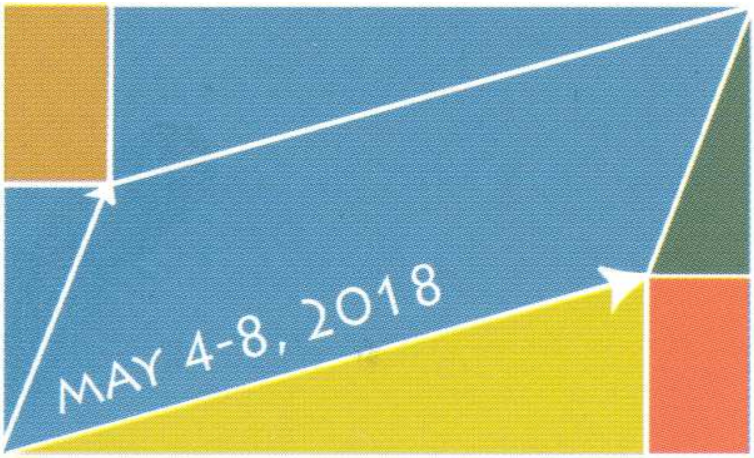
SIAM Conference on APPLIED LINEAR ALGEBRA

Program and Abstracts



Hong Kong Baptist University, Hong Kong

The SIAM Activity Group on Linear Algebra promotes research in linear algebra and its applications. The group organizes a triennial SIAM Conference on Applied Linear Algebra and a triennial International Summer School on Numerical Linear Algebra (ISSNLA) for graduate students. They also support smaller, less formal conferences as requested by the membership. Every three years the activity group awards prizes for the best paper and the best poster in linear algebra.

Society for Industrial and Applied Mathematics

www.math.hkbu.edu.hk/SIAM-ALA18/

Introduction

Linear algebra is an important area of mathematics and it is at the heart of many scientific, engineering, and industrial applications. Research and development in linear algebra include theoretical studies, algorithmic designs and implementations on advanced computer architectures, and applications to various disciplines. The SIAM Conferences on Applied Linear Algebra, organized by SIAM every three years, are the premier international conferences on applied linear algebra, which bring together diverse researchers and practitioners from academia, research laboratories, and industries all over the world to present and discuss their latest work and results on applied linear algebra.

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Conference Venue

Hong Kong Baptist University

Conference Sponsors

Centre for Mathematical Imaging and Vision, Hong Kong Baptist University

Croucher Foundation

Department of Mathematics, Hong Kong Baptist University

Faculty of Science, Hong Kong Baptist University

Hong Kong Baptist University

Hong Kong Pei Hua Education Foundation

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Cornell University
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Hong Kong Baptist University
Zhiwen Zhang
The University of Hong Kong
Xiaosheng Zhuang
City University of Hong Kong

SIAM ALA18 At-a-Glance

Friday May 4

8:00 AM - 11:30 AM
1:30 PM - 3:30 PM
Registration
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

8:40 AM - 8:45 AM
Welcoming Remarks
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

8:45 AM - 9:30 AM
IP1 Convergence Stories of Algebraic Iterative Reconstruction
Per Christian Hansen, Technical University of Denmark
(page 22)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

9:30 AM - 10:15 AM
IP2 Matrix Equation Techniques for a Class of PDE Problems with Data Uncertainty
Valeria Simoncini, Universita di Bolognà
(page 22)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

10:15 AM - 10:45 AM
Coffee Break
3/F Podium, Academic and Administration Building

10:45 AM - 12:45 PM
Concurrent Sessions
(page 23)

MS01 Advances in High-Performance Sparse Matrix Computation
WLB204
MS05 Coupled Matrix and Tensor Decompositions: Theory and Methods
WLB205
MS10 Part I Generalized Inverses and the Linear Least Squares
WLB104
MS15 Part I Low-Rank and Toeplitz-Related Structures in Applications and Algorithms
WLB109
MS19 Part I Nonlinear Eigenvalue Problems and Applications
WLB103
MS41 Part I The Spectrum of Hypergraphs via Tensors
WLB210
CS01 Contributed Session 01
WLB206
CS02 Contributed Session 02
WLB208
CS03 Contributed Session 03
WLB211

