlinear Model Predictive Control**

Christian Kirches (christian.kirches@gmail.com) IWR, Heidelberg University, Germany

We present multi-level SQP methods and QP hot starting techniques for nonlinear model predictive control of large-scale processes. First, multi-level SQP methods address the computational effort involved in derivative generation for large-scale dynamic processes by adaptive linearization of state equations. Parts of the QP data remain fixed for multiple iterations, and this knowledge may be exploited for QP hot starting. Second, for each new QP in the sequence, the method utilizes hot-starts that employ information computed by an active-set QP solver during the solution of the first QP. This avoids the computation and factorization of the full constraint and Hessian matrices for all but the first problem in the sequence. The practical performance of the proposed method is demonstrated on a sequence of QPs arising in nonlinear model predictive control and during the solution of a set of randomly generated nonlinear optimization problems using sequential quadratic programming. Part of the results presented in this talk are joint work with Felix Lenders, Travis Johnson, and Andreas Waechter.

■ Tue.C.5H

Tuesday, 14:45-16:00, Room 5H

Financial Decision Making under Distress

Cluster: Applications in Finance and Economics
Session organized by: *Jingnan Chen*

1. **To Track or Not to Track: Can Economic and Financial Indicators Help Smart-Beta Funds?**

Chanaka Edirisinghe (edirin@rpi.edu) Rensselaer Polytechnic Institute, USA, *Yonggan Zhao*

Fund management based on index-tracking is well-studied and widely-practiced. Stock index funds represent over than 75% of index mutual funds valued over 1.7 trillion dollars. Since S&P-500 index is market cap-based, index tracking funds suffer from inefficiencies due to biases in large-cap equities. As a remedy, smart beta has emerged, where the funds are styled after alternative criteria to increase the exposure to a broader group of asset categories. Smart indexing has had tremendous growth over the last decade, with market value exceeding 230 billion dollars. This paper presents a new and powerful optimization approach to smart indexing where holdings in market sectors are dynamically-adjusted based on shifts in the economic scenarios. Such shifts are evaluated using macro-economic and financial indicator monthly data under a hidden Markov model. The likelihood of a shift determines the risk optimization strategy for the fund, as well as in updating asset return distributions. Fund returns so-computed are regressed over FF 3-factor model to identify fund alpha.

2. **Optimally Manage Crash Risk**

Shushang Zhu (zhuss@mail.sysu.edu.cn) Sun Yat-Sen University, China, *Shushang Zhu, Wei Zhu, Xi Pei, Xueting Cui*

Crash of the financial market means that most of the financial assets suddenly lose a certain part of their nominal value, which implies almost all the assets become perfectly correlated in a crash. The diversification effect of portfolios in a typical markets condition and the corresponding risk measures do not work any longer in a crash situation. Thus the performance measures (risk and return) and the managerial point of view under a crash should be distinguished from the traditional ones under the normal conditions. In this work, we integrate crash risk into portfolio management and investigate the performance measures, hedging and optimization of portfolio selection while involving crash risk. A convex programming framework based on parametric method is proposed to formulate the problem as a tractable one. Comprehensive simulation and empirical study are performed to test the proposed approach.

3. **Optimal Portfolio Deleveraging under Cross-Asset Price Pressure**

Jingnan Chen (jingnan_chen@sutd.edu.sg) Singapore University of Technology and Design, Singapore, *Yufei Yang, Jie Zhang*

We study an optimal portfolio deleveraging problem, where the objective is to meet specified debt/equity requirements at the minimal execution cost. During the course of trading, permanent and temporary price impact is taken into account. In particular, we include the cross-asset price pressure which measures the impact on an asset caused by the trading of other assets. Mathematically, the optimal deleveraging problem is formulated as a non-convex quadratic program with quadratic and box constraints. We develop a sequential convex QP embedded box searching method to obtain the optimal deleveraging strategy.

■ Tue.C.5I

Tuesday, 14:45-16:00, Room 5I

Geometry, Duality and Complexity in Conic Linear Programming II

Cluster: Conic and Polynomial Optimization
Session organized by: *Gabor Pataki*

1. **A Reduction Method for SDP Based on Projection Lattices and Jordan Algebras**

Frank Noble Permenter (fperment@mit.edu) Massachusetts Institute of Technology, USA, *Pablo A Parrilo*

Symmetry reduction is a powerful technique for reducing the size of a structured semidefinite program (SDP). In symmetry reduction, one uses group theory to find projections mapping feasible points to feasible points and optimal solutions to optimal solutions. In this work, we find a minimum rank projection with these properties by solving a structured optimization problem over the projection lattice. As we show, this optimization problem is solved by lattice-theoretic techniques that do not leverage, nor require, any group structure. Moreover, its solution identifies a Euclidean Jordan algebra intersecting the SDP solution set, allowing reformulation of the SDP over a product of simpler symmetric cones. We illustrate effectiveness of our method on examples, showing it can significantly reduce total computational cost. Finally, we compare our method to related *-algebra-based reduction techniques.

2. **Duality of a Generalized Absolute Value Optimization Problem**

Shota Yamanaka (s.yamanaka63@gmail.com) Kyoto University, Japan, *Nobuo Yamashita*

We consider a generalized absolute value optimization problem that has nonlinear functions satisfying a Cauchy-Schwarz-like inequality. One of such nonlinear functions is the absolute value function. The problem is not necessarily convex, and it includes absolute value optimization, nonlinear second-order cone optimization, and quadratic optimization problems. For the generalized problem, we propose a new type of dual problem, which is formulated in a closed form. We then present some interesting dual properties. In particular, we discuss the relation between the Lagrangian duality and the one proposed here. We finally give some sufficient conditions under which these dual problems coincide.

3. **Weak Infeasibility, Facial Reduction, and Geometry in Second-Order Cone Programming**

Masakazu Muramatsu (MasakazuMuramatsu@uec.ac.jp) The University of Electro-Communications, Japan, *Bruno F Lourenço, Takashi Tsuchiya*

We consider a sequence of feasibility problems which mostly preserve the feasibility status of the original second-order cone program. This is used to show that for a given weakly infeasible problem at most m directions are needed to get a point arbitrarily close to the cone, where m is the number of second-order cones. We present some of the related topics including the connection between the sequence and the facial reduction, and an extension to general conic linear programming.

■ Tue.C.5J

Tuesday, 14:45-16:00, Room 5J

Fast Inertial Proximal-Gradient Methods for Structured Optimization: $O(1/k^2)$ and Beyond

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Hedy Attouch*

1. **The Rate of Convergence of Nesterov's Accelerated Forward-Backward Method is Actually Faster Than $1/k^2$**

Hedy Attouch (hedy.attouch@univ-montp2.fr) Université Montpellier 2, France, *Juan Peypouquet*

The forward-backward algorithm is a powerful tool for solving optimization problems with a additively separable and smooth plus nonsmooth structure. In the convex setting, a simple but ingenious acceleration scheme developed by Nesterov improves the theoretical rate of convergence for the function values from the standard $O(k^{-1})$ down to $O(k^{-2})$. In this lecture, we prove that the rate of convergence of a slight variant of Nesterov's accelerated forward-backward method, which produces convergent sequences, is actually $o(k^{-2})$ (small "o") rather than $O(k^{-2})$ (big "O"). Our arguments rely on the connection between this algorithm and a second-order differential inclusion with vanishing damping, recently introduced by Su, Boyd and Candès.

2. **A Fast Convergent First-Order Method bearing Second-Order Information**

   Juan Peypouquet (juan.peypouquet@usm.cl) Universidad Tecnica Federico Santa Maria, Chile, *Hedy Attouch, Patrick Redont*

We propose a model for a class of first-order methods as an inertial system with Hessian-driven damping. The model combines several features of the Levenberg-Marquardt algorithm and Nesterov's acceleration scheme for first-order algorithms. We obtain a second-order system (in time and space), which can be interpreted as a first-order one by an appropriate transformation. The resulting method is easily implementable, more stable than classical accelerated methods, and just as fast.

3. **Convergence Rates in Convex Optimization: Going beyond the Worst-Case Analysis**

   Garrigos Guillaume (guillaume.garrigos@gmail.com) Istituto Italiano di Tecnologia, Italy, *Lorenzo Rosasco, Silvia Villa, Pierre Frankel, Juan Peypouquet*

In general, first-order descent methods for solving convex optimization problems enjoy a $O(1/n)$ rate of convergence for the function values. But these rates come from a worst-case analysis, with no particular hypothesis being made on the function to minimize. It is well-known that, by restricting the analysis to strongly convex functions, we can obtain linear rates, for both the function values and the iterates. But this is a quite restrictive hypothesis, and one could reasonably ask whether these results can be obtained for a more general class of functions. We will show that, by exploiting the geometrical information that we know about the function to minimize, precise rates for the iterates and the values can be obtained. As a by-product, we recover the linear convergence for strongly convex functions, but also for any function presenting a quadratic 'shape' around its minimizers, even if it is not coercive. We also obtain a whole spectrum of convergence rates between the linear one and the worst case $O(1/n)$, recovering some well-known results in linear inverse problems. As an application, we will show how the knowledge of these new rates can be used to design a better early stopping rule for regularization schemes, which is a central theme in machine learning.

■ Tue.C.5L

Tuesday, 14:45-16:00, Room 5L

Notions of Robustness and Dynamics in Convex Optimization: Part III

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Benjamin Recht, Pablo A Parrilo*

1. **Fitting Convex Sets to Data via Matrix Factorization**

   Venkat Chandrasekaran (venkatc@caltech.edu) California Institute of Technology, USA, *Yong Sheng Soh*

High-dimensional datasets arise prominently in a range of contemporary problem domains throughout science and technology. In many of these settings, the data are often constrained structurally so that they only have a few degrees of freedom relative to their ambient dimension. Methods such as manifold learning, dictionary learning, and others aim at computationally identifying such latent low-dimensional structure. In this talk, we describe a new approach to inferring the low-dimensional structure underlying a dataset by fitting a convex set with favorable facial structure to the data (in a manner to be suitably defined). Our procedure is based on computing a structured matrix factorization, and it includes several previous techniques as special cases. We illustrate the utility of our method with experimental demonstrations in applications.

2. **Switched System Analysis via Dual/Sum-of-Squares Techniques**

   Pablo A Parrilo (parrilo@mit.edu) Massachusetts Institute of Technology, USA, *Benoit Legat, Raphael Jungers*

How to characterize the asymptotic convergence rate of an infinite product of matrices, taken from a given set? This question appears, for instance, when analyzing certain classes of decentralized/distributed optimization algorithms. A well-known approach is based on the "joint spectral radius" (JSR) of the set, a notion of importance in applications such as hybrid systems analysis. In this talk we describe a new approach to this question, using a sum of squares optimization program and its dual for JSR approximation. Our methods produce an infinite sequence of matrices with an asymptotic growth rate arbitrarily close to the JSR. The algorithm naturally extends to the case where the allowable switching sequences are determined by a graph or finite automaton. We provide approximation guarantees on the closeness of the approximation ratio, and numerical examples illustrating the good performance of the method.

■ Tue.D.1S

Tuesday, 16:30-17:45, Room 1S

Large-Scale Nonlinear Optimization

Cluster: Nonlinear Optimization

Session organized by: *Roummel Marcia, Jennifer Erway*

1. **An Active Set Algorithm for Nonlinear Optimization with Polyhedral Constraints**

   William W Hager (hager@ufl.edu) University of Florida, USA, *Hongchao Zhang*

A polyhedral active set algorithm PASA is developed for solving a nonlinear optimization problem whose feasible set is a polyhedron. Phase one of the algorithm is the gradient projection method, while phase two is any algorithm for solving a linearly constrained optimization problem. Rules are provided for branching between the two phases. Global convergence to a stationary point is established, while asymptotically PASA performs only phase two when either a nondegeneracy assumption holds, or the active constraints are linearly independent and a strong second-order sufficient optimality condition holds.

2. **A New Successive Subspace Method for Solving the Trust-Region Subproblem**

   Joshua D Griffin (Joshua.Griffin@sas.com) SAS Institute Inc., USA, *Ioannis Akrotirianakis, Melanie Gratton, Alireza Yektamaram, Wenwen Zhou*

A resurgence in Hessian-free methods for deep learning has sparked interest in new iterative methods capable of handling the unique requirements of deep learning problems. This talk will focus on methods for solving the trust-region sub-problem in the context of large-scale nonconvex optimization. An effective but simple successive subspace method is used to safe-guard the conjugate gradient method applied to the Newton equations. A novel feature of our approach is that the trust-region solver also doubles as an accurate and efficient extreme value eigensolver. Remarkably both the trust-region subproblem and the minimum eigenvalue problem are solved simultaneously for the cost of a single matrix multiply per iteration and nominal memory overhead. Numerical results demonstrate the effectiveness and efficiency of this approach, both as a trust-region solver and as a stand-alone eigenvalue solver.

3. **Methods for Large- and Medium-Scale Nonlinear Optimization**

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

We consider some theoretical and practical issues associated with the formulation of sequential quadratic programming (SQP) methods for large- and medium-scale nonlinear optimization problems. Issues that complicate the implementation of efficient SQP methods in the large-scale case are discussed. Numerical results are presented for the software packages DNOPT and SNOPT, which utilize an exact or approximate Hessian.

■ Tue.D.1A

Tuesday, 16:30-17:45, Room 1A

Nonconvex and Non-Lipschitz Optimization: Algorithms and Applications 4

Cluster: Nonlinear Optimization

Session organized by: *Ya-Feng Liu*

1. **New Strategies of Stochastic RBF Method for Expensive Black-Box Global Optimization**

   Dong Kang (kangdong@lsec.cc.ac.cn) Chinese Academy of Sciences, China

We are considering the bound constrained global optimization problem where the objective function is a continuous and computationally expensive black-box function with multiple local minima. There are many engineering optimization problems in which a single objective function evaluation may take from a few minutes to many hours, and the objective function formulation or the derivative information is unknown. Our goal is to approximate the global minimizer with only a relatively small number of function evaluations. Regis and Shoemaker (2007) proposed an efficient method (stochastic RBF) to solve this kind of problem. In this work, we propose some new strategies to improve the efficiency of stochastic RBF method by changing the way to generate candidate points, and design a new utility function to measure different candidate points.

2. **A Subspace Multilevel Method for Nonlinear Optimization**

Cheng Chen (cchen@lsec.cc.ac.cn) Chinese Academy of Sciences, China

We propose a new subspace multilevel method for solving general unconstrained infinite dimensional optimization problems. At each iteration, the algorithm executes a direct step on the current level or a coarse subspace correction step. For coarse subspace correction step, we induce a two-dimensional subspace, which is spanned by the current point and the gradient direction of current point, in the traditional coarse grid space. Following the optimize-then-discretize strategy, we derive the formulation of infinite dimensional coarse space subproblem first and solve its discretized version. Global convergence and convergence rate are proved under minimal conditions on discretized functions used at all grid levels. Some numerical experiments are presented in the last part, which show that our subspace multilevel method is promising.

3. **A General Proximal Quasi-Newton Method for Large Scale l_1 Penalized Optimization Problem**

Zhilong Dong (zldong@lsec.cc.ac.cn) Chinese Academy of Sciences, China, *Yu-Hong Dai, Zhao-Song Lu*

In this report, we propose an inexact proximal quasi-Newton method for solving large scale l_1 penalized optimization problem. The object function consists of one smooth convex part as well as a l_1 penalized term. Firstly, we use a limited memory BFGS framework to approximate the smooth part with a quadratic function. Then we solve the reformulated subproblem using an interior point method with wide neighborhood. We use Shermon-Morrison-Woodbury technique to reduce the computational complexity in each iteration, and propose several techniques to overcome the difficulty of generating computation error when computing the inverse of a matrix. Global convergence as well as the local Q-superlinear convergence rate are guaranteed for this algorithm. Numerical experiments show that our LBIPM algorithm runs faster and returns solutions not worse than those from the state-of-the-art algorithms.

■ Tue.D.1B

Tuesday, 16:30-17:45, Room 1B

PDE Optimization and Applications I

Cluster: PDE-constrained Optimization
Session organized by: *Tomoya Takeuchi*

1. **Receding Horizon Control for Spatiotemporal Dynamic Systems**

Tomoaki Hashimoto (tomoaki.hashimoto@oit.ac.jp) Osaka Institute of Technology, Japan

Receding horizon control is a type of optimal feedback control in which control performance over a finite future is optimized with a performance index that has a moving initial time and terminal time. Spatiotemporal dynamic systems characterized by both spatial and temporal variables often occur in many research fields. In this talk, a design method of receding horizon control for a generalized class of spatiotemporal dynamic systems is illustrated. Using the variational principle, we first derive the stationary conditions that must be satisfied for a performance index to be optimized. Next, we consider a numerical algorithm to solve the stationary conditions via a finite-dimensional approximation. Finally, the effectiveness of the control design method is verified by numerical simulations.

2. **Topology Optimization for Fluid Dynamics Problems and Its Applications in Flow Channel Design**

Kentaro Yaji (yaji@mech.eng.osaka-u.ac.jp) Osaka University, Japan

The application of structural optimization in fluid problems has been an attractive area of research for mathematicians and engineers. In this study, we show the applicability of topology optimization for fluid problems, whereas the most widely used approach is based on shape optimization. In particular, we focus on a flow channel design considering fluid and scalar transport, which is a pioneering research topic in the research field. Several numerical examples are provided to confirm the efficacy of proposed methodology for the design of flow channel devices such as heatsink and microreactor.

3. **Shape Optimization Approach to Free Boundary Problems by Traction Method**

Masato Kimura (mkimura@se.kanazawa-u.ac.jp) Kanazawa University, Japan, *Shogen Shioda, Maharani Ahsani Ummi, Hideyuki Azegami, Kohji Ohtsuka*

For an inverse free boundary problem governed by the Laplace equation, we consider a new approach by means of the shape optimization and propose a numerical scheme to solve it using the traction method. The traction method is a widely used numerical scheme for optimal shape design problems in engineering. We numerically check the efficiency of the traction method by using the exact solution of the free boundary problem. We can avoid the numerical difficulty in treating the curvature term arising in the shape derivative of the cost function using its weak formulation coupled with the traction method.

■ Tue.D.1C

Tuesday, 16:30-17:45, Room 1C

Advances in Derivative-free and Simulation-based Optimization II

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Warren L Hare*

1. **An Implicit Filtering-based Algorithm for Derivative Free Multiobjective Optimization**

Alessandra Papini (alessandra.papini@unifi.it) University of Florence, Italy, *Guido Cocchi, Giampaolo Liuzzi, Marco Sciandrone*

In this work we consider multiobjective optimization problems with bound constraints. We assume that the objective functions are continuously differentiable and that their gradients are not available. We present an algorithm combining direct search and implicit filtering approaches. At each iteration, a multiobjective variant of the classical coordinate search is performed. The implicit filtering phase starts whenever the coordinate search is unsuccessful, i.e. the coordinate search cannot produce a new nondominated point. The computed objective function values are employed to approximate the gradients of the objective functions, and a linear programming problem is solved to define a possible multiobjective descent direction. Then, a line search is performed along the computed direction. Global convergence results are stated. Computational experiments are performed and the obtained results are presented and discussed.

2. **Global Derivative-free Quasi-Newton Methods for Bound-constrained Nonlinear Systems**

Margherita Porcelli (margherita.porcelli@unifi.it) University of Firenze, Italy, *Benedetta Morini, Leopoldo Marini*

We address the solution of nonlinear systems of equations where the variables are subject to bound-constraints and where we assume that derivatives of the residual function may be difficult to compute or unavailable. We present a new globally convergent procedure that may be performed in a derivative-free regime. The development of such procedure is motivated by the need to develop efficient tools for solving large nonlinear systems accessible to non-expert users, i.e. people who have little or no skill in analyzing the specific structure of the problem at hand. The proposed method relies on the Quasi-Newton approach and comprises spectral residual methods. Since the search directions generated by these methods may be uphill for the merit function we employ a globalization strategy based on an approximate norm descent condition. We provide a theoretical analysis of the proposed approach and illustrate its numerical behaviour on problems from the literature and from the simulation of compressor trains for oil&gas applications and gas distribution pipeline network. Comparisons are also conducted with existing approaches.

3. **Using Inexact Subgradients to Compute Proximal Points of Convex Functions**

Warren L Hare (warren.hare@ubc.ca) University of British Columbia, Canada, *Chayne Planiden*

Proximal points play a central role in a number of nonsmooth optimization algorithms. Some recent work has extended these algorithms to a DFO setting. However, past work has focused on extending entire (complicated) algorithms, and any subroutine to compute a proximate point is hidden within the developed method, and only analyzed in light of the developed method. In this work, we develop such an inexact bundle method to find the proximal point of a convex function at a given point. This method can now be used as a foundation in proximal-based methods for nonsmooth convex functions where the oracle returns an exact function value and an inexact subgradient vector.

■ Tue.D.4A

Tuesday, 16:30-17:45, Room 4A

Optimization Models in Energy

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Javad Lavaei*

1. **Monotonicity Properties in Dissipative Flow Networks**

   Marc D Vuffray (vuffray@lanl.gov) Los Alamos National Laboratory, USA, *Sidhant Misra, Anatoly Zlotnik, Misha Chertkov*

Dissipative flow networks model flow of fluids or commodities across a network. The flow dynamics on edges are governed by non-linear dissipative partial differential equations. The dynamics on adjacent edges are coupled through Kirchhoff-Neumann boundary conditions that also account for the injection parameters at the nodes. We establish a monotonicity property which states that the ordering of the initial states (e.g. density) is preserved throughout the time evolution of the system whenever the nodal injection parameters also obey the same ordering. We show that the dynamic system resulting from an appropriate choice of spatial discretization of the system of PDEs inherits this monotonicity property and can be used within simulation and optimization. We also prove a monotonicity property for dissipative networks in steady state and establish a connection between the dynamic and steady state results. These results enable significant simplification in the representation and algorithms for robust optimization and control problems under uncertain nodal injections.

2. **Optimal Distributed Control of Power Systems with a High Level of Renewable Energy**

   Abdulrahman Kalbat (akalbat@gmail.com) United Arab Emirates University, United Arab Emirates, *Salar Fattahi, Javad Lavaei*

This talk is concerned with the optimal distributed control of power systems under a high penetration of renewable energy. This optimal control problem is highly nonlinear and NP-hard. In this work, we design an efficient computational method to find a near-global distributed controller for a large class of systems. We also study how the connectivity of its underlying communication network affects the optimal performance of the stochastic power system under control. As a case study, the proposed technique is used to design a distributed primary frequency controller for the IEEE 39-Bus New England test System.

3. **Power System State Estimation with a Limited Number of Measurements**

   Javad Lavaei (lavaei@berkeley.edu) University of California, Berkeley, USA, *Ramtin Madani, Yu Zhang, Morteza Ashraphijuo, Ross Baldick*

This work is concerned with the power system state estimation (PSSE) problem, which aims to find the unknown operating point of a power network based on a given set of measurements. The measurements of the PSSE problem are allowed to take any arbitrary combination of nodal active powers, nodal reactive powers, nodal voltage magnitudes and line flows. This problem is non-convex and NP-hard in the worst case. We develop a set of convex programs with the property that they all solve the non-convex PSSE problem in the case of noiseless measurements as long as the voltage angles are relatively small. This result is then extended to a general PSSE problem with noisy measurements, and an upper bound on the estimation error is derived. The objective function of each convex program developed in this paper has two terms: one accounting for the non-convexity of the power flow equations and another one for estimating the noise levels. The proposed technique is demonstrated on the 1354-bus European network.

■ Tue.D.4B

Tuesday, 16:30-17:45, Room 4B

Stochastic Optimization and Variational Inequality Problems

Cluster: Complementarity and Variational Inequalities
Session organized by: *Mengdi Wang, Shisheng Cui*

1. **On the Analysis of Three Stochastic Extragradient Variants for Monotone Stochastic Variational Inequality Problems**

   Shisheng Cui (suc256@psu.edu) The Pennsylvania State University, USA, *Uday V Shanbhag*

The stochastic generalizations of the extragradient methods are complicated by a key challenge: the scheme requires two projections on a convex set, which is a concern if the sets are complicated. Thus, there is a strong need for developing low-complexity schemes equipped with convergence theory and rate statements for resolving such problems. This provides a motivation for considering three related avenues where every iteration requires a single projection: (i) A projected reflected gradient method; (ii) A subgradient extragradient method; and (iii) A modified backward-forward splitting method. Unfortunately, little appears to be known regarding the convergence properties of these schemes in stochastic regimes. To this end, we make the following contributions: (a) We prove almost sure convergence of the iterates to a random point in the solution set; (b) Under strong monotonicity, we prove that the mean-squared error associated with the iterate sequence diminishes to zero at the optimal rate of $O(1/K)$ where K is the iteration index; (c) When the map is merely monotone, we prove that the gap function associated with the averaged sequence diminishes to zero at the optimal rate of $O(1/\sqrt{K})$. Preliminary numerics suggest that the schemes are competitive their extragradient counterparts.

2. **On the Resolution of Complementarity Formulations of the L_0-Norm Minimization Problem via ADMM Schemes**

   Yue Xie (yux111@psu.edu) The Pennsylvania State University, USA, *Uday V Shanbhag*

Recently, there has been an effort to resolve the L_0-norm optimization problem by considering a complementarity-based formulation. We adopt precisely such an approach and consider the use of an ADMM scheme. In particular, by exploiting the structure in the subproblems, we develop efficient variants of such schemes and provide preliminary numerics.

3. **A Distributionally Robust Model for Three Stage Stochastic Linear Optimization**

   Sun Jie (jie.sun@curtin.edu.au) Curtin University, Australia, *Bin Li, Kok Lay Teo, Changjun Yu*

Three-stage stochastic linear program is the most basic model of multi-stage stochastic optimization with nontrivial nonanticipativity constraints and conditional distributions. However, the practical usage of such model has been restricted by the inability of solving (although structured) linear programs of huge dimension resulted from the exponential growth of scenarios, which is particularly so if the scenarios are generated through discretization of certain continuous random varaibles. We therefore consider a distributionally robust version of this model that utilizes the worst-case recourse functions over a set of possible probability distributions. It is shown that under a standard set of regularity assumptions, this distributionally robust three-stage stochastic optimization problem is equivalent to a conic optimization problem that can be solved in polynomial time. A numerical example is provided to show the advantage of the distributionally robust approach.

■ Tue.D.5A

Tuesday, 16:30-17:45, Room 5A

Generalized Convexity and Set Optimization

Cluster: Multi-Objective and Vector Optimization
Session organized by: *Daishi Kuroiwa*

1. **Robust Vector Optimization: Well-Posedness, Sensitivity to Uncertainty and Generalized Convexity of Set-valued Maps**

   Matteo Rocca (matteo.rocca@uninsubria.it) Universita' degli Studi dell'Insubria, Italy, *Giovanni P Crespi, Daishi Kuroiwa, Nicolae Popovici*

Robust Optimization is growing as a powerful tool to handle parameters uncertainty in optimization models. Recently the relation between multicriteria robustness concepts and set valued optimization has been investigated (Ide, Köbis, Kuroiwa, Schöbel, Tammer). In this talk we deal with well-posedness properties of robust vector optimization problems. Furthermore, we investigate how robust solutions react to changes in the uncertainity set. As generalized convexity of set-valued maps plays a crucial role in the obtained results, we devote part of the talk to some characterizations of quasi–convexity for set-valued maps.

2. **Unified Approach in Set Optimization and Generalized Convexity for Set-valued Maps**

   Daishi Kuroiwa (kuroiwa@riko.shimane-u.ac.jp) Shimane University, Japan

We study set optimization, which is set-valued optimization with respect to set relations. Notions of solutions in set-valued optimization are classified into two types. One is based on the order of the range vector space. The other is based on set relations, which are binary relations on the family of the range space, and the problems based on set relations are called set optimization problems. In this talk, we propose a unified approach in such set optimization problems, and give generalized notions of convexity for set-valued maps.

3. **Generalized Convexity for Set-valued Maps and Its Applications**

Kazuki Seto (k.seto@math.shimane-u.ac.jp) Shimane University, Japan, *Daishi Kuroiwa*

We study generalized convexity for set-valued maps based on the unified apploach which was studied by Kuroiwa, one of the authors, and we consider applications with respect to such generalized convexity.

■ Tue.D.5D

Tuesday, 16:30-17:45, Room 5D

Sparse and Low Rank Approximation

Cluster: Sparse Optimization and Information Processing
Session organized by: *Coralia Cartis*
Session chair: *Maryam Fazel*

1. **Nonconvex Recovery of Low Complexity Models**

John Wright (johnwright@ee.columbia.edu) Columbia University, USA, *Ju Sun, Qing Qu*

We consider a complete dictionary recovery problem, in which we are given a data matrix Y, and the goal is to factor it into a product $Y\sim A_0X_0$, with A_0 a square and invertible matrix and X_0 is a sparse matrix of coefficients. This is an abstraction of the dictionary learning problem, in which we try to learn a concise approximation to a given dataset. While dictionary learning is widely (and effectively!) used in signal processing and machine learning, relatively little is known about it in theory. Much of the difficulty owes to the fact that standard learning algorithms solve nonconvex problems, and are difficult to analyze globally. We describe an efficient algorithm which provably learns representations in which the matrix X_0 has as many as $O(n)$ nonzeros per column, under a suitable probability model for X_0. Our results follow from a reformulation of the dictionary recovery problem as a nonconvex optimization over a high dimensional sphere. This particular nonconvex problem has a surprising property: once about n^3 data samples have been observed, with high probability the objective function has no spurious local minima. This geometric phenomenon, in which seemingly challenging nonconvex problems can be solved globally by efficient iterative methods, also arises in problems such as tensor decomposition and phase recovery from magnitude measurements.

2. **Breaking Sample Complexity Barriers via Nonconvex Optimization?**

Mahdi Soltanolkotabi (msoltoon@gmail.com) University of Southern California, USA

In the past decade there has been significant progress in understanding when convex relaxations are effective for finding low complexity models from a near minimal number of data samples (e.g. sparse/low rank recovery from a few linear measurements). Despite such advances convex optimization techniques are often prohibitive in practice due to computational/memory constraints. Furthermore, in some cases convex programs are suboptimal in terms of sample complexity and provably require significantly more data samples than what is required to uniquely specify the low complexity model of interest. In fact for many such problems certain sample complexity "barriers" have emerged so that there are no known computationally tractable algorithm that can beat the sample complexity achieved by such convex relaxations. Motivated by a problem in imaging, In this talk I will discuss my recent results towards breaking such barriers via natural nonconvex optimization techniques.

3. **A Semidefinite Relaxation for Computing Distances Between Metric Spaces**

Rachel Ward (rward@math.utexas.edu) University of Texas at Austin, USA, *Afonso Bandeira, Andrew Blumberg, Soledad Villar*

In this talk we explore a semidefinite relaxation for the (NP-hard to compute) Gromov-Hausdorff distance between metric spaces, focusing on distances between point clouds. We prove that the relaxed "distance" is in fact a metric, and serves as a lower bound for the Gromov-Hausdorff distance. We derive an algorithm based on alternating direction augmented Lagrangian that can efficiently compute the distance between point clouds with hundreds of points, and illustrate its effectiveness on several data sets.

■ Tue.D.5E

Tuesday, 16:30-17:45, Room 5E

Recent Advances in Data-driven Optimization

Cluster: Robust Optimization
Session organized by: *Vishal Gupta*

1. **Smart "Predict, Then Optimize"**

Adam Elmachtoub (adam@ieor.columbia.edu) Columbia University, USA, *Paul Grigas*

We consider a class of optimization problems where the objective is not explicitly provided, but contextual information can be used to predict the objective based on historical data. A traditional approach would be to simply predict the objective based on minimizing prediction error, and then solve the corresponding optimization problem. Instead, we provide a prediction framework that leverages the structure of the optimization problem that will be solved given the prediction. We provide theoretical, algorithmic, and computational results to show the validity and practicality of our framework.

2. **An Extended Frank-Wolfe Method with "In-Face" Directions, and Its Application to Low-Rank Matrix Completion**

Paul Grigas (pgrigas@mit.edu) Massachusetts Institute of Technology, USA, *Robert M Freund, Rahul Mazumder*

We present an extension of the Frank-Wolfe method that is designed to induce near-optimal low-rank solutions for matrix completion and, for more general problems, induces near-optimal well-structured solutions. We establish computational guarantees for the method that trade off efficiency in computing near-optimal solutions with upper bounds on the rank of iterates. We present extensive computational results on both real and artificial datasets that demonstrate that our extended Frank-Wolfe method (in different versions) shows significant computational advantages over existing related approaches, in terms of delivering low rank and low run time to compute a target optimality gap.

3. **Empirical Bayes and Optimization in the Small-Data Regime**

Vishal Gupta (guptavis@usc.edu) The University of Southern California, USA, *Paat Rusmevichientong*

Optimization applications frequently depend on a huge number of parameters that must be estimated from data. In many contexts, however, the amount of data per parameter is small. For example, an online retailer might stock millions of products, but most products only have a few sales per year. We propose a novel approach to optimization in this small-data/high dimensional regime for the special class of linear optimization problems with uncertain objectives. Unlike state-of-practice methods based on the "estimate then optimize" paradigm, our approach leverages ideas from empirical bayes to exploit Stein's phenomenon and pool information across parameters. Moreover, unlike other empirical bayes methods based on maximum likelihood or method of moments, our approach utilizes the linear optimization structure to improve performance. Because of these two features, we show our approach is never worse than, and often significantly better than, both the state-of-practice and traditional empirical Bayes methods. We prove that under mild conditions, as the number of objective coefficients in the linear optimization tends to infinity with the amount of data per coefficient fixed, our approach has performance comparable to the best-in-class estimator.

■ Tue.D.5G

Tuesday, 16:30-17:45, Room 5G

Linear Optimization and Computation

Cluster: Linear Optimization
Session organized by: *Selin D. Ahipasaoglu, Giacomo Nannicini*

1. **Improving the CPLEX LP Solver**

Roland Wunderling (roland.wunderling@at.ibm.com) IBM, Austria, *Bo Jensen*

Solving Linear Programs out of the box has become standard in the past decades, prompting practitioners to build larger and larger problem instances. We will discuss how these changes are recognised in the development of the CPLEX LP solver and provide a detailed performance evaluation of their effect.

2. **LP Solution Polishing to Improve MIP Performance**

Matthias Miltenberger (miltenberger@zib.de) Zuse Institute Berlin, Germany

In practice, the solution of a linear program (LP) is rarely unique. This is especially true in the context of mixed integer programming (MIP), where dual degeneracy is common. Here, the solution of the LP relaxation in the root node can strongly influence the later solving process. This performance variability may be exploited by choosing a particular candidate from this set of optimal basic solutions. We investigate how the minimization and maximization of the number of integer variables with fractional solution values affects MIP components such as branching, cutting plane separation, and primal heuristics.

3. **Primal-Dual Method for Decentralized Online Optimization**

Soomin Lee (s.lee@duke.edu) Duke University, USA, *Michael M Zavlanos*

We present a consensus-based primal-dual method for decentralized online convex optimization, where the system objective function varies arbitrarily over time subject to some global inequality constraints. At each stage, each agent in the network commits to an adaptive decision pertaining only to the past and locally available information, and incurs a new cost function reflecting the change in the environment. Our algorithm uses weighted averaging of the iterates for each agent to keep local estimates of the global constraints and dual variables. We define regret as the cost difference with the optimal action over time. We show that the proposed decentralized method achieves a regret of order $O(\sqrt{T})$ with the time horizon T, in scenarios when the underlying communication topology is time-varying and jointly-connected. The regret is measured in regard to the cost function value as well as the constraint violation. We also address the impact of the network topology as a factor on the speed of convergence. Numerical results for online routing in wireless multi-hop networks with uncertain channel rates will be provided to illustrate the performance of the proposed algorithm.

■ Tue.D.5H

Tuesday, 16:30-17:45, Room 5H

Optimization in Portfolio Selection and Risk Management

Cluster: Applications in Finance and Economics

Session organized by: *Duan Li*

1. **Portfolio Optimization with Non-recursive Reference Point Updating**

Moris Simon Strub (msstrub@se.cuhk.edu.hk) Chinese University of Hong Kong, Hong Kong, *Duan Li*

According to cumulative prospect theory, decision makers evaluate prospects in comparison to a reference point instead of with regards to resulting absolute terminal wealth levels. In a dynamic portfolio optimization setting it is thus crucial how investors form and update their reference points, as this directly influences optimal strategies. The empirical findings by Baucells et al. (2011) suggest that reference levels are updated in a non-recursive manner. Motivated by those results, we propose a dynamic portfolio choice model with non-recursive reference point updating which leads to a time-inconsistent problem. We determine the optimal investment strategy for different types of investors and compare the resulting trading behavior to those implied by other behavioral portfolio choice models in the existing literature.

2. **On Multiperiod Mean-CVaR Portfolio Optimization**

Jianjun Gao (gao.jianjun@shufe.edu.cn) Shanghai University of Finance and Economics, China, *Xiangyu Cui, Yun Shi, Shushang Zhu*

In this work, we study the multiperiod mean-CVaR portfolio optimization problem with conic constraint on portfolio decision. Although the conditional value-at-risk (CVaR) is widely used in static portfolio selection and risk management, the dynamic mean-CVaR portfolio selection problem in discrete time setting are seldom studied due to the time inconsistency and the computational issue of this problem. Time inconsistency, which originates from the conflicts between the global investment interest and the local investment interests of the investor, makes the investor have the tendency of bowing to local investment temptations and deviating from the global optimal strategy during the investment. Three types of dynamic mean-CVaR investment strategies, pre-committed strategy, time consistent strategy and self-control strategy, are discussed in this paper. The pre-committed strategy and time consistent strategy concerns the global investment interest and local investment interests respectively, while the self-control strategy balances the global and local investment interests. Furthermore, the comparison of three types of strategies is also shown through an illustrative example.

3. **Quadratic Convex Reformulations for Semi-continuous Quadratic Programming and Its Application in Cardinality Constrained Mean-Variance Portfolio Selection**

Duan Li (dli@se.cuhk.edu.hk) The Chinese University of Hong Kong, Hong Kong, *Baiyi Wu*

Modeling the cardinality constrained portfolio selection problem mathematically leads to a semi-continuous quadratic programming problem. We extend the quadratic convex reformulation approach in the literature to form new reformulations, which adds to the original objective function an additional function that is zero at all points of the feasible region and then convexifies the new objective function. Exploiting the structure of semi-continuous variables, we derive the most general set of quadratic functions that can be used to enhance the reformulation. Our numerical tests in cardinality constrained portfolio selection have demonstrated the effectiveness of our new reformulations and favorable comparison over the state-of-the-art perspective cut approach.

■ Tue.D.5I

Tuesday, 16:30-17:45, Room 5I

Barriers in Conic Optimization

Cluster: Conic and Polynomial Optimization

Session organized by: *Roland Hildebrand*

1. **New Upper Bounds for the Density of Translative Packings of Three-dimensional Convex Bodies with Tetrahedral Symmetry**

Cristobal Guzman (cguzman@gatech.edu) Centrum Wiskunde & Informatica, Netherlands, *Maria Dostert, Fernando Oliveira, Frank Vallentin*

We determine new upper bounds for the maximal density of translative packings of superballs in three dimensions (unit balls for the l_3^p-norm) and of Platonic and Archimedean solids having tetrahedral symmetry. These bounds give strong indications that some of the lattice packings of superballs found in 2009 by Jiao, Stillinger, and Torquato are indeed optimal among all translative packings. We improve Zong's recent upper bound for the maximal density of translative packings of regular tetrahedra from 0.3840 to 0.3745, getting closer to the best known lower bound of 0.3673. We apply the linear programming bound of Cohn and Elkies which originally was designed for the classical problem of packings of round spheres. The proofs of our new upper bounds are computational and rigorous. Our main technical contribution is the use of invariant theory of pseudo-reflection groups in polynomial optimization.

2. **The Entropic Barrier: A Universal and Optimal Self Concordant Barrier**

Ronen Eldan (roneneldan@gmail.com) Weizmann Institute, Israel, *Sebastien Bubeck*

A fundamental result in the theory of Interior Point Methods is Nesterov and Nemirovski's construction of a universal self-concordant barrier. In this talk, I will introduce the entropic barrier, a new, simple and in some sense optimal universal self-concordant barrier.

3. **Barriers on Symmetric Cones**

Roland Hildebrand (roland.hildebrand@imag.fr) Weierstrass Institute, Germany

A self-scaled barrier on a symmetric cone is a non-degenerate convex combination of the logarithms of the determinants of the irreducible factors of the cone. The special properties of the self-scaled barriers are at the heart of the interior-point methods used for solving conic optimization problems over symmetric cones. We introduce an analytic description of self-scaled barriers which is of local character and independent of the notion of a symmetric cone. Namely, we identify these barriers as the solutions of a certain quasi-linear fourth-order partial differential equation. Given such a solution in the neighbourhood of some point, it defines and can be extended to the interior of some symmetric cone on which it will represent a self-scaled barrier. This partial differential equation has a simple interpretation as the vanishing of a certain mixed covariant derivative of the metric defined by the Hessian of the solution with respect to the affine connection of the ambient real space and the Levi-Civita connection of the Riemannian metric defined by this Hessian. More precisely, the third derivative of the solution has to be invariant with respect to the geodesic flow defined by the Riemannian metric. Thus in a certain sense, self-scaled barriers resemble cubic polynomials.

■ Tue.D.5J

Tuesday, 16:30-17:45, Room 5J

Primal-Dual Algorithm for Convex Optimization

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Qihang Lin*

1. **Stochastic Dual Ascent for Solving Linear Systems**

Peter Richtarik (richtarik@gmail.com) University of Edinburgh, United Kingdom, *Robert Mansel Gower*

We develop a new randomized iterative algorithm—stochastic dual ascent (SDA)—for finding the projection of a given vector onto the solution space of a linear system. The method is dual in nature: with the dual being a non-strongly concave quadratic maximization problem without constraints. In each iteration of SDA, a dual variable is updated by a carefully chosen point in a subspace spanned by the columns of a random matrix drawn independently from a fixed distribution. The distribution plays the role of a parameter of the method. We prove that primal iterates associated with the dual process converge to the projection exponentially fast in expectation, and give a formula and an insightful lower bound for the convergence rate. We also prove that the same rate applies to dual function values, primal function values and the duality gap. Unlike traditional iterative methods, SDA converges under no additional assumptions on the system (e.g., rank, diagonal dominance) beyond consistency. In fact, our lower bound improves as the rank of the system matrix drops. Many existing randomized methods for linear systems arise as special cases of SDA, including randomized Kaczmarz, randomized Newton, randomized coordinate descent, Gaussian descent, and their variants.

2. **Remarks on Acceleration for Primal-Dual Algorithms**

Antonin Chambolle (antonin.chambolle@cmap.polytechnique.fr) Ecole Polytechnique, CNRS, France, *Thomas Pock, Pauline Tan*

We try to describe what "really" controls the type of quantities which are usually bound by accelerated primal-dual first order methods. Exploiting the relationship with ADMM type algorithms, we also can deduce relevant bound for some objectives of accelerated ADMM methods. This is joint work with T. Pock (Graz, Austria) and P. Tan (Palaiseau, France).

3. **A Randomized Asynchronous Algorithm for Distributed Optimization with Parameter Servers**

Lin Xiao (lin.xiao@microsoft.com) Microsoft Research, USA, *Adams Wei Yu, Qihang Lin, Weizhu Chen*

Machine learning with big data often involves big optimization models. For distributed optimization over a cluster of machines (each stores its own share of data), the number of parameters or optimization variables can be too large for frequent communication and synchronization. To overcome this difficulty, we can set up dedicated parameter servers, each maintaining a subset of the overall model parameters and updating them in an asynchronous distributed manner. Such a system may significantly increase our capacity of learning from big data, but at the same time, poses new challenges for developing efficient and robust distributed algorithms. We propose a DSCOVR (Doubly Stochastic Coordinate Optimization with Variance Reduction) algorithm, which exploits the simultaneous partitions in both data and model to gain parallelism, and employs periodic variance reduction to achieve a fast convergence rate, with small communication and computation overhead.

■ Tue.D.5K

Tuesday, 16:30-17:45, Room 5K

First Order Methods and Applications

Cluster: Convex and Nonsmooth Optimization

Session chair: *CH Jeffrey Pang*

1. **An Adaptive Restarting for Universal Gradient Method of Minimizing Strongly Convex Functions**

Masaru Ito (ito.m@math.cst.nihon-u.ac.jp) Nihon University, Japan

We consider convex optimization problems of minimizing strongly convex objective functions with Hölder continuous gradient. In the non-strongly convex case, the universal gradient method proposed by Nesterov achieves the optimal complexity without knowing the level of smoothness of the objective function. We consider a variant of the universal gradient method and propose a restarting storategy to adapt the convexity parameter of the objective function. The inputs of our method are the initial point, the required accuracy, and the (arbitrary) initial guess of the convexity parameter. We show a complexity result of the proposed method where the complexity analysis is discussed with respect to the norm of "gradient mapping."

2. **Fast Accelerated Proximal Gradient Method and Its Application to Unified Classification Algorithm**

Naoki Ito (naoki_ito@mist.i.u-tokyo.ac.jp) The University of Tokyo, Japan, *Akiko Takeda, Kim-Chuan Toh*

We develop a fast accelerated proximal gradient (FAPG) method. Our FAPG method employs various techniques such as backtracking line search and an adaptive restarting scheme in order to speed up the practical convergence. While restarting schemes have guaranteed convergence for strongly convex objective functions, the proposed algorithm has a rate of convergence $O((\log k/k)^2)$ even for non-strongly convex objective functions, where k is the iteration counter. We also provide a practical FAPG, which simplifies the line search procedure, and apply it to binary classification. To achieve a good prediction performance in binary classification, it is important to find a suitable model for a given dataset. Thus, it is desirable to have an efficient unified algorithm for solving different classification models to facilitate the evaluation of performance of various models for a given dataset. For the purpose, we have provided a unified formulation of various binary classification models and apply our FAPG to the formulation. Numerical experiments show that our unified algorithm is stable and highly competitive to specialized algorithms designed for specific classification models.

3. **The Supporting Halfspace-quadratic Programming Strategy for the Dual of the Best Approximation Problem**

CH Jeffrey Pang (matpchj@nus.edu.sg) National University of Singapore, Singapore

We consider the best approximation problem (BAP) of projecting a point onto the intersection of a number of convex sets. It is known that Dykstra's algorithm is alternating minimization on the dual problem. We extend Dykstra's algorithm so that it can be enhanced by the SHQP strategy of using quadratic programming to project onto the intersection of supporting halfspaces generated by earlier projection operations. By looking at a structured alternating minimization problem, we show the convergence rate of Dykstra's algorithm when reasonable conditions are imposed to guarantee a dual minimizer. We also establish convergence of using a warmstart iterate for Dykstra's algorithm, show how all the results for the Dykstra's algorithm can be carried over to the simultaneous Dykstra's algorithm, and discuss a different way of incorporating the SHQP strategy. Lastly, we show that the dual of the best approximation problem can have an $O(1/k^2)$ accelerated algorithm that also incorporates the SHQP strategy.

■ Tue.D.5L

Tuesday, 16:30-17:45, Room 5L

Algebraic Methods in Polynomial Optimization

Cluster: Conic and Polynomial Optimization

Session organized by: *Amir A Ahmadi*

1. **Spectrahedral Cones with Rank 1 Extreme Rays, Sums of Squares and Matrix Completion**

Greg Blekherman (greg@math.gatech.edu) Georgia Institute of Technology, USA, *Rainer Sinn, Mauricio Velasco*

A sprectrahedral cone C is a slice of the cone of positive semidefinite matrices with a linear subspace L. The ranks of extreme rays of spectrahderal cones have been a subject of extensive study. It is natural to ask for what subspaces L do all of the extreme rays of C have rank 1? When L is a union of coordinate subspaces the answer is given by the PSD Matrix Completion Theorem. It turns out that this question has an unexpected connection to algebraic geometry and I will present a full classification of such spectrahedral cones. I will also present some related new results on matrix completion problems.

2. **The Bounded SOS Hierarchy for Bilinear Programming**

Ahmadreza Marandi (a.marandi@uvt.nl) Tilburg University, Netherlands, *Joachim Dahl, Etienne de Klerk*

The bounded degree sum-of-squares (BSOS) hierarchy of Lasserre, Toh, and Yang [EURO J. Comput. Optim., to appear] constructs lower bounds for a general polynomial optimization problem with compact feasible set, by solving a sequence of semi-definite programming (SDP) problems. Lasserre, Toh, and Yang prove that these lower bounds converge to the optimal value of the original problem, under some assumptions. In this talk, we analyze the BSOS hierarchy and study its numerical performance on a specific class of bilinear programming problems, called pooling problems, that arise in the refinery and chemical process industries.

3. **Positive Maps and Separable Matrices**

Jiawang Nie (njw@math.ucsd.edu) University of California, San Diego, USA, *Xinzhen Zhang*

A linear map between real symmetric matrix spaces is positive if all positive semidefinite matrices are mapped to positive semidefinite ones. A real symmetric matrix is separable if it can be written as a summation of Kronecker products of positive semidefinite matrices. This paper studies how to check if a linear map is positive or not and how to check if a matrix is separable or not. We propose numerical algorithms, based on Lasserre type semidefinite relaxations, for solving such questions. To check the positivity of a linear map, we construct a hierarchy of semidefinite relaxations for minimizing the associated bi-quadratic forms over the unit spheres. We show that the positivity can be detected by solving a finite number of such semidefinite relaxations. To check the separability of a matrix, we construct a hierarchy of semidefinite relaxations. If it is not separable, we can get a mathematical certificate for that; if it is, we can get a decomposition for the separability.

■ Wed.A.1S

Wednesday, 13:45-15:00, Room 1S

MIP + NLP

Cluster: Nonlinear Optimization

Session organized by: *Oktay Gunluk*

1. **Optimization over Structured Subsets of Positive Semidefinite Matrices via Column Generation**

   Sanjeeb Dash (sanjeebd@us.ibm.com) IBM Research, USA, *Amir Ali Ahmadi, Georgina Hall*

We describe algorithms that optimize over certain structured subsets of the cone of positive semidefinite matrices (PSD cone) via linear programming and second order cone programming. Starting with an initial linear approximation of the PSD cone given by Ahmadi and Majumdar (2014), we improve the approximation in an iterative fashion using column generation. We apply our techniques to sum-of-squares (SOS) programming for nonconvex polynomial optimization problems, and to a copositive programming relaxation of the stable set problem.

2. **Cutting Planes to Strengthen Second Order Conic Relaxation of the OPF Problem**

   Andy Sun (andy.sun@isye.gatech.edu) Georgia Institute of Technology, USA, *Burak Kocuk, Santanu Subhas Dey*

The AC optimal power flow (OPF) problem is a key optimization problem in the area of electrical power systems operations. We compare the strength of linear programing (LP), second order cone programming (SOCP) and semi-definite relaxations (SDP) of two formulations of the OPF formulation. Then we present a few families of cutting-planes to strengthen the (standard) SOCP relaxation of this problem. The strengthened SOCP relaxation is incomparable to the (standard) SDP relaxation. Extensive computational experiments show that these relaxations have numerous advantages over existing convex relaxations in the literature: (i) their solution quality is extremely close to that of the SDP relaxations and consistently outperforms previously proposed convex quadratic relaxations of the OPF problem, and (ii) in terms of computation times, the strengthened SOCP relaxations can be solved an order of magnitude faster than standard SDP relaxations.

3. **Solving Box-constrained Nonconvex QPs**

   Oktay Gunluk (gunluk@us.ibm.com) IBM Research, USA, *Pierre Bonami, Jeff Linderoth*

We discuss effective computational techniques for solving nonconvex quadratic programs with box constraints (BoxQP). We first give computational evidence that cutting planes obtained from the Boolean Quadric Polytope might be very effective at reducing the relaxation gap. We next demonstrate the equivalence between the Chvátal-Gomory closure of a natural linear relaxation of BoxQP and the relaxation of the Boolean Quadric Polytope consisting of the odd-cycle inequalities. By using these cutting planes effectively at nodes of the branch-and-bound tree, in conjunction with additonal integrality-based branching and a strengthened convex quadratic relaxation, we demonstrate that we can effectively solve a well-known family of test instances—orders of magnitude faster than existing commercial and open-source solvers.

■ Wed.A.1A

Wednesday, 13:45-15:00, Room 1A

Optimization Methods for Inverse Problems 1

Cluster: Nonlinear Optimization

Session organized by: *Xin Liu, Yanfei Wang*

1. **Seismic Diffraction Extraction for Discontinuous Geologies using Sparse Regularization**

   Yanfei Wang (yfwang@mail.iggcas.ac.cn) Chinese Academy of Sciences, China, *Caixia Yu*

Seismic diffractions play an important role in characterizing and identifying discontinuous geological structures, such as tiny faults and cavities in Ordovician carbonate reservoirs. These faults and cavities are important because of their close relationship to the reservoir properties of oil and gas. The seismic responses of these objects in the sense of seismic wavelength are encoded in diffractions. Since diffractors are usually sparse and non-differentiable, we study diffraction extraction based on first and second-order of regularization modeling specially for detecting diffraction points. Optimization algorithms are addressed. Numerical examples based on synthetic data and field data are given.

2. **On a Special Structured Matrix Problem**

   Cong Sun (suncong86@bupt.edu.cn) Beijing University of Posts and Telecommunications, China

A special matrix problem is considered from the application in wireless communications. The objective function is approximated by a fraction function. The alternating minimization method is applied. Efficient methods are proposed for the subproblems as nonconvex quadratic constrained quadratic programming and those with orothogonality constraints, where KKT points or optimal solutions are guaranteed. Simulations show the good performances of our proposed models and algorithms.

3. **Semidefinite Penalty Method for Quadratically Constrained Quadratic Programming**

   Ran Gu (guran@lsec.cc.ac.cn) Chinese Academy of Sciences , China, *Yaxiang Yuan*

We present an algorithm for finding approximate global solutions to Quadratically Constrained Quadratic Programming with only equality constraints. In our method, we add a matrix viable and a penalty matrix to the model. The exactness properties of the penalty function is proved. SDP relaxation method can be regard as our new model with penalty matrix equaling to zero. We use a fixed point method to find a KKT point of the subproblem. Preliminary experiments show that our method is easier to obtain global solutions.

■ Wed.A.1B

Wednesday, 13:45-15:00, Room 1B

PDE Optimization and Applications II

Cluster: PDE-constrained Optimization

Session organized by: *Tomoya Takeuchi*

1. **Iterative Thresholding Algorithm for Inverse Source Problems for Hyperbolic-Type Equations**

   Yikan Liu (ykliu@ms.u-tokyo.ac.jp) The University of Tokyo, Japan, *Daijun Jiang, Masahiro Yamamoto*

In this talk, we investigate the reconstruction of the spatial component in the source term of hyperbolic-type equations with three kinds of observation data. In the cases of partial interior or boundary observation, we prove stability results based on newly established Carleman estimates. In case of the final observation, we employ the analytic Fredholm theory to show generic well-posedness. Numerically, we adopt the classical Tikhonov regularization to reformulate the inverse source problems into related optimization problems, for which we develop a universal iterative thresholding algorithm by using the corresponding adjoint systems. The proposed algorithm is computationally easy and efficient: the minimizer at each step has explicit solution. Extensive numerical examples are presented to demonstrate the accuracy and efficiency of the proposed algorithm.

2. **Optimization of Heat Transfer in Plane Couette Flow**

   Genta Kawahara (kawahara@me.es.osaka-u.ac.jp) Osaka University, Japan, *Shingo Motoki, Masaki Shimizu*

An optimal incompressible steady velocity field has been found numerically for heat transfer enhancement with less energy dissipation in plane Couette flow by using a variational method. The functional is defined as wall heat flux (scalar dissipation), from which energy dissipation has been subtracted, to be optimized under the constraints of the continuity equation and the advection-diffusion equation for temperature. It is shown that at high Reynolds numbers three-dimensional (streamwise-dependent) velocity field is optimal, while at low Reynolds numbers optimal heat transfer is given by a streamwise-independent field. A physical interpretation is proposed for the emergence of three-dimensional optimal velocity field.

3. **Optimal Control Problem for Allen-Cahn Type Equation Associated with Total Variation Energy**

   Takeshi Ohtsuka (tohtsuka@gunma-u.ac.jp) Gunma University, Japan

We introduce an optimal control problem for gradient flow with an energy by total variation and a double-well potential with constraint. One observes that the equation has singular diffusion and sub differential of the indicator function. For this problem we shall the existence of optimal control by the framework of variational inequaries. In this talk we also present some numerical results on this problem. To overcome the difficulities by the singularities of the equation we introduce an approximating problem regularizing the singularities. We derive a necessary condition for an optimal control for the approximating problem, and introduce a numerical scheme to solve the optimal control problem with this approximation proceduler.

■ Wed.A.1C

Wednesday, 13:45-15:00, Room 1C

Theoretical Aspects of Derivative-free Optimization

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Serge Gratton*

1. **On the Linear Convergence of Comparison-based Step-size Adaptive Randomized Search**

   Anne Auger (anne.auger@inria.fr) INRIA, France, *Nikolaus Hansen*

This presentation focuses on step-size adaptive randomized search (SARS), a general class of randomized derivative-free optimization algorithms that iteratively adapt a step-size and a favorite solution. We will present an approach to prove the linear convergence of a subclass of SARS algorithms that are comparison-based and satisfy scale and translation invariance. This class of algorithms includes simplified versions of the state-of-the-art CMA-ES algorithm. The approach relies on the following steps: (i) building a normalized process underlying the algorithm that derives from the invariance properties satisfied by the SARS. This process turns out to be an homogeneous Markov chain on scaling-invariant functions and (ii) studying the stability (formally irreducibility, positivity, ergodicity) of this Markov chain that entails linear convergence of the SARS. This methodology is applied to prove the linear convergence of some of the oldest derivative-free stochastic algorithms.

2. **Direct Search Based on Inaccurate Function Values**

   Serge Gratton (serge.gratton@enseeiht.fr) University of Toulouse, IRIT-ENSEEIHT, France, *Frédéric Delbos, Benoît Pauwels, Zaikun Zhang*

We consider direct search applied to a function whose value can only be provided by inaccurate oracles. We prove that the classical algorithm without adaptation can still achieve a certain accuracy even if the inaccuracy never vanishes, and that the worst case complexity to reach such an accuracy is essentially the same as the accurate case. We also provide a practical stopping criterion that guarantees this accuracy. Based on these results, we address the scenario where we have access to oracles with different inaccuracy levels corresponding to different costs. We give a simple strategy for choosing oracles according to the progress of the algorithm, which ensures the best possible accuracy while calling the low-cost oracles whenever possible.

■ Wed.A.4A

Wednesday, 13:45-15:00, Room 4A

Data and Networks I

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Arvind U Raghunathan*

1. **Parallel Multi-splitting Proximal Method**

   Ermin Wei (ermin.wei@northwestern.edu) Northwestern University, USA, *Yuanzhang Xiao, Chaithanya Bandi*

We develop a parallel algorithm based on proximal method to solve the problem of minimizing summation of convex (not necessarily smooth) functions. We show that this method converges to an optimal solution for any choice of constant stepsize for convex objective functions. Under further assumption of Lipschitz-gradient and strong convexity of objective functions, the method converges linearly.

2. **Dual Decomposition and Nonsmooth Equations**

   Arvind U Raghunathan (raghunathan@merl.com) Mitsubishi Electric Research Laboratories, USA, *Frank E Curtis*

Dual Decomposition has been effectively employed for optimization problems that possess a nearly-separable structure – objective function, (most) constraints are separable in subsets of variables and (a few) constraints couple all the subsets of variables. Algorithms that effectively exploit this structure are desired to: (a) preserve privacy of problem data (e.g. markets), or (b) employ parallel computations, improve scalability. We propose a novel semismooth Newton algorithm that works directly on the stationary conditions of the optimization as opposed to the dual function. Our approach: (i) retains the separability of dual decomposition, (ii) converges locally superlinearly and (iii) is applicable to non-convex problems. Global convergence of the method is promoted by enforcing decrease via a merit function or through a filter mechanism. We provide numerical results on solving convex and non-convex instances. Results from applications will also be presented.

■ Wed.A.4B

Wednesday, 13:45-15:00, Room 4B

Vector Variational Inequalities and Applications

Cluster: Complementarity and Variational Inequalities
Session organized by: *Shashi Kant Mishra*

1. **On New Discrete-Type Complementarity Functions**

   Jein-Shan Chen (jschen@math.ntnu.edu.tw) National Taiwan Normal University, Taiwan

It is well known that complementarity functions play an important role in dealing with complementarity problems. In this talk, we investigate a few new classes of complementarity functions for nonlinear complementarity problems and second-order cone complementarity problems. The constructions of such new complementarity functions are based on discrete generalization which is a novel idea in contrast to the continuous generalization of Fischer-Burmeister function. Surprisingly, the new families of complementarity functions possess continuous differentiability even though they are discrete-oriented extensions. This feature enables that some methods like derivative-free algorithm can be employed directly for solving nonlinear complementarity problems and second-order cone complementarity problems. This is a new discovery to the literature and we believe that such new complementarity functions can also be used in many other contexts.

2. **On Relations between Vector Variational-like Inequalities and Vector Optimization Problems in Asplund Spaces**

   Balendu Bhooshan Upadhyay (bhooshan@nitmanipur.ac.in) National Institute of Technology, Manipur, India

In this paper, we consider Minty and Stampacchia type vector variational like inequalities in Aplund space setting. Using the properties of Mordukhovich limting subdifferentials, we establish the relations between the considered vector variational-like inequality problems and nonsmooth vector optimization problem. An existence theorem of solutions for the weak Minty vector variational inequality is also established. The results presented in the paper are more general than those existing in the literature.

3. **Online Markovian Decision Problems as a Stochastic Minimax Problem**

   Mengdi Wang (mengdiw@princeton.edu) Princeton University, USA

We consider the online solution of discounted Markovian decision problems (MDP). We focus on the black-box model where transition probabilities and state transition cost are unknown. Instead, a simulator is available to generate random state transitions under randomized actions. We propose a stochastic primal-dual algorithm for solving the minimax formulation of the Bellman equation. The algorithm updates by using random sample transitions generated by the simulator. We show that the algorithm generates primal and dual iterates converging to the optimal value function and optimal policy, respectively. In particular, the dual variable produced by using n samples gives a mixed strategy for the MDP, achieving an efficiency loss of the order $1/\sqrt{n}$.

■ Wed.A.5D

Wednesday, 13:45-15:00, Room 5D

Computational and Complexity Challenges for Linear Conic Optimization

Cluster: Linear Optimization
Session organized by: *Miguel Anjos*

1. **A Random Projection Method for Solving Linear Programs**

   Leo S Liberti (liberti@lix.polytechnique.fr) CNRS LIX Ecole Polytechnique, France, *Ky Khac Vu, Pierre-Louis Poirion*

The Johnson-Lindenstrauss lemma allows dimension reduction on real vectors with low distortion on their pairwise Euclidean distances. This result is often used in algorithms such as k-means or k-nearest neighbours since they only use Euclidean distances, and has sometimes been used in optimization algorithms involving the minimization of such distances. We introduce a first attempt at using this lemma in the context of linear programming.

2. **A Polynomial Column-wise Rescaling von Neumann Algorithm**

Tamás Terlaky (terlaky@lehigh.edu) Lehigh University, USA, *Dan Li, Kees Roos*

Recently Chubanov proposed a method which solves homogeneous linear equality systems with positive variables in polynomial time. Chubanov's method can be considered as a column-wise rescaling procedure. We adapt Chubanov's method to the von Neumann problem, and so we design a polynomial time column-wise rescaling von Neumann algorithm. This algorithm is the first variant of the von Neumann algorithm with polynomial complexity.

3. **Computational Study of Some Valid Inequalities for k-Way Graph Partitioning**

Miguel Anjos (miguel-f.anjos@polymtl.ca) GERAD & Polytechnique Montreal, Canada, *Vilmar Jefte Rodrigues de Sousa, Sebastien Le Digabel*

We consider the maximum k-cut problem that consists in partitioning the vertex set of a graph into k subsets such that the sum of the weights of edges joining vertices in different subsets is maximized. We focus on identifying effective classes of inequalities to tighten the semidefinite programming relaxation. We carry out an experimental study of four classes of inequalities from the literature: clique, general clique, wheel and bicycle wheel. We considered 10 combinations of these classes and tested them on both dense and sparse instances for different values of k. Our computational results suggest that the bicycle wheel and wheel are the strongest inequalities for $k = 3$, and that for greater k, the wheel inequalities are the strongest by far. Furthermore, we observe an improvement in the performance for all choices of k when both bicycle wheel and wheel are used, at the cost of 72% more CPU time on average when compared with using only one of them.

■ Wed.A.5E

Wednesday, 13:45-15:00, Room 5E

Advances in Robust Optimization I

Cluster: Robust Optimization

Session organized by: *Omid Nohadani*

1. **Numerical Solution of Bilevel Programs using a Duality-based Approach**

Anil Aswani (aaswani@berkeley.edu) University of California, Berkeley, USA, *Aurelien Ouattara, Max Zuo-Jun Shen, Auyon Siddiq*

Existing numerical algorithms for solving bilevel programs suffer from difficulties caused by lack of constraint qualification, lack of differentiability, and general nonconvexities. In this talk, we describe a novel reformulation of bilevel programs where the (convex) lower level program is replaced by the optimality condition of upper-bounding the objective function of the lower level program by its dual. This reformulation leads to a single level optimization problem with appropriate constraint qualification and differentiability, which enables the development of (i) an enumeration algorithm, (ii) a semiparametric algorithm, and (iii) a descent algorithm for solving bilevel programs with a convex lower level program. This reformulation approach is demonstrated through applications to the problems of (1) inverse optimization with noisy data (e.g., estimating utility functions from noisy measurements of agent decisions), and (2) solving Stackelberg routing games.

2. **Accounting for the Tongue-and-Groove Effect in IMRT Treatment Planning using a Robust Direct Aperture Optimization Approach**

Edwin Romeijn (edwin.romeijn@isye.gatech.edu) Georgia Institute of Technology, USA, *Ehsan Salari, Chunhua Men*

Traditionally, the tongue-and-groove effect due to the multileaf collimator architecture in intensity-modulated radiation therapy (IMRT) has typically been deferred to the leaf sequencing stage. We propose a new direct aperture optimization method for IMRT treatment planning that explicitly incorporates dose calculation inaccuracies due to the tongue-and-groove effect into the treatment plan optimization stage. Using lower and upper bounds on the dose distribution delivered to the patient, we develop a model that yields a treatment plan that is robust with respect to the dose calculation inaccuracies. Tests on a set of ten clinical head-and-neck cancer cases demonstrate the effectiveness of the new method in developing robust treatment plans with tight dose distributions in targets and critical structures.

3. **Robust Maximum Likelihood Estimation with Application to Radiation Therapy**

Omid Nohadani (nohadani@northwestern.edu) Northwestern University, USA, *Dimitris Bertsimas*

In many applications, statistical estimators serve to derive conclusions from data, most prominently in finance, medical decision-making and clinical trials. However, the conclusions are typically dependent on uncertainties in the data. We use robust optimization principles to construct robust maximum likelihood estimators that are immune against data errors. Both error types are considered: a) adversarial type, modeled using the notion of uncertainty sets, and b) probabilistic type, modeled by distributions. We provide efficient local and global search algorithms to compute the robust estimators and discuss them in details for the case of multivariate normally distributed data. The estimator performance is demonstrated on two datasets. First, using computer simulations, we demonstrate that the proposed estimators are robust against both types of data uncertainty and provide significantly more accurate estimates, compared to classical estimators which degrade significantly, when errors are encountered. We establish a range of uncertainty sizes, for which robust estimators are superior. Second, we analyze deviations in cancer radiation therapy planning. Uncertainties amongst plans are caused by patients' individual anatomies and the trial-and-error nature of the process. Robust estimators prove to result in more reliable decisions when applied to a large set of past treatments.

■ Wed.A.5F

Wednesday, 13:45-15:00, Room 5F

Mathematical Programming and Economic Equilibria

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Jugal Garg*

1. **Computation of Fisher-Gale Equilibrium by Auction**

Vladimir Shikhman (vladimir.shikhman@uclouvain.be) Catholic University of Louvain, Belgium, *Yurii Nesterov*

We study the Fisher model of a competitive market from the algorithmic perspective. For that, the related convex optimization problem due to Gale and Eisenberg is used. The latter problem is known to yield a Fisher equilibrium under some structural assumptions on consumers' utilities, e.g. homogeneity of degree 1, homotheticity etc. Our goal is to examine the applicability of the convex optimization framework by departing from these traditional assumptions. We just assume the concavity of consumers' utility functions. For this case we suggest a novel concept of Fisher-Gale equilibrium by introducing consumers' utility prices. The prices of utility transfer the utility of a consumption bundle to a common numeraire. We develop a subgradient-type algorithm from Convex Analysis to compute a Fisher-Gale equilibrium. In order to decentralize prices, we additionally implement the auction design, i.e. consumers settle and update their individual prices and producers sell at the highest offer price. Our price adjustment is based on a tatonnement procedure, i.e. the prices change proportionally to consumers' individual excess supplies. Historical averages of consumption are shown to clear the market of goods. Our algorithm enjoys a convergence rate. In worst case, the number of price updates needed to achieve the ε-tolerance is proportional to $1/\varepsilon^2$.

2. **Polynomial-Time Complementary Pivot Algorithms for Market Equilibria**

Jugal Garg (jugal.garg@gmail.com) University of Illinois at Urbana Champaign, USA, *Ruta Mehta, Milind Sohoni, Nisheeth Vishnoi*

We consider the problem of computing market equilibria in the Fisher model for utility functions such as linear, spending constraint and perfect price-discrimination. In each case we start with a convex program that captures market equilibria, and in a systematic way, covert it into a linear complementary problem (LCP) formulation. To obtain a polynomial-time algorithm, we depart from previous approaches of pivoting on a single polyhedron associated with the LCP. Instead, we carefully construct a polynomial-length sequence of polyhedra, one containing the other, such that starting from an optimal solution to one allows us to obtain an optimal solution to the next in the sequence in a polynomial number of complementary pivot steps.

3. **Price-taking Equilibrium in Games**

Joseph M Ostroy (ostroy@ucla.edu) University of California, Los Angeles, USA, *Joon Song*

Similarities between price-taking utility maximization for Walrasian equilibrium in quasilinear models of exchange and correlated equilibrium in normal form games are demonstrated as expressions of conjugate duality. Similarities between tatonnement methods of convergence in exchange extend to games.

■ Wed.A.5G

Wednesday, 13:45-15:00, Room 5G

Algorithmic and Geometric Aspects of Linear Optimization

Cluster: Linear Optimization

Session organized by: *Antoine Deza*

1. **Improving Bounds on the Diameter of a Polyhedron in High Dimensions**

Noriyoshi Sukegawa (sukegawa@ise.chuo-u.ac.jp) Chuo University, Japan

In 1992, Kalai and Kleitman proved that the diameter of a d-dimensional polyhedron with n facets is at most $n^{\log(d)+2}$. Recently, in 2014, Todd improved Kalai–Kleitman bound to $(n - d)^{\log(d)}$, which is tight in low dimensions. In this talk, we introduce a proof method to improve the bounds in high dimensions. It proves, for example, a bound which improves Todd bound for $d \geq 7$, and by three orders of magnitude in high dimensions.

2. **On the Diameter of Lattice Polytopes**

George Oreste Manoussakis (gomanous@gmail.com) University Paris Sud, France, *Antoine Deza, Shmuel Onn*

A lattice (d,k)-polytope is the convex hull of a set of points in dimension d whose coordinates are integers between 0 and k. Let $D(d,k)$ be the maximum possible edge-diameter over all lattice (d,k)-polytopes. Naddef showed in 1989 that $D(d,1) = d$, Kleinschmidt and Onn generalized this result in 1992 showing that $D(d,k)$ is at most kd, before Del Pia and Michini strengthened in 2016 the upper bound for $D(d,k)$ to at most $kd - \lceil d/2 \rceil$ and showed that $D(d,2) \quad \lfloor 3d/2 \rfloor$. $D(2,k)$ was investigated independently in the early nineties by Thiele, Balog and Barany, and Acketa and Zunic. We introduce a family of lattice polytopes whose diameter achieves $D(2,k)$ in dimension 2 and achieves $(k+1)d/2$ for any d and $k = 2d - 1$.

3. **Star Sets/Star Complements of Graph Eigenvalues and Simplex Like Techniques in Combinatorial Problems**

Domingos Moreira Cardoso (dcardoso@ua.pt) University of Aveiro, Portugal, *Carlos J Luz, Maria F Pacheco*

There are many combinatorial problems in graphs equivalent to the recognition of a (k,t)-regular set (a vertex subset S inducing a k-regular subgraph such that every vertex not in S has t neighbors in it). Considering a graph H, if k-t is not an adjacency eigenvalue (an eigenvalue of H), then to decide whether H has a (k,t)-regular set is easy, otherwise this problem can be hard. When h is an eigenvalue of H with multiplicity q, a vertex subset X with cardinality q such that h is not an eigenvalue of $H - X$ is called an h-star set of H, while $H - X$ is an h-star complement. We deal with the vertex set of a $(k - t)$-star complement $H - X$ as a basis in a simplex-like approach to the determination of (k,t)-regular sets. Several combinatorial and spectral properties of (k,t)-regular sets are summarized and a simplex like algorithm based on a sequence of star complements, towards to a star complement which includes a $(0,t)$-regular set, when there exists, is presented.

■ Wed.A.5H

Wednesday, 13:45-15:00, Room 5H

Robust Portfolio Optimization

Cluster: Applications in Finance and Economics

Session organized by: *Jun-ya Gotoh*

1. **A Robust Perspective on Transaction Costs in Portfolio Optimization**

Alba Victoria Olivares-Nadal (aolivares@us.es) University of Seville, Spain, *Víctor DeMiguel*

We show how to use a transaction cost term in a portfolio optimization problem to compute portfolios that are both efficient in terms of transaction costs and robust to estimation error. Theoretically, we prove that the portfolio problem with transaction costs is equivalent to three different problems designed to alleviate the impact of estimation error: a robust portfolio optimization problem, a robust regression problem, and a Bayesian portfolio problem. Motivated by these results, we propose a data-driven approach to portfolio optimization that calibrates the transaction cost term taking into account both transaction costs and estimation error. Our empirical results demonstrate that the data-driven portfolios perform favorably because they strike an optimal trade-off between rebalancing the portfolio to capture the information in recent historical return data, and avoiding the large transaction costs and impact of estimation error associated with excessive trading.

2. **Higher Factor Dependency of Robust Portfolios for Achieving Robustness**

Jang Ho Kim (janghokim@khu.ac.kr) Kyung Hee University, Korea, *Woo Chang Kim, Frank J Fabozzi*

Robust portfolio optimization resolves the sensitivity of mean-variance portfolios and thus allows portfolios to achieve robust performance. There have been many developments on formulating robust portfolios, and common formulations include uncertainty sets on expected security returns defined as intervals or ellipsoids. In this study, we focus on these formulations to analyze their attributes, mainly the dependency on factors of robust portfolios. We find that robust portfolios show higher dependency to the Fama-French three factors and the principal components of the data. Furthermore, it is observed that robust formulations that penalize variance of returns show higher factor dependency as well as increased robustness. We provide empirical and analytical support for this finding, which may explain how robust formulations achieve robustness.

3. **Robust Empirical Optimization**

Andrew Lim (andrewlim@nus.edu.sg) National University of Singapore, Singapore, *Jun-ya Gotoh, Michael Jong Kim*

We analyze the out of sample performance of robust empirical optimization and introduce a data driven method for calibrating the robust problem. Applications to finance will be discussed.

■ Wed.A.5I

Wednesday, 13:45-15:00, Room 5I

Stochastic Optimization: Theory and Algorithms

Cluster: Stochastic Optimization

Session chair: *Mariusz Michta*

1. **Riemannian Stochastic Variance Reduced Gradient on Grassmann Manifold**

Hiroyuki Kasai (kasai@is.uec.ac.jp) The University of Electro-Communications, Japan, *Hiroyuki Sato, Bamdev Mishra*

Stochastic variance reduction algorithms have recently become popular for minimizing the average of a large, but finite, number of loss functions. To the best of our knowledge, all the earlier algorithms are proposed in the Euclidean space. We propose a novel Riemannian extension of the Euclidean stochastic variance reduced gradient algorithm to a compact manifold search space. To this end, we show the developments on the Grassmann manifold. The key challenges of averaging, addition, and subtraction of multiple gradients are addressed with notions like logarithm mapping and parallel transport of vectors on the Grassmann manifold. We show that the proposed method generates globally convergent sequences under some natural assumptions. The proposed algorithm is applied to a number of regression problems on the Grassmann manifold like principal components analysis, low-rank matrix completion, and the Karcher mean computation. In all these cases, the proposed algorithm outperforms the Riemannian stochastic gradient descent algorithm.

2. **Strong Convexity in Two-Stage Linear Stochastic Programs with Partially Random Right-Hand Side**

Kai Arne Spürkel (kai.spuerkel@uni-due.de) University of Duisburg-Essen, Germany

In the literature, analysis of structure and stability of two-stage linear programs is usually done assuming random right-hand side (RHS), i.e. no constants occurring among the RHS-components. For differentiability and strong convexity with respect to the full tender-variable randomness of the full RHS is required. The talk addresses the relaxation of this condition to partially random RHS, presents geometric insights and conclusions on model-structure.

3. **Properties of Weak Solutions to Stochastic Inclusions and Their Applications in Optimization Problems**

Mariusz Michta (m.michta@wmie.uz.zgora.pl) University of Zielona Gora, Poland

Stochastic inclusions appear in a natural way as a reduced or theoretical description of stochastic control problems (see e.g. [1-6] and ref. therein). The talk deals with properties of weak solutions to stochastic inclusions via a martingale problem approach. Such approach is used first to analyze compactness and continuous dependence of solution sets to stochastic differential inclusions of Ito type with convex integrands on the initial distributions. Next the problem of existence of optimal weak solutions to such inclusions and their dependence on initial distributions is discussed. Finally, we show that this general approach can be applied to some financial and economic optimization problems. References [1] M. Kisielewicz, Stochastic Differential Inclusions and Applications, Springer, New York, 2013. [2] M. Kisielewicz, M. Michta, J. Motyl, Set-valued approach to stochastic control. Part I. Existence and regularity properties, Dynam. Systems Appl., 12:405-431, 2003. [3] M. Michta, Optimal solutions to stochastic differential inclusions, Appl. Math. 29(4) (2002) 387-398. [4] M. Michta, On weak solutions to stochastic differential inclusions driven by semimartingales, Stoch. Anal. Appl. 22(5) (2004) 1341-1361. [5] M. Michta, J. Motyl, Stochastic inclusion with a non-lipschitz right hand side, In: Stochastic Differential Equations, Ed. N. Halidas, Nova Science Publ. (2011).

■ Wed.A.5J

Wednesday, 13:45-15:00, Room 5J

Matrix Optimization Problems: Recent Advances in Convergence Rate Analysis and Recovery Guarantees

Cluster: Conic and Polynomial Optimization

Session organized by: *Anthony Man-Cho So*

1. **Convex Optimization Learning of Faithful Euclidean Distance Representations in Nonlinear Dimensionality Reduction**

Chao Ding (dingchao@amss.ac.cn) Chinese Academy of Sciences, China, *Houduo Qi*

Classical multidimensional scaling only works well when the noisy distances observed in a high dimensional space can be faithfully represented by Euclidean distances in a low dimensional space. Advanced models such as Maximum Variance Unfolding (MVU) and Minimum Volume Embedding (MVE) use Semi-Definite Programming (SDP) to reconstruct such faithful representations. While those SDP models are capable of producing high quality configuration numerically, they suffer two major drawbacks. One is that there exist no theoretically guaranteed bounds on the quality of the configuration. The other is that they are slow in computation when the data points are beyond moderate size. In this talk, we propose a convex optimization model of Euclidean distance matrices. We establish a non-asymptotic error bound for the random graph model with sub-Gaussian noise, and prove that our model produces a matrix estimator of high accuracy when the order of the uniform sample size is roughly the degree of freedom of a low-rank matrix up to a logarithmic factor. Our results partially explain why MVU and MVE often work well. Moreover, we develop a fast inexact accelerated proximal gradient method. Numerical experiments show that the model can produce configurations of high quality on large data points that the SDP approach would struggle to cope with.

2. **Quadratic Optimization with Orthogonality Constraints: Explicit Lojasiewicz Exponent and Linear Convergence of Line-Search Methods**

Huikang Liu (hkliu@se.cuhk.edu.hk) The Chinese University of Hong Kong, Hong Kong, *Weijie Wu, Anthony Man-Cho So*

A fundamental class of matrix optimization problems that arise in many areas of science and engineering is that of quadratic optimization with orthogonality constraints. Such problems can be solved using line-search methods on the Stiefel manifold, which are known to converge globally under mild conditions. To determine the convergence rates of these methods, we give an explicit estimate of the exponent in a Łojasiewicz inequality for the (non-convex) set of critical points of the aforementioned class of problems. This not only allows us to establish the linear convergence of a large class of line-search methods but also answers an important and intriguing problem in mathematical analysis and numerical optimization. A key step in our proof is to establish a local error bound for the set of critical points, which may be of independent interest.

3. **A Unified Approach to Error Bounds for Structured Convex Optimization**

Zirui Zhou (zrzhou@se.cuhk.edu.hk) The Chinese University of Hong Kong, Hong Kong, *Anthony Man-Cho So*

Error bounds, which refer to inequalities that bound the distance of vectors in a test set to a given set by a residual function, have proven to be extremely useful in analyzing the convergence rates of a host of iterative methods for solving optimization problems. In this paper, we present a new framework for establishing error bounds for a class of structured convex optimization problems, in which the objective function is the sum of a smooth convex function and a general closed proper convex function. Such a class encapsulates not only fairly general constrained minimization problems but also various regularized loss minimization formulations in machine learning, signal processing, and statistics. Using our framework, we show that a number of existing error bound results can be recovered in a unified and transparent manner. To further demonstrate the power of our framework, we apply it to a class of nuclear-norm regularized loss minimization problems and establish a new error bound for this class under a strict complementarity-type regularity condition. We then complement this result by constructing an example to show that the said error bound could fail to hold without the regularity condition. We believe that our approach will find further applications in the study of error bounds for structured convex optimization problems.