12:45 PM - 1:45 PM
Lunch Break

1:45 PM - 2:30 PM
IP3 Interpolative Decomposition and Its Applications
Lexing Ying, Stanford University
(page 27)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

2:30 PM - 3:00 PM
Coffee Break
3/F Podium, Academic and Administration Building

3:00 PM - 5:00 PM
Concurrent Sessions
(page 27)

MS02 Advances in Preconditioning and Iterative Methods
WLB204
MS10 Part II Generalized Inverses and the Linear Least Squares
WLB104
MS13 Large-Scale Matrix and Tensor Optimization
WLB205
MS15 Part II Low-Rank and Toeplitz-Related Structures in Applications and Algorithms
WLB109
MS19 Part II Nonlinear Eigenvalue Problems and Applications
WLB103
MS41 Part II The Spectrum of Hypergraphs via Tensors
WLB210
CS04 Contributed Session 04
WLB211
CS05 Contributed Session 05
WLB206

5:15 PM - 6:00 PM
SIAG/LA Business Meeting
WLB103

6:00 PM - 8:00 PM
Welcoming Reception
Renfrew Restaurant, 2/F, David C Lam Building

Saturday May 5

8:30 AM - 11:30 AM
1:30 PM - 3:30 PM
Registration
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

8:45 AM - 9:30 AM
IP4 Comparative Spectral Decompositions for Personalized Cancer Diagnostics and Prognostics
Orly Alter, University of Utah
(page 31)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

9:30 AM - 10:15 AM
IP5 Theory and Computation of 2D Eigenvalue Problems
Yangfeng Su, Fudan University
(page 31)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

10:15 AM - 10:45 AM
Coffee Break
3/F Podium, Academic and Administration Building

10:45 AM - 12:45 PM
Concurrent Sessions
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MS03 Asynchronous Iterative Methods in Numerical Linear Algebra and Optimization
WLB210
MS06 Part I Discovery from Data
AAB201
MS07 Part I Domain Decomposition Methods for Heterogeneous and Large-Scale Problems
WLB103
MS12 Part I Large-Scale Eigenvalue Problems and Applications
WLB104
MS18 Part I Matrix Optimization and Applications
WLB109
MS22 Part I Numerical Methods for Ground and Excited State Electronic Structure Calculations
WLB204
MS35 Part I Some Recent Applications of Krylov Subspace Methods
WLB205
CS06 Contributed Session 06
WLB208

12:45 PM - 1:45 PM
Lunch Break

1:45 PM - 3:45 PM
Concurrent Sessions
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MS07 Part II Domain Decomposition Methods for Heterogeneous and Large-Scale Problems
WLB103
MS12 Part II Large-Scale Eigenvalue Problems and Applications
WLB104
MS18 Part II Matrix Optimization and Applications
WLB109
MS22 Part II Numerical Methods for Ground and Excited State Electronic Structure Calculations
WLB204
MS27 Part I Preconditioners for Ill-Conditioned Linear Systems in Large Scale Scientific Computing
WLB201
MS33 Part I Recent Advances in Tensor Based Data Processing
WLB207
MS35 Part II Some Recent Applications of Krylov Subspace Methods
WLB205

3:45 PM - 4:15 PM
Coffee Break
Lobby of Lam Woo International Conference Centre

4:15 PM - 6:15 PM
Concurrent Sessions
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MS12 Part III Large-Scale Eigenvalue Problems and Applications
WLB104
MS18 Part III Matrix Optimization and Applications
WLB109
MS20 Nonlinear Perron-Frobenius Theory and Applications
WLB103
MS26 Preconditioners for Fractional Partial Differential Equations and Applications
WLB204
MS27 Part II Preconditioners for Ill-Conditioned Linear Systems in Large Scale Scientific Computing
WLB201
MS33 Part II Recent Advances in Tensor Based Data Processing
WLB207
MS35 Part III Some Recent Applications of Krylov Subspace Methods
WLB205