■ Wed.A.5L

Wednesday, 13:45-15:00, Room 5L

Moments, Positive Polynomials & Optimization: Part III

Cluster: Conic and Polynomial Optimization

Session organized by: *Jiawang Nie, Jean B Lasserre*

1. **On Stability and Genericity Results for Polynomial Optimization Problems**

Gue Myung Lee (gmlee@pknu.ac.kr) Pukyong National University, Korea, *Tien Son Pham*

In this talk, we consider the class of polynomial optimization problems, in which the objective functions are perturbed, and stability results of the global solution map, of the Karush-Kuhn-Tucker set-valued map, and of the optimal value function for all problems in the class. Moreover, we present genericity results which hold almost every polynomial optimization problem.

2. **Globally Solving Polynomial Mathematical Programs with Equilibrium Constraints**

Jeya Jeyakumar (v.jeyakumar@unsw.edu.au) University of New South Wales, Australia

In this talk, as an application of a powerful algebraic technique, that employs Putinar positivestellentz and semidefinite linear programming (SDP), we establish convergent SDP relaxations to globally solving nonconvex polynomial optimization problems with broad classes of complex constraints, such as generalized equilibrium constraints and bi-level constraints. We first show that the global optimal value of a polynomial mathematical program with a generalized equilibrium constraint is the limiting value of a sequence of optimal values of a hierarchy of its semidefinite linear programming (SDP) relaxations. Consequently, we obtain convergent SDP hierarchies for globally solving polynomial mathematical programs with equilibrium constraints and for solving various classes of global bilevel polynomial mathematical programs.

3. **Convergent Robust SDP Approximations for Semialgebraic Optimization**

Victor Liev Magron (victor.magron@imag.fr) CNRS VERIMAG, France

We present a new hierarchy of convergent robust semidefinite (SDP) approximations for certain classes of semialgebraic optimization problems. This hierarchy yields a monotone non-increasing sequence of upper bounds converging to the global minimum of a polynomial f over a simple compact semialgbraic set (e.g. box or simplex) $K = X \times E$, in the case when f has linear dependency on the variables in E. By contrast with the converging sequence of SDP upper bounds in [J.B. Lasserre, A new look at nonnegativity on closed sets and polynomial optimization, SIAM J. Optim. 21, pp. 864–885, 2010], we prove that nonnegativity of f over K is equivalent to semidefinite positiveness of countably many uncertain moment matrices, with perturbations defined over E. Each resulting robust program in this hierarchy can be exactly solved via SDP by using [L. El Ghaoui, F. Oustry and H. Lebret, Robust solutions to uncertain semidefinite programs, SIAM J. Optim. 9, pp. 33–52, 1998]. This methodology is successfully applied to obtain lower bounds on absolute roundoff errors occurring while implementing numerical programs with finite-precision. In this context, we illustrate the performance and precision of our robust semidefinite approximations on non-trivial programs coming from biology, optimization and space control.

■ Wed.A.m3S

Wednesday, 13:45-15:00, Room m3S

Recent Advances in First-Order Methods: Part I

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Marc Teboulle, Shoham Sabach*

1. **Sequential Convex Programming, Value Function and**

Convergence

Edouard Pauwels (edouard.pauwels@irit.fr) IRIT, France, *Jérôme Bolte*

Many iterative processes in nonlinear optimization rely on sequentially solving simple approximate models of a more difficult problem. In this work, we focus on complex geometric settings for which constraints or non smoothness cannot be dealt with directly and must be approximated. In this context, sequential convex programming approaches consist in producing sequences of iterates based on solutions of local convex approximate problems (e.g. SQP, Gauss-Newton, ...). Contrary to favorable geometric settings (e.g. proximal decomposition), the convergence of iterates produced by these types of methods is hardly understood. We address this question under the hypothesis that problem data is semi-algebraic, a mild and easy to check assumption which admits many extensions and encompasses most problems met in practice. The key insight of the analysis relies on the introduction of the value function and the understanding of sequential convex programs as implicitly performing approximate gradient steps for which convergence is well understood.

2. **On Computing the Proximal Mapping Associated with the ℓ_0-Norm over Symmetric Sets**

Nadav Hallak (ndvhllk@campus.technion.ac.il) Technion, Israel, *Amir Beck*

We consider the problem of computing the proximal mapping associated with a symmetric function, in particular with a function composed of a sparsity term and the indicator function of a symmetric set. We study the properties of the prox mapping and derive an efficient method for computing the prox associated with the ℓ_0-norm and the indicator function for a symmetric set. We show that under a property called “second order monotonicity” (SOM), the problem can be solved via a binary search method. Finally, we show that interesting sets such as the simplex and the ℓ_1, ℓ_2, ℓ_∞ balls, satisfy the SOM property.

3. **Beyond Lipschitz Gradient Continuity: A Novel Path for First Order Methods**

Marc Teboulle (teboulle@post.tau.ac.il) Tel Aviv University, Israel, *Heinz H Bauschke, Jerome Bolte*

The proximal gradient and its variants is one of the most attractive first order algorithm for minimizing the sum of two convex functions, with one being nonsmooth. However, it requires the differentiable part of the objective to have a Lipschitz continuous gradient, thus precluding its use in many applications. We introduce a simple and elegant framework which allows to circumvent the intricate question of Lipschitz continuity of the gradient. This translates into a new descent lemma which natuarally leads to first oder methods with a proven global sublinear rate of convergence. This opens a new path to tackle a broad spectrum of problems arising in key applications which were until now, considered as out of reach via proximal gradient methods. We illustrate this potential by showing how our results can be applied to derive new and simple schemes in some applications.

■ Wed.A.m3AB

Wednesday, 13:45-15:00, Room m3AB

Advances in Deterministic Global Optimization I

Cluster: Global Optimization

Session organized by: *Ruth Misener*

1. **Convergence-Order Analysis of Lower Bounding Schemes for Constrained Global Optimization Problems**

Rohit Kannan (rohitk@mit.edu) Massachusetts Institute of Technology, USA, *Paul I Barton*

The performance of branch-and-bound algorithms for continuous global optimization is strongly dependent on the ability to construct tight and rapidly convergent schemes of lower bounds. A popular technique for constructing lower bounding schemes is to replace the nonconvex functions involved in the optimization problem with schemes of (convex and concave) relaxations. Recently, Bompadre and coworkers (JOGO, 52(1):1–28, 2012 and JOGO, 57(1):75–114, 2013) analyzed the propagation of convergence orders of McCormick, Taylor, and McCormick-Taylor model relaxations. They derived sufficient conditions for schemes of relaxations constructed using the above models to have second-order pointwise convergence, which has important implications towards mitigating the cluster problem in unconstrained global optimization. In this talk, we propose a definition of convergence order for lower bounding schemes for constrained problems, and analyze the convergence orders of widely applicable full-space and reduced-space lower bounding schemes for continuous global optimization. A recent analysis of the cluster problem in constrained global optimization is used to evaluate the effectiveness of these schemes.

2. **Enhancing the Performance of BASBL: Branch-And-Sandwich BiLevel Solver with the Adaptive Branching, Domain Reduction and Parallel Computing Schemes**

Remigijus Paulavicius (remigijus.paulavicius@imperial.ac.uk) Imperial College London, United Kingdom, *Nikos Kazazakis, Polyxeni M Kleniati, Claire S Adjiman*

In this talk, we enhance the performance of the recently presented BASBL, a Branch-And-Sandwich algorithm [1, 2] based BiLevel solver [3] for nonlinear bilevel problems, implemented within the MINOTAUR toolkit [4]. First, the BASBL solver is extended to include adaptive branching schemes where at some stages of the algorithm branching is allowed only on a subset of the variables. Further, we introduce and incorporate a domain reduction scheme for bilevel problems. We evaluate the impact of the introduced enhancements on a set of nonconvex bilevel problems from a test library. Finally, we will briefly present an initial parallel approach for shared memory multi-core computers and will compare BASBL performance by using different threading frameworks. References [1] Kleniati, P.-M., Adjiman, C.S., Branch-and-Sandwich: a deterministic global optimization algorithm for optimistic bilevel programming problems. Part I: Theoretical development, J Glob Optim, 60(3), 425–458 (2014). [2] Kleniati, P.-M., Adjiman, C.S., Branch-and-Sandwich: a deterministic global optimization algorithm for optimistic bilevel programming problems. Part II: Convergence analysis and numerical results, J Glob Optim, 60(3), 459–481 (2014). [3] BASBL solver’s homepage: http://basblsolver.github.io/home/ [4] MINOTAUR toolkit homepage: https://wiki.mcs.anl.gov/minotaur/index.php/MINOTAUR

3. **A Parametric Approach to Solving the Pooling Problem**

Radu Baltean-Lugojan (rb2309@ic.ac.uk) Imperial College London, United Kingdom, *Ruth Misener*

We develop an algorithm that solves specialized pooling problem instances to global optimality and integrate it within a Branch and Bound framework for more generic instances. The approach parameterizes the optimization problem with respect to the pool concentration variables and uncovers embedded sparsity and polyhedral/topological properties for a variety of instances. The presentation generalizes and extends recent work analyzing computational complexity of the pooling problem [Boland et al. 2015, Haugland 2016]. Our analysis also integrates source-to-output streams and both upper and lower bounds on the network parameters.

■ Wed.B.1S

Wednesday, 15:15-16:30, Room 1S

Optimization Methods and Its Applications

Cluster: Nonlinear Optimization

Session organized by: *Cong Sun*

1. **Column-wise Block Coordinate Descent Approach for Orthogonal Constrained Optimization Problems**

Xin Liu (liuxin@lsec.cc.ac.cn) Chinese Academy of Sciences, China, *Bin Gao, Xiaojun Chen, Ya-xiang Yuan*

We propose a column-wise block coordinate descent approach for solving a class of orthogonal constrained optimization problems. This approach combines a Gauss-Sedeil type of iteration with a multiplier symmetrization step to guarantee the stationarity satisfied at any cluttering point. We prove the global convergence of the proposed approach. Preliminary experiments illustrate that the new algorithm performs well and is of great potential.

2. **L_p-Norm Regularization Algorithms for Optimization over Permutation Matrices**

Bo Jiang (jiangbo@njnu.edu.cn) Nanjing Normal University, China, *Ya-Feng Liu, Zaiwen Wen*

Optimization problems over permutation matrices appear widely in facility layout, chip design, scheduling, pattern recognition, computer vision, graph matching, etc. Since this problem is NP-hard due to the combinatorial nature of permutation matrices, we relax the variable to be the more tractable doubly stochastic matrices and add an L_p-norm ($0 < p < 1$) regularization term to the objective function. The optimal solutions of the L_p-regularized problem are the same as the original problem if the regularization parameter is sufficiently large. A lower bound estimation of the nonzero entries of the stationary points and some connections between the local minimizers and the permutation matrices are further established. Then we propose an L_p regularization algorithm with local refinements. The algorithm approximately solves a sequence of L_p regularization subproblems by the projected gradient method using a nonmontone line search with the Barzilai-Borwein step sizes. Its performance can be further improved if it is combined with certain local search methods, the cutting plane techniques as well as a new negative proximal point scheme. Extensive numerical results on QAPLIB and the bandwidth minimization problem show that our proposed algorithms can often find reasonably high quality solutions within a competitive amount of time.

3. **A Quadratically Convergent Regularized Semismooth Newton Method for Nonlinear Equations under Error Bound Conditions**

   Qingna Li (qnl@bit.edu.cn) Beijing Institute of Technology, China, *Qi Zhang, Xueying Ni, Anthony Man-Cho So*

In this paper, we propose an inexact regularized semismooth Newton method for solving the nonsmooth equations, strongly motivated from minimizing a nonsmooth convex function $\theta = f+g$ in machine learning fields such as l_1 regularized problem. By exploiting the strongly semismoothness of F and error bound assumption, the proposed algorithm has a local quadratically convergence rate. Further, A globalized version is proposed while maintaining the local quadratic convergence rate. Simulation results demonstrate the efficiency of the method.

■ Wed.B.1A

Wednesday, 15:15-16:30, Room 1A

Optimization Methods for Inverse Problems 2

Cluster: Nonlinear Optimization
Session organized by: *Xin Liu, Yanfei Wang*

1. **Inverse Max+Sum Spanning Tree Problem under Hamming Distance by Modifying the Sum-Cost Vector**

   Xiucui Guan (101010763@seu.edu.cn) Southeast University, China, *Xinyan He, Binwu Zhang*

On an undirected network $G(V,E,c,w)$, a cost $c(e)$ and a weight $w(e)$ are prescribed for each e. The max+sum spanning tree (MSST) problem is to find a spanning tree T_* which makes the combined weight max $w(e)$+sum $c(e)$ as small as possible. Whereas, in an inverse MSST problem, T_0 is a given spanning tree, which is not an optimal MSST. We modify c to $\bar{c}$ so that T_0 becomes an optimal MSST of the new network $G(V,E,\bar{c},w)$. The goal is to minimize the cost incurred by modifying c under Hamming Distance. First, we present a mathematical model for the inverse MSST problem and a method to check the feasibility. Then, under the weighted bottleneck-type Hamming distance, we design a binary search algorithm. Next, under the unit sum-type Hamming distance, which is also called l_0 norm, we show that the inverse problem IMSST0 is NP-hard. Assuming NP $\not\subset DTIME(m^{poly \log m})$, IMSST0 is not approximable within a factor of $2^{\log^{1-\varepsilon} m}$, for any $\varepsilon > 0$. Finally, we consider the augmented problem AIMSST0, whose objective function is $M\|x\|_0+\|x\|_1$. We show that the augmented problem and the l_1 norm problem have the same Lagrange dual problems. Therefore, the l_1 norm problem is the closest convex relaxation of the AIMSST0, which has the same optimal solution as that of the inverse problem IMSST0.

2. **Linear Convergence of Proximal Gradient Algorithm with Extrapolation for a Class of Nonconvex Nonsmooth Minimization Problems**

   Bo Wen (bo.wen@connect.polyu.hk) Harbin Institute of Technology/Hong Kong Polytechnic University, Hong Kong, *Xiaojun Chen, Ting Kei Pong*

In this paper, we study the proximal gradient algorithm with extrapolation for minimizing the sum of a Lipschitz differentiable function and a proper closed convex function. Under the error bound condition, we show that there exists a threshold such that if the extrapolation coefficients are chosen below this threshold, then the sequence generated converges R-linearly to a stationary point of the problem. Moreover, the corresponding sequence of objective values is also R-linearly convergent. In addition, the threshold reduces to 1 for convex problems and, as a consequence, we obtain the R-linear convergence of the sequence generated by the FISTA with the fixed restart. Finally, again for convex problems, we show that the successive changes of the iterates vanish for many choices of sequences of extrapolation coefficients that approach the threshold. In particular, this conclusion can be shown to hold for the sequence generated by the FISTA.

■ Wed.B.1B

Wednesday, 15:15-16:30, Room 1B

PDE-constrained Optimization in Electromagnetism

Cluster: PDE-constrained Optimization
Session organized by: *Fredi Tröltzsch, Irwin Yousept*

1. **Optimization of Non-smooth Hyperbolic Evolution Maxwell's Equations in Type-II Superconductivity**

   Irwin Yousept (irwin.yousept@uni-due.de) University Duisburg-Essen, Germany

This talk presents recent results on the optimization of an evolution electromagnetic process in type-II superconductivity. The optimization problem is to find an optimal applied current density, which steers the electromagnetic fields to the desired ones in the presence of a type-II superconductor. The governing PDE system for the electromagnetic fields consists of hyperbolic evolution Maxwell's equations with a non-smooth constitutive law for the electric field and the current density based on the Bean critical-state model. We develop a rigorous mathematical theory including an existence analysis and first-order necessary optimality conditions for the non-smooth PDE-constrained optimization problem.

2. **Sensitivity-based Topology and Shape Optimization of an Electric Motor**

   Peter Gangl (gangl@numa.uni-linz.ac.at) Johannes Kepler University Linz, Austria, *Ulrich Langer, Kevin Sturm, Antoine Laurain, Samuel Amstutz*

We consider the design optimization of an electric motor by means of sensitivity-based topology and shape optimization. The optimization problem is subject to the equations of nonlinear two-dimensional magnetostatics. The shape derivative of a domain-dependent functional provides information about its sensitivity with respect to a change of the shape of the underlying domain. On the other hand, the topological derivative gives information about the sensitivity of the functional with respect to the introduction of a hole or of an inclusion of a different material. We aim at finding the optimal distribution of ferromagnetic material in a design subregion of the computational domain by means of these two kinds of sensitivities. In the course of the optimization procedure, the interface between the different materials evolves. We present an easy to implement locally modified fitted finite element method that allows to resolve the interface exactly and show optimal convergence independent of the location of the interface relative to the mesh.

3. **Optimal Control of Some Quasilinear Parabolic Maxwell Equations**

   Fredi Tröltzsch (troeltzsch@math.tu-berlin.de) Technische Universität Berlin, Germany, *Serge Nicaise*

An optimal control problem is discussed for a quasilinear parabolic Maxwell system. Well-posedness of the quasilinear equation, existence of an optimal control, and weak Gateaux-differentiability of the control-to-state mapping are proved. Based on these results, first-order necessary optimality conditions and an associated adjoint calculus are derived.

■ Wed.B.1C

Wednesday, 15:15-16:30, Room 1C

Derivative-free Optimization Algorithms for Stochastic Problems

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Youssef M Marzouk*

1. **Probabilistically Fully Linear Models in STORM**

   Matt Menickelly (mjm412@lehigh.edu) Lehigh University, USA, *Katya Scheinberg*

In previous work, Chen, M., and Scheinberg developed an algorithmic framework, called STORM, for the unconstrained minimization of a stochastic nonconvex function, based on the class of derivative-free trust-region methods. In that work, the authors proved the almost sure convergence of the iterates of STORM to a stationary point, under the assumption of the existence of what they called a probabilistically fully linear sequence of models. Essentially, this assumption says that on each iteration, the models of the stochastic function should be fully linear in the iteration's trust region with some fixed probability (that need not converge to 1). In this talk, we will discuss the use of least squares regression models in STORM as a means to satisfy the probabilistically fully linear assumption, and discuss how it relates to model-building in general derivative-free optimization.

2. **On the Implementation of a Trust Region-based Algorithm for**

Derivative-free Optimization over Stochastic Simulations

Satyajith Amaran (samaran@dow.com) The Dow Chemical Company, USA, *Nikolaos V Sahinidis*

Simulation optimization involves the optimization over stochastic simulations such as discrete-event simulations and stochastic differential equation systems. We develop a provably convergent trust region-based method for continuous simulation optimization. We describe the details of our implementation which alternates between interpolation and regression (with a learned error), and incorporates careful management of the trust region to balance model accuracy and the ability to distinguish between solution candidates. We also demonstrate the practical use of the method through its success on a large test bed, and its application to numerous problems from chemical engineering, including inventory optimization in chemical supply chains, and optimal sizing of obstructions for DNA separation.

3. **A Gaussian Process Trust-Region Method for Derivative-free Nonlinear Constrained Stochastic Optimization**

Youssef M Marzouk (ymarz@mit.edu) Massachusetts Institute of Technology, USA, *Florian Augustin*

We present the algorithm (S)NOWPAC for derivative-free constrained stochastic optimization. The method uses a generalized trust region approach that accounts for noisy evaluations of the objective and constraints. To reduce the impact of noise, we fit Gaussian process models to past evaluations. Our approach incorporates a wide variety of probabilistic risk or deviation measures in both the objective and the constraints. We demonstrate the efficiency of the approach via several numerical benchmarks and comparisons.

■ Wed.B.4A

Wednesday, 15:15-16:30, Room 4A

Data and Networks II

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Nai-Yuan Chiang*

1. **Online Blind Deconvolution in Through-the-Wall Radar Imaging**

Hassan Mansour (mansour@merl.com) Mitsubishi Electric Research Laboratories, USA, *Ulugbek Kamilov, Dehong Liu, Petros Boufounos, Philip Orlik, Kieran Parsons, Anthony Vetro*

We propose an online radar imaging scheme that recovers a sparse scene and removes the multipath ringing induced by the front wall in a Through-the-Wall-Imaging (TWI) system without prior knowledge of the wall parameters. Our approach uses online measurements obtained from individual transmitter-receiver pairs to incrementally build the primary response of targets behind the front wall and find a corresponding delay convolution operator that generates the multi-path reflections available in the received signal. In order to perform online sparse imaging while removing wall clutter reflections, we developed a deconvolution extension of the Sparse Randomized Kaczmarz (SRK) algorithm. Our scheme constitutes an online generalization of blind-deconvolution using convex programming techniques such as SparseLift.

2. **Using Functional Programming to Recognize Named Structure in an Optimization Problem: Application to Pooling**

Ruth Misener (r.misener@imperial.ac.uk) Imperial College London, United Kingdom, *Francesco Ceccon, Georgia Kouyialis*

Branch-and-cut optimization solvers typically apply generic algorithms, e.g., cutting planes or primal heuristics, to expedite performance for many mathematical optimization problems. But solver software receives an input optimization problem as vectors of equations and constraints containing no structural information. This paper proposes automatically detecting named special structure using the pattern matching features of functional programming. Specifically, we deduce the industrially-relevant nonconvex nonlinear Pooling Problem within a mixed-integer nonlinear optimization problem and show that we can uncover pooling structure in optimization problems which are not pooling problems. Previous work has shown that preprocessing heuristics can find network structures; we show that we can additionally detect nonlinear pooling patterns. Finding named structures allows us to apply, to generic optimization problems, cutting planes or primal heuristics developed for the named structure. To demonstrate the recognition algorithm, we use the recognized structure to apply primal heuristics to a test set of standard pooling problems.

3. **A Regularized Augmented Lagrangian Filter Method for Nonlinear Building MPC Problems**

Nai-Yuan Chiang (chiangn@utrc.utc.com) United Technologies Research Center, USA, *Rui Huang, Victor M Zavala*

We present a detailed filter line-search method for nonlinear optimization that uses an augmented Lagrangian regularization to compute search steps. The method is motivated by real-time optimization applications on embedded computing platforms that require low-complexity linear algebra routines such as Cholesky decomposition. We prove that the proposed the algorithm is globally convergent and we demonstrate the developments using a nonlinear MPC model for building HVAC system. Our numerical studies demonstrate that the proposed approach is as efficient as common filter line-search method that requires symmetric indefinite factorizations.

■ Wed.B.4B

Wednesday, 15:15-16:30, Room 4B

Algorithms for Complementarity and Equilibrium Problems

Cluster: Complementarity and Variational Inequalities
Session organized by: *Uday Shanbhag*

1. **Lexicographic Pivoting for Mixed Linear Complementarity Problems**

Todd Munson (tmunson@mcs.anl.gov) Argonne National Laboratory, USA

Degeneracy gives rise to cycling for standard linear complementarity problems unless special pivoting rules are applied. A key feature to prevent cycling is invertibility: the pivot sequence moving forward is uniquely determined and the same sequence in reverse is obtain moving backward. Rules such as devex with an index-based tie breaker are not invertible even though they produce unique forward and backward pivot sequences, while lexicographic pivoting is invertible. For mixed linear complementarity problems, we can transform the problems into larger standard linear complementarity problems and apply lexicographic pivoting at the cost of extra computations. In this talk, we construct invertible pivoting rules for the compact system that guarantee our pivoting method cannot cycle.

2. **New Projection Methods for Monotone Variational Inequalities**

Yura Malitsky (y.malitsky@gmail.com) Graz University of Technology, Austria

We consider some new first-order methods for variational inequalities. These methods are very flexible and work under quite general assumptions. They use a very simple linesearch procedure that takes into account a local information of the operator. Moreover, this linesearch does not require any extra projections and in the same time it allows to increase steps from iteration to iteration. Because of this, the proposed algorithms may be quite efficient for difficult convex optimization problems.

3. **Value Function Based Non-cooperative Games**

Tianyu Hao (tianyuha@usc.edu) University of Southern California, USA, *Jong-Shi Pang*

We introduce value function based Nash games, where the objective function of each player includes a point-wise maximum or minimum function. We discuss a special class of such games — network interdiction games, which model interdictions among multiple interdictors with different objectives operating on a common network. Since the resulting optimization problem of each player may have a non-convex combined objective, we use a relaxed equilibrium concept, called quasi-Nash equilibrium (QNE).We first establish results regarding the existence of a QNE. To compute a QNE, we present a reformulation of such game, which leads to a pulled-out game with convex objective functions for each player. Then we establish an equivalence between a Nash equilibrium (NE) of the pulled-out game with a QNE of the value function based game. We show further that for the linear-quadratic case, a linear complementarity problem (LCP) can be formulated. Under Slater conditions and some other conditions, we show that the LCP can be solved by Lemke's algorithm.

■ Wed.B.5A

Wednesday, 15:15-16:30, Room 5A

Optimality and Algorithm for Convex and Multiple-Objective Optimization

Cluster: Multi-Objective and Vector Optimization
Session organized by: *Rabian Wangkeeree, Narin Petrot*

1. (**No talk is allocated at the first-speaker spot.**)

2. **On Optimality Theorems for Multiobjective Optimization Problems over Feasible Set Defined by Tangentially Convex Inequalities**

Rabian Wangkeeree (rabianw@nu.ac.th) Naresuan University, Thailand, *Nithirat Sisarat*

This paper is concerned with the optimality conditions for nonsmooth Convex Multiobjective Optimization problems (MOP) over a feasible set which is described by inequality constraints that are tangentially convex. We prove nonsmooth optimality theorems for weakly Pareto optimal solutions and properly Pareto optimal solutions of (MOP). We present examples illustrating our results.

3. **Methods for Finding Solutions of Convex Optimization and Feasibility Problem without Convex Representation**

Narin Petrot (narinp@nu.ac.th) Naresuan University, Thailand, *Nimit Nimana, Porntip Promsinchai*

In this talk, we will focus on the following two problems: (a) The convex optimization problem when the objective function may not smooth and the constraint set is represented by constraint functions that are locally Lipschitz and directionally differentiable, but neither necessarily concave nor continuously differentiable. (b) A type of generalized convex optimization problem, named a split quasi-convex feasibility problem. This problem is to find a point in a sublevel set of a quasi-convex function in one space and its image under a bounded linear operator is contained in a sublevel set of another quasi-convex function in the image space. We propose a new algorithm for solving these considered problems and discuss the convergence theorems of the constructed algorithms.

■ Wed.B.5D

Wednesday, 15:15-16:30, Room 5D

Recent Advances in Linear Optimization

Cluster: Linear Optimization
Session organized by: *Tamás Terlaky*

1. **Inexact Directions in Interior Point Methods**

Lukas Schork (L.Schork@ed.ac.uk) University of Edinburgh, United Kingdom, *Jacek Gondzio*

Inexact directions occur in interior point methods when iterative schemes are employed to solve the linear equation systems. Basing inexact algorithms on solid theory requires an analysis that is close to a practical implementation. We argue that the path-following framework, which currently forms the basis for most efficient interior point solvers, limits the use of inexact directions. Next, we demonstrate how the potential reduction approach combined with particular conditions on the inexactness can be used to analyse a practical algorithm.

2. **Euler Polytopes and Convex Matroid Optimization**

Antoine Deza (deza@mcmaster.ca) McMaster University, Canada, *George Manoussakis, Shmuel Onn*

We introduce a family of polytopes associated with several combinatorial objects such as the permutahedron of type B_d, or with the regions of hyperplane arrangements formed by normal vector with coordinates drawn from $\{-1,0,1\}$. We consider a class of optimization problems of convex multicritera objective functions over matroids. Such problems can be reduced to a number of linear optimization counterparts that is independent of the underlying matroid. We show that the introduced Euler polytopes improve the bounds on the number of linear counterparts needed to solve the convex multicritera optimization problem.

3. **Long and Winding Central Paths**

Pascal Benchimol (pascal.benchimol@polytechnique.edu) EDF R&D, France, *Xavier Allamigeon, Stephane Gaubert, Michael Joswig*

We construct a family of linear programs with $3r+4$ inequalities in dimension $2r+2$ on which an interior point method will perform a number of iterations exponential in r. This holds when the iterates produced by the method, and line segments in-between, stay within a neighborhood of the central path. Moreover, these linear programs have a total curvature exponential in r. This disprove a continuous analogue of the Hirsch conjecture proposed by Deza, Terlaky and Zinchenko. Our method is to tropicalize the central path in linear programming. The tropical central path is the piecewise-linear limit of the central paths of parameterized families of classical linear programs viewed through logarithmic glasses

■ Wed.B.5E

Wednesday, 15:15-16:30, Room 5E

Advances in Robust Optimization II

Cluster: Robust Optimization
Session organized by: *Vinh Doan*

1. **Fréchet Bounds and Distributionally Robust Optimization**

Xuan Vinh Doan (Xuan.Doan@wbs.ac.uk) University of Warwick, United Kingdom, *Xiaobo Li, Karthik Natarajan*

We develop Fréchet bounds for the class of convex piecewise linear functions given overlapping marginals. To guarantee the existence of a joint multivariate distribution consistent with the overlapping marginal information, we make use of a graph theoretic property known as the running intersection property. Building on this property, we develop a tight linear programming formulation to find the Fréchet bounds under the discrete setting. We compare our bounds with some existing bounds and show that they can be better.

2. **Tight Moments-based Bounds for Queueing Systems**

Varun Gupta (varun9upta@gmail.com) University of Chicago, USA, *Takayuki Osogami*

Despite the long history of queueing theory, numerous fundamental queueing systems have defied exact analysis so far. In this talk we will focus on three: (i) the classical M/G/k multi-server system; (ii) queueing systems with semi-markov modulated arrival and service rates; and (iii) the M/G/1 round-robin queue. We argue that rather than looking for exact expressions for the mean sojourn time as a function of the job-size distribution, a more fruitful approach is to obtain tight bounds on the mean sojourn time as functions of the moments of the job-size distribution. Analogous to the classical Markov-Krein theorem, we conjecture that the extremal distributions achieving these moments-based bounds correspond to the upper/lower principal representations of the moment sequence. We present both analytical and numerical evidence in support of our conjectures.

3. **The Empirical Divergence-based Distributionally Robust Optimization**

Henry Lam (khlam@umich.edu) University of Michigan, USA

We introduce what we call empirical divergence-based distributionally robust optimization (DRO) as a tractable tool to provide, close to the best, asymptotic statistical guarantees for the feasibility of expectation constraints under uncertain probability distributions. Unlike the standard rationale of data-driven DRO, our empirical uncertainty sets, which are balls measured by the Burg-entropy divergence, can have low or even zero probability of covering the true distribution. Rather, their statistical performances are endowed via linking the dual of the empirical DRO with likelihood theory in statistics. We show how to calibrate the size of these uncertainty sets using the quantiles of the excursion of chi-square processes.

■ Wed.B.5F

Wednesday, 15:15-16:30, Room 5F

Low Complexity Models and Applications

Cluster: Sparse Optimization and Information Processing
Session organized by: *Martin Lotz*

1. **A Provable Nonconvex Algorithm for Spectrally Sparse Signal Reconstruction**

Ke Wei (kewei@math.ucdavis.edu) University of California, Davis, USA, *Jian-Feng Cai, Tianming Wang*

We consider the reconstruction of spectrally sparse signals. Suppose such a signal is a mixture of complex sinusoids at r distinct continuous-valued frequencies, sampled at n equally-spaced points but only observed at m out of n random locations. We propose an efficient non-convex algorithm to reconstruct the signal via the low rank Hankel matrix completion. The proposed algorithm with a carefully selected initial guess is guaranteed to reconstruct the partial observed signal when the number of measurements is proportional to the intrinsic dimension of the problem.

2. **Tomography with Nonlinear Compressed Sensing**

Raphael Andreas Hauser (hauser@maths.ox.ac.uk) Oxford Mathematical Institute, United Kingdom, *Maria Klodt*

A new generation of low cost 3D tomography systems is based on multiple emitters and sensors that partially convolve measurements. A successful approach to deconvolve the measurements is to use nonlinear compressed sensing models. We discuss such models, as well as algorithms for their solution.

3. **Compressed Sensing Stability through High-dimensional Geometry**

   Axel Flinth (flinth@math.tu-berlin.de) Technische Universität Berlin, Germany

The main aim of compressed sensing is to recover a low-dimensional object (e.g. a sparse vector, a low-rank matrix, ...) from few linear measurements. Many algorithms for this task (e.g. Basis Pursuit, nuclear norm-minimization) consists of minimizing a structure-promoting function f over the set of possible solutions. Over the course of the last few years, researchers have succeeded at calculating threshold amounts of linear measurements that are needed to guarantee that the solution of such problems is equal to the ground truth signal with high probability. The idea consists of analyzing the probability that the kernel of the measurement matrix intersects the descent cone of f at the ground truth signal non-trivially. An important feature of programs of the type described above is that regularized versions of them can be used to recover signals that are only close to having a low-dimensional structure, and when the measurements are contaminated with noise. Can we use a geometric approach to explain also this phenomenon? In this talk, we will give a positive answer to this question. We will present an intuitive criterion and compare it to several other criteria for stability in compressed sensing.

■ Wed.B.5G

Wednesday, 15:15-16:30, Room 5G

Perspectives on Simplex Algorithms

Cluster: Linear Optimization
Session organized by: *Thomas Dueholm Hansen*

1. **The Simplex Algorithm is NP-mighty**

   Yann Disser (yanndisser@gmail.com) TU Berlin, Germany, *Martin Skutella*

We propose to classify the power of algorithms by the complexity of the problems that they can be used to solve. Instead of restricting to the problem a particular algorithm was designed to solve explicitly, however, we include problems that, with polynomial overhead, can be solved 'implicitly' during the algorithm's execution. For example, we allow to solve a decision problem by suitably transforming the input, executing the algorithm, and observing whether a specific bit in its internal configuration ever switches during the execution. We show that the Simplex Method, the Network Simplex Method (both with Dantzig's original pivot rule), and the Successive Shortest Path Algorithm are NP-mighty, that is, each of these algorithms can be used to solve any problem in NP. This result casts a more favorable light on these algorithms' exponential worst-case running times. Furthermore, as a consequence of our approach, we obtain several hardness results.

2. **An Improved Version of the Random-Facet Pivoting Rule for the Simplex Algorithm**

   Thomas Dueholm Hansen (tdh@cs.au.dk) Aarhus University, Denmark, *Uri Zwick*

The Random-Facet pivoting rule of Kalai and of Matousek, Sharir, and Welzl is an elegant, randomized pivoting rule for the simplex algorithm, the classical combinatorial algorithm for solving linear programs. The expected running time of the simplex algorithm when using this rule is subexponential in the combinatorial size–the number of variables and inequalities–of the linear program. This is currently the best known combinatorial bound for solving general linear programs. Other polynomial time algorithms are known, but their running time depends also on the number of bits in the representation of the linear program. We present a slightly improved version of the Random-Facet pivoting rule, thus obtaining the fastest known combinatorial algorithm for solving linear programs, the first improvement in over 20 years. Our results apply not only to linear programs, but also to more general, abstract LP-type problems. In particular we also obtain the fastest known algorithm for solving two-player turn-based stochastic games, a natural generalization of Markov decision processes.

3. **A Directed Steinitz Theorem for Oriented Matroid Programming**

   Walter Morris (wmorris@gmu.edu) George Mason University, USA

Holt and Klee proved that if P is a d-dimensional polytope and f is a linear function on P that is not constant on any edge of P, there are d independent monotone paths from the source to the sink of the digraph defined by the vertices and edges of P directed according to the directions of increase of f. Mihalisin and Klee proved that every orientation of the graph of a 3-polytope that is acyclic and admits 3 independent monotone paths from the source to the sink is obtained from some 3-polytope P and some linear function f on P. We prove analogs of Mihalisin and Klee's theorem and the 3 and 4-dimensional versions of Holt and Klee's theorem for oriented matroid programs. Here acyclicity is replaced by the requirement that there be no directed cycle contained in a face of the polytope.

■ Wed.B.5H

Wednesday, 15:15-16:30, Room 5H

Optimization Approaches for Derivative Pricing and Risk Management

Cluster: Applications in Finance and Economics
Session organized by: *Cedric Yiu*

1. **Hybrid Laplace Transform and Finite Difference Methods for Pricing American Options**

   Jingtang Ma (mjt@swufe.edu.cn) Southwestern University of Finance and Economics, China, *Zhiqiang Zhou*, *Zhenyu Cui*

In this talk, we present a novel Laplace transform and finite difference method to price (finite-maturity) American options, which is applicable to a wide variety of asset price models including constant elasticity of variance (CEV), hyper-exponential jump-diffusion (HEJD), and Markov regime switching models. We first apply Laplace transforms to free boundary partial differential equations (PDEs) governing the Amer-ican option prices with respect to time, and obtain second order ordinary differential equations (ODEs) with free boundary. Then we develop a novel iterative algorithm based on finite difference methods to solve the ODEs together with the unknown free boundary values in the Laplace space. Both the early exercise boundary and the prices of American options are recovered through inverse Laplace transforms.

2. **Optimal Portfolio and Insurance Problems with Risk Constraint**

   Cedric Yiu (cedric.yiu@polyu.edu.hk) The Hong Kong Polytechnic University, Hong Kong, *Jingzhen Liu*

We consider the risk-constrained portfolio selection problems arising from an ordinary investor or an insurer who can invest her surplus into financial market. For an insurer, the optimal investment and reinsurance problem is studied. The goal is to maximize the expected utility of terminal wealth. By using the principle of dynamic programming, the Hamilton-Jacobi-Bellman (HJB) equation can be derived. We will examine a few scenarios with different stochastic processes and discuss how to solve the resulting HJB equation. Furthermore, we will investigate the impacts of the risk constraint on the optimal strategies.

■ Wed.B.5J

Wednesday, 15:15-16:30, Room 5J

Sparse Optimization: Algorithms and Applications

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Michael Friedlander*

1. **Inexact Proximal Newton Methods for Composite Minimization**

   Cho-Jui Hsieh (chohsieh@ucdavis.edu) University of California, Davis, USA, *Inderjit S Dhillon*

Proximal Newton Methods have been widely used for solving composite minimization problems. Unfortunately, in many cases the subproblems do not have a closed form solution and thus have to be solved by another iterative solver with some stopping condition. These "inexact" proximal Newton methods have been implemented in many state-of-the-art software libraries, but in many case the convergence rate is unknown. In this talk we will formally analyze the global and local convergence rate for inexact proximal Newton methods and discuss how to make those algorithms efficient for large-scale problems. The resulting algorithms are efficient for solving many important machine learning problems, including sparse logistic regression and sparse inverse covariance estimation.

2. **Making Sketchy Decisions: Semidefinite Programming with Optimal Storage**

   Madeleine Udell (madeleine.udell@gmail.com) Cornell University, USA, *Joel A Tropp*, *Volkan Cevher*, *Alp Yurtsever*

Is it possible to solve an optimization problem using far less memory than the natural size of the decision variable? In this talk, we propose an (affirmative) answer to this question when both the problem data and the solution have a concise representation. We present an algorithm for provably solving many semidefinite programming problems (whose natural size is $O(n^2)$) using no more than $O(n)$ memory.

3. **Global Optimality in Matrix and Tensor Factorization, Deep Learning, and Beyond**

   Rene Vidal (rvidal@cis.jhu.edu) Johns Hopkins University, USA, *Benjamin Haeffele*

Matrix, tensor, and other factorization techniques are used in many applications and have enjoyed significant empirical success in many fields. However, common to a vast majority of these problems is the significant disadvantage that the associated optimization problems are typically non-convex due to a multilinear form or other convexity destroying transformation. Building on ideas from convex relaxations of matrix factorizations, in this talk I will present a very general framework which allows for the analysis of a wide range of non-convex factorization problems - including matrix factorization, tensor factorization, and deep neural network training formulations. In particular, I will present sufficient conditions under which a local minimum of the non-convex optimization problem is a global minimum and show that if the size of the factorized variables is large enough then from any initialization it is possible to find a global minimizer using a local descent algorithm.

■ Wed.B.5K

Wednesday, 15:15-16:30, Room 5K

Some New Results on Conic Optimization and Its Applications to Machine Learning

Cluster: Conic and Polynomial Optimization
Session organized by: *Akiko Yoshise*

1. **Inner and Outer Approximations of the Semidefinite Cone using SD Bases and Their Applications to Some NP-hard Problems**

   Daigo Narushima (s1620483@sk.tsukuba.ac.jp) University of Tsukuba, Japan, *Akihiro Tanaka, Akiko Yoshise*

Some of the authors in previous paper introduced a semidefinite basis which is a basis of the space of symmetric matrices consisting of rank-1 semidefinite matrices. In this talk, we present polyhedral inner and outer approximations of the positive semidefinite cone and the completely positive cone by using semidefinite bases. The conical hull of a semidefinite basis gives an inner approximation of the positive semidefinite cone. If elements of a semidefinite basis are nonnegative matrices, it gives an inner approximation of the completely positive cone. Supporting hyperplanes at every point of a semidefinite basis configure an outer approximation of these cones. Preliminary numerical experiments suggest that linear optimization problems over our polyhedral cones give a good upper and lower bounds of standard quadratic programming and randomly generated doubly nonnegative programming.