Sunday May 6

9:30 AM - 11:30 AM
1:30 PM - 3:30 PM
Registration
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

8:45 AM - 9:30 AM
IP6 On the Design of Algebraic Multigrid for High Performance Computers
Ulrike Meier Yang, Lawrence Livermore National Laboratory
(page 44)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

9:30 AM - 10:15 AM
IP7 Nonlinear Eigenvalue Problems: Interpolatory Algorithms and Transient Dynamics
Mark Embree, Virginia Tech
(page 44)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

10:15 AM - 10:45 AM
Coffee Break
3/F Podium, Academic and Administration Building

10:45 AM - 12:45 PM
Concurrent Sessions
(page 44)

Mini-Tutorial Tensor Eigenvectors and Stochastic Processes
A. Benson, Cornell University and D. Gleich, Purdue University
AAB201

MS16 Machine Learning: Theory and Practice
WLB204
MS24 Parallel Sparse Triangular Solve on Emerging Platforms
WLB205
MS28 Preconditioning for PDE Constrained Optimization
WLB211
MS32 Part I Recent Advances in Linear Algebra for Uncertainty Quantification
WLB210
MS36 Part I Tensor Analysis, Computation, and Applications I
WLB103
MS40 Part I The Perturbation Theory and Structure-Preserving Algorithms
WLB104

CS07 Contributed Session 07
WLB109
CS08 Contributed Session 08
WLB206

12:45 PM - 1:45 PM
Lunch Break

1:45 PM - 3:45 PM
Concurrent Sessions
(page 48)

MS06 Part II Discovery from Data
AAB201
MS17 Part I Matrix Functions and Their Applications
WLB210
MS30 Part I Rank Structured Methods for Challenging Numerical Computations
WLB204
MS31 Part I Rational Krylov Methods and Applications
WLB205
MS34 Part I Recent Applications of Rank Structures in Matrix Analysis
WLB109
MS36 Part II Tensor Analysis, Computation, and Applications I
WLB103
MS40 Part II The Perturbation Theory and Structure-Preserving Algorithms
WLB104
CS09 Contributed Session 09
WLB211

3:45 PM - 4:15 PM
Coffee Break
Lobby of Lam Woo International Conference Centre

4:15 PM - 6:15 PM
Concurrent Sessions
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MS17 Part II Matrix Functions and Their Applications
WLB210
MS29 Randomized Algorithms for Factorizing Matrices
WLB211
MS30 Part II Rank Structured Methods for Challenging Numerical Computations
WLB204
MS31 Part II Rational Krylov Methods and Applications
WLB205
MS34 Part II Recent Applications of Rank Structures in Matrix Analysis
WLB109
MS38 Tensor-Based Modelling
WLB103
MS40 Part III The Perturbation Theory and Structure-Preserving Algorithms
WLB104
CS10 Contributed Session 10
WLB206

Monday May 7

9:30 AM - 11:30 AM
1:30 PM - 3:30 PM
Registration
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

8:45 AM - 9:30 AM
SIAG/Linear Algebra Best Paper Prize Lecture Generating Polynomials and Symmetric Tensor Decompositions
Jiawang Nie, University of California, San Diego
(page 57)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

9:30 AM - 10:05 AM
SIAG/Linear Algebra Early Career Prize Lecture The Ultraspherical Spectral Method
Alex Townsend, Cornell University
(page 58)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

10:05 AM - 10:35 AM
Coffee Break
3/F Podium, Academic and Administration Building

10:35 AM - 12:35 PM
Concurrent Sessions
(page 58)

MS06 Part III Discovery from Data
AAB201
MS09 Part I Exploiting Low-Complexity Structures in Data Analysis: Theory and Algorithms
WLB104
MS14 Part I Low Rank Matrix Approximations with HPC Applications
WLB109
MS23 Part I Optimization Methods on Matrix and Tensor Manifolds
WLB204
MS25 Part I Polynomial and Rational Matrices
WLB205
MS37 Part I Tensor Analysis, Computation, and Applications II
WLB211
CS11 Contributed Session 11
WLB103
CS12 Contributed Session 12
WLB210

12:35 PM - 1:35 PM
Lunch Break

1:35 PM - 3:00 PM
Poster Sessions
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building
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3:00 PM - 3:30 PM
Coffee Break
3/F Podium, Academic and Administration Building

3:30 PM - 5:30 PM
Concurrent Sessions
(page 63)

MS09 Part II Exploiting Low-Complexity Structures in Data Analysis: Theory and Algorithms
WLB104
MS14 Part II Low Rank Matrix Approximations with HPC Applications
WLB109
MS23 Part II Optimization Methods on Matrix and Tensor Manifolds
WLB204
MS25 Part II Polynomial and Rational Matrices
WLB205
MS32 Part II Recent Advances in Linear Algebra for Uncertainty Quantification
WLB210
MS37 Part II Tensor Analysis, Computation, and Applications II
WLB211
CS13 Contributed Session 13
WLB103

6:30 PM - 9:00 PM
Conference Banquet
Palace Wedding Banquet Specialist, L13, The ONE, 100 Nathan Road, Tsim Sha Tsui (page 15)

Tuesday May 8

9:30 AM - 11:30 AM
Registration
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

8:45 AM - 9:30 AM
IP8 Enlarged Krylov Subspace Methods and Robust Preconditioners
Laura Grigori, INRIA Paris
(page 67)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

9:30 AM - 10:15 AM
IP9 Null-space Based Block Preconditioners for Saddle-Point Systems
Chen Greif, The University of British Columbia
(page 67)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

10:15 AM - 10:45 AM
Coffee Break
3/F Podium, Academic and Administration Building

10:45 AM - 12:45 PM
Concurrent Sessions
(page 68)

MS04 Part I Constrained Low-Rank Matrix and Tensor Approximations
WLB103
MS08 Part I Efficient Kernel Methods and Numerical Linear Algebra
WLB104
MS11 Iterative Solvers for Parallel-in-Time Integration
WLB109
MS21 Part I Numerical Linear Algebra Algorithms and Applications in Data Science
WLB204
MS39 Part I Tensors and Multilinear Algebra
WLB205
MS42 Part I Tridiagonal Matrices and Their Applications in Physics and Mathematics
WLB210
CS14 Contributed Session 14
WLB211

12:45 PM - 1:45 PM
Lunch Break

1:45 PM - 2:30 PM
IP10 Fast Algorithms from Low-Rank Updates
Daniel Kressner, École Polytechnique Fédérale de Lausanne
(page 71)
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

2:30 PM - 3:00 PM
Coffee Break
3/F Podium, Academic and Administration Building

3:00 PM - 5:00 PM
Concurrent Sessions
(page 71)

MS04 Part II Constrained Low-Rank Matrix and Tensor Approximations
WLB103
MS08 Part II Efficient Kernel Methods and Numerical Linear Algebra
WLB104
MS21 Part II Numerical Linear Algebra Algorithms and Applications in Data Science
WLB204
MS39 Part II Tensors and Multilinear Algebra
WLB205
MS42 Part II Tridiagonal Matrices and Their Applications in Physics and Mathematics
WLB210
CS15 Contributed Session 15
WLB211
CS16 Contributed Session 16
WLB109

Conference Talk Arrangement

All plenary talks and SIAG/LA best paper prize lecture will be 45 minutes in duration, with 5 of the 45 minutes reserved for questions and discussion. SIAM/LA early career prize lecture will be 35 minutes in duration, with 5 of the 35 minutes reserved for questions and discussion.

The minitutorial will be 2 hours in duration.

All minisymposia talks and contributed talks will be 30 minutes in duration, with 5 of the 30 minutes reserved for questions and discussion.

In case you need to copy your presentation slides from your USB to a computer in lecture hall or meeting room, please do it in advance before the session starts.