2. **Diversity Extraction via Condition Number Constrained Matrix Factorization**

   Mirai Tanaka (mirai@rs.tus.ac.jp) Tokyo University of Science, Japan, *Takanori Maehara*

In machine learning context, we often decompose a data matrix to the product of two matrices and interpret them as in the singular value decomposition and the nonnegative matrix factorization. The columns and rows of the output matrices are sometimes referred to as bases and they are interpreted as features of extracted topics or clusters. In practice, it is desirable that the bases differ from each other since the extracted topics have diversity. In this talk, we propose a matrix factorization method that guarantees the diversity of the output. We formulate such matrix factorization as an optimization problem with condition number constraints and propose an alternative direction multiplier method.

3. **Rank Minimization Approach to Collaborative Filtering Based on the Nuclear Norm Minimization**

   Akiko Yoshise (yoshise@sk.tsukuba.ac.jp) University of Tsukuba, Japan, *Tomotaka Yokoo, Akihiro Tanaka*

Recht, Fazel and Parrilo(2010) gave a theoretical characterization of the nuclear norm minimization relaxation of the affine rank minimization problem and suggested many applications of the result including collaborative filtering. However, very few results have been reported on collaborative filtering using the rank minimization approach. In this talk, we will present some numerical results using this approach and compare them with the results using singular value decomposition approach.

■ Wed.B.5L

Wednesday, 15:15-16:30, Room 5L

Moments, Positive Polynomials & Optimization: Part IV

Cluster: Conic and Polynomial Optimization
Session organized by: *Jiawang Nie, Jean B Lasserre*

1. **BSOS: A Bounded-Degree SOS Hierarchy for Polynomial Optimization**

   Jean B Lasserre (lasserre@laas.fr) LAAS-CNRS, France, *Kim Chuan Toh, Shouguang Yang*

The powerful SOS-based hierarchy of semidefinite programs based on Putinar's positivity certificate is penalized by the fast growth of the size of the involved semidefinite matrices. The BSOS hierarchy uses a different positivity certificate (mixing Krivine-Handelman's and Putinar's), and involves semidefinite matrices of fixed size. In contrast to the Krivine-Handelman LP-hierarchy, finite convergence for SOS-convex programs is guaranteed.

2. **Computing the Distance between the Linear Matrix Pencil and the Completely Positive Cone**

   Jinyan Fan (jyfan@sjtu.edu.cn) Shanghai Jiao Tong University, China, *Anwa Zhou*

In this talk, we show how to compute the distance between the linear matrix pencil and the completely positive cone. We formulate this problem as a linear optimization problem with the moment cone and the second order cone. A semidefinite relaxation algorithm is presented. A new model for checking the membership in the completely positive cone is also be proposed.

3. **DC Decomposition of Nonconvex Polynomials with Algebraic Techniques**

   Georgina Hall (gh4@princeton.edu) Princeton University, USA, *Amir Ali Ahmadi*

The concave-convex procedure is a majorization-minimization algorithm for difference of convex (DC) optimization, where the constraints and the objective function are given as the difference of two convex functions. Although several important problems (e.g., in machine learning) already appear in DC form, such a decomposition is not always available. We consider this decomposition question for polynomial optimization. We introduce LP, SOCP, and SDP based algorithms for finding optimal DC decompositions by appealing to the algebraic concepts of "DSOS-Convex, SDSOS-Convex, and SOSConvex" polynomials. We also study structural properties of these polynomials and answer existence questions about polynomial DC decompositions

■ Wed.B.m3S

Wednesday, 15:15-16:30, Room m3S

Recent Advances in First-Order Methods: Part II

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Marc Teboulle, Shoham Sabach*

1. **The Exact Information-based Complexity of Smooth Convex Minimization**

   Yoel Drori (yoel.drori@gmail.com) Google, Israel

We present a new lower bound on the information-based complexity of first-order minimization of smooth and convex functions. The new bound matches the worst-case performance of the recently introduced Optimized Gradient Method thereby establishing that the bound is tight and can be realized by an efficient algorithm. The proof is based on a novel construction technique of smooth and convex functions.

2. **A First Order Method for Solving Convex Bi-Level Optimization Problems**

   Shoham Sabach (ssabach@ie.technion.ac.il) Technion, Israel, *Shimrit Shtern*

We study convex bi-level optimization problems for which the inner level consists of minimization of the sum of smooth and nonsmooth functions. The outer level aims at minimizing a smooth and strongly convex function over the optimal solutions set of the inner problem. We analyze a first order method which is based on an existing fixed-point algorithm. Global sublinear rate of convergence of the method is established in terms of the inner objective function values.

3. **Primal and Dual Predicted Decrease Approximation Methods**

   Amir Beck (becka@ie.technion.ac.il) Technion, Israel, *Edouard Pauwels, Shoham Sabach*

We introduce the notion of predicted decrease approximation (PDA) for constrained optimization, a flexible framework which includes as special cases known algorithms such as generalized conditional gradient, proximal gradient, greedy coordinate descent for separable constraints and working set methods for linear equality constraints with bounds. This allows to provide a unified convergence analysis for these methods. We further consider a partially strongly convex nonsmooth model and show that dual application of PDA-based methods yields new sublinear convergence rate estimates in terms of both primal and dual objectives. As an example of an application, we provide an explicit working set selection rule for SMO-type methods for training the support vector machine with an improved primal convergence analysis.

■ Wed.B.m3AB

Wednesday, 15:15-16:30, Room m3AB

Advances in Deterministic Global Optimization II

Cluster: Global Optimization
Session organized by: *Chris Floudas, Nikolaos Sahinidis*
Session chair: *Pietro Belotti*

1. **A Branch and Bound Procedure for a Quadratic Reverse Convex Programming Problem by Listing FJ Points**

   Syuuji Yamada (yamada@math.sc.niigata-u.ac.jp) Niigata University, Japan

In this talk, we propose a branch and bound procedure for a quadratic reverse convex programming problem (QRC) whose feasible set is expressed as the area excluded the interior of a convex set from another convex set. It is known that many global optimization problems can be transformed into or approximated by such a problem. We observe that the feasible set of QRC is not always connected. Moreover, one of the reason of the difficulty for solving QRC is that all locally optimal solutions do not always satisfy KKT conditions. In order to overcome this drawback, we introduce a procedure for listing FJ points of QRC. By utilizing such a procedure, we can calculate all FJ points contained in the intersection of the boundaries of convex sets defining the feasible set. Further, we propose an algorithm for finding a globally optimal solution of QRC by incorporating such a procedure into a branch and bound procedure.

2. **Generalized Nash Games and Cap and Trade Environmental Models**

   Monica Gabriela Cojocaru (mcojocar@uoguelph.ca) University of Guelph, Canada, *Allison Small*

Environmental policy change is coming to the forefront of discussion and innovation due to the negative effects of climate change. Cap and trade is a market based policy that aims to reduce emissions of major polluters to protect the environment and human health. In this work, we extend the model presented in Breton et al., 2005 to three players (or countries) and evaluate the value of a cap and trade system. We aim to assess the merit of such a policy by using a generalized Nash game, and compare our results to a cap and "notrade" system modelled by a regular Nash game. We apply a newly developed computational method based on variational inequalities to solve the generalized game.

3. **Solving Hard Mixed Integer Quadratic and Conic Optimization Problems**

   Pietro Belotti (pietrobelotti@fico.com) Fair Isaac, United Kingdom

We report on the recent developments in the Xpress Optimizer for solving large scale mixed integer problems with quadratic and second-order cone constraints. In particular, we show some presolving and model reformulation techniques and their impact on the performance of the Optimizer for public benchmark problems.

■ Wed.C.1S

Wednesday, 17:00-18:15, Room 1S

Advances in Large-Scale Optimization

Cluster: Nonlinear Optimization
Session organized by: *Marianna De Santis*

1. **A Global Optimization Approach for the Valve Setting Problem**

   Bissan Ghaddar (bghaddar@uwaterloo.ca) IBM Research, Ireland

In this talk, we present a new quadratic optimization model for setting pressure reducing valves in water networks. A key advantage of the development of a quadratic formulation for the valve setting problem is that it provides computationally efficient solutions, and increases the network size that can be solved to global optimality. Polynomial optimization techniques are utilized to derive globally optimal bounds on the quadratic formulation of the valve setting problem and approximate globally optimal solutions. Computational results of the new formulation are presented on four water networks.

2. **Worst-Case and Sparse Portfolio Selection: Insights and Alternatives**

   Yufei Yang (yufei_yang@mymail.sutd.edu.sg) Singapore University of Technology and Design, Singapore, *Selin Damla Ahipasaoglu, Jingnan Chen*

In this talk, we will discuss a robust portfolio selection problem under fixed transaction costs. Based on Markowitz's mean-variance framework, we investigate a stylized model that incorporates an ellipsoidal uncertainty set and fixed transaction costs. We explore the portfolio composition and characterize the impact of parameter uncertainty and fixed transaction costs on portfolio weights.

3. **An Active Set Strategy for Nonlinear Programming Problems with Box Constraints**

   Marianna De Santis (marianna.desantis@gmail.com) Alpen-Adria Universität Klagenfurt, Austria, *Andrea Cristofari, Stefano Lucidi, Francesco Rinaldi*

We present an active-set strategy that has been recently used in different contexts and we will focus in particular on large scale problems with bound constraints. A two-stage algorithm will be introduced. At each iteration, in a first stage we estimate the active variables and fix them to the bounds, and in a second stage we perform a line search along a projected truncated-Newton direction computed in the subset of the estimated non-active variables. The proposed algorithm embeds these two stages within a nonmonotone stabilization framework. Global convergence to stationary points is established. Promising results were obtained on bound-constrained problems from the CUTEst collection.

■ Wed.C.1A

Wednesday, 17:00-18:15, Room 1A

Optimization Methods for Inverse Problems 3

Cluster: Nonlinear Optimization
Session organized by: *Xin Liu, Yanfei Wang*

1. **Solving Constrained TV2L1-L2 MRI Signal Reconstruction via an Efficient Alternating Direction Method of Multipliers**

   Tingting Wu (wutt@njupt.edu.cn) Nanjing University of Posts and Telecommunications, China, *Wenxing Zhang, Ke Guo, Deren Han*

High order total variation(TV2) and ℓ_1(TV2L1) based model has its advantage over the TVL1 for its ability in avoiding the staircases; and a constrained model has its advantage over its unconstained counterpart for its simple in estimating the parameters. In this paper, we consider the solving the TV2L1 based magnetic resonance imaging (MRI) signal reconstruction problem by an efficient alternating direction method of multipliers. By sufficiently utilizing the problem's special structure, we manage to make all subproblems either posses closed-form solution or can be solved via Fast Fourier Transform (FFT), which makes the cost per iteration is very low. We prove the convergence of the algorithm under mild conditions. Experimental results for MRI reconstruction are presented to illustrate the new model and algorithm. Comparison with its recent unconstained counterpart is also reported.

2. **Asymmetric Proximal Point Algorithms with Moving Proximal Centers**

   Deren Han (handeren@njnu.edu.cn) Nanjing Normal University, China, *Xiaoming Yuan*

We discuss the classical proximal point algorithm (PPA) with a metric proximal parameter in the variational inequality context. The metric proximal parameter is usually required to be positive definite and symmetric in the PPA literature, because it plays the role of the measurement matrix of a norm in the convergence proof. Our main goal is to show that the metric proximal parameter can be asymmetric if the proximal center is shifted appropriately. The resulting asymmetric PPA with moving proximal centers maintains the same implementation difficulty and convergence properties as the original PPA; while the asymmetry of the metric proximal parameter allows us to design highly customized algorithms that can effectively take advantage of the structures of the model under consideration. In particular, some efficient structure-exploiting splitting algorithms can be easily developed for some special cases of the variational inequality. We illustrate these algorithmic benefits by a saddle point problem and a convex minimization model with a generic separable objective function, both of which have wide applications in various fields. We present both the exact and inexact versions of the asymmetric PPA with moving proximal centers; and analyze their convergence including the estimate of their worst-case convergence rates measured by the iteration complexity under mild assumptions and their asymptotically linear convergence rates under stronger assumptions.

3. **A Proximal Alternating Direction Method for Multi-Block Coupled Convex Minimization**

   Lingling Xu (xulingling@njnu.edu.cn) Nanjing Normal University, China, *Foxiang Liu, Deren Han*

In this paper, we extend a proximal alternating direction method (PADM) for solving the convex minimization problems with linear constraints whose objective function is the sum of multi-block separable functions and coupled quadratic function. The algorithm generates iterate via a simple correction step, where the decent direction is based on the PADM. For the multiple-block case, which is the same structure with three-block case, we prove the convergence of the generated sequence under some mild assumptions. Finally, some preliminary numerical results are reported to support the efficiency of the new algorithms.

■ Wed.C.1B

Wednesday, 17:00-18:15, Room 1B

Recent Developments in PDE-constrained Optimization I

Cluster: PDE-constrained Optimization
Session organized by: *Stefan Ulbrich*

1. **Optimal Control of Multiphase Fluids and Droplets**

   Michael Hintermüller (michael.hintermueller@wias-berlin.de) Weierstrass Institute for Applied Analysis and Stochastics (WIAS) and Humboldt-Universität zu Berlin, Germany

Motivated by control problems in fluid dynamics, two classes of mathematical programs with equilibrium constraints are considered. As a first problem class, Cahn-Hilliard Navier-Stokes systems with non smooth potentials are considered for the optimal control of multiphase fluids. Secondly, for problems involving droplets, the Hele-Shaw model with contact line pinning is utilized. For both cases stationarity systems are derived and numerical results are discussed.

2. **A Nonlinear Primal-Dual Extragradient Method for Nonsmooth PDE-constrained Optimization**

   Christian Clason (christian.clason@uni-due.de) University Duisburg-Essen, Germany, *Tuomo Valkonen*

This talk is concerned with the extension of the Chambolle-Pock primal-dual algorithm to nonsmooth optimization problems involving nonlinear operators between function spaces. The proof of local convergence rests on verifying the Aubin property of the inverse of a monotone operator at the minimizer, which is difficult as it involves infinite-dimensional set-valued analysis. However, for nonsmooth functionals that are defined pointwise – such as L_1 norms or indicator functions of pointwise constraints – it is possible to apply simpler tools from the finite-dimensional theory, which allows deriving explicit conditions for the convergence. This is illustrated using an inverse problem with L_1-fitting and an optimal control problem with state constraints, where the parameter resp. control enters into a potential term.

3. **Preconditioners for Time-dependent PDE-constrained Optimization and an Implementation Based on Parareal Time-Domain Decomposition**

   Stefan Ulbrich (ulbrich@mathematik.tu-darmstadt.de) Technische Universitaet Darmstadt, Germany, *Anton Schiela*

We consider optimization problems governed by time-dependent parabolic PDEs and discuss the construction of parallel preconditioners based on the parareal method for the solution of quadratic subproblems which arise within SQP methods. In the case without control constraints, the optimality system of the subproblem is directly reduced to a symmetric PDE system, for which we propose a preconditioner that decouples into a forward and backward PDE solve. In the case of control constraints we apply a semismooth Newton method and apply the preconditioner to the semismooth Newton system. We prove bounds on the condition number of the preconditioned system which shows no or only a weak dependence on the size of regularization parameters for the control. We propose to use the parareal time domain decomposition method for the forward and backward PDE solves within the PDE preconditioner to construct an efficient parallel preconditioner. Numerical results are presented.

■ Wed.C.1C

Wednesday, 17:00-18:15, Room 1C

Advances in Derivative-free and Simulation-based Optimization III

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Jeffrey Larson*

1. **A New Derivative-free Method for Integer Programming Problems**

   Francesco Rinaldi (rinaldi@math.unipd.it) University of Padova, Italy, *Giampaolo Liuzzi, Stefano Lucidi*

In this work, we consider integer programming problems with both bound constraints on the variables and general nonlinear constraints, where objective and constraint function values can only be obtained by querying a black box. We define a new derivative-free method that combines the use of suitably generated sets of search directions with a specific penalty approach. Furthermore, we report the results of some preliminary numerical experiments on both bound constrained and nonlinearly constrained problems.

2. **Asynchronously Parallel Optimization Solver for Finding Multiple Minima**

   Jeffrey Larson (jmlarson@anl.gov) Argonne National Laboratory, USA, *Stefan M Wild*

We propose and analyze an asynchronously parallel optimization algorithm for finding multiple, high-quality minima of nonlinear optimization problems. Our multistart algorithm considers all previously evaluated points when determining where to start or continue a local optimization run. Theoretical results show that, under certain assumptions, the algorithm almost surely starts a finite number of local optimization runs and identifies, or has a single local optimization run converging to, every minimum. The algorithm is applicable to general optimization settings, but our numerical results focus on the case when derivatives are unavailable. In numerical tests, a Python implementation of the algorithm is shown to yield good approximations of many minima (including a global minimum), and this ability scales well with additional resources. Our implementation's time to solution is shown also to scale well, even when the time to evaluate the function evaluation is highly variable.

■ Wed.C.4A

Wednesday, 17:00-18:15, Room 4A

Data and Networks III

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Gesualdo Scutari*

1. **Decomposing Linearly Constrained Nonconvex Problems by a Proximal Primal-Dual Approach**

   Mingyi Hong (mingyi@iastate.edu) Iowa State University, USA

We propose a new decomposition approach named the proximal primal dual algorithm (Prox-PDA) for smooth nonconvex linearly constrained optimization problems. The proposed approach is primal-dual based, where the primal step minimizes certain approximation of the augmented Lagrangian of the problem, and the dual step performs an approximate dual ascent. Theoretically, we show that whenever the penalty parameter in the augmented Lagrangian is larger than a given threshold, the Prox-PDA converges to the set of stationary solutions, globally and in a sublinear manner (i.e., certain measure of stationarity decreases in the rate of $O(1/r)$, where r is the iteration counter). Interestingly, when applying a variant of the Prox-PDA to the problem of distributed nonconvex optimization (over a connected undirected graph), the resulting algorithm coincides with the popular EXTRA algorithm, which is only known to work in convex cases. Our analysis implies that EXTRA and its variants converge globally sublinearly to stationary solutions of certain nonconvex distributed optimization problem.

2. **Accelerated Hybrid Steepest Descent Method for Solving Affinely Constrained Composite Convex Optimization Problems**

   Konstantinos Slavakis (kslavaki@buffalo.edu) University at Buffalo, USA, *Isao Yamada*

The hybrid steepest descent method (HSDM) [Yamada '01] was introduced as a low-computational complexity tool for solving convex variational inequality problems over the fixed point set of nonexpansive mappings in Hilbert spaces. Borrowing ideas from conjugate gradient methods, HSDM versions that accelerate its rate of convergence were very recently introduced. However, to secure strong convergence to an optimal point in general Hilbert spaces, the sequence of step-size parameters is required to be diminishing, iterates are forced to belong to a bounded set, and the loss function is assumed to be differentiable with a strongly monotone gradient. This study offers a notable relaxed version of HSDM for affinely constrained composite optimization problems over Euclidean spaces, where the convex loss function consists of a smooth and a non-smooth part, the step-size parameter stays constant, the domain over which minimization is performed need not be bounded, and the smooth part of the loss is only required to have a Lipschitz continuous gradient operator. Results on the rate of convergence to an optimal point are presented, together with implementations of this accelerated version of HSDM in hierarchical optimization tasks for big-data applications.

3. **In-Network Nonconvex Large-Scale Optimization**

Gesualdo Scutari (gscutari@purdue.edu) Purdue University, USA

Consider a network composed of agents aiming to distributively minimize a (nonconvex) smooth sum-utility function plus a nonsmooth (nonseparable), convex one. The agents have access only to their local functions but not the whole objective, and the network is modeled as a directed, time-varying, T-strongly connected graph. We propose a distributed solution method for the above optimization wherein the agents in parallel minimize a convex surrogate of the original nonconvex objective while using dynamic consensus to distribute the computations over the network. Convergence to stationary solutions is established. Numerical results show that our new algorithm outperforms current schemes on both convex and nonconvex problems

■ Wed.C.4B

Wednesday, 17:00-18:15, Room 4B

Algorithms for Variational Inequality and Optimization Problems

Cluster: Complementarity and Variational Inequalities

Session organized by: *Uday Shanbhag*

1. **Convergence Analysis of Fixed Point Optimization Algorithm for the Triple-hierarchical Constrained Optimization Problem**

Thanyarat Jitpeera (t.jitpeera@hotmail.com) Rajamangala Technology Lanna University, Thailand, *Tamaki Tanaka, Poom Kumam*

An explicit algorithm is introduced to solve the monotone variational inequality over triple hierarchical problem. The strong convergence for the proposed algorithm to the solution is guaranteed under some assumptions. Our results extend ones of Iiduka(2009), Iiduka and Yamada(2009), Iiduka(2012) and study ones of Ceng et al.(2011), Yao et al.(2011).

2. **On the Global Convergence of Nonlinear Optimization Algorithms under Weak Assumptions**

Gabriel Haeser (ghaeser@gmail.com) University of Sao Paulo, Brazil, *Roberto Andreani, Alberto Ramos, Paulo JS Silva*

In this work we are interested in identifying first and second order properties satisfied by a local minimizer of a nonlinear optimization problem. Our main goal is to find conditions that can be verified by practical algorithms. We define first and second order optimality conditions stronger than the usual ones, requiring less restrictive assumptions on the problem, and as a consequence, we show global convergence to stationarity of several classes of first and second order algorithms under less restrictive assumptions.

3. **Characterization of Weakly Sharp Solutions of a Variational Inequality by Its Primal Gap Function**

Yina Liu (Yina.Liu@xjtlu.edu.cn) Xi'an Jiaotong-Liverpool University, China, *Zili Wu*

Our aim is to study weakly sharp solutions of a variational inequality in terms of its primal gap function g. We discuss sufficient conditions for the Lipschitz continuity and subdifferentiability of the primal gap function. Several sufficient conditions for the relevant mapping to be constant on the solutions have also been obtained. Based on these, we characterize the weak sharpness of the solutions of a variational inequality by g. Some finite convergence results of algorithms for solving variational inequality problems are also included.

■ Wed.C.5A

Wednesday, 17:00-18:15, Room 5A

Set-valued Analysis and Nonlinear Scalarization

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Tamaki Tanaka*

1. **On Generalization of a Fixed Point Theorem for Set-valued Maps**

Yutaka Saito (ysaito@m.sc.niigata-u.ac.jp) Niigata University, Japan, *Tamaki Tanaka, Syuuji Yamada*

The main topic of this talk is some generalization of several results for real-valued functions to set-valued map by using scalarization methods. We define a preorder induced by a convex cone in a topological vector space, and rewrite classical results based on the total order on the one dimensional real space R by the preorder. The original theorem related to this talk given by B.Ricceri has a conclusion with inequality conditions for some real-valued maps. The conclusion is same as Fan-Takahashi minimax inequality, which is equivalent to KyFan fixed point theorem. In this talk, we use a certain scalarizing function for set-valued maps proposed by Kuwano, Tanaka and Yamada. The composite function of a set-valued map and its scalarizing function has kinds of some convexities and continuities if the set-valued map has a certain convexity and continuity, respectively. Moreover, the scalarizing function has monotonicity between some set-relations and the classical order on R. We prove a generalized theorem of the original theorem to some set-valued versions by inherited properties above. In this talk, we introduce the mechanism of scalarization, and prove a Ricceri type minimax theorem.

2. **Generalized Alternative Theorems Based on Set-Relations and an Application to Semidefinite Programming Problems**

Yuto Ogata (y-ogata@m.sc.niigata-u.ac.jp) Niigata University, Japan, *Gue Myung Lee, Jae Hyoung Lee, Yutaka Saito, Tamaki Tanaka*

Gordan's theorem which is known as the earliest alternative theorem plays important roles in optimization. There are some kinds of extensions; Jeyakumar produces a generalized Gordan's theorem for vector-valued functions in 1986; Li in 1999 and Yang et al. in 2000 extend it to the case of set-valued maps. These theorems rely on assumptions related to convexity to make their systems in bilinear forms. In this talk, I would like to introduce alternative theorems from a set-valued analytic point of view, using set-relations proposed by Kuroiwa, Tanaka, and Ha in 1997. A similar approach with scalarizing functions for vectors had been done by Nishizawa, Onodsuka, and Tanaka in 2005. They omit the convexity with nonlinear scalarizations. We revised them to generalize these results. Also, we suggest an application of giving a judgement of Slater condition in semidefinite programming problems.

3. **A Scalar Characterization of Set-valued Optimization Problems**

Issei Kuwano (kuwano@kanagawa-u.ac.jp) Kanagawa University, Japan

In this talk, we introduce scalarization functions of sets and their some properties including monotonicity, continuity and convexity. Moreover, we characterize several set-valued optimization problems with set-criterion via scalarization. As an application, we give sufficient conditions for the existence of common solutions of some vector optimization problems.

■ Wed.C.5C

Wednesday, 17:00-18:15, Room 5C

Set-valued and Vector Optimization

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Tomas Bajbar*

1. **Order Convex Selections of Set-valued Functions and Their Applications to Convex Optimization**

Jerzy Motyl (j.motyl@wmie.uz.zgora.pl) Zielona Gora University, Poland

Let X be a Banach space while Y a Banach lattice. We consider the class of upper separated set-valued functions F acting from X to subsets of Y and investigate the problem of the existence of order-convex selections of F. Next we will discuss applications of obtained selection results to the theory of differential and stochastic inclusions. We will investigate the existence and properties of solutions of such inclusions, like stability or lower-upper bounds. In the second part of the talk we will discuss the applicability of obtained selection results to some deterministic and stochastic optimal control problems. Some examples will be presented also. References 1. J. Motyl, Caratheodory convex selections of set-valued functions in Banach lattices, Topol. Meth. Nonlin. Anal. 43 (2014) 2. J. Motyl, Stochastic retarded inclusion with Caratheodory-upper separated multifunctions, Set-Valued and Variational Analysis (2016, to appear) DOI 10.1007/s11228-015-0324-9 3. J. Motyl, Caratheodory-convex selections of multifunctions and their applications, Journal of Nonlinear and Convex Analysis, (accepted for publication) 4. J. M. Bismut, Conjugate Convex Functions in Optimal Stochastic Control, J. Math. Anal. Appl. 44 (1973), 5. R.T. Rockafellar, Duality in optimal controls, Math. Control Theory, Lecture Notes in Math. 680 (1978),

2. **Existence of Set Equilibrium Problem via Ekeland's Variational Principle**

Yousuke Araya (yousuke.araya@p.chibakoudai.jp) Chiba Institute of Technology, Japan

There are two types of criteria of solutions for the set-valued optimization problem, the vectorial criterion and set optimization criterion. The first criterion consists of looking for efficient points of set valued map and is called set-valued vector optimization problem. On the other hand, Kuroiwa-Tanaka-Ha and Jahn-Ha started developing a new approach to set-valued optimization which is based on comparison among values of the set-valued map. In this presentation, we treat the second type criterion and call set optimization problem. In this presentation, first we introduce several types of set equilibrium problem which are generalizations of vector equilibrium problem and set optimization problem, respectively. We also investigate relationships between the above problem. By using some types of nonlinear scalarizing functions for set-valued maps which are generalization of Tammer-Weidner's scalarizing functions for vectors, we give several types of a set-valued Ekeland's variational principles related to equilibrium problem. We also investigate relationships between the above existence theorems.

3. **On the Real Jacobian Conjecture and Newton Polytopes**

Tomas Bajbar (bajbar@kit.edu) Karlsruhe Institute of Technology, Germany, *Oliver Stein*

We discuss the relationship between the global diffeomorphism property of polynomial maps and the non-vanishing determinant of the corresponding Jacobian matrix by analysing the coercivity property of some specific sum of squares polynomials via their Newton polytopes.

■ Wed.C.5D

Wednesday, 17:00-18:15, Room 5D

Nonconvex Splitting Methods and Applications

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Wotao Yin*

1. **Alternating Direction Method of Multipliers for a Class of Nonconvex and Nonsmooth Problems with Applications to Background/Foreground Extraction**

Lei Yang (lei.yang@connect.polyu.hk) The Hong Kong Polytechnic University, China, *Ting Kei Pong, Xiaojun Chen*

We study a general optimization model, which covers a large class of existing models in many applications as special cases. In particular, it can be nuclear-norm-free, and can incorporate different possibly nonconvex sparsity inducing regularization functions, such as the ℓ_p quasi-norm for $0 < p < 1$, for the background/foreground extraction problem. To solve the resulting possibly nonconvex optimization problem, we adapt the alternating direction method of multipliers (ADMM) with a general dual step-size to solve a reformulation that contains three blocks of variables, and analyze its convergence. We show that for any dual step-size less than the golden ratio, there exists a computable threshold such that if the penalty parameter is chosen above such a threshold and the sequence thus generated by our ADMM is bounded, then the cluster point of the sequence gives a stationary point of the nonconvex optimization problem. We achieve this via a potential function specifically constructed for our ADMM. Moreover, we establish the global convergence of the whole sequence if, in addition, this special potential function is a Kurdyka-Łojasiewicz function. Some numerical results are given to show the efficiency of our ADMM with a nontrivial dual step-size.

2. **ExtraPush for Convex Decentralized Optimization over Directed Networks with Extensions**

Jinshan Zeng (jsh.zeng@gmail.com) Jiangxi Normal University, China, *Wotao Yin*

In this talk, we extend the existing algorithms Extra and subgradient-push to a new algorithm ExtraPush for convex consensus optimization over a directed network. When the stationary distribution of the network is easily computed in advance, we propose a simplified algorithm called Normalized ExtraPush. These algorithms use a fixed step size like in Extra and accept the column-stochastic mixing matrices like in subgradient-push. We present preliminary analysis for ExtraPush under a bounded sequence assumption. For Normalized ExtraPush, we show that it naturally produces a bounded, linearly convergent sequence provided that the objective function is strongly convex. In numerical experiments, ExtraPush and Normalized ExtraPush performed similarly. With a proper step size, they are significantly faster than subgradient-push, even if the latter uses a hand-optimized step size. Lastly, we show several extensions of the proposed algorithms.

■ Wed.C.5E

Wednesday, 17:00-18:15, Room 5E

Advances in Robust Optimization III

Cluster: Robust Optimization

Session organized by: *Bart Van Parys*

1. **A New Perspective on Boosting in Linear Regression via Subgradient Optimization and Relatives**

Rahul Mazumder (rahul@vanparys.ch) Massachusetts Institute of Technology, USA

Boosting is one of the most powerful and popular tools in machine learning/statistics that is widely used in practice. They work extremely well in a variety of applications. However little is known about many of the statistical and computational properties of the algorithm, and in particular their interplay. We analyze boosting algorithms in linear regression from the perspective modern first-order methods in convex optimization. We show that classic boosting algorithms in linear regression, namely the incremental forward stagewise algorithm (FSe) and least squares boosting (LS-Boost-e), can be viewed as subgradient descent to minimize the maximum absolute correlation between features and residuals. We also propose a modification of FSe that yields an algorithm for the LASSO, and that computes the LASSO path. We derive novel comprehensive computational guarantees for all of these boosting algorithms, which provide, for the first time, a precise theoretical description of the amount of data-fidelity and regularization imparted by running a boosting algorithm with a pre-specified learning rate for a fixed but arbitrary number of iterations, for any dataset.

2. **Stochastic Optimization with Data: Large Deviation Limits**

Bart Van Parys (bart@vanparys.ch) Massachusetts Institute of Technology, USA, *Bart PG Van Parys, Peyman Mohajerin Esfahani, Daniel Kuhn*

A large deviation theory perspective is offered on distributionally robust optimization for stochastic programming with both independent identically distributed (i.i.d.) as well as Markov dependent data. In any robust approach there is an inherent competition between robustness and optimality. An intuitive Pareto optimality condition between both interests is offered by large deviation theory. In a common framework, we show that the relative entropy and conditional relative entropy balls are Pareto optimal for either i.i.d. and Markov data respectively.

■ Wed.C.5F

Wednesday, 17:00-18:15, Room 5F

Novel Perspectives on Nonlinear Optimization

Cluster: Sparse Optimization and Information Processing

Session organized by: *Coralia Cartis*

Session chair: *Martin Lotz*

1. **Global Optimization via Eigenvalues**

Yuji Nakatsukasa (Yuji.Nakatsukasa@maths.ox.ac.uk) University of Oxford, United Kingdom, *Satoru Adachi, Satoru Iwata, Shinsaku Sakaue, Akiko Takeda*

While non-convex optimization problems are generally regarded as difficult or computationally intractable, the Courant-Fischer theorem for symmetric eigenvalue problems suggests that each eigenpair corresponds to a stationary point of a non-convex optimization problem (in this case the Rayleigh quotient). More generally, matrix eigenvalue problems form an important class of problems that can be solved efficiently; this includes generalized, polynomial and multiparameter eigenvalue problems. This observation suggests conversely that perhaps a global solution for some non-convex optimization problems can be obtained by solving an eigenvalue problem. In this work we identify such optimization problems: namely, we show that a global solution for non-convex QCQP with one or two constraints can be reduced to an eigenvalue problem. As in the Courant-Fisher theorem, the (multiparameter) eigenvalues represent the KKT Lagrange multipliers, and the eigenvectors–which have a low-rank structure when matricized–represent the KKT points. This talk focuses on the simple case of QCQP with one constraint (including the trust-region subproblem), for which our algorithm is a single-step method (without iterations aside from the eigenvalue computation) and performs well relative to existing algorithms.

2. **On Multigrid Methods in Convex Optimization**

Michal Kocvara (m.kocvara@bham.ac.uk) University of Birmingham, United Kingdom, *Coralia Cartis, Nick Gould*

The aim of this talk is to design an efficient multigrid method for constrained convex optimization problems arising from discretization of some underlying infinite dimensional problems. Due to problem dependency of this approach, we only consider bound constraints with (possibly) a linear equality constraint. As our aim is to target large-scale problems, we want to avoid computation of second derivatives of the objective function, thus excluding Newton like methods. We propose a smoothing operator that only uses first-order information and study the computational efficiency of the resulting method. In the second part, we consider application of multigrid techniques to more general optimization problems, in particular, the topology design problem.

3. **Randomized Quasi-Newton Updates are Linearly Convergent Matrix Inversion Algorithms**

   Robert Mansel Gower (r.m.gower@sms.ed.ac.uk) University of Edinburgh, United Kingdom, *Peter Richtarik*

We develop and analyze a family of stochastic/randomized algorithms for inverting a matrix. We also develop specialized variants maintaining symmetry or positive definiteness of the iterates. All methods in the family converge globally and linearly (the error decays exponentially), with explicit rates. In special cases, we obtain stochastic block variants of several quasi-Newton updates, including good/bad Broyden, Powell-symmetric-Broyden (PSB), Davidon-Fletcher-Powell (DFP) and Broyden-Fletcher-Goldfarb-Shanno (BFGS). Ours are the first stochastic versions of these updates shown to converge to an inverse of a fixed matrix. Through a dual viewpoint we uncover a fundamental link between quasi-Newton updates and approximate inverse preconditioning. Further, we develop an adaptive variant of randomized block BFGS, where we modify the distribution underlying the stochasticity of the method throughout the iterative process to achieve faster convergence. By inverting several matrices from varied applications, we demonstrate that our method is highly competitive when compared to the well established Newton-Schulz and minimal residual methods. On large-scale problems our method outperforms the standard methods by orders of magnitude. Development of efficient methods for estimating the inverse of very large matrices is a much needed tool for preconditioning and variable metric optimization methods in the advent of the big data.

■ Wed.C.5G

Wednesday, 17:00-18:15, Room 5G

Theoretical and Algorithmic Developments of Linear Optimization and Semi-infinite Linear Optimization

Cluster: Linear Optimization

Session organized by: *Shiqian Ma*

1. **Projection: A Unified Approach to Semi-infinite Linear Programs and Duality in Convex Programming**

   Amitabh Basu (basu.amitabh@jhu.edu) Johns Hopkins University, USA, *Richard Kipp Martin, Christopher Thomas Ryan*

Fourier-Motzkin elimination is a projection algorithm for solving finite linear programs. We extend Fourier-Motzkin elimination to semi-infinite linear programs which are linear programs with finitely many variables and infinitely many constraints. Applying projection leads to new characterizations of important properties for primal-dual pairs of semi-infinite programs such as zero duality gap, feasibility, boundedness, and solvability. Extending the Fourier-Motzkin elimination procedure to semi-infinite linear programs yields a new classification of variables that is used to determine the existence of duality gaps. In particular, the existence of what we call "dirty" variables can lead to duality gaps. Our approach has interesting applications in finite-dimensional convex optimization. For example, sufficient conditions for a zero duality gap, such as the Slater constraint qualification, are reduced to guaranteeing that there are no "dirty" variables. This leads to completely new proofs of such sufficient conditions for zero duality.

2. **Strong Duality and Sensitivity Analysis in Semi-infinite Linear Programming**

   Christopher Thomas Ryan (chris.ryan@chicagobooth.edu) University of Chicago, USA, *Amitabh Basu, Kipp Martin*

Finite-dimensional linear programs satisfy strong duality (SD) and have the "dual pricing" (DP) property. The (DP) property ensures that, given a sufficiently small perturbation of the right-hand-side vector, there exists a dual solution that correctly "prices" the perturbation by computing the exact change in the optimal objective function value. These properties may fail in semi-infinite linear programming where the constraint vector space is infinite dimensional. Unlike the finite-dimensional case, in semi-infinite linear programs the constraint vector space is a modeling choice. We show that, for a sufficiently restricted vector space, both (SD) and (DP) always hold, at the cost of restricting the perturbations to that space. The main goal of the paper is to extend this restricted space to the largest possible constraint space where (SD) and (DP) hold. Once (SD) or (DP) fail for a given constraint space, then these conditions fail for all larger constraint spaces. We give sufficient conditions for when (SD) and (DP) hold in an extended constraint space. Our results require the use of linear functionals that are singular or purely finitely additive and thus not representable as finite support vectors. We use the extension of the Fourier-Motzkin elimination procedure to semi-infinite linear systems to understand these linear functionals.

3. **Faster Algorithms for Convex and Submodular Function Minimization**

   Sam Wong (sam.cw.wong@gmail.com) University of California, Berkeley, USA, *Yin Tat Lee, Aaron D Sidford, Sam Chiu-wai Wong*

The ellipsoid method, as analyzed by Khachiyan in 1979, is the first algorithm for solving linear and convex programming, and belongs to a larger family known as the cutting plane methods. Following a series of improvements over Khachiyan's work, the cutting plane method of Vaidya from 1989 achieved the fastest possible theoretical running time. In this talk I will discuss a new improvement to Vaidya's algorithm that nearly matches the theoretical limit of the cutting plane methods. Our techniques draw on ideas from recent advances in spectral graph theory and randomized linear algebra. Surprisingly, we are able to apply our result to obtain faster algorithm not only for convex programming but also for classic problems in combinatorial optimization. As applications, we demonstrate that our algorithm yields faster algorithms for matroid intersection and submodular function minimization, two of the most important problems in combinatorial optimization. For matroid intersection this is the first improvement since Cunningham's in 1986.

■ Wed.C.5H

Wednesday, 17:00-18:15, Room 5H

Stability Analysis in Stochastic Programming

Cluster: Stochastic Optimization

Session organized by: *Matthias Claus*

1. **Stability Analysis for Mathematical Programs with Distributionally Robust Chance Constraint**

   Huifu Xu (h.xu@soton.ac.uk) University of Southampton, United Kingdom, *Shaoyan Guo, Liwei Zhang*

Stability analysis for optimization problems with chance constraints concerns impact of variation of probability measure in the chance constraints on the optimal value and optimal solutions and research on the topic has been well documented in the literature of stochastic programming. In this paper, we extend such analysis to optimization problems with distributionally robust chance constraint where the true probability is unknown, but it is possible to construct an ambiguity set of distributions and the chance constraint is based on the most conservative selection of probability distribution from the ambiguity set. The stability analysis focuses on impact of the variation of the ambiguity set on the optimal value and optimal solutions. We start by looking into continuity of the robust probability function and followed with a detailed analysis of approximation of the function. Sufficient conditions have been derived for continuity of the optimal value and outer semicontinuity of optimal solution set. Case studies are carried out for ambiguity sets being constructed through moments and samples.

2. **On Stability of Risk Averse Complementarity Problems under Uncertainty**

   Johanna Burtscheidt (johanna.burtscheidt@uni-due.de) University of Duisburg-Essen, Germany

Inspired by structural similarities to risk neutral one-stage stochastic optimization a risk averse formulation for general stochastic complementarity problems (SCP) based on the expected residual minimization (ERM) model will be presented. In particular, qualitative stability of the optimal value function of this problem under perturbation of the underlying Borel probability measure will be investigated for a special class of risk measures with respect to weak convergence of probability measures. An overview of NCP functions which can be used in the stated problem concludes the talk.

3. **On Stability of Stochastic Bilevel Programs with Risk Aversion**

   Matthias Claus (matthias.claus@uni-due.de) University of Duisburg-Essen, Germany

Two-stage stochastic programs and bilevel problems under stochastic uncertainty bear significant conceptual similarities. However, the step from the first to the latter mirrors the step from optimal values to optimal solutions and entails a loss of desirable analytical properties. The talk focuses on mean risk formulations of stochastic bilevel programs where the lower level problem is quadratic. Based on a growth condition, weak continuity of the objective function with respect to perturbations of the underlying measure is derived. Implications regarding stability for a comprehensive class of risk averse models are pointed out.