Important Notice to Poster Presenters

The poster session is scheduled for Monday, May 7 at 1:35 PM. Poster presenters are requested to set up their poster material on the provided 4'x6' poster boards at the Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building between the hours of 10:00 AM and 1:35 PM. All materials must be posted by Monday, May 7 at 1:35 PM, the official start time of the session. Posters displays must be removed by 4:00 PM. Posters remaining after this time will be discarded. The conference is not responsible for discarded posters.

Registration Desk

The registration desk is located in Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building, and is open during the following times:

Friday, May 4

8:00 AM - 11:30 AM

1:30 PM - 3:30 PM

Saturday, May 5

8:30 AM - 11:30 AM

1:30 PM - 3:30 PM

Sunday, May 6

9:30 AM - 11:30 AM

1:30 PM - 3:30 PM

Monday, May 7

9:30 AM - 11:30 AM

1:30 PM - 3:30 PM

Tuesday, May 8

9:30 AM - 11:30 AM

Name Badges

Carry your name badge during the conference so that you can admit to all technical sessions, coffee breaks, reception and banquet.

Registration Fee Includes

- Admission to all technical sessions
- Conference Material
- Campus Wifi access during conference period
- Coffee and tea breaks daily
- Reception
- Conference Banquet

Lunches

Conference participants arrange their own lunches during the conference. There are some places available in the campus:

- Refrew Cafeteria, 2/F David C Lam Building,
- Refrew Restaurant, 2/F David C Lam Building,
- Main Canteen, 5/F Academic and Administration Building,
- Biston Bon, Ground Floor, Ng Tor Tai International House,
- BU Fiesta, Ground Floor, Student Residence Hall.

There are also two coffee shops in the campus,

- iCafé (Pacific Coffee), 3/F The Wing Lung Bank Building for Business Studies,
- Staff and Alumni Lounge (Star-Bucks), 1/F, Jockey Club Academic Community Centre.

Their locations can be found in the conference venue map (page 12).

Conference participants can also travel to nearby two shopping centers: Lok Fu Shopping Centre (at Lok Fu MTR station) and Festival Walk (at Kowloon Tong MTR station). Lok Fu has a more local flavour while Festival Walk is more modern and more expensive. It is a 15-minute walk from the University to either of these shopping centers (page 11).

Wi-Fi Access

The username and password of your account during the conference period (May 4-8) can be found in the name badge. Please make sure you have your own name badge so that you can access your device by your account. Your account is only allowed to be used by one device at any time.

Get-togethers

- Business Meeting (open to SIAG/LA members) Friday May 4 5:15 PM - 6:00 PM
- Welcoming Reception, Friday May 4 6:00 PM - 8:00 PM
- Banquet, Monday May 7 6:30 PM - 9:00 PM

Conference Banquet

The conference banquet will be held on Monday, May 7 at Palace Wedding

Banquet Specialist, L13, The ONE, 100 Nathan Road, Tsim Sha Tsui, which can be reached by MTR, Exit B1 of Tsim Sha Tsui station or Exit N5 of East Tsim Sha Tsui station. Location can be referred to the map on page 15.
Additional conference banquet tickets for the accompanying guests of conference participants are available. Please check and buy at the registration counter on or before May 5 2018 afternoon. The price of a banquet ticket is HK$600.

Standard Visual Set-Up in Meeting Rooms

Computers and video projectors are provided in the meeting rooms. USB is not supplied. Please make sure you can copy your presentation slides to the computers in the meeting rooms. Speakers can also use their own computers. Cables or adaptors for Macbook computers are not supplied. Please bring your own cable/adaptor if using a Macbook computer. Also the conference is not responsible for the safety and security of speakers' computers.

Recording of Presentations

Audio and video recording of presentations at the conference is prohibited without the written permission of the presenter and the conference.

Please Note

Complimentary wireless Internet access in the conference venue and meeting rooms will be available for conference participants. The conference does not provide email stations for conference attendees.

The conference is not responsible for the safety and security of attendees' computers. Do not leave your laptop computers and personal things unattended. Please remember to turn off your cell phones, pagers, etc in all the sessions.

The conference cannot provide photocopying and dollar exchange service. The bank within campus can be found in the conference venue map.