■ Wed.C.5J

Wednesday, 17:00-18:15, Room 5J

Advances in Nonlinear Optimization I

Cluster: Nonlinear Optimization
Session chair: *Yi-Shuai Niu*

1. **On New Classes of Nonnegative Symmetric Tensors and Applications**

   Bilian Chen (blchen@xmu.edu.cn) Xiamen University, China, *Simai He, Zhening Li, Shuzhong Zhang*

In this paper we introduce three new classes of nonnegative forms (or equivalently, symmetric tensors) and their extensions. The newly identified nonnegative symmetric tensors constitute distinctive convex cones in the space of general symmetric tensors (order 6 or above). For the special case of quartic forms, they collapse into the set of convex quartic homogeneous polynomial functions. We discuss the properties and applications of the new classes of nonnegative symmetric tensors in the context of polynomial and tensor optimization. Numerical experiments for solving certain polynomial optimization models based on the new classes of nonnegative symmetric tensors are presented.

2. **A Mixed Integer Semidefinite Programming Approach for Variable Selection Avoiding Multicollinearity**

   Ryuta Tamura (s154558y@st.go.tuat.ac.jp) Tokyo University of Agriculture and Technology, Japan, *Ken Kobayashi, Yuichi Takano, Ryuhei Miyashiro, Kazuhide Nakata, Tomomi Matsui*

This research considers a mixed integer semidefinite programming approach for variable selection avoiding multicollinearity. Variable selection is a problem of selecting a better subset of explanatory variables. For variable selection, selected subsets are generally evaluated by information criteria, such as AIC and BIC. Minimizing those criteria, however, does not necessarily avoid multicollinearity, which causes several defects such as unreliable estimation and numerical instability. Multicollinearity in linear regression can be observed as a large condition number of a correlation coefficient matrix of selected explanatory variables. To obtain a good subset of explanatory variables without multicollinearity, we formulate it as two mixed integer semidefinite programming (MISDP) problems, which minimize the residual sum of squares under the constraint such that the corresponding condition number is at most a given upper bound. In addition, we perform computational experiments to solve those MISDP problems using SCIP and SCIP-SDP, a MIP solver and MISDP plugin for SCIP, respectively.

3. **On Global Optimization of Mixed-01 Nonlinear Program via DC Algorithms**

   Yi Shuai Niu (niuyishuai@sjtu.edu.cn) Shanghai Jiao Tong University, China

Mixed-01 nonlinear program could be reformulated as DC (Difference of convex functions) programming problems. We will investigate its DC programming reformulations and propose new hybrid global optimization algorithms based on a well-known and efficient local optimization algorithm-DCA, and in combination with global optimization techniques: Branch-and-Bound (B&B), DC/SDP relaxations and DC-Cutting planes. We consider reformulating a mixed-01 nonlinear program as a DC program via continuous representation of discrete sets and penalization techniques on nonconvex constraints. Then we investigate its DC Algorithm for local optimization which will be used as upper bound estimation in B&B; The DC/SDP relaxations will be considered as lower bound estimation; And the DC-Cutting plane helps to cut off local minimizers so as to reduce the feasible set and accelerate the convergence of B&B. Some preliminary numerical simulation results will be also reported.

■ Wed.C.5K

Wednesday, 17:00-18:15, Room 5K

SDP and DNN Relaxations of Discrete Polynomial Optimization Problems

Cluster: Conic and Polynomial Optimization
Session organized by: *Sunyoung Kim, Masakazu Kojima*

1. **Exact SDP Relaxations with Truncated Moment Matrix for Binary Polynomial Optimization Problems**

   Shinsaku Sakaue (sakaue.1229@gmail.com) NTT Communication Science Laboratories, Japan, *Akiko Takeda, Sunyoung Kim, Naoki Ito*

For binary polynomial optimization problems (POPs) of degree d with n variables, we prove that a semidefinite (SDP) relaxation problem in Lasserre's hierarchy of the SDP relaxations provides the exact optimal value when the relaxation order is $\lceil (n+d-1)/2 \rceil$. If binary POPs involve only even-degree monomials, we show that the relaxation order can be further reduced to $\lceil (n+d-2)/2 \rceil$. This bound on the relaxation order coincides with the conjecture by Laurent in 2003, which was recently proved by Fawzi, Saunderson and Parrilo, on binary quadratic optimization problems where $d=2$. More precisely, Fawzi et al. proved a more general result on POPs on a finite abelian group, which we use to show our aforementioned results. We also numerically confirm that the bound is tight; we present instances of binary POPs that require solving at least $\lceil (n+d-1)/2 \rceil$ th SDP relaxation for general binary POPs and $\lceil (n+d-1)/2 \rceil$ th SDP relaxation for even-degree binary POPs to obtain the exact optimal values.

2. **A Robust Lagrangian-DNN Method for a Class of Quadratic Optimization Problems**

   Sunyoung Kim (skim@ewha.ac.kr) Ewha University, Korea South, *Naohiko Arima, Masakazu Kojima, Kim-Chuan Toh*

We discuss methods for improving the Lagrangian-doubly nonnegative (DNN) relaxation proposed in 2016 to solve a large class of nonconvex quadratic optimization problems. To enhance the performance of the bisection method for the Lagrangian-DNN relaxation, a new technique is introduced to guarantee the validity of the computed lower bound at each iteration of the bisection method. Computational results are presented to demonstrate the robustness of the proposed method.

3. **A Lagrangian and Doubly Nonnegative Relaxation for Polynomial Optimization Problems in Binary Variables**

   Masakazu Kojima (kojimamasakazu@icloud.com) Chuo University, Japan, *Sunyoung Kim, Kim-Chuan Toh*

We discuss an extension of the Lagrangian-DNN method, which was originally proposed for a class of quadratic optimization problems with equality and complementatity constraints in nonnegative and binary variables, to a hierarchy of DNN relaxations of polynomial optimization problems in binary variables. We also show its effectiveness and computational efficiency through numerical results.

■ Wed.C.5L

Wednesday, 17:00-18:15, Room 5L

Advances in First-Order Methods and Handling Uncertainty

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Fatma Kilinc-Karzan*

1. **First-Order Methods for Robust Convex Optimization**

   Nam Ho-Nguyen (hnh@andrew.cmu.edu) Carnegie Mellon University, USA, *Fatma Kilinc-Karzan*

Robust optimization is a framework to model parameter uncertainty in optimization problems. Inspired by recent developments, we present several efficient first-order methods to approximately solve robust convex optimization problems. We also introduce the notion of weighted regret online learning and the online saddle-point problem, which form key building blocks for our methods. Finally, we discuss some proximal-type algorithms for these problems.

2. **Incremental Methods for Additive Convex Cost Optimization**

   Mert Gurbuzbalaban (mert.gurbuzbalaban@gmail.com) Massachusetts Institute of Technology, USA, *Asu Ozdaglar, Pablo A Parrilo*

Motivated by machine learning problems over large data sets and distributed optimization over networks, we consider the problem of minimizing the sum of a large number of convex functions. We develop and study incremental methods for solving such problems, in particular for the random reshuffling method we provide a sharp convergence rate result which answers an open question.

3. **A Second-Order Cone Based Approach for Solving the Trust Region Subproblem and Its Variants**

Fatma Kilinc-Karzan (fkilinc@andrew.cmu.edu) Carnegie Mellon University, USA, *Nam Ho-Nguyen*

We study the trust region subproblem (TRS) of minimizing a nonconvex quadratic function over the unit ball with additional conic constraints. Despite having a nonconvex objective, it is known that the TRS and a number of its variants are polynomial-time solvable. In this paper, we follow a second-order cone based approach to derive an exact convex formulation of the TRS. As a result, our study highlights an explicit connection between the nonconvex TRS and smooth convex quadratic minimization, which allows for the application of cheap iterative methods such as Nesterov's accelerated gradient descent, to the TRS. Under slightly stronger conditions, we give a low-complexity characterization of the convex hull of its epigraph without any additional variables. We also explore the inclusion of additional hollow constraints to the domain of the TRS, and convexification of the associated epigraph.

■ Thu.A.1S

Thursday, 9:00-10:15, Room 1S

ADMM-like Methods for Convex Optimization and Monotone Inclusions

Cluster: Nonlinear Optimization

Session organized by: *Jonathan Eckstein*

1. **Distributed Proximal Gradient Methods for Cooperative Multi-Agent Consensus Optimization**

Necdet Serhat Aybat (nsa10@psu.edu) Pennsylvania State University, USA, *Shiqian Ma*

In this talk, decentralized methods for solving cooperative multi-agent consensus optimization problems over an undirected network of agents will be discussed, where only those agents connected by an edge can directly communicate with each other. The objective is to minimize the sum of agent-specific composite convex functions, i.e., each term in the sum is a private cost function belonging to an agent. The first part of the talk is on the unconstrained case, and the second part focuses on the constrained case, where each agent has a private conic constraint set. For the constrained case the optimal consensus decision should lie in the intersection of these private sets. This optimization model abstracts a number of applications in machine learning, distributed control, and estimation using sensor networks. Distributed methods based on linearized ADMM, and saddle point methods will be discussed. I will provide convergence rates both in sub-optimality error and consensus violation; examine the effect of underlying network topology on the convergence rates of the proposed decentralized algorithms; and discuss how to extend these methods to time-varying topology.

2. **ARock: Asynchronous Parallel Coordinate Update Framework and Its Application to ADMM**

Wotao Yin (wotaoyin@math.ucla.edu) University of California, Los Angeles, USA, *Brent Edmunds, Zhimin Peng, Tianyu Wu, Yangyang Xu, Ming Yan*

Single-core performance stopped improving around 2005. However, the number of cores has grown quikcly. Today 64 cores workstations, 2k-core GPUs, and even 8-core cellphones are available. To take advantages of all the cores available, we must parallelize our algorithms. With asynchrony, the performance of parallel algorithms is no longer determined by the slowest core, the most difficult task, or the longest communication delay. This talk explains why asynchronous computing is both theoretically sound and practically attractive. In particular, we study a randomized version of asynchronous coordinate updates to a fixed point problem and show its point convergence. The guarantee is that the performance scales linearly with the number of cores used as long as that number is no more than the square root of the number of variables. As special cases, novel asynchronous algorithms such as ADMM and EXTRA for parallel and distributed computing are presented. We present the ARock package for quick prototyping of asynchronous algorithms based on coordinate update and operator splitting. Numerical results will be presented.

3. **Asynchronous Projective Monotone Operator Splitting Algorithms**

Jonathan Eckstein (jeckstei@rci.rutgers.edu) Rutgers University, USA, *Patrick L Combettes*

We describe a new family of decomposition algorithms for finding zeroes of sums of maximal monotone set-valued operators and solving related problems of a generalized Fenchel form. The basic algorithmic framework unifies several prior classes of decomposition methods in which the coordination step involves projection onto a separating hyperplane constructed from the results of the subproblem evaluations. However, the key innovation is that only a subset of the subproblems need be evaluated between coordination steps, and subproblem evaluations and coordination steps may be overlapped asynchronously. Applications include asynchronous ADMM-like convex optimization methods.

■ Thu.A.1A

Thursday, 9:00-10:15, Room 1A

Optimization Methods for Inverse Problems 4

Cluster: Nonlinear Optimization

Session organized by: *Xin Liu, Yanfei Wang*

1. **A Parallel Line Search Subspace Correction Method for Convex Optimization Problems**

Qian Dong (dongqian@lsec.cc.ac.cn) Chinese Academy of Sciences, China, *Xin Liu, Zaiwen Wen, Yaxiang Yuan*

We investigate a parallel subspace correction framework for composite convex optimization based domain decomposition method. At each iteration, the algorithms solve subproblems on subspaces simultaneously to construct a search direction and take the Armijo line search to find a new point. They are called PSCLN and PSCLO, respectively, depending on whether there are overlapping variables. Their convergence is established under mild assumptions. We compare them with state-of-the-art algorithms for solving LASSO problems, which shows that PSCLN and PSCLO can run fast and return solutions no worse than those from the others. It is also observed that the overlapping scheme is helpful for the structured-data problem.

2. **Generalized Newton Method for Globally Solving the Total Least Squares with Tikhonov Regularization**

Yong Xia (dearyxia@gmail.com) Beihang University, China, *Meijia Yang, Jiulin Wang*

The Tikhonov regularization of the total least squares (TRTLS) is a nonconvex optimization problem. According to Dinkelbach's parametric strategy, it can be equivalently reduced to finding a zero point of a decreasing concave but possibly nonsmooth univariate function. We propose a generalized Newton method by replacing the derivative with thesubgradient. It globally converges to the root. Under a mild assumption, we show that the asymptotic rate of convergence is superlinear. The worst-case time complexity is less than that of the existing global solution methods based on bisection. Finally, we report numerical results.

3. **Conditional Gradient Algorithms for Rank-k Matrix Approximations with a Sparsity Constraint**

Hongying Liu (liuhongying@buaa.edu.cn) Beihang University, China, *Qian Yang*

The sparsity constrained rank-k matrix approximation problem 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. In this talk, we propose the gradient method for the task. Two conditional gradient algorithms are given for the cases without the orthogonality constraint and with the orthogonality constraint respectively. The proposed method can be referred as a dual version of the well-known generalized power method for sparse principal component analysis. The low complexity of the proposed algorithms makes them well suited to handle large-scale problem of sparse rank-k matrix approximations with a sparsity constraint. As illustrations, the algorithms are applied to real and simulated data with encouraging results.

■ Thu.A.1B

Thursday, 9:00-10:15, Room 1B

Recent Developments in PDE-constrained Optimization II

Cluster: PDE-constrained Optimization

Session organized by: *Stefan Ulbrich*

1. **PDE Constrained Optimization with Pointwise Gradient Constraints**

Winnifried Wollner (wollner@mathematik.tu-darmstadt.de) TU Darmstadt, Germany

In this talk, we will review several recent result in PDE constrained optimization with pointwise constraints on the gradient of the state. This includes barrier and penalty methods in a function space setting to eliminate the constraint on the gradient. Convergence of such methods is discussed. Further, we will consider the discretization of such problems in particular for non smooth domains, where the control to state mapping does not assert the gradient to be Lipschitz.

2. **Optimal Control of the Thermistor Problem in Three Spatial Dimensions**

Hannes Meinlschmidt (meinlschmidt@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Joachim Rehberg, Christian Meyer*

We consider the optimal control of the thermistor problem in three spatial dimensions, where the latter models the heating of a conducting material by means of direct current. Here, the aim is to achieve a prescribed temperature distribution after a given simulation time. The underlying partial differential equations are given as a coupled system of a parabolic- and elliptic PDE, the latter with mixed boundary conditions, and the system is complemented by control- and state constraints. Both PDEs are of quasilinear structure, with nonlinear coupling, and the solutions ultimately depend nonlinearly on the control. Nevertheless, we show that solutions to the PDE system exist uniquely, albeit generally only locally in time. We thus work with the set of controls admitting solutions which exist globally in time and prove existence of optimal solutions to the optimal control problem for this class of controls. Moreover, we obtain a well-rounded optimality theory which does not need to refer to the set of controls which admit only global-in-time solutions. The theoretical findings are complemented by numerical results.

3. **Controlling Feasibility and Optimality in Iterative Solvers for Optimality Systems**

Roland Herzog (roland.herzog@mathematik.tu-chemnitz.de) Technische Universität Chemnitz, Germany, *Kirk M Soodhalter*

Optimality systems for equality constrained optimization exhibit a saddle-point structure. In PDE-constrained optimization, the solution of such large-scale systems by direct solvers is prohibitive, and iterative solvers must be used. The precontioned minimal residual method (MINRES) is a natural candidate due to the self-adjointness and indefiniteness of optimality systems. Traditional implementations of MINRES provide access only to the norm of the full residual, and it serves as a stopping criterion. However, MINRES does not normally expose the residual subvector norms, which correspond to optimality and feasibility, respectively. We present a modified implementation of MINRES which allows to monitor these quantities independently. Applications in PDE-constrained optimization are given.

■ Thu.A.1C

Thursday, 9:00-10:15, Room 1C

Derivative-free Optimization Algorithms for Large-Scale Problems

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Youhei Akimoto*

1. **Efficiency of Random Search on Structured Problems**

Sebastian Stich (sebastian.stich@uclouvain.be) Université Catholique de Louvain, Belgium

Coordinate Descent methods are among the most efficient schemes for high-dimensional optimization and their complexity is well understood. Under certain structural assumptions, also the use of accelerated versions of these schemes is theoretically justified. In this talk, we study the complexity of randomized derivative-free schemes. Especially, we will also discuss the benefits of acceleration techniques on high-dimensional problems.

2. **An Indicator for the Switch from Derivative-free to Derivative-based Optimization**

Nacer Eddine Soualmi (soualmi@cerfacs.fr) Cerfacs, France, *Luis Nunes Vicente, Segre Gratton*

In some optimization problems found in applications, the derivative of the objective function are available but at an expensive cost, and it is desirable to know when to use derivative-free methods (such as direct search, for instance) or derivative-based methods (such as gradient or quasi-Newton methodsà. In general, derivative-free methods tend to make a steady initial progress when first applied and then become slower or even stagnate due to the lack of derivatives. It is thus of interest to provide a way to appropriately switch from a derivative-free method to a derivative-based one. In this paper we develop a family of indicators for such a switch based on decrease properties of both classes ofo methods (typically used when deriving worst case complexity bounds).

3. **Comparison-based Stochastic Algorithm with Adaptive Gaussian Model for Large-Scale Continuous Optimization**

Youhei Akimoto (y_akimoto@shinshu-u.ac.jp) Shinshu University, Japan, *Nikolaus Hansen*

The covriance matrix adaptation evolution strategy (CMA-ES) is recognized as a state-of-the-art comparison-based stochastic algorithm for continuous optimization, especially when the objective function is black-box. Due to its ranking-based property and the adaptation of the covariance matrix of the Gaussian distribution, from which candidate solutions are generated, the CMA-ES exhibits several invariance properties such as monotone transformation of the objective function and affine transformation of the search space, which are essential for a black-box scenario where a prior knowledge is limited. However, its computational time and space complexity scales up quadratically and the adaptation time for the covariance matrix increases as the number of variables incerases. In this talk we present a variant of CMA-ES with a restricted covariance model and the adaptation mechanism for the complexity of the restricted covariance model. The algorithm is based on the projection between the manifold of the positive definite symmetric matrices and its submanifold of restricted covariance matrices. The proposed algorithm, VkD-CMA, has advantages both in the internal complexity and in the number of function evaluations.

■ Thu.A.4A

Thursday, 9:00-10:15, Room 4A

Optimization in Energy Management Systems with Integrated Economic/Physical Models

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Toshiyuki Ohtsuka*

1. **Distributed Optimal Power Management Based on Dynamic Pricing in Multi-Period Electricity Market**

Toru Namerikawa (namerikawa@sd.keio.ac.jp) Keio University, Japan, *Yoshihiro Okawa*

This paper deals with a novel distributed optimal power supply-demand management method based on dynamic pricing in the deregulated electricity market. Since power consumers and generators determine their own power demand or supply selfishly in the deregulated electricity market trading, distributed power management methods are required to maintain the power supply-demand balance in power grids. For this problem, the proposed method integrates two different time-periods electricity market, Day-ahead and Real-time market, and solves this management problem in a distributed manner using electricity prices through market trading. Specifically, the proposed method, first, derives the optimal locational electricity prices which maximize social welfare of the entire power network in the day-ahead market based on alternating decision makings of market players. Then, the proposed method compensates the power imbalance caused by some problems such as prediction errors via negawatt trading in the real-time market, in which power consumers reduce their demand, while they receive monetary incentives from the market operator. The proposed method shows the optimal incentive design method using the day-ahead prices to minimize the power adjustment cost in real-time market trading. Finally, numerical simulation results are shown to demonstrate the effectiveness of the proposed method.

2. **Real-Time Pricing Leading to Optimal Operation and Applications to Energy Management Systems**

Kenji Hirata (hirata@nagaokaut.ac.jp) Nagaoka University of Technology, Japan, *Kenko Uchida*

We consider interactions between an independent entity, called a utility, and multiple agents, which correspond to generators or consumers in power networks. The utility wants to realize the socially optimal solution that fulfills power supply demand balancing. Each agent is allowed to determine its desired set-point according to the individual profit. In order to align the individual decision makings of the agents with the socially optimal solution, the utility is allowed to provide an additional price, which conceptually represents tax or subsidy. We propose a real-time pricing strategy of the utility and show three application case studies: a distributed voltage regulation of a distribution power gird in which a voltage rise occurs due to revers power flow from PV generators of households, a distributed voltage regulation for a large scale PV system with experimental case study results, a distributed management of EV/PHEV storage charging to fulfill the power flow balancing between a prediction based power supply and actual demands.

3. **A Study on Modeling and Optimization of an Energy Demand Network with Strategic Aggregators**

Yusuke Okajima (y_okajima@aoni.waseda.jp) Waseda University, Japan, *Toshiyuki Murao, Takeshi Hatanaka, Kenji Hirata, Kenko Uchida*

In this research, we address modeling of energy market with aggregators, which are expected to implement demand response and negotiate with utility companies on behalf of customers. We model the aggregator as a strategic player since it is regarded as an organization for profit. The decision variable is the incentive transferred to the customers who are also strategic and choose an aggregator maximizing their own benefit including the transferred incentive. In the formulation of the aggregator's cost, our main focus is placed on the concept of market power, which represents the economic impact on the market price. The aggregators are assumed to aim at maximizing the market power by collecting as many customers as possible in order to maximize the income, while minimizing the outcome paid to the customers. Then, after fixing decision-making rules of the customers, utility and aggregators, we discuss the benefit of introducing the aggregators.

■ Thu.A.4B

Thursday, 9:00-10:15, Room 4B

Applications to Practical Problems

Cluster: Applications in Energy, Science and Engineering
Session chair: *Renan S Maglasang*

1. **A Successive LP Approach with C-VaR Type Constraints for IMRT Optimization**

   Shogo Kishimoto (kishimoto.s.ac@m.titech.ac.jp) Tokyo Institute of Technology, Japan, *Makoto Yamashita*

An important optimization problem arising from intensity-modulated radiation therapy (IMRT) is to determine the intensities of beams so that the beam irradiation effectively reduces cancer tumors. On the one hand we should give high dose volume to tumors, but on the other hand we need to keep the dose volume for critical organs under certain threshold. Since the dose volume constraints (DVCs) are closely related to the average of a fractional volume of a target structure, Romeijn et al. introduced C-VaR (conditional value at risk) type constraints in order to model the beam intensity problem as an LP problem. However, their approach was very sensitive to outliers in the structure and failed in some test instances to find a feasible solution that satisfies all the DVCs. We propose a successive LP approach that incorporates the C-VaR type constraints and the effective framework due to Romeijn et al. Using the solutions from LP problems, we identify the outliers and remove them from the C-VaR type constraints. We verified through numerical tests that our approach successfully found a feasible solution in practical computation time.

2. **A Tri-Level Optimization Model for Private Road Competition Problem with Traffic Equilibrium Constraints**

   Gu Yan (yukiguyan@outlook.com) Kyoto University, Japan, *Xingju Cai, Deren Han, David ZW Wang*

Build–Operate–Transfer scheme is widely applied in many cities, wherein the firms compete to invest in the road building and aim at maximizing their profits via collecting tolls from users traveling on the roads under their control. In many research works on analyzing the private road competition problem in the existing literature, it is assumed that all the new roads would be constructed and operated by private firms under BOT scheme. In this case, as the primary objective of private firms is profit maximization, the system would be less efficient in terms of managing the network traffic and achieving the government's goal of maximizing social welfare. Therefore, in this study, we propose that the government should take more proactive participation into the new road construction and operation, imposing impacts on the private firms' investment and tolling strategy so that a certain social objective could be fulfilled. We characterize this problem into a tri-level optimization model. In such a multi-competition game, strategic interaction and market equilibrium must be taken into consideration to determine their investment and price. We then propose a heuristic approach to solve the model and finally its validity is verified by a simple network numerical example.

3. **The Shelf Space Allocation Problem under Carbon Tax and Emission Trading Policies**

   Renan S Maglasang (maglasangrenan@gmail.com) National Taiwan University of Science and Technology, Taiwan, *Vincent F Yu, Yu-Chung Tsao*

A mixed integer non-linear programming (MINLP) model is formulated for the shelf space allocation problem (SSAP) under two common environmental policies: the Carbon Tax System and the Emission Trading System. For each system, the impact on profitability and the opportunities for emission cuts are presented. Specifically, we explore via numerical experiments the impact of fixed carbon tax, emission permit, and emission price on two of the most important in-store management decisions in retail, the shelf space capacity and the product allocation decisions. Real-life retail data of four product categories are tested and solved to optimality using COUENNE. Optimal solutions are analyzed to gain insights important to inform both retailers and governmental decision makers.

■ Thu.A.5A

Thursday, 9:00-10:15, Room 5A

Applications in Production and Energy Economics

Cluster: Applications in Energy, Science and Engineering
Session chair: *Parlo Krokhmal*

1. **To Predict the Bottleneck Node by Queueing Network Modeling of a Production Model with Long Lead Time and Large Variety of Small Quantity Production**

   Takako Hoshiyama (thoshiyama@mirror.ocn.ne.jp) The University of Tokyo, Japan, *Toshio Akimitsu*

To evaluate the production operations of large variety of small quantity production and long lead time production in a wide range activity, we look for an easy to handle evaluation method than ordinary product simulator. This paper is adapting the Jackson network model for open networks, which has been utilized to mathematically understanding the behaviour of packets in the communication and network industry. We have done the scenarios and numerical sampling experiments. This was set metrics to evaluate the performance of the model, i.e. the waiting time, the standard deviation of the waiting time, and the delay probability of a node with multiple receptors. We present a case study of a construction vehicle manufacturer. This has large variety small quantity production and long lead-time production, i.e. 3 weeks for one vehicle assembly lead time, dealing with the mathematical nature of GI/G/1, GI/G/m queues. From the numerical sampling experiments, we discovered that has a long production lead time imposes a great burden on its node. This evaluation method is able to discover the bottleneck nodes (process). This is also able to serve as reference materials of the inventory reduction rescheduler by TOC (theory of constraints).

2. **Shape Optimization for Contact Problems Based on Isogeometric Analysis and Nonconvex Bundle Methods**

   Benjamin Manfred Horn (bhorn@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

Mechanical connectors appear in many real life optimization problems. We consider the shape optimization of such a connector, where the connector are modeled as a contact problem in linear elasticity. In order to avoid a gap between the the representation in CAD systems and the finite element simulation used by the mathematical simulation we choose an isogeometric approach to solve the contact problem within the optimization method. Additionally we get an exact geometry description with smooth boundaries. We handle the contact conditions using the mortar method and solve the resulting contact problem with a semismooth Newton method. The optimization problem is nonconvex and nonsmooth due to the contact conditions. To keep the number of the time consuming simulations as low as possible, we use a derivative based optimization method. The design derivatives can be efficiently calculated with the adjoint approach. The resulting optimization problem is solved with a modified bundle trust region algorithm.

3. **A Semidefinite Programming Approach to Computing Bounds on the Overall Properties of Composite Materials with Randomly Oriented Fibers**

   Pavlo Krokhmal (krokhmal@email.arizona.edu) University of Arizona, USA, *Olesya I Zhupanska, Yana Morenko*

This work is concerned with evaluation of the overall elastic properties and development of improved variational bounds on the overall elastic properties of fiber-reinforced composites with arbitrary orientational distribution of fibers. The problem of finding the tightest bounds for the elastic tensor of a composite material with non-aligned phases is formulated as a nonlinear semidefinite programming (SDP) problem. The conducted analysis of the feasible region and the objective function allows one to reduce the obtained nonlinear SDP problem to a nonlinear programming problem, for which a semi-analytic solution is derived. The computational results show that the constructed solution improves the Hashin-Schtrikman-Walpole bounds, which are the only known in the literature bounds for the composites with non-aligned microstructures and are only valid for the case of uniform random distributions of microstructure.

■ Thu.A.5C

Thursday, 9:00-10:15, Room 5C

Non-convex Vector Optimization and Applications

Cluster: Multi-Objective and Vector Optimization
Session organized by: *Christian Günther, Marcus Hillmann*
Session Chair: *Marius Durea*

1. **Minimal Time Function with Respect to a Set of Directions and Applications**

   Marius Durea (durea@uaic.ro) Alexandru Ioan Cuza University, Romania

We introduce a new type of minimal time function with respect to a set of directions and we study several of its properties such as semicontinuity, convexity, Lipschitz behavior, and subdifferential calculus. Then we show that these properties are good enough in order to derive a generalized version of Ekeland Variational Principle (using this new minimal time function instead of the distance function) and to get necessary optimality conditions for a location vector optimization problem. At the end of the presentation we show how this study opens some new possibilities to define and to explore directional behavior of single and set-valued mappings, which act as objectives for various optimization problems.

■ Thu.A.5D

Thursday, 9:00-10:15, Room 5D

Extended Formulations and Related Topics

Cluster: Linear Optimization
Session organized by: *David Bremner*

1. **Strong Reductions for Linear and Semidefinite Programs**

   Sebastian Pokutta (sebastian.pokutta@isye.gatech.edu) Georgia Institute of Technology, USA, *Gábor Brown, Aurko Roy*

Linear and semidefinite programming are two core optimization paradigms with many important applications. However, the expressive power of these modeling paradigms is only partially understood so far and extended formulations are a powerful and natural tool to analyze the possibilities and limitations of linear and semidefinite programming formulations. We will present a strong reduction mechanism both for LPs and SDPs, which allows to establish strong inapproximability results for various problems, including e.g., vertex cover, bounded-degree matching, and sparsest cut. Moreover, the reduction mechanism induces an ordering of relative hardness of the underlying problems.

2. **A Note on Extended Formulations of Lower-truncated Transversal Polymatroids**

   Hidefumi Hiraishi (hiraishi1729@is.s.u-tokyo.ac.jp) The University of Tokyo, Japan, *Shuichi Hirahara, Hiroshi Imai*

Extended formulations of $(k;l)$-sparsity matroids of n-vertex and m-edge graph are investigated by (Iwata et al., Mathematical Programming, 2015). This talk shows the results can be obtained by interpreting results on $(k;l)$-lower-truncated transversal (poly)matroids in (Imai, JORSJ, 1983) from the viewpoint of extended formulations, the same $O(mn)$ bound when $k \geq l$ and a better bound $O(m^2)$ when $k < l$. A unified polymatroidal approach is given to derive more general understandings. Some extensions of these results will be touched upon.

3. **Small Linear Programs for Decision Problems**

   David Bremner (bremner@unb.ca) University of New Brunswick, Canada, *David Avis, Hans Raj Tiwary, Osamu Watanabe*

In the classical "Edmonds" model of solving combinatorial optimization problems with linear programs, one can read the problem objective directly from the linear program optimal solution. Results of Rothvoß (2014) showed the limitations of this approach, since no polynomial size LP that projects onto Edmond's matching polytope exists. Several authors have studied more general kinds of reductions where strong hardness results still hold. For decision problems the picture is rather different. In this talk I'll discuss two main ideas - "Weak extended formulations", where we only insist on projecting integer vertices, - "Compiling" algorithms to LPs that simulate running those algorithms for a bounded amount of time. With those ideas in hand we can derive polynomial size polytopes for the (weighted) matching decision problem.

■ Thu.A.5E

Thursday, 9:00-10:15, Room 5E

Advances in Robust Optimization IV

Cluster: Robust Optimization
Session organized by: *Wolfram Wiesemann*

1. **Duality in Two-Stage Adaptive Linear Optimization: Faster Computation and Stronger Bounds**

   Frans de Ruiter (f.j.c.t.deruiter@uvt.nl) Tilburg University, Netherlands, *Dimitris Bertsimas*

In this talk we derive and exploit duality in general two-stage adaptive linear optimization models. The resulting model is again a two-stage adaptive linear optimization model. The new dualized model differs from the primal formulation in its dimension and uses a different description of the uncertainty set. We show that the optimal primal affine policy can be directly obtained from the optimal affine policy in the dual formulation. We provide empirical evidence that the dualized model in the context of two-stage lot-sizing on a network and two-stage facility location problems solves an order of magnitude faster than the primal formulation with affine policies. We also provide an explanation and associated empirical evidence that offer insight on which characteristics of the dualized formulation make computations faster. Furthermore, the affine policy of the dual formulations can be used to provide stronger lower bounds on the optimality of affine policies.

2. **Regularization via Mass Transportation**

   Daniel Kuhn (daniel.kuhn@epfl.ch) École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, *Soroosh Shafieezadeh Abadeh, Peyman Mohajerin Esfahani*

The goal of regression and classification methods in supervised learning is to minimize the empirical risk, that is, the expectation of some loss function quantifying the prediction error under the empirical distribution. When facing scarce training data, overfitting is typically mitigated by adding regularization terms to the objective that penalize hypothesis complexity. In this paper we introduce new regularization techniques using ideas from distributionally robust optimization, and we give new probabilistic interpretations to existing techniques. Specifically, we propose to minimize the worst-case expected loss, where the worst case is taken over the ball of all (continuous or discrete) distributions that have a bounded transportation distance from the (discrete) empirical distribution. By choosing the radius of this ball judiciously, we can guarantee that it contains the unknown data-generating distribution with high confidence, thus facilitating new out-of-sample performance guarantees. We prove that the resulting regularized learning problems are tractable and can be tractably kernelized for many popular loss functions. We validate our theoretical out-of-sample guarantees through simulated and empirical experiments.

3. **Ambiguous Joint Chance Constraints under Mean and Dispersion Information**

   Wolfram Wiesemann (ww@imperial.ac.uk) Imperial College Business School, United Kingdom, *Grani Hanasusanto, Vladimir Roitch, Daniel Kuhn*

We study joint chance constraints where the distribution of the uncertain parameters is only known to belong to an ambiguity set characterized by the mean and support of the uncertainties and by an upper bound on their dispersion. This setting gives rise to pessimistic (optimistic) ambiguous chance constraints, which require the corresponding classical chance constraints to be satisfied for every (for at least one) distribution in the ambiguity set. We provide tight conditions under which pessimistic and optimistic joint chance constraints are computationally tractable, and we show numerical results that illustrate the power of our tractability results.

■ Thu.A.5F

Thursday, 9:00-10:15, Room 5F

Low-Order Algorithms for Nonlinear Optimization

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Shuzhong Zhang*

1. **Barzilai-Borwein Step Size for Stochastic Gradient Descent**

   Shiqian Ma (sqma@se.cuhk.edu.hk) The Chinese University of Hong Kong, Hong Kong, *Conghui Tan, Yu-Hong Dai, Yuqiu Qian*

In stochastic gradient descent (SGD) methods, a key issue is how to select an appropriate step size. The common practice in SGD is to either use a diminishing step size, or to tune a fixed step size by hand. Diminishing step size usually leads to very slow convergence. Tuning a fixed step size by hand is usually time consuming and needs a priori knowledge about the problem. In this talk, we propose to use the Barzilai-Borwein (BB) method to compute step size for SGD and SVRG, which lead to two new methods: SGD-BB and SVRG-BB. We prove that SVRG-BB converges linearly for strongly convex objective function. As a by-product, we also prove the linear convergence of the SVRG with Option I proposed in (Johnson & Zhang, 2013), which has been missing in the literature.

The computational efforts needed by SGD-BB and SVRG-BB are almost the same as the ones needed by the original SGD and SVRG, respectively. Numerical experiments show that the performance of SGD-BB and SVRG-BB are comparable to and sometimes even better than the SGD and SVRG with best-tuned step sizes.

2. **Distributed Stochastic Variance Reduced Gradient Methods and a Lower Bound for Communication Complexity**

Qihang Lin (qihang-lin@uiowa.edu) The University of Iowa, USA, *Jason Lee, Tengyu Ma, Tianbao Yang*

We study distributed optimization algorithms for minimizing the average of convex functions. The applications include empirical risk minimization problems in statistical machine learning where the datasets are large and have to be stored on different machines. We design a distributed stochastic variance reduced gradient algorithm that, under certain conditions on the condition number, simultaneously achieves the optimal parallel runtime, amount of communication and rounds of communication among all distributed first-order methods up to constant factors. Our method and its accelerated extension also outperform existing distributed algorithms in terms of the rounds of communication as long as the condition number is not too large compared to the size of data in each machine. We also prove a lower bound for the number of rounds of communication for a broad class of distributed first-order methods including the proposed algorithms in this paper. We show that our accelerated distributed stochastic variance reduced gradient algorithm achieves this lower bound so that it uses the fewest rounds of communication among all distributed first-order algorithms.

3. **Distributional Robust Optimization for IFR Distributions**

Simai He (simaihe@mail.shufe.edu.cn) Shanghai University of Finance and Economics, China, *Bo Jiang, Chris Ryan, Teng Zhang*

One of the major critiques of the distributional free robust bounds is the discrete nature of its optimum distribution. Increasing failure rate (IFR) and log-concave are two widely accepted and used distribution classes in various research domains. Even though the corresponding math programming problem is highly non-convex, we establish its optimal solution structure via analyzing a relaxed problem. Furthermore, we develop numerical toolbox for optimally solving the distributional free moment problems with IFR and log-concave distribution assumptions.

■ Thu.A.5G

Thursday, 9:00-10:15, Room 5G

Advanced Topics of Linear Optimization

Cluster: Linear Optimization

Session chair: *Aurelio Oliveira*

1. **Weak Duality Theorems for Two Families of Complex Optimization Problems**

Toshihiro Kosaki (toshihirokosaki@gmail.com) Stera Link Co.,Ltd, Japan

We consider two families of complex problems, which are LPs, QPs and two SOCPs. The former family of formulation is based on complex inner product in both objective function and constraint functions. The latter family of formulation is based on complex inner product based on complex inner product in only objective function. We show weak duality theorems for the complex optimization problems.

2. **A Client's Health from the Point of View of the Nutrition Adviser using Operational Research**

Lucie Schaynová (lucie.schaynova@osu.cz) University of Ostrava, Czech Republic

In this talk, we analyse daily nutrient requirements of an individual person from the point of view of the nutrition adviser. The goal is to simplify the adviser's menu planning for a client as much as possible. After that, we design an individual eating plan for a week using a linear optimization model. The model respects eating habits and it follows the client's or adviser's recommended recipes taking the compatibility of foods into account. The model involves linear constraints to ensure that two incompatible foods are not used in the same course. The model comprises further constraints to guarantee the diversity of the courses. The purpose of other constraints is to use an exact amount of some food, e.g. one whole egg or 100 grams of cheese, during the week. The model is made up so that the final dietary plan for the client is as natural as possible. The model gives recommended amounts of foods for recipe weekly planning.

3. **Reducing Interior Point Method Iterations via Continued Directions**

Aurelio Oliveira (aurelio@ime.unicamp.br) University of Campinas, Brazil, *Lilian Berti, Carla Ghidini*

The continued iteration is used with the predictor corrector interior point method with multiple centrality directions in order to reduce the number of iterations to achieve an optimal solution for the linear programming problem. The continued iteration can be interpreted as the projection of the search direction, already determined by the predictor corrector method. It can be used in two different forms, before or after of a complete predictor corrector iteration. The new direction, called continued direction, is computed with very low effort compared to an iteration method. Although there is an increase of the computational effort per iteration to use the continued iteration, the expected reduction in the number of iterations, enables the reduction of the total computational time. Some proposals for the continued direction are developed with the purpose of increasing the reduction of primal and dual infeasibility in each iteration of the predictor corrector method. The multiple centrality directions are computed only after the continued directions are applied. A computational experiments comparison with large-scale problems for the predictor corrector method with and without continued iteration is performed, showing that the method achieves good performance using the proposed approach.

■ Thu.A.5H

Thursday, 9:00-10:15, Room 5H

Stochastic Complementarity Problems and Sample Average Approximation

Cluster: Stochastic Optimization

Session organized by: *Hailin Sun, Dali Zhang*

1. **Distributionally Robust Games with an Application to Environmental Problem**

Shaojian Qu (qushaojian@163.com) University of Shanghai for Science and Technology, China, *Mark Goh, Robert de Souza*

In this paper, we propose a distributionally robust optimization approach for N-player, nonzero sum finite state/action games with incomplete information where the payoff matrix is stochastic with an imprecise distribution which is assumed to be attached to an a-prior known set. A distributionally robust approach is used to cope with our setting in the games by combining the stochastic optimization approach and the robust optimization approach which can be called the distributionally robust games. We show that the existence of the equilibria for the distributionally robust games. The computation method for equilibrium point, with the first- and second information about the uncertain payoff matrix, can be reformulated as semidefinite programming problems which can be tractably realized. An environmental game with uncertainty is analyzed by applying the distributionally robust game theory.

2. **Computation of Stochastic Nash Equilibrium via Variable Sample**

Dali Zhang (dali.zhang@outlook.com) Shanghai Jiao Tong University, China, *Lizhi Wang, Ming Dong*

In this paper, we propose a variable sample distributed algorithm for the computation of stochastic Nash equilibrium in which the objective functions are replaced, at each iteration, by sample average approximations. We investigate the contraction mapping properties of the variable sample distributed algorithm and show that the accuracy of estimators yielded in the algorithms to their true counterparts are determined by both the sample size schedules and the contraction mapping parameters. We also investigate conditions on the sample size schedules under which the accumulation point generated by the algorithm asymptotically converges to the true Nash equilibrium. In the numerical tests, we comparatively analyze the accuracy and precision errors of estimators with different sample size schedules with respect to the sampling loads and the computational times. Finally, we present numerical results on the effectiveness of different cumulative sampling schemes for the algorithm.