SIAM Books and Journals

Display copies of books and complimentary copies of journals are available on site at Lam Woo Conference Center WLB105

Friday, May 4

11:00 AM - 12:45 PM

1:45 PM - 4:00 PM

Saturday, May 5

10:00 AM - 12:45 PM

1:45 PM - 4:00 PM

Sunday, May 6

10:00 AM - 12:45 PM

1:45 PM - 4:00 PM

Monday, May 7

10:0 0AM - 12:35 PM

1:35 PM - 4:00 PM

Tuesday, May 8

10:00 AM - 12:45 PM

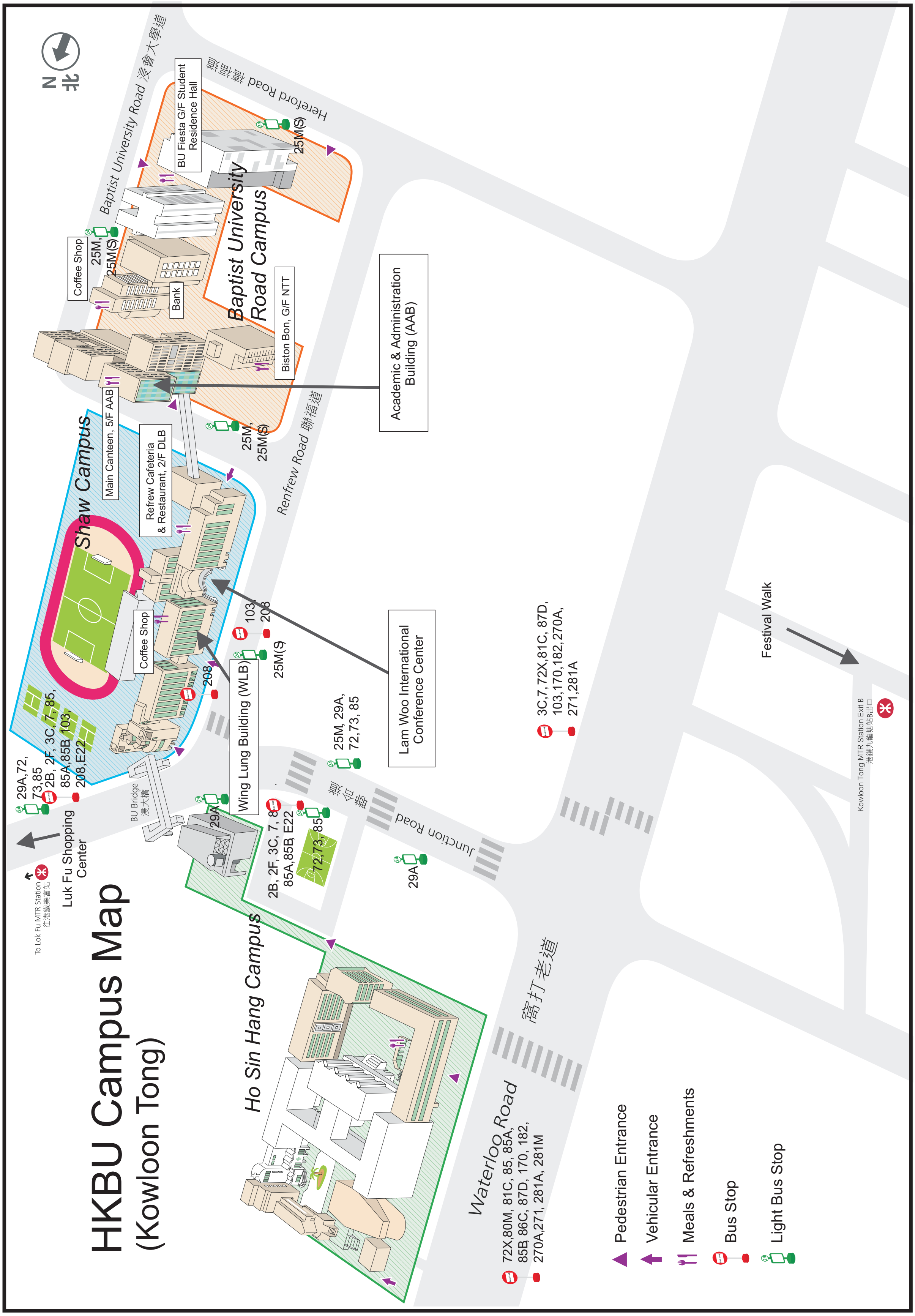
SIAM books are available at a discounted price during the conference. Completed order forms should be emailed or faxed to the SIAM office directly. It is not allowed to carry out on site transaction during the conference period.