3. **SAA-Regularized Methods for Multiproduct Price Optimization under the Pure Characteristics Demand Model**

Hailin Sun (hlsun@njust.edu.cn) Nanjing University of Science and Technology, China, *Chelin Su, Xiaojun Chen*

Utility-based choice models are often used to determine a consumer's purchase decision among a list of available products; to provide an estimate of product demands; and, when data on purchase decisions or market shares are available, to infer consumers' preferences over observed product characteristics. They also serve as a building block in modeling firms' pricing and assortment optimization problems. We consider a firm's multiproduct pricing problem, in which product demands are determined by a pure characteristics model. A sample average approximation (SAA) method is used to approximate the expected market share of products and the firm profit. We propose a SAA-regularized method for the multiproduct price optimization problem. We present convergence analysis and numerical examples to show the efficiency and the effectiveness of the proposed method.

■ Thu.A.5J

Thursday, 9:00-10:15, Room 5J

Advances in Conic Optimization

Cluster: Conic and Polynomial Optimization
Session chair: *Antonios Varvitsiotis*

1. **A Two-Phase Algorithm for Large-Scale QPLogdet Optimization Problem**

   Tang Peipei (tangpp@zucc.edu.cn) Zhejiang University City College, China, *Wang Chengjing, Wang Jiahuan*

In this paper, we present a two-phase algorithm to solve a large-scale nonlinear semidefinite programming problem whose objective function is a sum of a convex quadratic function and a log-determinant term (QPLogdet). In phase I, we adopt an inexact symmetric Gauss-Seidel (sGS) technique based alternating direction method of multipliers (ADMM)-type method to obtain a moderately accurate solution or generate a reasonably good initial point. In Phase II, we design an inexact accelerated block coordinate descent (ABCD) based augmented Lagrangian method (ALM) to obtain a highly accurate solution, where the inexact sGS techinque and the semismooth Newton-CG method are employed to solve the inner problem at each iteration. Numerical experiments demonstrate that our two-phase algorithm is efficient and robust.

2. **Robust Topology Design of Mechanical Systems under Uncertain Dynamic Loads via Nonlinear Semidefinite Programming**

   Anja Kuttich (kuttich@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

We consider the problem of robust topology optimization of mechanical systems, for example truss or beam structures whose dynamic behavior can be described by a linear time-invariant system. Of particular interest in our application is the consideration of uncertain dynamic loads. We reformulate the robust topology optimization of mechanical systems under uncertain dynamic loads as a nonlinear semidefinite programming problem by using the H^∞-norm of the transfer function and the Bounded-Real Lemma. We solve the resulting optimization problem using a sequentially semidefinite programming approach. Furthermore we extend our model with a static output feedback controller design. This approach allows to optimize the topology of the mechanical structure and the design of the feedback controller simultaneously. The considerations are complemented by numerical results for robust truss topology design.

3. **Completely Positive Semidefinite Rank**

   Antonios Varvitsiotis (avarvits@gmail.com) Nanyang Technological University, Singapore, *Anupam Prakash, Jamie Sikora, Zhaohui Wei*

An $n\times n$ matrix X is called completely positive semidefinite (cpsd) if there exist $d\times d$ Hermitian positive semidefinite matrices $\{P_i\}_{i=1}^n$ (for some $d\geq 1$) such that $X_{ij}=\mathrm{tr}(P_iP_j)$, for all $1\leq i,j\leq n$. The cpsd-rank of a cpsd matrix is the smallest $d\geq 1$ where such a representation exists. We initiate the study of the cpsd-rank which we motivate twofold. First, the cpsd-rank is a non-commutative analogue of the cp-rank of a completely positive matrix. Second, the cpsd-rank is physically motivated as it can be used to upper and lower bound the size of a quantum system needed to generate a quantum behavior. Unlike the cp-rank which is at most quadratic in the size, no general upper bound is known on the cpsd-rank of a cpsd matrix. In fact, for any $n\geq 1$, we construct a cpsd matrix of size $2n$ whose cpsd-rank is $2^{\Omega(\sqrt{n})}$. Our construction is based on Gram matrices of Lorentz cone vectors which we show are cpsd. The proof relies on a known lower bound on the size of matrix representations of extremal quantum correlations which we apply to high-rank extreme points of the n-dimensional elliptope. We also study cpsd-graphs, i.e., graphs G with the property that every doubly nonnegative matrix whose support is given by G is cpsd. We show that a graph is cpsd if and only if it has no odd cycle of length at least 5 as a subgraph.

■ Thu.A.5K

Thursday, 9:00-10:15, Room 5K

Algorithms and Applications for Conic and Related Optimization Problems

Cluster: Conic and Polynomial Optimization
Session organized by: *Yu Xia*
Session chair: *Ting Kei Pong*

1. **Finding Decompositions for Completely Positive Matrices using Orthogonal Transformations**

   Patrick Groetzner (groetzner@uni-trier.de) University of Trier, Germany, *Mirjam Dür*

Completely positive matrices play a crucial role in solving combinatorial or quadratic problems. Using this matrix cone helps to keep up the structure of the underlying problem and allows to use several additional approaches to solve the problem. One key point for this approach is to figure out whether a matrix is completely positive or not. For this it is necessary to find a feasible decomposition for a given matrix, delivering a certificate for complete positivity. Numerical methods to find a decomposition are only available for specially structured matrices. In this talk I will introduce a method to derive a factorization in the general case using certain orthogonal transformations. The approach provides very promising numerical results in nearly every case and also offers the possibility to check whether a matrix is in the interior of the completely positive cone.

2. **A Fast Approximation Method for Nonconvex Quadratic Optimizations with Few Constraints**

   Shinji Yamada (shinji_yamada@mist.i.u-tokyo.ac.jp) The University of Tokyo, Japan, *Akiko Takeda*

In this talk, we propose a new convex relaxation method for Quadratically Constrained Quadratic Programming (QCQP). SDP relaxation is one of well-known approaches for QCQP; especially in the case when there is only one constraint (we call it "1-QCQP" for simplicity), the SDP relaxation is known to be tight. Our relaxation method for QCQP is weaker than SDP relaxation, however, our method can solve 1-QCQP exactly, same as SDP relaxation. The numerical experiments show that as far as the number of constraints is much smaller than that of variables, our method finds a relaxed solution which has almost the same relaxation value with SDP relaxation, and its computational time is faster than SDP relaxation.

3. **Explicit Estimation of KL Exponent and Linear Convergence of 1st-Order Methods**

   Ting Kei Pong (tk.pong@polyu.edu.hk) The Hong Kong Polytechnic University, Hong Kong, *Guoyin Li*

In this talk, we study the Kurdyka-Lojasiewicz (KL) exponent, an important quantity for analyzing the convergence rate of first-order methods. Specifically, we show that many convex or nonconvex optimization models that arise in applications such as sparse recovery have objectives whose KL exponent is 1/2: this indicates that various first-order methods are locally linearly convergent when applied to these models. Our results cover the sparse logistic regression problem and the least squares problem with SCAD or MCP regularization. We achieve this by relating the KL inequality with an error bound concept due to Luo and Tseng (1992), and developing calculus rules for the KL exponent. This is a joint work with Guoyin Li.

■ Thu.A.5L

Thursday, 9:00-10:15, Room 5L

Polynomial Optimization: Theory and Applications I

Cluster: Conic and Polynomial Optimization
Session organized by: *Luis F Zuluaga*

1. **Penalized Semidefinite Programming Relaxation for Polynominal Optimization Problems**

   Ramtin Madani (ramtin.madani@berkeley.edu) University of California, Berkelely, USA, *Morteza Ashraphijuo, Javad Lavaei*

NP-hardness of combinatorial optimization and several other problems is due to the complexity of finding the inverse of a set of polynomial equations. In this talk, we show that the inverse of an arbitrary polynomial system is equal to the argmin of some semidefinite program (SDP) at the neighborhood of any given nominal point. We then prove that there is a finite set of SDPs, whose argmins all together establish the inverse of the polynomial system globally. Using this result, we develop a series of penalized SDPs to find near-global solutions of every arbitrary polynomial optimization problem.

2. **A Sampling Kaczmarz-Motzkin Algorithm for Linear Feasibility**

   Jamie Haddock (jhaddock@ucdavis.edu) University of California, Davis, USA, *Jesus De Loera, Deanna Needell*

We combine two algorithmic techniques for determining the feasibility of systems of linear inequalities, $Ax\leq b$, the relaxation method (RM) of Agmon, Motzkin and Schoenberg, and the randomized Kaczmarz method (RK). Each of these are iterative methods which consists of a series of alternating projections. In each iteration, these methods select a violated constraint from among the rows of A and project towards the hyperplane it defines. Our proposed family of methods, which we refer to as the Sampling Kaczmarz-Motzkin (SKM) methods, blend the deterministic constraint selection of RM and the randomized constraint selection of RK. While we prove that the method will converge linearly in expectation and recover the convergence rates of the previously defined methods, experiments suggest that the SKM method often vastly outperforms its predecessors. Furthermore, we demonstrate that the method can detect feasibility and infeasibility of the system.

3. **Positive Polynomials on Unbounded Domains**

Juan C Vera (juancavera@gmail.com) Tilburg University, Netherlands, *Javier Pena, Luis F Zuluaga*

Certificates of non-negativity such as Putinar's Positivstellensatz have been used to obtain powerful numerical techniques to solve polynomial optimization (PO) problems. These certificates generally assume compactness of the domain. In this paper we characterize the existence of a certificate of non-negativity for polynomials over a possibly unbounded domain, without the use of the associated quadratic module. We also show that this certificate can be used to construct convergent SDP hierarchies for PO problems with unbounded feasible sets.

■ Thu.B.1S

Thursday, 10:45-12:00, Room 1S

Optimization in Machine Learning II

Cluster: Nonlinear Optimization
Session organized by: *Martin Takac*

1. **Stop Wasting My Gradients: Practical SVRG**

Reza Babanezhad Harikandeh (babanezhad@gmail.com) University of British Columbia, Canada, *Mohamed Osama Ahmed, Alim Virani, Mark Schmidt, Jakub Konecny, Scott Sallinen*

I present and analyze several strategies for improving the performance of stochastic variance-reduced gradient (SVRG) methods. I first show that the convergence rate of these methods can be preserved under a decreasing sequence of errors in the control variate, and use this to derive variants of SVRG that use growing-batch strategies to reduce the number of gradient calculations required in the early iterations. I further (i) show how to exploit support vectors to reduce the number of gradient computations in the later iterations, (ii) prove that the commonly-used regularized SVRG iteration is justified and improves the convergence rate, (iii) consider alternate mini-batch selection strategies, and (iv) consider the generalization error of the method.

2. **Fast Optimization for Non-Lipschitz Poisson Regression**

Niao He (niaohe@illinois.edu) University of Illinois at Urbana-Champaign, USA, *Zaid Harchaoui, Yichen Wang, Le Song*

We propose a novel family of first-order optimization algorithms for penalized Poisson regression. The Poisson log-likelihood is concave but not Lipschitz-continuous. Most existing first-order optimization algorithms relying on Lipschitz-continuity would fail to work for Poisson regression. We present a new perspective allowing to efficiently optimize penalized Poisson regression objectives. We show that an appropriate saddle point reformulation enjoys a favorable geometry and a smooth structure. Therefore, we can design a composite Mirror Prox algorithm with $O(1/t)$ convergence rate, in contrast to the typical $O(1/\sqrt{t})$ rate for non-smooth optimization. To tackle problems with large samples, we also develop a randomized block updating scheme with same convergence rate yet more efficient iteration cost. Experimental results on several applications, including positron emission tomography, social network estimation, and temporal recommendation systems, show that the proposed algorithm and its randomized block variant outperform existing methods both on synthetic and real-world datasets.

3. **Primal-Dual Rates and Certificates**

Martin Takac (martin.taki@gmail.com) Lehigh University, USA, *Celestine Dunner, Simone Forte, Martin Jaggi*

We propose an algorithm-independent framework to equip existing optimization methods with primal-dual certificates. Such certificates and corresponding rate of convergence guarantees are important for practitioners to diagnose progress, in particular in machine learning applications. We obtain new primal-dual convergence rates e.g. for the Lasso as well as many L_1, Elastic-Net and group-lasso-regularized problems. The theory applies to any norm-regularized generalized linear model. Our approach provides efficiently computable duality gaps which are globally defined, without modifying the original problems in the region of interest.

■ Thu.B.1A

Thursday, 10:45-12:00, Room 1A

Numerical Linear Algebra and Optimization I

Cluster: Nonlinear Optimization
Session organized by: *Annick Sartenaer, Dominique Orban*

1. **Preconditioning KKT Systems in Interior Point Methods**

Jacek Gondzio (J.Gondzio@ed.ac.uk) Edinburgh University, United Kingdom, *Lukas Schork*

Preconditioning of reduced KKT systems arising in interior point algorithms for linear and quadratic programming will be discussed. A new class of methods which exploit advantages offered by the (indefinite) augmented system form will be presented. The preconditioners rely on the null space representation of linear constraints. Some known techniques used in implementations of the revised simplex method are combined with new ideas for finding stable null space representations.

2. **The DQQ Procedure for Multiscale Optimization**

Michael Saunders (saunders@stanford.edu) Stanford University, USA, *Ding Ma*

Systems biology models of metabolic networks can lead to challenging optimization problems for which standard solvers are not sufficiently accurate, while the rational arithmetic of exact simplex solvers is extremely slow. Quad-precision floating-point (even in software) offers a practical compromise. We combine Double and Quad versions of MINOS, with and without scaling, to overcome the difficulty of unscaling multiscale problems. This has enabled solution of the Meszaros "problematic" LPs and increasingly large linear and nonlinear ME models in systems biology.

3. **A Tridiagonalization Method for Saddle-Point and Quasi-definite Systems**

Dominique Orban (dominique.orban@gerad.ca) GERAD and Ecole Polytechnique, Canada, *Alfredo Buttari, David Titley-Peloquin, Daniel Ruiz*

The tridiagonalization process of Simon, Saunders and Yip (1988) applied to a rectangular operator A gives rise to USYMQR, which solves a least-squares problem with A, and USYMLQ, which solves a least-norm problem with A'. Symmetric saddle-point systems may be viewed as a pair of least-squares/least-norm problems. This allows us to merge USYMQR and USYMLQ into a single method that solves both problems in one pass. We present preconditioned and regularized variants that apply to symmetric and quasi-definite linear systems and illustrate the performance of our implementation on systems coming from optimization.

■ Thu.B.1B

Thursday, 10:45-12:00, Room 1B

Risk-averse Optimization with PDE Constraints I

Cluster: PDE-constrained Optimization
Session organized by: *Denis Ridzal, Drew Philip Kouri, Bart van Bloemen Waanders*

1. **Risk Averse PDE-constrained Optimization using Coherent Measures of Risk**

Thomas M Surowiec (surowiec@math.hu-berlin.de) Humboldt University of Berlin, Germany, *Drew P Kouri*

The incorporation of uncertainty into models in engineering and the natural sciences typically leads to partial differential equations (PDEs) with uncertain parameters. As a result, the state and objective functions are implicitly random variables. In order to control or optimize these infinite-dimensional systems in a risk-averse way, we employ so-called "coherent risk measures." The potential non-smoothness of these risk measure poses additional challenges theoretically and numerically. We discuss meaningful conditions on the random variable objective functional and derive first-order optimality conditions. In order to solve these problems numerically, we make use of an epi-regularization technique and a continuation strategy. Restricting to the Conditional-Value-at-Risk, we illustrate the results by several numerical examples.

2. **Trust-Region Algorithms for Large-Scale Stochastic Optimization with PDE Constraints**

Denis Ridzal (dridzal@sandia.gov) Sandia National Laboratories, USA, *Drew Kouri*

Trust regions provide a robust framework for model management in the optimization process. In the context of reduced-space formulations for PDE-constrained optimization, trust-region methods are used to adaptively control the accuracy of numerical discretizations. We present conditions for inexact objective function and gradient evaluations that are well suited for exploiting adaptive sparse-grid discretizations of stochastic optimization problems. Our algorithms rapidly identify the stochastic variables that are relevant to obtaining an accurate optimal solution, and, in some cases, exhibit computational costs that are nearly independent of stochastic dimension. In the context of full-space formulations, trust-region methods enable efficient stopping conditions for iterative linear system solves. We present multiply distributed scalable solvers for optimality systems arising in optimization problems governed by PDEs with random inputs. We conclude the presentation with numerical examples including risk-neutral acoustic control, risk-averse topology optimization and risk-averse control of thermal fluids.

3. **The Rapid Optimization Library: A PDE-constrained Optimization under Uncertainty Framework**

Bart van Bloemen Waanders (bartv@sandia.gov) Sandia National Laboratories, USA, *Denis Ridzal, Drew Kouri*

The Trilinos Rapid Optimization Library (ROL) provides an object-oriented framework for large-scale, derivative-based optimization. The library is matrix-free and linear-algebra agnostic permitting easy interface with application code. ROL implements a suite of unconstrained and constrained optimization algorithms including: gradient descent, quasi-Newton, and inexact-Newton with line-search and trust-region globalization. A stochastic optimization subpackage (SOL) supplies default implementations of numerous risk measures and adaptive sampling capabilities. Several examples demonstrate the solution of large optimization problems with model uncertainties.

■ Thu.B.1C

Thursday, 10:45-12:00, Room 1C

Applications of Derivative-free and Simulation-based Optimization

Cluster: Derivative-free and Simulation-based Optimization
Session organized by: *Francesco Rinaldi, Zaikun Zhang*
Session chair: *Matteo Diez*

1. **Derivative Free Optimization for Automated, Efficient Tuning of Predictive Models**

Patrick Koch (patrick.koch@sas.com) SAS Institute, Inc., USA, *Josh Griffin, Steve Gardner, Oleg Golovidov, Scott Pope*

With the continual projected exponential growth rate of digital data the challenge of managing, understanding, and capitalizing on this data also continues to grow. Facilitating effective decision making requires the transformation of relevant data to high quality descriptive and predictive models. Machine learning modeling algorithms are commonly used to find hidden value in big data. These algorithms are governed by 'hyper-parameters' with no clear defaults agreeable to a wide range of applications. Ideal settings for these hyper-parameters significantly influences the resulting accuracy of the predictive models. In this talk we discuss the use of derivative free optimization for hyper-parameter tuning. As a complex black-box to the tuning process, machine learning algorithms are well suited to derivative free optimization for tuning. We employ a Local Search Optimization (LSO) procedure, which performs parallel hybrid derivative-free optimization for problems with functions that are nonsmooth, discontinuous, or computationally expensive to evaluate directly. LSO permits both continuous and integer decision variables, and can operate in single-machine mode or distributed mode. We will present tuning results for multiple examples, compared to default model training, and discuss and demonstrate the use of distributed processing to reduce the tuning expense.

2. **A Hybrid Global/Local Multi-Objective Approach to Simulation-based Design Optimization: Deterministic Particle Swarm with Derivative-free Local Searches**

Matteo Diez (matteo.diez@cnr.it) CNR-INSEAN, Natl. Research Council-Marine Technology Research Inst., Italy, *Riccardo Pellegrini, Andrea Serani, Giampaolo Liuzzi, Stefano Lucidi, Francesco Rinaldi, Umberto Iemma, Emilio Fortunato Campana*

Simulation Based Design Optimization (SBDO) supports the designer in the design of complex engineering systems. The process integrates numerical simulations with optimization algorithms, to the aim of exploring design opportunities and addressing multiple design objectives. These may be noisy and often the simulation tools do not directly provide their derivatives. Therefore, derivative-free algorithms are used as a viable option in the SBDO process. Local or global algorithms are used, whether the search region is known a priori, or not. Local algorithms explore accurately a limited region, whereas global algorithms explore the entire space, providing approximate solutions. In order to combine the accuracy of local algorithms with the exploration capability of global methods for multi-objective problems, the multi-objective deterministic particle swarm optimization (MODPSO) is combined with a derivative-free multi-objective (DFMO) local algorithm. Two implementations of MODPSO and their hybridizations with DFMO are presented. The resulting hybrid global/local implementations are tested using 30 test problems. Their performance is assessed considering six metrics, providing the proximity of the solutions to a reference Pareto front and the continuity of the approximated Pareto front.

■ Thu.B.4A

Thursday, 10:45-12:00, Room 4A

Applications of Optimal Control

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Maria Rosario de Pinho*

1. **Multiattribute Pricing**

Thomas A Weber (thomas.weber@epfl.ch) École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

We provide a technique for constructing second-best multiattribute screening contracts in a general setting with one-dimensional types based on necessary optimality conditions. Our approach allows for type-dependent participation constraints and arbitrary risk profiles. As an example we discuss optimal insurance contracts.

2. **Optimally Control Treatment of Psoriasis Skin Disease**

Ellina V Grigorieva (egrigorieva@twu.edu) Texas Woman's University, USA, *Evgenii N Khailov*

Psoriasis is a chronic inflammation of the skin that changes the life cycle of skin cells. Psoriasis causes these cells to build up quickly on the skin surface, which makes the skin appear red, dry with scaly patch. Adequate treatment for psoriasis is very challenging, and a total cure of the disease still does not exist. Mathematical models have long been effective means to predict cellular behaviors of the skin regulation for a normal or pathological circumstance. In this paper, a proposed control model of psoriasis skin disease is described by a nonlinear control system of three differential equations involving the concentration of Dendritic Cells (Tissues Macrophages), T-Lymphocytes and Keratinocytes with medication intake as control. An optimal control problem of minimizing the release of Keratinocytes to standardize the growth of the Dendritic Cells is stated and solved using Pontryagin Maximum Principle. The type of the optimal control is obtained analytically. Numerical simulations of the optimal solutions at different model's parameters are presented. Possible applications to an optimal drug therapy are discussed.

3. **Optimal Control for Path Planning of AUV using Simplified Models**

Maria do Rosario de Pinho (mrpinho@fe.up.pt) Universidade do Porto, Portugal, *Anibal Matos*

In this talk we illustrate different numerical optimal control techniques when applied to a simplified model for path planning of an autonomous underwater vehicle (AUV). We consider the movement of an AUV in an horizontal plane. The aim is to reach a position with a determined configuration in minimum time. Ocean current are considered and bounds on the maximum velocity of the vehicle as well as bounds on the controls, the heading angle and the thruster force are considered. This turns out to be an optimal control problem. Numerical solutions using the direct method implemented via AMPL calling IPOTS are considered. We also present some preliminaries results on the numerical reconstruction of trajectories using Hamiltion Jacobi Belmmand equation.

■ Thu.B.4B

Thursday, 10:45-12:00, Room 4B

Informatics and Geometric Problems

Cluster: Applications in Energy, Science and Engineering
Session chair: *Dirk Oliver Theis*

1. **Sequential Equality Programming for Topology Optimization**

Luis Felipe Bueno (lfelipebueno@gmail.com) Federal University of Sao Paulo, Brazil, *Thadeu Senne*

In this work we analyse the applicability of the Sequential Equality Programming method to solve Topology Optimization problems. In this context, we examine how to use an Augmented Lagrangian strategy, penalizing simple constraints, to solve subproblems of some methods traditionally used in Topology Optimization. In particular, we study how to use Newtonian techniques in the penalized subproblems of the Sequential Linear Programming, the Sequential Piecewise Linear Programming, and the Moving Asymptotes methods.

2. **Location Problem of Supply Facilities in Gas Distribution Networks**

Naoshi Shiono (gian.naoshi@gmail.com) Tokyo Gas Energy Corporation, Japan, *Yasufumi Saruwatari*

This study addresses the location problem of supply facilities in gas distribution networks. In Japan, gas distribution networks consist of high, medium and low pressure pipes and pressure regulators are installed in pipes to reduce the lower pressure. When we design the distribution networks for a large number of customers that use low pressure gas, we have to decide the pipe diameters in medium and low pressure distribution networks and the location of regulators to minimize the construction cost. In this study, we present a mathematical model to decide the number of regulators, i.e. supply facilities for low pressure networks. We assume a rectangular grid road network on the plane and each customer with an identical demand is placed on an intersection of the network. After we formulate the optimization problem where supply facilities are located at regular intervals, we solve the problem approximately. As the result, we derive the relationship between the number of facilities and demand, length of grid and each construction cost. In addition, we incorporate uncertainties, such as demand, in the model and obtain some properties.

3. **Computing Unique Information**

Dirk Oliver Theis (dotheisatutdotee@gmail.com) University of Tartu, Estonia

Let X,Y,Z be random variables. Bertschinger, Rauh, Olbrich, Jost, and Ay proposed a definition "unique information": the amount of information about X contained exclusively in either Y or Z. They present convex programs by which unique information can be computed, and point out some subtle problems with the approach. In our talk, we present code and give computational results for estimating the unique information of X,Y,Z from a series of independent samples. We also discuss stability results.

■ Thu.B.5C

Thursday, 10:45-12:00, Room 5C

Variational Analysis, Optimization, and Applications

Cluster: Multi-Objective and Vector Optimization

Session organized by: *Luis Manuel Briceño-Arias*

1. **New Advances in Sensitivity Analysis of Solution Maps to Parameterized Equilibria with Conic Constraints**

Hector Ramirez (hramirez@dim.uchile.cl) Universidad de Chile, Chile

In this talk we present new calculations of the graphical derivative, limiting coderivative and others generalized derivatives for the solution map to parameterized generalized equations/KKT systems associated with conic constraints. These computations are first derived provided the feasible set appearing in the KKT system is convex. They provide verifiable conditions for sensitivity properties (such as, for instance, isolated calmness) of the corresponding solution map. We are able to extend the computation of the graphical derivative to the nonconvex case. The latter requires, however, an additional condition of geometric nature imposed on the considered cone. This is related to the sigma-term associated with projection onto this cone and has a local character. Under this condition our formula for the graphical derivative has the same form as the formula resulting in VI over polyehdral sets, and so, it can be viewed as its generalization to a class of nonpolyhedral cones.

2. **On the Linear Convergence of Forward-Backward Splitting Methods**

Nghia TA Tran (nttran@oakland.edu) Oakland University, USA

In this talk we mainly analyze the local linear convergence of the forward-backward splitting methods for solving nonsmooth convex problems by using tools of generalized differentiations and variational analysis. Local and global linear convergences of this method in some special cases such as ℓ_1, nuclear norm, TV seminorm-regularized optimization problems are also discussed.

3. **Projected Chambolle-Pock Splitting for Solving Monotone Inclusions**

Luis Manuel Briceño-Arias (luis.briceno@usm.cl) Universidad Técnica Federico Santa María, Chile

In this talk a modification of Chambolle-Pock splitting for solving primal-dual optimization problems is presented. In the case when the primal solution is known to be in some convex closed set, the proposed primal-dual method performs an additional projection step which guarantees that the primal sequence belongs in that set. This feature is desired, for instance, in optimization problems with linear constraints, in which the solution must be feasible and, hence, an algorithm whose primal iterates satisfy the constraints is useful. In this case, the flexibility of the method allows to consider different sets to perform the projection allowing, for example, to choose some of the linear constraints in order to obtain a projection easy to compute. In some cases this can help to improve the performance of the algorithm with respect to the original method. Finally, a generalization to composite primal-dual monotone inclusions is provided.

■ Thu.B.5D

Thursday, 10:45-12:00, Room 5D

Discrete and Computational Geometry

Cluster: Linear Optimization

Session organized by: *Yoshio Okamoto*

1. **Redundancy Detection for Linear Programs with Two Variables per Inequality**

May Krisztina Szedlák (may.szedlak@inf.ethz.ch) ETH Zurich, Switzerland, *Komei Fukuda*

The problem of detecting and removing redundant constraints is fundamental in optimization. We focus on the case of linear programs (LPs) in normal form, given by d variables with n inequality constraints. A constraint is called redundant, if after removing it, the LP still has the same feasible region. The currently fastest method to detect all redundancies is the one by Clarkson: it solves n linear programs, but each of them has at most s constraints, where s is the number of nonredundant constraints. In this talk, we study the special case where every constraint has at most two variables with nonzero coefficients. This family, denoted by LI(2), has some nice properties. Namely, given a variable x and a value a, we can test in time $O(nd)$ whether there is a feasible solution with $x_i = a$. Hochbaum and Naor present an $O(nd^2 \log n)$ algorithm for solving feasibility (and finding a solution) in LI(2). Their technique makes use of the Fourier-Motzkin elimination method and the aforementioned result by Aspvall and Shiloach. We present a strongly polynomial algorithm that solves redundancy detection in time $O(nd^2 s \log s)$. It uses a modification of Clarkson's algorithm, together with a revised version of Hochbaum and Naor's technique.

2. **On Classes of Oriented Matroids That Admit 2-dimensional Topological (Geometric) Representations**

Hiroyuki Miyata (hmiyata@cs.gunma-u.ac.jp) Gunma University, Japan

Oriented matroids are a common combinatorial abstraction of various geometric objects such as hyperplane arrangements, polytopes and point configurations. One of the outstanding results in oriented matroid theory is the Topological Representation Theorem, which asserts that every oriented matroid of rank r can be represented as an arrangement of pseudospheres in the $(r-1)$-dimensional sphere. In this talk, we discuss a possibility that oriented matroids can be represented as topological (geometric) objects in the 2-dimensional Euclidean space. We show that matroid polytopes of rank 4 and degree-k oriented matroids(, which were introduced by the speaker as an abstraction of configurations of points and degree-k polynomial functions) of rank k+1 have 2-dimensional topological (geometric) representations.

3. **Geometric Optimization Related with an LCP with SPD-Matrices**

Sonoko Moriyama (moriso@chs.nihon-u.ac.jp) Nihon University, Japan, *Bernd Gaertner, Hiroshi Imai, Hiroyuki Miyazawa, Jiro Nishitoba*

The linear complementarity problem (LCP) was introduced as a generalization of linear programs, quadratic programs and bimatrix games. Given a matrix $M \in \Re^{n \times n}$ and a vector $q \subset \Re^n$, the problem is to find two non-negative vectors $w, z \in \Re^n$ satisfying $w - Mz = q$ and $w^T z = 0$. When M is symmetric positive semidefinite, the associated LCP is solved in polynomial time. In this talk, we focus on the LCP with symmetric positive definite (for short SPD) matrices, and provide some geometric interpretations. Firstly, we show that any LCP with SPD-matrices corresponds to a polyhedron distance problem, which is to find a point of a given polytope with the smallest Euclidean distance to the origin. Particularly if an SPD-matrix M and q satisfy some conditions, we show that the associated LCP is interpreted as a smallest enclosing ball (for short SEB) problem, which is to compute the smallest enclosing ball of a given set of points. Note that a symmetric matrix is positive definite if and only if it is a P-matrix. In the process, we utilize a framework of unique sink orientations representing the LCP with P-matrices and the SEB problem.

■ Thu.B.5E

Thursday, 10:45-12:00, Room 5E

Advances in Robust Optimization V

Cluster: Robust Optimization
Session organized by: *Ihsan Yanıkoğlu*

1. **Robust Optimal Control using Generalized Higher Order Moment Expansions**

   Boris Houska (borish@shanghaitech.edu.cn) ShanghaiTech University, China

This talk is about an algorithm for solving worst-case robust optimal control problems with potentially nonlinear dynamics. The uncertainty is assumed to be a time-varying function which is known to be bounded point-wise in time by a given compact set. The aim is to optimize the control input in such a way that constraints on the output of the dynamic system are satisfied for all possible uncertainty scenarios. In this paper, we propose a robust optimal control algorithm, which is based on a non-trivial combination of existing uncertainty set propagation and chaos expansion based methods. Here, we introduce a new concept which considers higher order Taylor expansion with respect to the most important moments of the uncertainty functions. The remaining infinite dimensional terms are bounded in a rigorous way using ellipsoidal set-bounding methods. We illustrate the applicability and precision of our approach with a numerical example.

2. **Robust Optimization with Ambiguous Stochastic Constraints under Mean and Dispersion Information**

   Krzysztof Postek (k.postek@tilburguniversity.edu) Tilburg University, Netherlands, *Aharon Ben-Tal, Dick den Hertog, Bertrand Melenberg*

We consider ambiguous stochastic constraints under partial information consisting of means and dispersion measures of the underlying random parameters. Whereas the past literature used the variance as the dispersion measure, here we use the mean absolute deviation from the mean (MAD) which allows us to use old bounds on the expectations of convex functions. First, we use these results to treat ambiguous expected feasibility constraints. This approach requires, however, the independence of the random variables and, moreover, may lead to an exponential number of terms in the resulting robust counterparts. We then show how upper bounds can be constructed that alleviate the independence restriction and require only a linear number of terms, by exploiting models in which random variables are linearly aggregated. In a numerical study, we demonstrate the efficiency of our method in solving stochastic optimization problems under mean-MAD ambiguity

3. **Decision Rule Bounds for Stochastic Bilevel Programs**

   Ihsan Yanıkoğlu (ihsan.yanikoglu@ozyegin.edu.tr) Özyeğin University, Turkey, *Daniel Kuhn*

We study stochastic bilevel programs where the leader chooses a binary here-and-now decision and the follower responds with a continuous wait-and-see-decision. Using modern decision rule approximations, we construct lower bounds on an optimistic version and upper bounds on a pessimistic version of the leader's problem. Both bounding problems are equivalent to explicit mixed-integer linear programs that are amenable to efficient numerical solution. The method is illustrated through a facility location problem involving sellers and the customers with conflicting preferences.

■ Thu.B.5F

Thursday, 10:45-12:00, Room 5F

Sparsity and Semidefinite Programming Connections

Cluster: Sparse Optimization and Information Processing
Session organized by: *Coralia Cartis*
Session chair: *Martin Lotz*

1. **Large-Scale Graphical Lasso Problems**

   Somayeh Sojoudi (sojoudi@berkeley.edu) University of California, Berkeley, USA

Sparse inverse covariance estimation from a small number of samples is an important problem with a wide variety of applications. Graphical lasso is a popular technique for addressing this problem. This technique relies on solving a computationally-expensive semidefinite program (SDP). We derive sufficient conditions under which the solution of this large-scale SDP has a simple formula. We test these conditions on electrical circuits and functional MRI data. This talk develops new insights into regularized SDP problems.

2. **Bounds on the Rank of Solutions to Sparse Semidefinite Programs**

   Raphael Louca (rl553@cornell.edu) Cornell University, USA, *Subhonmesh Bose, Eilyan Yamen Bitar*

We consider semidefinite programs in which the problem data have a collective sparsity pattern, which can be described by a graph. For each maximal clique of a chordal extension of the graph, we define an affine subspace, which depends on both the cardinality of its intersection with neighboring maximal cliques and on the problem data characterizing the problem. A new upper bound on the minimum rank of feasible solutions to the sparse semidefinite program is derived. This bound is a function of the codimension of said affine subspaces. For certain problem families, this bound is shown to improve upon related bounds in the literature. In addition to the upper bound, we derive, for the special case of chordal graphs, a generic lower bound on the rank of optimal solutions to the semidefinite program. The lower bound is derived through a characterization of the tangent cone to a suitably defined chordal matrix cone at an arbitrary point and relies on the notion of constraint nondegeneracy of conic linear programs.

■ Thu.B.5G

Thursday, 10:45-12:00, Room 5G

Routing and Related Problems

Cluster: Applications in Energy, Science and Engineering
Session chair: *Kazuhiro Kobayashi*

1. **A Meta-heuristic for the Location Routing Problem with Time-dependent Travel Times**

   Achmad Maulidin (achmad.maulidin@hotmail.com) National Taiwan University of Science and Technology, Taiwan, *Vincent F Yu, TMA Ari Samadhi, Hadi Susanto*

We study the location routing problem with time-dependent travel times (TDLRP), which is a new variant of the location routing problem (LRP). In TDLRP, the travel time between each pair of nodes in the network may change depending on the time at which the travel occurs. The objective is to determine optimal depot locations and vehicle routes to minimize total cost consisting of fixed depot opening cost, fixed vehicle activation cost, and variable vehicle travel cost. A mixed integer linear programming model is formulated for the problem. Small TDLRP instances can be solved to optimality by commercial solver CPLEX. A new metaheuristic is developed to solve large TDLRP instances.

2. **A Capacitated Vehicle Routing Problem Approach for Solving Clustering Problem: A Case Study from Chiang Mai, Thailand**

   Chulin Likasiri (julin.likasiri@gmail.com) Chiang Mai University, Thailand

In northern Thailand, the sizes and topography structures of farmlands make it necessary that operators of small-scale waste management systems be able to reach their clients in an effective manner. This work focuses on finding clusters for these waste disposal centers. Since these facilities are small with limited capacities and their clients are scattered, sometimes without decent traffic between two points, Euclidean distances are used to estimate distances between clients. Capacitated vehicle routing problem (CVRP) is modified to solve the clustering problem by creating a dummy node with zero distance to all the other nodes. The number of required clusters is equivalent to the number of trucks available in the CVRP, where the capacities of the trucks become the capacities of the disposal facilities. The model is then solved using the modifying bender decomposition method along with branch and bound techniques. The results indicate that the number of clients essentially affects the performance of the procedure. The case study is maize production management in Chiang Mai, the region's economic capital, with 18 entrepreneurs and 73 groups of fields.

3. **MISOCP Formulation for the Optimal Fuel Routing Problem and the Route Generation Algorithm**

   Kazuhiro Kobayashi (kazuhir2@gmail.com) Tokyo University of Science, Japan, *Mirai Tanaka*

We consider a problem to find a shipping route and shipping speed which minimize the total fuel consumption between two ports. This problem can be formulated as an MINLP (mixed-integer nonlinear optimization problem). The MINLP is represented as an MISOCP (mixed-integer second-order optimization problem) in particular case. The authors propose a practical algorithm for solving this problem named the route generation algorithm. A basic idea of the proposed algorithm is to implicitly enumerate feasible shipping routes. The algorithm may return an optimal solution without enumerating all feasible shipping routes by computing lower bounds for the optimal value. Numerical results that verify the effectiveness of our algorithm are also reported.

■ Thu.B.5H

Thursday, 10:45-12:00, Room 5H

Applications of Stochastic Programming in Finance and Economics

Cluster: Stochastic Optimization

Session organized by: *Hailin Sun, Dali Zhang*

1. **Sparse Portfolio Selection via Linear Complementarity Approach**

   Qiyu Wang (qiyu.wang@connect.polyu.hk) Hong Kong Polytechnic University, China, *Hailin Sun*

In the framework of the classical Markowitz mean-variance model when multiple solutions exist, among which the sparse solutions are stable and cost-efficient, we propose a two-phase stochastic linear complementarity approach. This approach stabilizes the optimization problem, finds the sparse asset allocation that saves the transaction cost, and results in the solution set of the Markowitz problem. Our approach could be applied to short-selling-not-allowed portfolios and short-selling-allowed portfolios. We apply the sample average approximation (SAA) method to the two-phase optimization approach and give detailed convergence analysis. The approach is implemented on the empirical data-sets of Fama and French 100 (FF100), S&P 500 and the newly-launched Shanghai-Hong Kong Stock Connect scheme. With mock investment in training data, we construct portfolios, test them in the out-of-sample data and find their Sharpe ratios outperform the $1/N$ strategy, 1-norm regularized portfolios and p-norm regularized portfolios. Moreover, we show the advantage in risk management of our approach by using Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR).

2. **Convex Risk Measures: Efficient Computations via Monte Carlo**

   Zhaolin Hu (huzhaolin@gmail.com) Tongji University, China, *Dali Zhang*

With the development of financial risk management, the notion of convex risk measures has been proposed and has gained more and more attentions. Utility-based shortfall risk (SR), as a specific and important class of convex risk measures, has become popular in recent years. In this paper we focus on computational aspects of SR, which are significantly understudied but fundamental for risk assessment and management. We discuss efficient estimation of SR, sensitivity analysis for SR, as well as optimization of SR, based on Monte Carlo techniques and stochastic optimization methods. We also conduct extensive numerical study on the proposed approaches. The numerical results further demonstrate the effectiveness of these approaches.

3. **Dynamic Pricing and Return Pricing for Airline Industry**

   Bintong Chen (bchen@udel.edu) University of Delaware, USA, *Ye Tian, Jing Chen*

Dynamic pricing has been developed to increase profits of the airline industry for decades. This strategy adjusts the ticket prices based on the option value of future sales, which varies with time and units available. The return policy, which is also an important strategy in the airline industry, however, has not been considered yet in previous models. In this paper, we extend the classical continuous time dynamic pricing model by taking into consideration several return policies. These new models simultaneously decide the optimal dynamic sale prices and return prices to maximize the total profit.

■ Thu.B.5J

Thursday, 10:45-12:00, Room 5J

Advances in Nonlinear Optimization II

Cluster: Nonlinear Optimization

Session chair: *Fernando ACC Fontes*

1. **A Hybrid Algorithm for Split Hierarchical Optimization Problems with Fixed Point Constraints in Hilbert Spaces**

   Nimit Nimana (nimitn@hotmail.com) Naresuan University, Thailand, *Narin Petrot*

We emphasize a split-type problem of some integrating ideas of the split feasibility problem and the hierarchical optimization problem with fixed point constraints. Working on real Hilbert settings, we propose an iterative method for approximation a solution of the problem, and we discuss its convergence results. We also show an implication of the proposed problem to a problem of multi-agent networked system, that consists of a centralized mediator and a finite number of independent agents in each individual domains. Finally, a computational example is discussed.

2. **Modulus Methods for Box Constrained Least Squares Problems**

   Ning Zheng (nzheng@nii.ac.jp) The Graduate University for Advanced Studies, Japan, *Ken Hayami, Jun-Feng Yin*

For the solution of large sparse box constrained least squares problems (BLS), a new class of iterative methods is proposed by utilizing modulus transformation, which converts the solution of the BLS into a sequence of unconstrained least squares problems. Efficient Krylov subspace methods with suitable preconditioners are applied to solve the inner unconstrained least squares problems for each outer iteration. In addition, the method can be further enhanced by incorporating the active set strategy, which contains two stages where the first stage consists of modulus iterations to identify the active set, while the second stage solves the reduced unconstrained least squares problems only on the inactive variables, and projects the solution into the feasible region. We also analyze the convergence of the method including the choice of the parameter. Numerical experiments show the efficiency of the proposed methods in comparison to the gradient projection methods, the Newton like methods and the interior point methods.

3. **Optimal Control of Constrained Nonlinear Systems: An Adaptive Time-Grid Refinement Algorithm Guided by the Adjoint Multipliers**

   Fernando ACC Fontes (faf@fe.up.pt) Universidade do Porto, Portugal, *Luis T Paiva*

This work addresses numerical methods for optimal control problems of nonlinear systems with pathwise state-constraints. These are challenging optimization problems for which the number of time-discretization points is a major factor determining the computational time. Also, the location of these points has a major impact in the accuracy of the solutions. We propose an algorithm that, guided by information of the adjoint multipliers, iteratively selects an adequate time-grid to satisfy some predefined error estimate on the obtained trajectories. The results show a favorable comparison against the traditional equidistant-spaced time-grid methods, including the ones using discrete-time models. This way, continuous-time plant models can be used directly: the discretization procedure can be automated and there is no need to select a priori an adequate time step. Even if the optimization procedure is forced to stop in an early stage, as might be the case in real-time problems, we can still obtain a meaningful solution, although a less accurate one. Extension of the procedure to a Model Predictive Control (MPC) context is also discussed. By defining a time-dependent accuracy threshold, we can generate solutions that are more accurate in the initial parts of the receding horizon, which are the most relevant for MPC.

■ Thu.B.5L

Thursday, 10:45-12:00, Room 5L

Polynomial Optimization: Theory and Applications II

Cluster: Conic and Polynomial Optimization

Session organized by: *Luis F Zuluaga*

1. **A New Approximation Hierarchy for Polynomial Conic Optimization**

   Janez Povh (janez.povh@fis.unm.si) Faculty of information studies in Novo mesto, Slovenia, *Peter JC Dickinson*

In this talk we consider polynomial conic optimization problems, where the feasible set is defined by constraints in the form of given polynomial vectors belonging to given nonempty closed convex cones, and we assume that all the feasible solutions are nonnegative. After translation, this family of problems captures in particular compact polynomial optimization problems, compact polynomial semidefinite problems and compact polynomial second order cone optimization problems. We propose a general hierarchy of conic linear programming relaxations which is under some classical assumptions monotonic and converges to the optimal value of the original problem. The members of this hierarchy provide strong bounds for the optimum value and are in special cases from previous paragraph much easier to compute compared to classical SOS and moment approximations.

2. **New Bounds for Scheduling on Two Unrelated Selfish Machines**

Olga Kuryatnikova (o.kuryatnikova@tilburguniversity.edu) Tilburg University, Netherlands, *Juan Carlos Vera*

Consider the minimum makespan problem with n tasks on two unrelated selfish machines. Given n, we look for the best approximation ratio $R(n)$ of randomized monotone scale free algorithms as they provide for truthful scheduling. We optimize over distributions of random bits used in the algorithms and formulate two sequences of optimization programs converging to $R(n)$ from below and from above respectively. These bounds are obtained using copulas. The upper bound computation is constructive: we build a piecewise rational distribution such that performance of the corresponding algorithm matches the bound. Our method improves upon the existing bounds on $R(n)$ for small n. In particular, it shows that $|R(2)-1.505996| < 10^{-6}$, which provides the best upper bound for any truthful mechanism in the case of two tasks.

3. **Moment/Sum-of-Squares Hierarchy for Complex Polynomial Optimization**

Cedric Josz (cedric.josz@gmail.com) INRIA Paris, France

Polynomial optimization where the variables and data are complex numbers is an NP-hard problem that arises in various applications such power systems, signal processing, imaging science and control. Complex numbers are typically used to model oscillatory phenomena which are omnipresent in physical systems. Based on recent advances in algebraic geometry, we transpose Lasserre's hierarchy to complex numbers for enhanced tractability. We'll highlight the differences between the real and complex hierarchies and present numerical results on problems arising from industry with several thousand complex variables.

■ Thu.B.m3S

Thursday, 10:45-12:00, Room m3S

First-Order Methods for Convex Optimization: New Complexity/Convergence Theory

Cluster: Conic and Polynomial Optimization

Session organized by: *Robert Freund*

1. **Linear Rate Convergence of the Alternating Direction Method of Multipliers for Convex Composite Quadratic and Semi-definite Programming**

Defeng Sun (matsundf@nus.edu.sg) National University of Singapore, Singapore, *Deren Han, Liwei Zhang*

Under a mild error bound condition, we establish the global linear rate of convergence for a rather general semi-proximal ADMM with the dual steplength being restricted to be in $(0,(1+\sqrt{5})/2)$ for solving linearly constrained convex composite optimization problems. In our analysis, we assume neither the strong convexity nor the strict complementarity except the error bound condition, which holds automatically for convex composite quadratic programming. This semi-proximal ADMM, which covers the classic one, has the advantage to resolve the potentially non-solvability issue of the subproblems in the classic ADMM and possesses the abilities of handling the multi-block cases efficiently. We shall use convex composite quadratic programming and quadratic semi-definite programming to demonstrate the significance of the obtained results. Of its own novelty in second-order variational analysis, a complete characterization is provided on the isolated calmness for the convex semi-definite optimization problem in terms of its second order sufficient optimality condition and the strict Robinson constraint qualification for the purpose of proving the linear rate convergence of the semi-proximal ADMM when applied to two- and multi-block convex quadratic semi-definite programming. [This is a joint work with Deren Han and Liwei Zhang].

2. **On the Global Linear Convergence of Frank-Wolfe Optimization Variants**

Simon Lacoste-Julien (simon.lacoste-julien@inria.fr) INRIA / ENS, France, *Martin Jaggi*

The Frank-Wolfe (FW) optimization algorithm has lately re-gained popularity thanks in particular to its ability to nicely handle the structured constraints appearing in machine learning applications. However, its convergence rate is known to be slow (sublinear) when the solution lies at the boundary. In this talk, I will present some less well-known variants of the FW algorithm for which we proved their global linear convergence rate recently for the first time, highlighting at the same time an interesting geometric notion of "condition number" for the constraint set appearing in the constant.

3. **New Computational Guarantees for Solving Convex Optimization Problems with First Order Methods, via a Function Growth Condition Measure**

Robert M Freund (rfreund@mit.edu) Massachusetts Institute of Technology, USA, *Haihao Lu*

Motivated by recent work of Renegar, we present new computational methods and associated computational guarantees for solving convex optimization problems using first-order methods. Our problem of interest is the general convex optimization problem $f^* = \min f(x)$ subject to $x \in Q$, where we presume knowledge of a strict lower bound $SLB < f^*$. [Indeed, SLB is naturally known when optimizing many loss functions in statistics and machine learning (least-squares, logistic loss, exponential loss, total variation loss, etc.) as well as in Renegar's transformed version of the standard conic optimization problem; in all these cases one has $SLB = 0 < f^*$.] We present new computational guarantees for the Subgradient Descent Method, for smoothing methods, and for an accelerated gradient method, that can improve existing computational guarantees in several ways, most notably when the initial iterate x^0 is far from the optimal solution set. Furthermore, our accelerated gradient method performs parametric increased smoothing and periodic re-starting, even when $f(\cdot)$ is not strongly convex.

■ Thu.B.m3AB

Thursday, 10:45-12:00, Room m3AB

Advances in Large-Scale Nonsmooth Optimization

Cluster: Convex and Nonsmooth Optimization

Session organized by: *Stephen Becker*

1. **GAP Safe Screening Rule for Sparsity Enforcing Penalties**

Joseph Salmon (joseph.salmon@telecom-paristech.fr) Télécom ParisTech, France, *Eugene Ndiaye, Olivier Fercoq, Alexandre Gramfort*

High dimensional regression benefits from sparsity promoting regularizations. Screening rules leverage the known sparsity of the solution by ignoring some variables in the optimization, hence speeding up solvers. When the procedure is proven not to discard features wrongly the rules are said to be "Safe". I will derive new safe rules for generalized linear models regularized with sparsity enforcing norms. GAP Safe rules can cope with any iterative solver and we illustrate their performance on coordinate descent for various applications (eg. multi-task Lasso, binary and multinomial logistic regression) demonstrating significant speed ups.

2. **Nuclear Norms for Collaborative Filtering**

Jessica Gronski (jessica.gronski@colorado.edu) University of Colorado Boulder, USA, *Aleksandr Aravkin, Stephen Becker, Derek Driggs*

Recommender systems are commonly used to predict a user's preference or rating based off their past behaviors. One approach to designing recommender systems is collaborative filtering in which large yet sparse datasets are collected and analyzed for user information. For collaborative filtering, it is standard to consider a penalized regression model imposing a penalty on the trace or max-norm. The trace norm is often referred to as the Schatten-1 or "the" nuclear norm and is used to promote sparsity in the target solution, preserving the structure of the original problem. The aim of our work is to consider nuclear norms in the more general setting described by G.J.O. Jameson and test the utility of their novel formulations against existing optimization algorithms. We will use collaborative filtering for the Netflix prize dataset to compare our formulations.

3. **Stochastic Numerical Methods for Monotone Inclusions in Hilbert Spaces**

Bang Cong Vu (bang.vu@epfl.ch) École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

In this talk, we present some stochastic numerical methods for solving monotone inclusions in real Hilbert spaces. We derive the stochastic approximation of the forward-backward, forwardbackward-forward and forward-Douglas Rachford splitting. The weak almost sure convergence are proved under suitable conditions. Applications to large-scale convex optimizations are demonstrated.

■ Thu.C.1S

Thursday, 13:30-14:45, Room 1S

Recent Advances in Coordinate Descent Algorithms

Cluster: Nonlinear Optimization

Session organized by: *Martin Takac*

1. **Is Greedy Coordinate Descent a Terrible Algorithm?**

Julie Nutini (jnutini@cs.ubc.ca) University of British Columbia, Canada, *Mark Schmidt, Issam H Laradji, Michael Friedlander, Hoyt*

Koepke

There has been significant recent work on the theory and application of randomized coordinate descent algorithms, beginning with the work of Nesterov, who showed that a random-coordinate selection rule achieves the same convergence rate as the Gauss-Southwell selection rule. This result suggests that we should never use the Gauss-Southwell rule, as it is typically much more expensive than random selection. However, the empirical behaviours of these algorithms contradict this theoretical result: in applications where the computational costs of the selection rules are comparable, the Gauss-Southwell selection rule tends to perform substantially better than random coordinate selection. We give a simple analysis of the Gauss-Southwell rule showing that—except in extreme cases—it's convergence rate is faster than choosing random coordinates. Further, we (i) show that exact coordinate optimization improves the convergence rate for certain sparse problems, (ii) propose a Gauss-Southwell-Lipschitz rule that gives an even faster convergence rate given knowledge of the Lipschitz constants of the partial derivatives, and (iii) analyze proximal-gradient variants of the Gauss-Southwell rule.

2. **Flexible Coordinate Descent**

   Rachael Tappenden (rachael.tappenden@canterbury.ac.nz) University of Canterbury, New Zealand, *Kimonas Fountoulakis*

I will present a novel randomized block coordinate descent method for the minimization of a convex composite objective function. The method uses (approximate) partial second-order (curvature) information, so that the algorithm performance is more robust when applied to highly nonseparable or ill conditioned problems. We call the method Flexible Coordinate Descent (FCD). At each iteration of FCD, a block of coordinates is sampled randomly, a quadratic model is formed about that block and the model is minimized approximately/inexactly to determine the search direction. An inexpensive line search is then employed to ensure a monotonic decrease in the objective function and acceptance of large step sizes. I present preliminary numerical results to demonstrate the practical performance of the method.

3. **Coordinate Descent with Arbitrary Sampling: Algorithms and Complexity**

   Zheng Qu (zhengqu@maths.hku.hk) The University of Hong Kong, China, *Peter Richtarik*

In this talk we present a randomized coordinate descent method for solving the problem of minimizing the sum of a smooth convex function and a convex block-separable regularizer. Our method at every iteration updates a random subset of coordinates, following an arbitrary distribution. In special cases, it reduces to deterministic and randomized methods such as gradient descent, coordinate descent, parallel coordinate descent and distributed coordinate descent both in non-accelerated and accelerated variants. The variants with arbitrary (or importance) sampling are new. We provide a unified complexity analysis, from which we deduce as direct corollary complexity bounds for its many variants, all matching or improving best known bounds.

■ Thu.C.1A

Thursday, 13:30-14:45, Room 1A

Numerical Linear Algebra and Optimization II

Cluster: Nonlinear Optimization

Session organized by: *Annick Sartenaer, Dominique Orban*

1. **On Solving an Unconstrained Quadratic Program by the Method of Conjugate Gradients and Quasi-Newton Methods**

   Anders Forsgren (andersf@kth.se) KTH Royal Institute of Technology, Sweden, *Tove Odland*

Solving an unconstrained quadratic program means solving a linear equation where the matrix is symmetric and positive definite. This is a fundamental subproblem in nonlinear optimization. We discuss the behavior of the method of conjugate gradients and quasi-Newton methods on a quadratic problem. We show that by interpreting the method of conjugate gradients as a particular exact linesearch quasi-Newton method, necessary and sufficient conditions can be given for an exact linesearch quasi-Newton method to generate a search direction which is parallel to that of the method of conjugate gradients. The analysis gives a condition on the quasi-Newton matrix at a particular iterate, the projection is inherited from the method of conjugate gradients. We also analyze update matrices and show that there is a family of symmetric rank-one update matrices that preserve positive definiteness of the quasi-Newton matrix. This is in contrast to the classical symmetric-rank-one update where there is no freedom in choosing the matrix, and positive definiteness cannot be preserved.

2. **BFGS-like Updates of Constraint Preconditioners for Sequences of KKT Linear Systems**

   Daniela di Serafino (daniela.diserafino@unina2.it) Second University of Naples, Italy, *Luca Bergamaschi, Valentina De Simone, Ángeles Martínez*

We focus on the iterative solution of sequences of KKT linear systems such as those arising in interior point methods for large-scale quadratic programming. In this case, the use of effective preconditioners is a key issue to achieve efficiency in the optimization procedure. Constraint Preconditioners (CPs) are a successful choice as long as the computational cost of their setup is not too high. When this is not the case, a strategy for updating CPs can be a reasonable alternative to computing CPs from scratch, since it offers a tradeoff between cost and convergence, which can result into enhanced performance of the overall optimization method. In this work we present a technique which computes a preconditioner for any KKT system of a given sequence by performing a BFGS-like update of a CP available for a previous system. A theoretical analysis as well as numerical experiments support the proposed strategy.

3. **Refining the Bounds from Rusten-Winther with Insights on the Interaction between the Blocks (Hessian vs Constraints) in KKT Systems**

   Daniel Ruiz (daniel.ruiz@enseeiht.fr) Université Fédérale de Toulouse - INPT, France, *Annick Sartenaer, Charlotte Tannier*

The need to efficiently solve linear systems such as KKT ones, arising from the first order necessary optimality conditions, is crucial in many algorithms for solving constrained nonlinear continuous optimization problems. Such systems can be very ill-conditioned, in particular when the (1,1) block A has few very small eigenvalues (see Rusten and Winther, 1992). However, it is commonly observed that despite this possible ill-conditioning, some sort of interaction between A and the constraints (1,2) block actually occurs, that can either spoil the convergence of Krylov subspace methods like MINRES, or not at all. In this talk, we highlight some aspects of this interaction and give deeper insights on how and in which circumstances the bad conditioning contained in these few very small eigenvalues of the (1,1) block A effectively spoils the convergence of MINRES. Our study is based on theoretical arguments and supported by numerical illustrations.

■ Thu.C.1B

Thursday, 13:30-14:45, Room 1B

Risk-averse Optimization with PDE Constraints II

Cluster: PDE-constrained Optimization

Session organized by: *Denis Ridzal, Drew Philip Kouri, Bart van Bloemen Waanders*

1. **A Data-driven Approach to PDE-constrained Optimization under Uncertainty**

   Drew Philip Kouri (dpkouri@sandia.gov) Sandia National Laboratories, USA

Many science and engineering applications require the control or design of a physical system governed by partial differential equations (PDEs). More often then not, PDE inputs such as coefficients, boundary conditions, or initial conditions are unknown and estimated from experimental data. In this talk, I will discuss some theoretical challenges associated with such PDE-constrained optimization problems, including their mathematical formulation and their efficient numerical solution. First, I will assume that we know the probability distributions that characterize the uncertain PDE inputs. For this case, I will introduce the notion of a risk measure as a means to quantify the "hazard" associated with large objective function values. Next, to handle the situation of an unknown probability distribution, I will introduce and analyze a distributionally-robust formulation for the optimization problem. To enable numerical solutions, I will present a novel discretization for the unknown probability measure and provide rigorous error bounds for this approximation. I will conclude with numerical results confirming the aforementioned error bounds.

2. **Optimizing the Kelvin Force in a Moving Target Subdomain**

   Harbir Antil (hantil@gmu.edu) George Mason University, USA, *Ricardo H Nochetto, Pablo Venegas*

In order to generate a desired Kelvin (magnetic) force in a target subdomain moving along a prescribed trajectory, we propose a minimization problem with a tracking type cost functional. We use the so-called dipole approximation to realize the magnetic field, where the location and the direction of the magnetic sources are assumed to be fixed. The magnetic field intensity acts as the control and exhibits limiting pointwise constraints. We address two specific problems:

the first one corresponds to a fixed final time whereas the second one deals with an unknown force to minimize the final time. We prove existence of solutions and deduce local uniqueness provided that a second order sufficient condition is valid. We use the classical backward Euler scheme for time discretization. For both problems we prove the H^1-weak convergence of this semi-discrete numerical scheme. This result is motivated by Γ-convergence and does not require second order sufficient condition. If the latter holds then we prove H^1-strong local convergence. We report computational results to assess the performance of the numerical methods. As an application, we study the control of magnetic nanoparticles as those used in magnetic drug delivery, where the optimized Kelvin force is used to transport the drug to a desired location.

3. **Nonlinear Robust Optimization using Second-Order Approximations and an Application to the Shape Optimization of Hyperelastic Load-carrying Structures**

   Philip Kolvenbach (kolvenbach@mathematik.tu-darmstadt.de) TU Darmstadt, Germany, *Stefan Ulbrich*

We consider the robust counterpart of a shape optimization problem with a nonlinear objective function and a nonlinear state equation, both of which depend on uncertain parameters from an elliptic uncertainty set. For a given shape, we approximate the worst-case function by the maximum of the second-order Taylor expansion of the reduced objective function, which depends solely on the uncertain parameters. This maximum can be computed efficiently with trust-region methods. To bypass differentiability issues – the approximated worst-case function is not always differentiable with respect to the shape parameters – we reformulate the approximated robust counterpart as an MPEC. Since the resulting objective function and constraints are differentiable functions, standard gradient-based optimization methods can then be used to find a robust optimal shape. We discuss how the required derivative terms can be computed efficiently. In the second part of the talk, we apply the presented method to the shape optimization of a load-carrying structure that is governed by a nonlinear hyperelastic constitutive model and is subject to an uncertain load. We briefly consider the finite-element discretization and present numerical results.

■ Thu.C.1C

Thursday, 13:30-14:45, Room 1C

Nonlinear Optimization: Algorithms and Implementations

Cluster: Nonlinear Optimization
Session chair: *Paulo JS Silva*

1. **Implementation of NLP Solver with Multiple Precision Arithmetic and Numerical Behavior Analysis of SQP Method for Ill-posed NLPs**

   Hiroshige Dan (dan@kansai-u.ac.jp) Kansai University, Japan, *Yuya Matsumoto*

For achieving superlinear or quadratic convergence for nonlinear programming problems (NLPs) theoretically, algorithms for NLPs usually require some assumptions, such as appropriate constraint qualifications, strict complementarity conditions, local strictness of a solution, and so on. However, when we solve NLPs which do not satisfy such assumptions, algorithms for NLPs often show sufficiently fast convergence experimentally. To analyze such situations, we first implement an NLP solver based on the SQP method by using multiple precision arithmetic for the floating-point computation. Multiple precision arithmetic enables us to perform arbitrary precision arithmetic supported by software. In this presentation, we would like to introduce the detail of the implementation of our NLP solver, including automatic differentiation technique. Moreover, we can observe the detail of numerical behavior of the SQP method for NLPs by using this solver. In this research, we solve various NLPs which do not satisfy assumptions for fast convergence necessarily, and analyze numerical behavior of the SQP method. Especially, we would like to clarify the difference of numerical behavior between double precision arithmetic and multiple precision arithmetic.

2. **A Memoryless Sized Symmetric Rank-One Method with Sufficient Descent Property for Unconstrained Optimization**

   Shummin Nakayama (1416702@ed.tus.ac.jp) Tokyo University of Science, Japan, *Yasushi Narushima, Hiroshi Yabe*

Quasi-Newton methods are widely used for solving unconstrained optimization problems. However, it is difficult to apply quasi-Newton methods directly to large-scale unconstrained optimization problems, because they need the storage of memories for matrices. In this talk, we consider a memoryless quasi-Newton method with the sized symmetric rank-one formula that does not need any storage of memories for matrices. We call the method the memoryless sized symmetric rank-one method. The existing method generates a sufficient descent direction for uniformly convex objective functions, but the method may not always generate the sufficient descent direction for general objective functions. We propose a new memoryless sized symmetric rank-one method which always generates the sufficient descent direction under the Wolfe conditions (or the strong Wolfe conditions), and present new sizing factors of the method. Furthermore, we prove the global convergence properties of the proposed method for uniformly convex and general objective functions, respectively. Finally, some numerical results are shown to investigate the effectiveness of sizing factors of the memoryless sized symmetric rank-one method.

3. **Strict Constraint Qualifications and Sequential Optimality Conditions for Constrained Optimization**

   Paulo JS Silva (pjssilva@ime.unicamp.br) University of Campinas, Brazil, *Roberto Andreani, Alberto Ramos Flor, Jose Mario Martinez*

Sequential optimality conditions for constrained optimization are necessarily satisfied by local minimizers, independently of the fulfillment of constraint qualifications. These conditions support different stopping criteria for practical optimization algorithms. On the other hand, when an appropriate strict constraint qualification together with the associated sequential optimality condition holds at a point, it is possible to show that it satisfies the Karush-Kuhn-Tucker conditions. As a consequence, for each sequential optimality condition, it is natural to ask for its weakest strict constraint qualification. In this talk we will present such contraints qualifications starting with the one associated with the Approximate Karush-Kuhn-Tucker sequential optimality condition. Aftwards we will also briefly characterize the weakest strict constraint qualifications associated with other sequential optimality conditions that are useful for defining stopping criteria of algorithms. In addition, we will present all the implications between the new strict constraint qualifications and other constraint qualifications.

■ Thu.C.4A

Thursday, 13:30-14:45, Room 4A

Engineering Applications for Large Scale Nonlinear Optimization

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Christof Büskens, Mitja Echim*

1. **Large-Scale Trajectory Optimization for Autonomous Deep Space Missions**

   Mitja Echim (mitja@math.uni-bremen.de) University of Bremen, Germany, *Anne Schattel, Christof Büskens*

Trajectory planning for deep space missions has become a recent topic of great interest. The mathematical field of optimization and optimal control can be used to realize autonomous missions while protecting recourses and making them safer. The project KaNaRiA ('Kognitionsbasierte, autonome Navigation am Beispiel des Ressourcenabbaus im All') investigates the possibilities of cognitive autonomous navigation on the example of an asteroid mining mission. This paper focuses on the specific challenge of the guidance during the cruise phase of the spacecraft, i.e. trajectory optimization and optimal control, including numerical solutions and results. The movement of the spacecraft due to gravitational influences of the Sun and other planets as well as the thrust commands is described through ordinary differential equations (ODEs). Competitive mission aims like short flight times and low energy consumption are considered by using a multi-criteria objective function. A Comparison of two different approaches for solving the optimal control problem will be presented. The so called full discretization approach leads to large-scale nonlinear optimization problems where sparsity information has to be considered for efficiency. On the other hand, when using the multiple-shooting approach the problem has a lower dimension but a higher degree of nonlinearity.

2. **Optimization of Large Scale Characteristics for the Automotive Industry**

   Matthias Knauer (knauer@math.uni-bremen.de) Universität Bremen, Germany, *Christof Büskens*

The automotive industry is highly competitive and ruled by governmental and economical laws. For the application of a component in a modern car, e.g. engines or brakes, precise mathematical models are needed for the controllers to work satisfactorily. Based on physical and technical laws engineers develop parameter dependent models. In the simplest case these parameters can consist of single values. In reality, parameters depend on the system's states, and can be represented by characteristic maps in several dimensions. Using measurement data, these characteristics can be identified solving large scale optimization problems. The industry is asking for the best data fit while maintaining desired smoothness properties and fulfilling user defined constraints for the characteristics. To solve these problems in acceptable time using gradient based methods, the sparsity of the problem has to be utilized. In this talk we present techniques and results for solving these large scale problems using the NLP solver WORHP. Additionally, as models might be time dependent, methods closely related to methods of optimal control can be used to perform parameter identification of dynamical processes. For this the transcription method TransWORHP will be used.

3. **Mixed-Integer Optimal Control Problems with Indicator Constraints in Automotive Applications**

Clemens Zeile (clemens.zeile@ovgu.de) University of Magdeburg, Germany, *Sebastian Sager*

Autonomous driving has become one of the most heavily researched areas in the automotive industry. In addition to driver comfort, it offers the opportunity for drastic emission reduction due to optimized individual driving and to optimized traffic systems, such as systems of traffic lights. We give illustrating examples and motivate how both approaches result in optimal control problems with indicator constraints, i.e., constraints that only need to be considered for certain choices of the integer valued control. In the second part we survey direct methods for mixed-integer optimal control and discuss our contributed extensions to treat indicator constraints.

■ Thu.C.4B

Thursday, 13:30-14:45, Room 4B

Newton-Krylov Methods in Real-Time Optimization for Nonlinear Model Predictive Control

Cluster: Applications in Energy, Science and Engineering
Session organized by: *Toshiyuki Ohtsuka*

1. **Recent Advances in Newton-Krylov Methods for NMPC**

Andrew Knyazev (Andrew.Knyazev@merl.com) Mitsubishi Electric Research Laboratories, USA, *Alexander Malyshev*

We present Newton-Krylov (AKA continuation) methods for NMPC, pioneered by Prof. Ohtsuka. Our main results is efficient preconditioning, leading to dramatically improved real-time Newton-Krylov MPC optimization. One idea is solving a forward recursion for the state and a backward recursion for the costate approximately, or reusing previously computed solutions, for the purpose of preconditioning. Another ingredient is sparse factorizations of high-quality preconditioners. Altogether, our fast and efficient preconditioning leads to optimal linear complexity in the number of gridpoints on the prediction horizon, for iterative solution of forward-difference Newton-Krylov NMPC. We suggest scenario/particle Newton-Krylov MPC in the case, where system dynamics or constraints discretely change on-line, for ensembles of predictions to various scenarios of anticipated changes, and test it for minimum time problems. On-line computation of ensembles of controls, for several scenarios of changing in real time system dynamics/constraints, allows choosing and adapting the optimal destination. The Newton-Krylov MPC approach is extended to the case, where the state is implicitly constrained to a manifold, and demonstrate its effectiveness for a hemisphere. References: arXiv:1512.00375 DOI:10.1016/j.ifacol.2015.11.282 DOI:10.1016/j.ifacol.2015.11.102 DOI:10.1016/j.ifacol.2015.11.071

2. **Manycore Execution of Model Predictive Control**

Koji Inoue (inoue@ait.kyushu-u.ac.jp) Kyushu University, Japan, *Satoshi Kawakami, Takatsugu Ono*

This talk focuses on a novel manycore execution strategy for real-time model predictive controls. The key idea is to exploit predicted input values, which are produced by the model predictive control itself, to speculatively solve optimal control problems. It is well known that control applications are not suitable for manycore processors, because feedback-loop systems inherently stand on sequential operations. Since the proposed scheme does not rely on conventional thread-/data-level parallelism, it can be easily applied to such control systems. An analytical evaluation using a real application demonstrates the potential of performance improvement achieved by the proposed speculative executions.

3. **Velocity Form Nonlinear Model Predictive Control of a Diesel Engine Air Path**

Mike Huang (mike.huang@toyota.com) University of Michigan/TOYOTA, USA, *Ilya Kolmanovsky, Ken Butts*

The Diesel Air Path (DAP) system has been traditionally challenging to control due to its highly coupled nonlinear behavior and the need for constraints to be considered for drivability and emissions. Nonlinear Model Predictive Control (NMPC) has been viewed as a way to handle these challenges. However, current NMPC strategies for DAP control are still limited due to the very limited computational resources in engine control units. In this presentation, the development of a NMPC strategy for the DAP is given where the objective is to track intake manifold pressure and Exhaust Gas Recirculation (EGR) rate targets through coordinated control of the variable geometry turbine, EGR valve, and throttle. In the past, MPC controller performance has commonly been sacrificed to satisfy a stringent computational budget, e.g., short prediction horizons are commonly used in DAP MPC applications. To achieve both low complexity and high performance, a novel NMPC formulation, velocity form NMPC, and associated modelling structure is developed. Additionally, the synergies of this strategy to NMPC solver techniques utilizing inexact solutions and distributed-over-time computations will be explored. Experiment results will be given that demonstrate the effectiveness of the resulting NMPC at achieving the control objectives.

■ Thu.C.5C

Thursday, 13:30-14:45, Room 5C

Vector Equilibrium Problems and Vector Optimization

Cluster: Multi-Objective and Vector Optimization
Session organized by: *Dinh The Luc*

1. **Vector Quasi-Equilibrium Problems for the Sum of Two Multivalued Mappings**

Gábor Kassay (kassay@math.ubbcluj.ro) Babes-Bolyai University Cluj, Romania, *Mihaela Miholca, Nguyen The Vinh*

We study vector quasi-equilibrium problems for the sum of two multivalued bifunctions. The assumptions are required separately on each of these bifunctions. Sufficient conditions for the existence of solutions of such problems are shown in the setting of topological vector spaces. The results unify, improve and extend some well-known existence theorems from the literature.

2. **A New Type of Directional Regularity for Multifunctions with Applications to Optimization**

Radu Strugariu (rstrugariu@tuiasi.ro) Gheorghe Asachi Technical University of Iasi, Romania

The concepts of linear openness, metric regularity and Aubin property of mappings were intensively studied in the last three decades, due to their importance as qualification conditions in mathematical programming with single and set-valued objectives. In this talk, we discuss a new type of directional regularity for mappings, constructed by the use of a minimal time function, given with respect to a set of directions. We present several properties, concerning continuity, convexity, Lipschitz behavior and subdifferential calculus of this function. Next, we introduce the directional triplet of regularities for multifunctions which naturally appears, as shown by several examples. We investigate necessary and sufficient conditions for the new directional regularity properties, formulated in terms of generalized differentiation objects of Fréchet type. Finally, applications to necessary and sufficient optimality conditions for Pareto minima of sets and multifunctions are provided, making use by the regularity concepts analyzed before. In all the results we present, the directional character of both hypotheses and conclusions is emphasized.

3. **On Equilibrium in Multi-Criteria Transportation Networks**

Dinh The Luc (dtluc@univ-avignon.fr) Avignon University, France, *Truong TT Phuong*

We develop a new method to generate the set of equilibrium flows of a multi-criteria transportation network. To this end we introduce two optimization problems by using a vector version of the Heaviside Step function and the distance function to Pareto minimal elements and show that the optimal solutions of these problems are exactly the equilibria of the network. We study the objective functions by establishing their generic differentiability and local calmness at equilibrium solutions. Then we present an algorithm to generate a discrete representation of equilibrium solutions by using a modified Frank-Wolfe reduced gradient method and prove its convergence. We give some numerical examples to illustrate our algorithm and show its advantage over a popular method by using linear scalarization.

■ Thu.C.5D

Thursday, 13:30-14:45, Room 5D

Linear Optimization in the Context of Solving NP-hard Problems

Cluster: Linear Optimization
Session organized by: *Sergei Chubanov*

1. **Extended Formulations for Vertex Cover**

Austin Buchanan (buchanan@okstate.edu) Oklahoma State University, USA

The vertex cover polytopes of graphs do not admit polynomial-size extended formulations. This motivates the search for polyhedral analogues to approximation algorithms and fixed-parameter tractable (FPT) algorithms. In this presentation, we take the FPT approach and study the k-vertex cover polytope (the convex hull of vertex covers of size k). Our main result is that there are extended formulations of size $O(1.47^k+kn)$. We also provide FPT extended formulations for solutions of size k to instances of d-hitting set.

2. **New Search Direction-based Interior-Point Algorithm for $P_*(K)$ Horizontal Linear Complementarity Problems over Cartesian Product of Symmetric Cones**

Petra Renáta Takács (t_petra92@yahoo.com) Babeş-Bolyai University, Romania, *Zsolt Darvay*

We introduce a new interior-point method, which is suitable for solving $P_*(\kappa)$ horizontal linear complementarity problems over Cartesian product of symmetric cones. We achieve this by using Euclidean Jordan algebras. The novelty of this method consists of the fact that it is based on a new search direction. In order to obtain this we use the method of algebraically equivalent transformation on the nonlinear equation of the system which defines the central path. This search direction can also be derived by considering a special class of barriers that can not be determined by usual kernel functions. The particularity of these kernel functions is that they are defined only for values that are greater than a strictly positive constant. Despite this we prove the polynomiality of the introduced algorithm.

3. **A Polynomial Projection Algorithm and Its Applications in Integer Linear Programming and Combinatorial Optimization**

Sergei Chubanov (sergei.chubanov@uni-siegen.de) University of Siegen, Germany

In this talk, I will present a polynomial algorithm for linear programming based on a parallel application of the alternating projections. This projection algorithm can also solve a class of combinatorial problems, including the non-bipartite maximum matchings, in polynomial time. Another application is approximate solution of integer linear problems in time which is polynomial in the size of the problem and in the reciprocal of a bound on the maximum violation of constraints of the extended formulation.

■ Thu.C.5E

Thursday, 13:30-14:45, Room 5E

Advances in Robust Optimization VI

Cluster: Robust Optimization

Session organized by: *Huan Xu*

1. **Simulation-based Algorithms for Robust Markov Decision Processes**

William Benjamin Haskell (wbhaskell@gmail.com) National University of Singapore, Singapore, *Huan Xu, Pengqian Yu*

Robust Markov decision processes (MDPs) are an important problem class that address uncertainty in sequential decision-making problems. However, this problem class inherits the computational challenges of classical MDPs - especially when the state and action spaces are large. In this talk, we describe some methods for the solution of large-scale robust MDPs by using simulation-based algorithms. In particular, we exploit the connection between robust and risk-aware optimization to identify equivalent risk-aware MDPs for which simulation is possible. Using the equivalent risk-aware MDPs, we show how to construct a near-optimal policy for the original robust MDP.

2. **Learning the Uncertainty in Robust Markov Decision Processes**

Huan Xu (isexuh@nus.edu.sg) National University of Singapore, Singapore, *Shiau-Hong Lim, Shie Mannor*

Abstract: An important challenge in Markov decision processes is to ensure robustness with respect to unexpected or adversarial system behavior, i.e., the parameter uncertainty. A standard paradigm to tackle this problem is the robust MDP framework, which models the parameters as arbitrary element of pre-defined "uncertainty sets", and seeks the minimax policy - the policy that performs the best under the worst realization of the parameters in the uncertainty set. A crucial problem of robust MDP, largely unaddressed in literature, is how to find appropriate description of the uncertainty in a principled data-driven way. In this talk we address this problem using an online learning approach: we devise an algorithm that, without knowing the true uncertainty model, is able to adapt its level of protection to uncertainty, and in the long run performs as good as the minimax policy as if the true uncertainty model is known. Indeed, the algorithm achieves similar regret bounds as standard MDP where no parameter is adversarial, which shows that with virtually no extra cost we can adapt robust learning to handle uncertainty in MDPs. To the best of our knowledge, this is the first attempt to learn uncertainty in robust MDPs.

■ Thu.C.5H

Thursday, 13:30-14:45, Room 5H

Stochastic Optimization: Theory and Applications

Cluster: Stochastic Optimization

Session chair: *Alexei A Gaivoronski*

1. **Subdifferentials of Nonconvex Integral Functionals in Banach Spaces with Applications to Stochastic Dynamic Programming**

Nobusumi Sagara (nsagara@hosei.ac.jp) Hosei University, Japan, *Boris S Mordukhovich*

The paper concerns the investigation of nonconvex and nondifferentiable integral functionals on general Banach spaces, which may not be reflexive and/or separable. Considering two major subdifferentials of variational analysis, we derive nonsmooth versions of the Leibniz rule on subdifferentiation under the integral sign, where the integral of the subdifferential set-valued mappings generated by Lipschitzian integrands is understood in the Gelfand sense. Besides examining integration over complete measure spaces and also over those with nonatomic measures, our special attention is drawn to a stronger version of measure nonatomicity, known as saturation, to invoke the recent results of the Lyapunov convexity theorem type for the Gelfand integral of the subdifferential mappings. The main results are applied to the subdifferential study of the optimal value functions and deriving the corresponding necessary optimality conditions in nonconvex problems of stochastic dynamic programming with discrete time on the infinite horizon.

2. **Achieving Consistency in Intertemporal Decisions via Stochastic and Robust Approaches**

Jorge R Vera (jvera@ing.puc.cl) Pontificia Universidad Catolica de Chile, Chile, *Alfonso Lobos, Ana Batista*

In many applications, decisions are made in different stages or horizons. For instance, aggregate production planning decisions are done in tactical horizons and then the detail is managed in 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 different levels of aggregation and several sources of uncertainty are present in the different decisions stages. This work is motivated by problems in production planning in the forest industry, as well as recent questions in a model used for intertemporal planning of hospital capacity. In both cases, we want tactical decisions that can generate feasible and efficient decisions in the short term. We show how we have addressed this question using various approaches: the Robust Optimization paradigm, using both polyhedral as well as ellipsoidal uncertainty sets, including some estimates of probabilities of consistency; a more classical 2-stage stochastic approach, and a recent idea that try to achieve consistency by making tactical decisions in such a way that they guarantee certain sensitivity and stability characteristics of the short term problem. These results should be relevant in other situations where consistency is desirable.

3. **Design of Reconfigurable Networks under Uncertainty by Concurrent Stochastic Optimization and Simulation**

Alexei A Gaivoronski (Alexei.Gaivoronski@iot.ntnu.no) Norwegian University of Science and Technology, Norway, *Jacopo Napolitano, Giovanni Sechi, Paola Zuddas*

We consider design of networks consisting of supply nodes, demand nodes and transshipment nodes, which have to satisfy demand for some scarce resource. We are specifically interested in the situation, when such networks have variable topology due to different of reasons: high operation cost of certain links prohibiting continuous operation, need for regular maintenance, congestion, etc. The network manager can dynamically change the network topology according to certain parametrized rules. The network operates under conditions of substantial uncertainty due to variable demand, uncertain supply and other reasons. Examples of such networks arise in telecommunications, water resources management, transportation. We show how to design the optimal rules for operation of such networks by combining simulation and stochastic optimization with stochastic gradient methods. A practical example is provided, which deals with water resource management in southern Sardinia, where opening and closing of certain links corresponds to switching on and off water pumps.

■ Thu.C.5J

Thursday, 13:30-14:45, Room 5J

Advances in Nonlinear Optimization III

Cluster: Nonlinear Optimization
Session chair: *Peter Kirst*

1. **A Method of Multipliers with Alternating Constraints for Nonlinear Optimization Problems**

Hassan Siti Nor (siti.hassan.82e@st.kyoto-u.ac.jp) Kyoto University, Japan, *Niimi Tomohiro* , *Yamashita Nobuo*

In this paper, a new method of multipliers is proposed to solve constrained minimization problems which consist of equality and inequality constraints. The method solves a sequence of subproblems whose objective functions are an augmented Lagrangian function. The distinguishing feature of this method is that it allows the augmented Lagrangian function and its minimization problem to alternate the constraints at each iteration, that is some constraints are included in the augmented Lagrangian function, and the others remain in the subproblems. By alternating constraints, this method able to get more accurate estimated Lagrange multipliers by exploiting Karush-Kuhn-Tucker (KKT) points of the subproblems, and consequently it will converge more efficient and steady. For efficiency, some special structures of the subproblems are discussed. Numerical experiments are presented where this method were applied with a proximal gradient method to solve the subproblems of the large scale convex programming problems with linear constraints.