Twitter

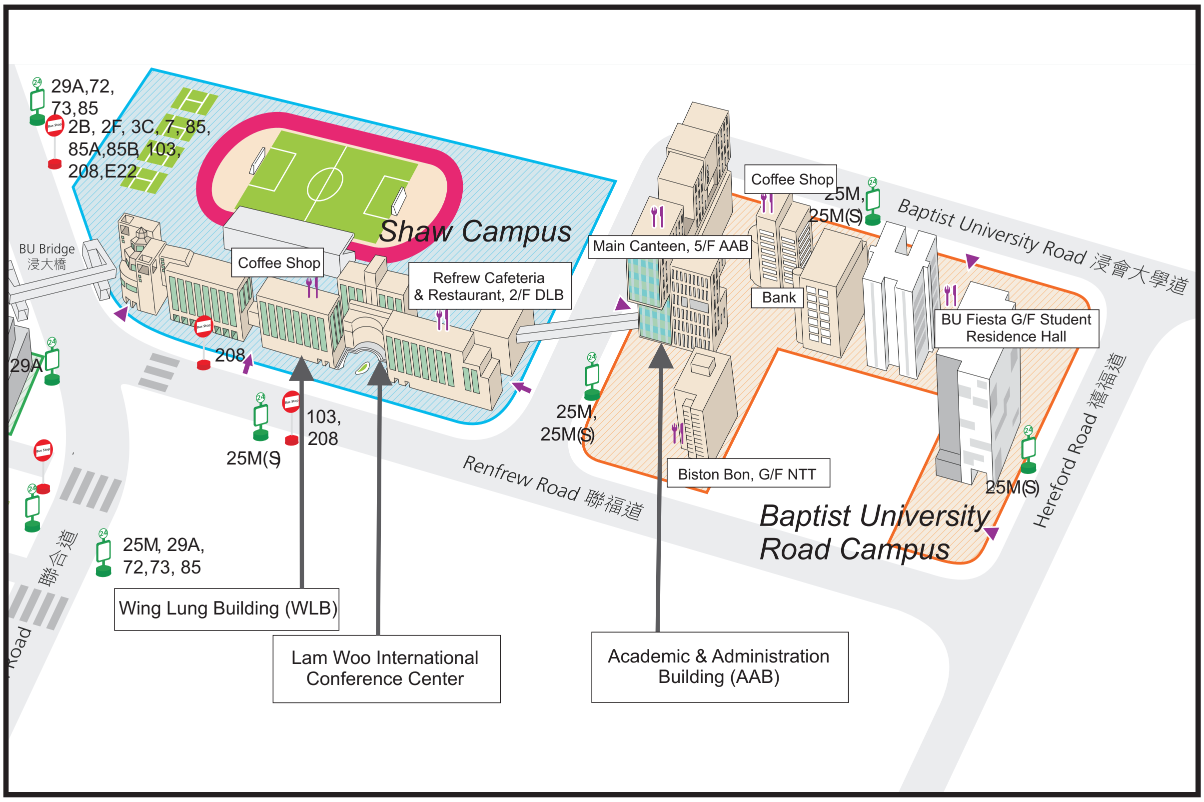
If you are tweeting about the conference, please use the designated hashtag to enable other attendees to keep up with the Twitter conversation and to allow better archiving of our conference discussions. The hashtag for this meeting is #SIAMLA18.