2. **The Common Limit in the Range of Property for Two Nonlinear Mappings**

Pakeeta Sukprasert (happy_t_ik@hotmail.com) King Mongkut's University of Technology Thonburi, Thailand, *Pakeeta Sukprasert*, *Poom Kumam*

In this work, we give some common fixed point results for two nonlinear mappings are satisfying generalized contractive condition by using the common limit in the range of property due to Sintunavarat and Kumam. The presented results extend, generalize, and improve many existing results in the literature.

3. **Solving Disjunctive Optimization Problems by Generalized Semi-infinite Optimization Techniques**

Peter Kirst (peter.kirst@kit.edu) Karlsruhe Institute of Technology, Germany, *Oliver Stein*

We describe a new possibility to model disjunctive optimization problems as generalized semi-infinite programs. In contrast to existing methods, for our approach neither a conjunctive nor a disjunctive normal form is expected. Applying existing lower level reformulations for the corresponding semi-infinite program we derive conjunctive nonlinear problems without any logical expressions, which can be locally solved by standard nonlinear solvers.

■ Thu.C.5K

Thursday, 13:30-14:45, Room 5K

Algorithms for Nonsmooth Optimization

Cluster: Convex and Nonsmooth Optimization
Session chair: *André Uschmajew*

1. **A Primal Majorized Semismooth Newton-CG Augmented Lagrangian Method for Large-Scale Linearly Constrained Convex Programming**

Chengjing Wang (renascencewang@hotmail.com) Southwest Jiaotong University, China, *Tang Peipei*

In this paper, we propose a primal majorized semismooth Newton-CG augmented Lagrangian method for large-scale linearly constrained convex programming problems, especially for some difficult problems which are nearly degenerate. The basic idea of this method is to apply majorized semismooth Newton-CG augmented Lagrangian method to the primal convex problem. And we take two special nonlinear semidefinite programming problems as examples to illustrate the algorithm. Furthermore, we establish the iteration complexity of the algorithm. Numerical experiments demonstrate that our method works very well for the testing problems, especially for many ill-conditioned ones.

2. **Bundle Trust-Region Method for Marginal Functions using Outer Subdifferentials**

Martin Knossalla (knossalla@math.fau.de) Friedrich-Alexander University Erlangen-Nürnberg, Germany

The theory of subdifferentials provides adequate methods and tools to put descent methods for nonsmooth optimization problems into practice. But in application it is often difficult to decide on a suitable subdifferential to construct a descent method. Furthermore there is often no exact information about the whole subdifferential for locally Lipschitz continuous functions, e.g. for marginal functions in parametric mathematical programming. In these cases the semismoothness of the cost functions cannot be proven or is violated. Basing on the (continuous) outer subdifferentials we have developed, this talk presents a new strategy for optimization problems with locally Lipschitz continuous cost functions. At first a descent method will be developed for arbitrary locally Lipschitz continuous functions, which is realized by projections on the outer subdifferential of the function. Possibly, it can happen that the computation of the whole outer subdifferential is too heavy. For this reason we will approximate outer subdifferentials especially for marginal functions. Basing on this approximation a bundle trust-region method will be developed and its global convergence will be proven.

3. **A Riemannian Gradient Sampling Algorithm for Nonsmooth Optimization on Manifolds**

André Uschmajew (uschmajew@ins.uni-bonn.de) University of Bonn, Germany, *Seyedehsomayeh Hosseini*

We present a generalization of the gradient sampling algorithm for nonsmooth locally Lipschitz functions to a Riemannian setting. The method is based on approximating the subdifferential of the cost function at every iteration by the convex hull of transported gradients from randomly generated nearby points to the current iterate. The main advantage is a relatively strong convergence result that can be obtained under the assumption that the cost function is continuously differentiable on an open dense subset, and that the employed vector transport and retraction satisfy certain conditions, which hold for instance for the exponential map and parallel transport. Then with probability one the algorithm is feasible, and each cluster point of the iterates is a Clarke stationary point (provided the cost function is bounded below). We illustrate the efficiency of Riemannian gradient sampling algorithms in a numerical comparison regarding the problem of finding the sparsest vector in a linear subspace.

■ Thu.C.m3S

Thursday, 13:30-14:45, Room m3S

Augmented Lagrangian-based Algorithms for Large-Scale Conic Programming

Cluster: Convex and Nonsmooth Optimization
Session organized by: *Kim-Chuan Toh*

1. **Fast Algorithm for Lasso**

Xudong Li (matlixu@nus.edu.sg) National University of Singapore, Singapore, *Defeng Sun*, *Kim-Chuan Toh*

In this talk, we present a fast algorithm for solving large-scale l_1-regularized least square regression (the Lasso) problems. The algorithm consists of two phases with Phase I to solve the problem to moderate accuracy or using it to warm start Phase II which aims at obtaining an accurate solution efficiently. The global convergence and local (super-)linear convergence results are established. Numerical results including the comparison between our approach and several state-of-the-art solvers on real data sets are presented to demonstrate the high efficiency and robustness of our proposed algorithm in solving large-scale problems.

2. **Semidefinite Inverse Quadratic Eigenvalue Problem with Prescribed Entries and Partial Eigendata**

Ying Cui (matcuiy@nus.edu.sg) National University of Singapore, Singapore, *Zhengjian Bai*, *Defeng Sun*

The semidefinite inverse quadratic eigenvalue problem (SDIQEP) is to find a quadratic pencil such that it is nearest to the original analytic pencil in the Frobenius norm, satisfies the measured eigendata and preserves the positive semidefiniteness and prescribed entries. In this talk, we first show that SDIQEP can be taken as unconstrained multi-block convex composite programming via the dual approach. Following that, an efficient accelerated block coordinate descent method would be introduced. We shall also discuss the augmented Lagrangian method for solving the dual problem if the weighted distance is adopted in the primal objective function. Numerical results demonstrate that the proposed method outperforms the state-of-the-art algorithms, especially when a large amount of eigendata has been observed.

3. **SDPNAL+: A Matlab Software for Semidefinite Programming with Bound Constraints**

Kim-Chuan Toh (mattohkc@nus.edu.sg) National University of

Singapore, Singapore, *Defeng Sun, Liuqin Yang, Xinyuan Zhao*

SDPNAL+ is a Matlab software package that implements an augmented Lagrangian based method to solve large scale semidefinite programming problems with bound constraints. The implementation was initially based on a majorized semismooth Newton-CG augmented Lagrangian method, but we subsequently implement it within an inexact symmetric Gauss-Seidel based semi-proximal ADMM/ALM (alternating direction method of multipliers/ augmented Lagrangian method) framework for the convenience of deriving simpler stopping conditions. Numerous problems arising from combinatorial optimization and binary integer quadratic programming problems have been tested to evaluate the performance of the solver. Extensive numerical test results show that the proposed method is quite efficient and robust.

■ Thu.C.m3AB

Thursday, 13:30-14:45, Room m3AB

Conic and Polynomial Optimization: Copositive Optimization

Cluster: Conic and Polynomial Optimization

Session organized by: *Luis F Zuluaga*

1. **Inner Approximations of Completely Positive Reformulations of Mixed Binary Quadratic Programs**

E Alper Yildirim (alperyildirim@ku.edu.tr) Koc University, Turkey

Every quadratic programming problem with a mix of continuous and binary variables can be equivalently reformulated as a completely positive optimization problem, i.e., a linear optimization problem over the convex but computationally intractable cone of completely positive matrices. In this talk, we focus on general inner approximations of the cone of completely positive matrices on instances of completely positive optimization problems that arise from the reformulation of mixed binary quadratic programming problems. We provide a characterization of the feasibility of such an inner approximation as well as the optimal value of a feasible inner approximation. For polyhedral inner approximations, our characterization implies that computing an optimal solution of the corresponding inner approximation reduces to an optimization problem over a finite set. Our characterization yields, as a byproduct, an upper bound on the gap between the optimal value of an inner approximation and that of the original instance. We discuss the implications of this error bound for standard and box-constrained quadratic programs.

2. **On Completely Positive Modeling of Quadratic Problems**

Van Nguyen (nguyen@uni-trier.de) Trier University, Germany, *Mirjam Dür*

Copositive programming deals with linear optimization problems over the copositive cone and its dual, the completely positive cone. The motivation to study this type of problem is that many nonlinear quadratic problems (even with binary constraints) can be cast in this framework. In order to have strong duality in conic optimization, strict feasibility of the problems is required. Strict feasibility is also advantagous in numerical solution approaches, for example when inner approximations of the copositive cone are used. We show that not all of the known completely positive formulations of quadratic and combinatorial problems are strictly feasible and discuss conditions which ensure this property.

3. **Copositive Certificates of Non-negativity**

Luis F Zuluaga (lzuluagag@gmail.com) Lehigh University, USA, *Juan Vera, Bissan Ghaddar, Joe Naoum-Sawaya, Xiaolong Kuang*

Classical certificates of non-negativity for polynomials over semialgebraic sets such as Schmudgen's or Putinar's Positivstellensatz are typically written in terms of sums-of-squares polynomials whose degree is not known a priori. In this talk we show that the non-negativity of a polynomial over a general class of semialgebraic sets can be certified using copositive polynomials of known degree. As a consequence, a very rich class of convergent hierarchies of LMI problems can be constructed to approximate the solution of general polynomial optimization (PO) problems. In particular, Polya's Positivstellensatz can be used to construct new convergent linear, second-order cone, and semidefinite programming hierarchies to address the solution of (PO) problems.

Abstracts Of Poster Presentations

The Poster Session will take place on Monday, August 8th at the Foyer of GRIPS on the 1st floor from 17:30 to 19:30.

P1. Optimal Wind Turbine Placement considering Power Demand and Wind Uncertainties in Taiwan

Peng-Yeng Yin (pengyengyin@gmail.com) National Chi Nan University, Taiwan, *Tsai-Hung Wu, Ching-Hui Chao, Ping-Yi Hsu*

The awareness of climate change has gathered over 196 countries in Paris to put forward a protocol for restraining the emission of greenhouse gases. This commitment relies on an anticipation of a future rapid growth in renewable energy capacity. Wind energy plays a central role in Taiwan's renewable energy development. The simulation for optimal wind turbine placement is a technology for minimizing the cost of energy (COE) and mitigating the wake effect. However, little literature addresses this problem considering both power demand and wind uncertainties. This talk first presents a multi-expert demand forecasting method based on a repository of historical demand data. The multi-expert method uses a reinforcement learning framework to optimally select the best experts at various prediction stages. Then, a model for obtaining optimal COE and reducing the gap between the production and predicted demand is proposed. The simulation is conducted with historical data of wind condition and power demand in central Taiwan area. The experimental results show that the proposed model can deal with uncertainties regarding wind and demand. Convergence and worst-case analyses are conducted to provide a reliable evaluation of our approach.

P2. Tensor and Its Tucker Core: the Invariance Relationships

Fan Yang (fannyfanyang@stanford.edu) Shanghai University of Finance and Economics, China, *Bo Jiang, Shuzhong Zhang*

In Most Tensor Problems Are NP-hard, Hillar and Lim famously demonstrated that "multilinear (tensor) analogues of many efficiently computable problems in numerical linear algebra are NP-hard". Despite many recent advancements, the state-of-the-art methods for computing such 'tensor analogues' still suffer severely from the curse of dimensionality. In this paper we show that the Tucker core of a tensor however, retains many properties of the original tensor, including the CP rank, the border rank, the tensor Schatten quasi norms, and the Z-eigenvalues. Since the core is typically smaller than the original tensor, this property leads to considerable computational advantages, as confirmed by our numerical experiments. In our analysis, we in fact work with a generalized Tucker-like decomposition that can accommodate any full column-rank factor matrices.

P3. New DC Diagonal Bundle Method for Clustering in Very Large Data Sets

Napsu Karmitsa (napsu@karmitsa.fi) University of Turku/ Federation University Australia, Finland, *Adil Bagirov, Sona Taheri*

Clustering is among most important tasks in data mining. This problem in very large data sets is challenging for most existing clustering algorithms. It is important to develop clustering algorithms which are accurate and can provide real time clustering in such data sets. Now we introduce one such algorithm: namely, the DC Diagonal Bundle Method (DCD-Bundle). Using nonsmooth optimization formulation of the clustering problem the objective function in this problem can be represented as a difference of two convex functions (DC). The new DCD-Bundle explicitly utilizes this structure to solve clustering problems. The method is evaluated using real world data sets with both the large number of attributes and/or large number of data points. The new algorithm is also compared with an other algorithm based on DC representation.

P4. QPLIB — A Library of Quadratic Programming Instances

Fabio Furini (fabio.furini@dauphine.fr) LAMSADE - Paris Dauphine, France, *Emiliano Traversi*

In this work we present a library of Quadratic Programming Instances (QPLIB). Quadratic programming (QP) problems have received an increasing amount of attention in recent years, both from theoretical and practical points of view. The QPLIB balances instances from real-world applications and academic problems. The QPLIB aims at being used as reference for the community and the practitioner involved in QP.

P5. Dantzig Wolfe Decomposition and Simplicial Decomposition in Quadratic Programming

Emiliano Traversi (emiliano.traversi@gmail.com) University of Paris 13, France, *Enrico Bettiol, Alberto Ceselli, Lucas Létocart, Francesco Rinaldi*

In this work we deal with problems with a Quadratic objective function and linear constraints. We will show how to solve the Quadratic Knapsack Problem with cardinality constraint using Danzig-Wolfe Decomposition and in a second step, we will use Simplicial Decomposition to solve the Portfolio Optimization problem. A comparison of both decompositions will be finally provided.

P6. An Index Tracking Model Embedded Stratified Sampling in Optimal Allocation

Meihua Wang (yuyu0504@163.com) Xi'an Jiaotong University, China, *Fengmin Xu, Yu-Hong Dai*

This paper focuses on the strategy of tracking portfolio decision in the field of passive fund management. To include adequate practical information and promote better out-of-sample performance, a novel strategy is proposed which combines the existing stratified and optimized sampling strategies. Specifically, we build a mixed integer program model to represent the stratification information, the cardinality requirement and other practical constraints. The resulting model is shown to have satisfactory ability of forecasting and generate optimal tracking portfolios owning inspiring performances especially in out-of-sample time period. Moreover, a stratified hybrid genetic algorithm with a new designed crossover operator is proposed for solving the proposed model. Computational tests on practical data sets from China Stock Exchange Market demonstrate the efficiency of the algorithm and the superiority of the new indexation strategy over the existing strategies from various perspectives.

P7. A Decomposition Method for a Class of Distributionally Robust Multistage Stochastic Optimization Problems

Haodong Yu (nianchuixiao@msn.com) Shanghai Lixin University of Commerce, China, *Jie Sun*

We consider distributionally robust multistage stochastic optimization problems. For simplicity, we assume that the involved random process is stagewise independent. At each stage, the decision maker has to solve a min-max problem with the ambiguity set described by moment constraints or chi-square distance. The method constructs a sequence of approximations to different scenarios and each approximation problem is transformed to a conic programming problem. Convergence of the approximation procedure is proven. A numerical example is presented to show the effectiveness of the proposed method.

P8. Optimal Stopping for Risk Measures

Masayuki Kageyama (kageyama@sda.nagoya-cu.ac.jp) Nagoya City University, Japan, *Qi Wang*

We consider the optimal stopping problems in an uncertain environment. In the classical optimal stopping problems, we consider maximizing the expected value. However, in Markov decision processes many authors study a problem in which we minimizing a risk. We deal with a risk minimizing optimal stopping problem concerning with the secretary problem.

P9. A Mixed-Integer SOCP Model for Robust and Power Efficient Networks

Bimal Chandra Das (bcdasdiu@gmail.com) The University of Electro-Communications, Japan, *Ihsen Aziz Ouedraogo, Eiji Oki, Masakazu Muramatsu*

We propose a model that considers fluctuation in data of power efficient networks, formulate it into a mixed-integer second-order cone programming(MISOCP), and solve it by using modern MISOCP solvers. In power efficient network problems, the operator tries to save energy by powering off some of their links based on estimated demands. We deal with the case where the estimated demands could have some errors. Compared to the models proposed on similar idea, our model has an advantage that we can set the subtotal amount of errors. We will report results of experiments of this model on the examples in the literatures.

P10. Analysis of an EOQ Inventory Model with Backordering and Time-and-Price Dependent Demand

Joaquin Sicilia-Rodriguez (jsicilia@ull.es) Universidad de La Laguna, Spain, *Luis A San-Jose*

The article presents a new economic order quantity (EOQ) model in which shortages are allowed and completely backordered. It is assumed that the demand rate is the product of a price-dependent algebraic function and a time-dependent power function. The net inventory level that describes the evolution of the inventory and the cost functions related to the inventory management are formulated. The aim consists of obtaining the optimal inventory policy and the optimal selling price which maximize the profit per unit time. An exhaustive solution procedure to determine the best inventory policy is developed. Several numerical examples to illustrate the theoretical results are presented.

P11. Establishing Big Data Analysis Framework for Computing Optimal Parameters

Yu-Ching Lee (yclee@ie.nthu.edu.tw) National Tsing Hua University, Taiwan, *Yi-Hao Huang, Si-Jheng Ciou*

Data analysis on scalable framework has already been a popular and widely employed technique for plenty of years. The technique is able to process and analyze the data that is unable to be dealt with by the general software. Hadoop is one of the robust and well-behaved tools in views of parallel computing and distributed storage. We employ big data analysis to discover the potential information and patterns on Hadoop. The aim is to generate a quantifiable value to represent the customers' willingness to buy products. Our case study is the vehicle data. First, we split the whole data into training data and testing data. Second, we combine Hadoop with R so that we can analyze the training data on R by keying in the commands of Hadoop Distributed File System. Third, the Nash equilibrium of customers' choice on R platform is solved. Finally, the proposal method is further validated by the real data of vehicles. This paper is aimed to provide a method to connect the advanced game-based model with the existing scalable computing system.

P12. Interval Constraint Solving Techniques for Prediction and Control of Dynamic System Behavior

Martine C Ceberio (mceberio@utep.edu) The University of Texas at El Paso, USA, *Leobardo Valera*

Many natural phenomena are dynamic systems, which can often be modeled as nonlinear systems of equations. Solving such nonlinear systems can be tricky because fine-grain or long simulations can yield very large dimensions. Uncertainty is also an issue as handling it reliably remains a hard problem to solve. Finally, what if we'd like to identify initial conditions or other parameters to ensure some conditions / control the behavior of the system at hand? Reduced-Order Modeling (ROM) allows to address dimension issues, often via Proper Orthogonal Decomposition (POD). On the other hand, interval constraint-solving techniques (ICST) allow to handle uncertainty and ensure reliability and completeness of results. In this work, we propose to use and embed ICST in traditional approaches to ROM, so as to address both dimension and uncertainty. We also show that ICST allow us to model problems in a way that makes it possible to not only predict but control dynamic systems' behavior. We present and analyze preliminary results on benchmarks such as Burgers' equation, Fitz-Hugh Nagumo equations, and other problems to demonstrate how prediction and control are achieved with ICST even when solving in smaller dimensions.

P13. A Gauss-Seidel Method for Multi-Leader-Follower Games

Atsushi Hori (m16ss004@nanzan-u.ac.jp) Nanzan University, Japan, *Masao Fukushima*

The multi-leader-follower game is an important model of noncooperative games. The game is comprised of two or more leaders and followers. A special case of multi-leader-follower game is the Stackelberg game (single-leader-follower game), which has been studied for many years. The Stackelberg game may be reformulated as a mathematical problem with equilibrium constraints (MPEC), which has also been studied extensively in recent years. On the other hand, the multi-leader-follower game may be formulated as an equilibrium problem with equilibrium constraints (EPEC), in which each leader's problem is an MPEC. But finding an equilibrium in such an EPEC is much more difficult than solving a single MPEC, because each leader's MPEC contains those variables which are common to other players' MPECs. In this work, we propose a Gauss-Seidel-type algorithm with a penalty technique for solving an EPEC associated with the multi-leader-follower game. We report numerical results to illustrate the behavior of the algorithm.

P14. Effect of Subsidies on Reverse Supply Chains: A Variational Inequality Approach

I-Hsuan Hong (ihong@ntu.edu.tw) National Taiwan University, Taiwan, *Pin-Chun Chen, Hsien-Ting Yu*

This study examines the effect of government subsidies on recycled flows in reverse supply chains by using the approach of variational inequalities. We present a four-tiered chain model consisting of sources, collectors, processors and demand markets. The modified projection method is applied to solving for the equilibrium flows of each node. The case study results demonstrate the scheme of subsidy to processors outperforms other subsidy schemes.

P15. Application of FEM and Abductive Network to Determine the Optimum Machine Power and Billet Dimensions of Near Net-Shape Spiral Bevel Gear Forging

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In this paper, the use of the finite element method in conjunction with abductive network is presented to predict the maximum forging force and the volume of billet during near net-shape spiral bevel gear forging. The maximum forging load, effective stress and volume of billet are influenced by the process parameters such as modules, number of teeth, and workpiece temperature. A finite element method is used to investigate the forging of spiral bevel gear. In order to verify the prediction of FEM simulation for forging load, the experimental data are compared with the results of current simulation. A finite element analysis is also utilized to investigate the process parameters on forging load, maximum effective stress and volume of billet. Additionally, the abductive network was applied to synthesize the data sets obtained from the numerical simulation. The prediction models are then established for the maximum forging load, maximum effective stress and volume of billet of near net-shape spiral bevel gear forging under a suitable range of process parameters. After the predictions of the maximum forging force and the volume of billet, the optimum of the power of forging machine and the dimensions of billet are determined.

P16. A Multi-Material Phase Field Approach for the Optimal Design of Germanium-on-Silicon Microbridges

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The reduction in microprocessor size lead to a significant increase in computational power. However, there is a physical limit to this increase. Instead of transmitting information via electricity, it has been recently proposed to transmit it via light. This idea is based on generating large strain in a germanium/silicon device to allow it to emit light. Unfortunately, due to heating issues the operational time of such lasers is currently limited to minutes. By maximizing strain in the optical cavity, the lasing threshold should be reduced and the lasing device become more heat resistant. We model the laser and strain maximization as an optimal control problem. By using optimization techniques to solve it we have managed to obtain approximately 30% larger strain than the original configuration.

Index Of Speakers, Session Organizers And Chairs

Sessions where the person is a speaker are listed in **bold**. Sessions where the person is an organizer or a chair are listed in regular text.

A

B

C

D

Z

GRIPS, the National Art Center, Tokyo, and surrounding area

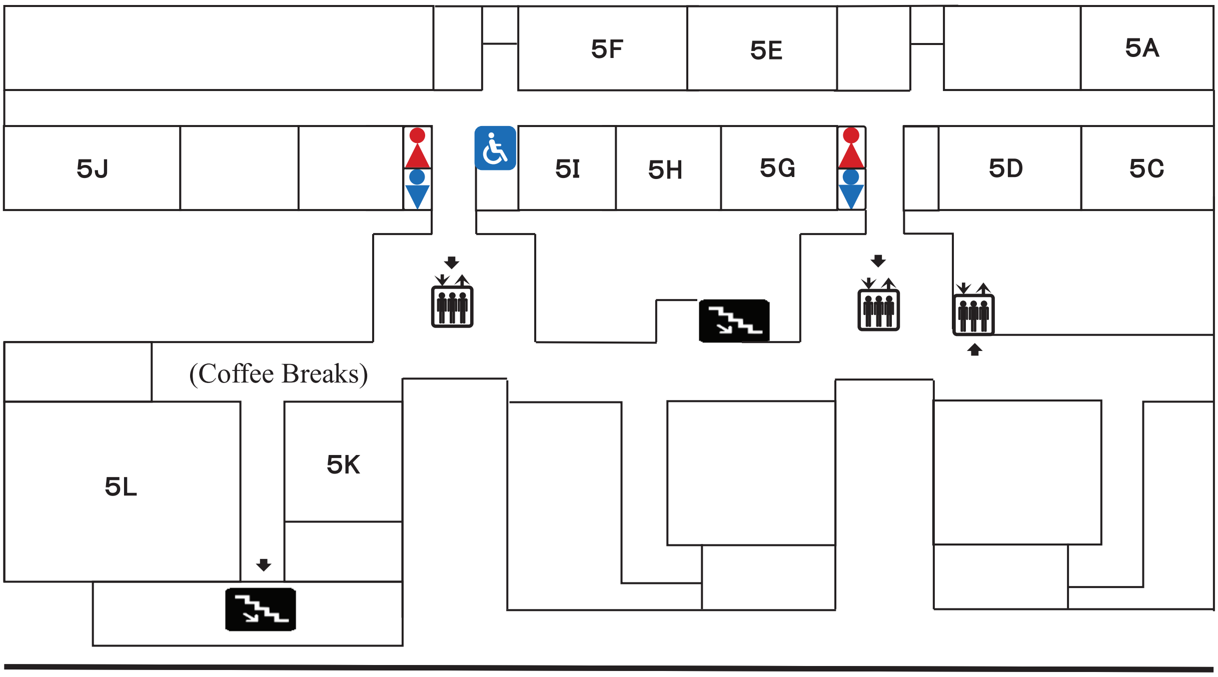
The two closest stations to GRIPS are **Nogizaka** and **Roppongi.** Just follow the dotted lines in the map above. You can also reach the Main Gate of GRIPS through the National Art Center, Tokyo (NACT) from Nogizaka. In that case, use the exit 6. (This route is not available on August 9th, Tuesday when NACT is closed.)

Important Notice:

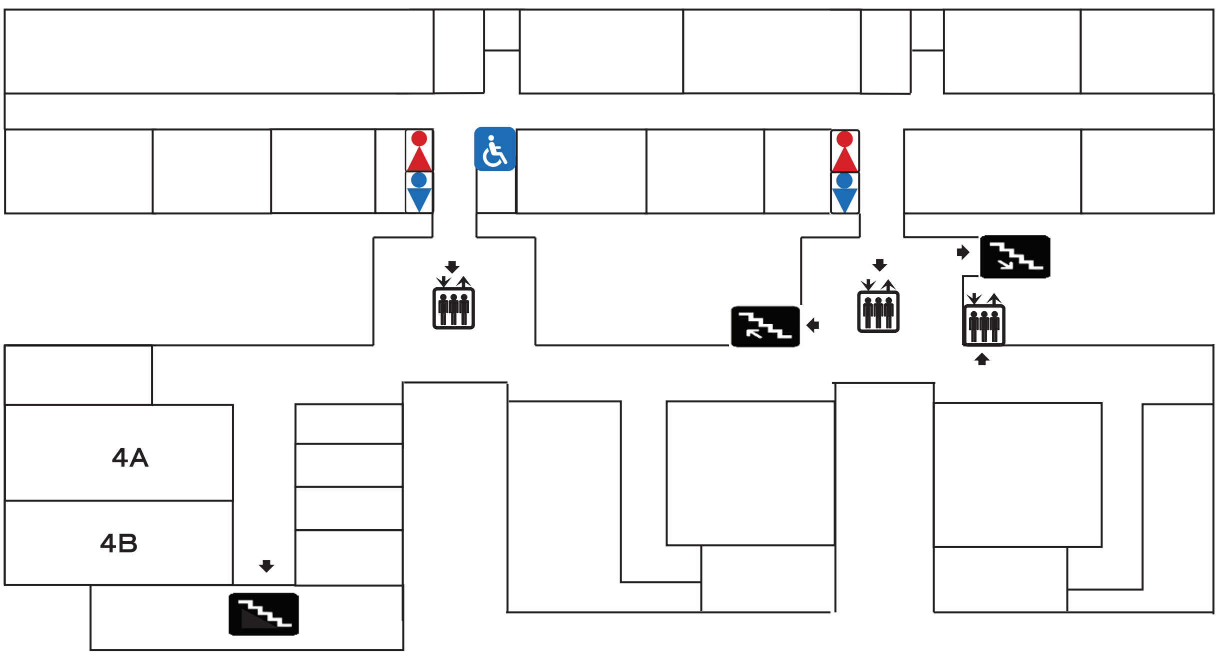
1. The Main Entrance of GRIPS is closed on August 7th, Sunday. Participants are asked to use South Gate and South Entrance.
2. Some sessions are held on the third floor of NACT. The Main Gate of NACT is just next to the Main Gate of GRIPS. So it is very easy to get there. (It takes just one minute or even less!)

5th and 4th floors of GRIPS

5th floor

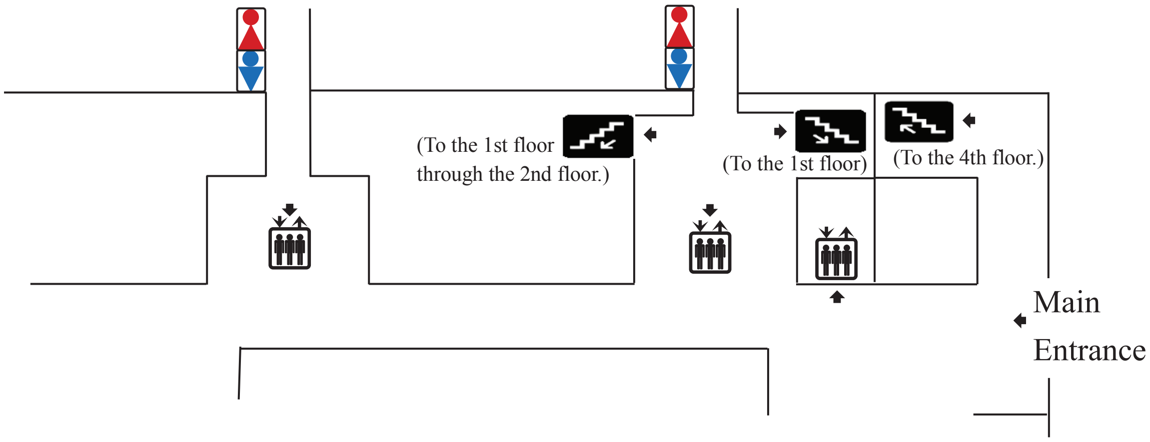


4th floor

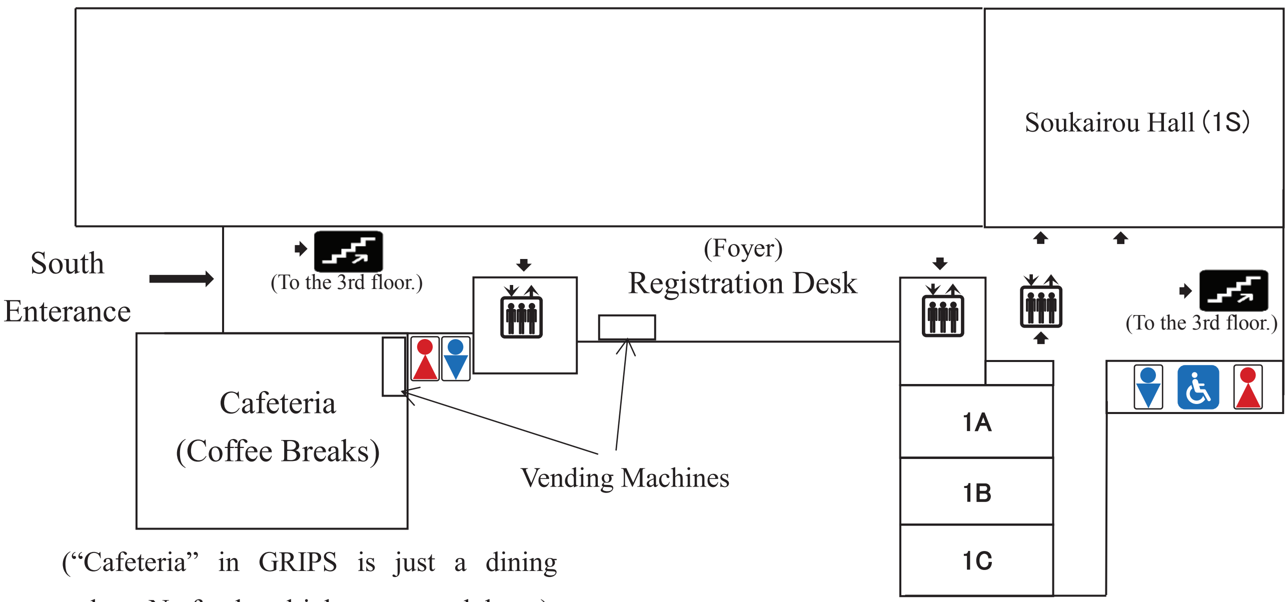


3rd and 1st floors of GRIPS

3rd floor

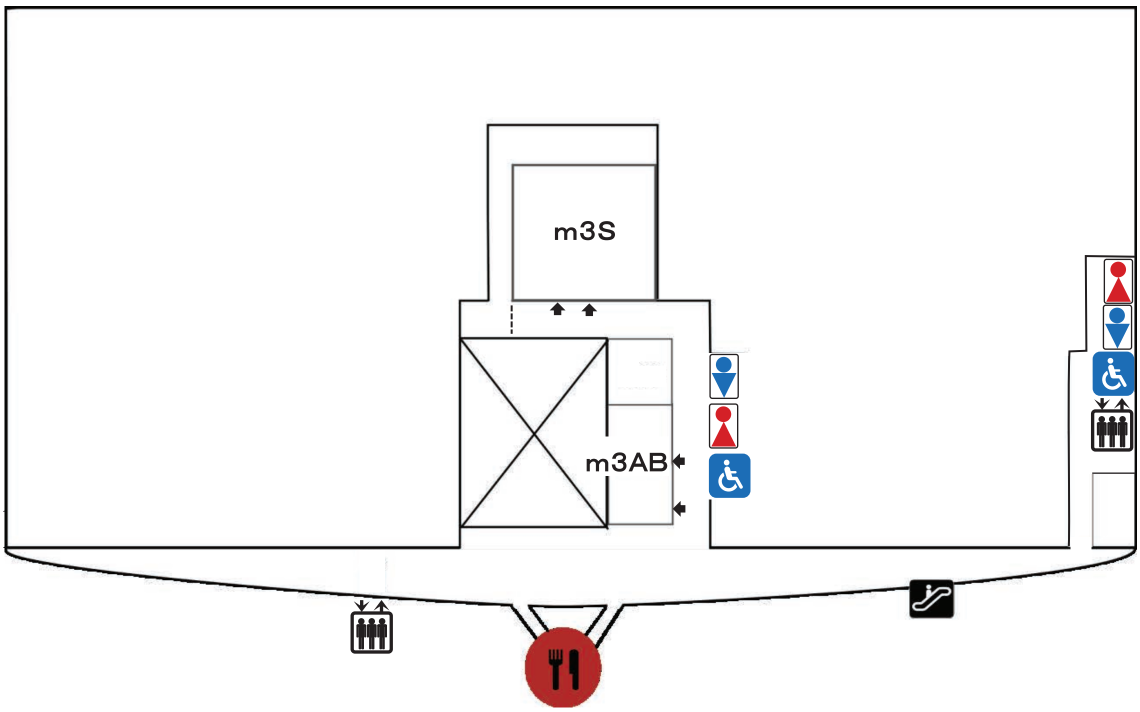


1st floor



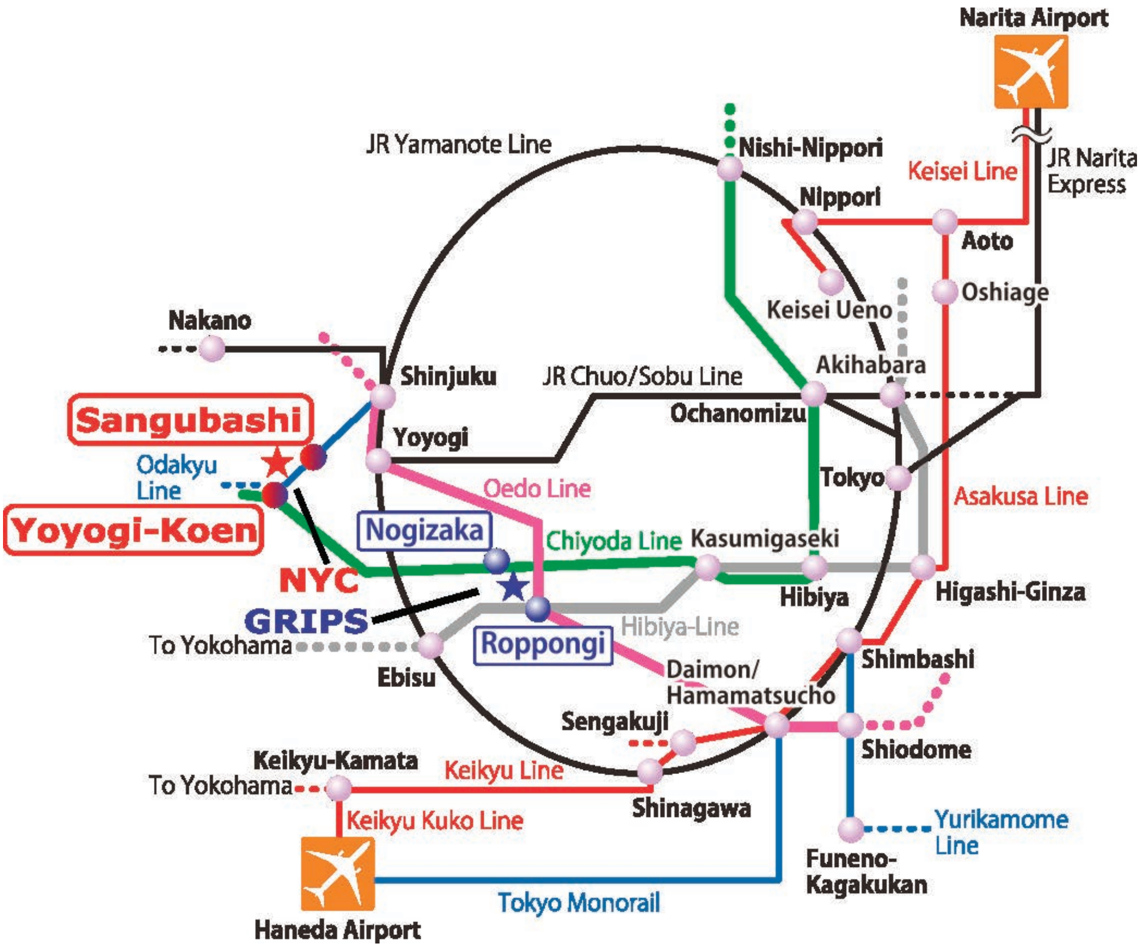
("Cafeteria" in GRIPS is just a dining place. No food or drinks are served there.)

3rd floor of the National Art Center, Tokyo



How to Get to the Session Rooms at the National Art Center, Tokyo (NACT)
The Main Gate of NACT is just next to the Main Gate of GRIPS. So it is very easy to get to NACT. (It takes just one minute!). From the Main Gate of NACT, you can see the Main Entrance of NACT just a few dozen meters ahead. Enter through the Main Entrance and you will find an escalator in front which goes up to the 2nd floor. Get on this escalator, and go up to the 3rd floor. (You need to change escalator once more on the 2nd floor.) In total, it should be around 4 minutes to reach the 3rd floor of NACT from the Main Entrance of GRIPS.

Access to GRIPS and NYC from Narita/Haneda Airport



<u>From Narita/Haneda Airport to GRIPS</u>

1. **Narita Airport** = (Narita Express (70 min)) = **Tokyo** = (Marunouchi line (7 min)) = **Kasumigaseki** = (Hibiya line (5 min)) = **Roppongi** = (walk (10 min)) = **GRIPS** (Required Time: 2 hours, Fair: approx. 3000 yen)

2. **Narita Airport** = (Keisei Skyliner (36 min)) = **Nippori** = (Yamanote Line (2 min)) = **Nishi-Nippori** = (Chiyoda Line (21 min)) = **Nogizaka** = (walk (10 min)) = **GRIPS** (Required Time: 1 hour 30 min, Fair: approx. 2500 yen))

3. **Haneda Airport** = (Tokyo Monorail (25 min)) = **Hamamatsucho/Daimon** = (Oedo line (10 min)) = **Roppongi** = (walk (10 min)) = **GRIPS** (Required Time: 1 hour, Fair: approx. 500 yen)

From Narita/Haneda Airport to NYC

1. **Narita Airport** = (Narita Express (90 min)) = **Shinjuku** = (Odakyu line (3 min)) = **Sangubashi** = (walk (10 min)) = **NYC** (Required Time: 1 hour 45 min, Fair: approx. 3000 yen)

2. **Narita Airport** = (Keisei Skyliner (36 min)) = **Nippori** = (Yamanote line (25 min)) = **Shinjuku** = (Odakyu line (3 min)) = **Sangubashi** = (walk (10 min)) = **NYC** (Required Time: 1 hour 30 min, Fair: approx. 2500 yen)

3. **Haneda Airport** = (Keikyu line (25 min)) = **Shinagawa** = (Yamanote line (20 min)) = **Shinjuku** = (Odakyu line (3 min)) = **Sangubashi** = (walk (10 min)) = **NYC** (Required Time: 1 hour 15 min, Fair: approx. 500 yen)

From NYC to GRIPS

NYC = (walk (9 min)) = **Yoyogi-koen** = (Chiyoda line (6 min)) = **Nogizaka** = (walk (10 min)) = **GRIPS** (Required time: 25 min, Fair: 160 yen)

The area around the National Olympics Memorial Youth Center (NYC)

From Sangubashi Station to NYC

From Yoyogikoen Station to NYC