Comments

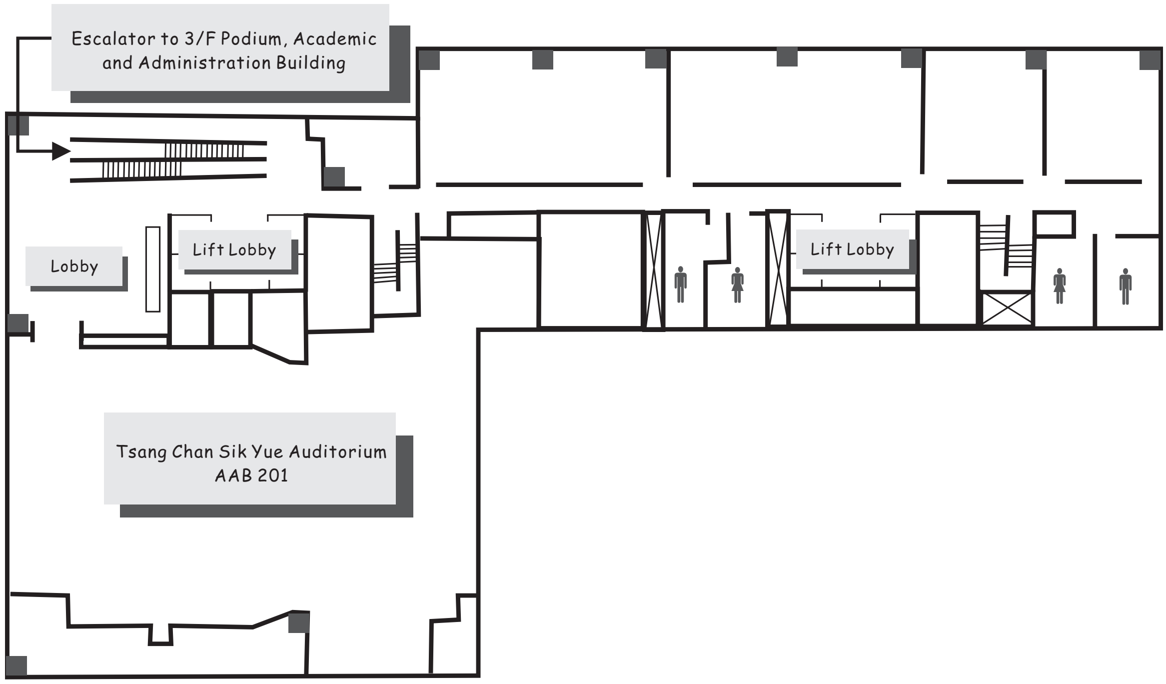
Comments about SIAM LA18 are encouraged! Please send it to Cynthia Phillips, SIAM Vice President for Programs (vpp@siam.org)


HKBU Campus Map
(Kowloon Tong)
N 北
Baptist University Road 浸會大學道
Hereford Road 禧福道
Renfrew Road 聯福道
Junction Road
Waterloo Road
窩打老道
BU Fiesta G/F Student Residence Hall
Coffee Shop
25M, 25M(S)
Bank
Baptist University Road Campus
Biston Bon, G/F NTT
Academic & Administration Building (AAB)
Main Canteen, 5/F AAB
Refrew Cafeteria & Restaurant, 2/F DLB
Shaw Campus
Coffee Shop
Wing Lung Building (WLB)
Lam Woo International Conference Center
BU Bridge 浸大橋
Ho Sin Hang Campus
Luk Fu Shopping Center
To Lok Fu MTR Station
29A,72, 73,85
2B, 2F, 3C, 7, 85, 85A,85B, 103, 208,E22
208
103 208
25M(S)
25M, 29A, 72,73, 85
29A
2B, 2F, 3C, 7, 8 85A,85B, E22
72,73, 85
29A
3C,7,72X,81C, 87D, 103,170,182,270A, 271,281A
72X,80M, 81C, 85, 85A, 85B, 86C, 87D, 170, 182, 270A,271, 281A, 281M
Festival Walk
Kowloon Tong MTR Station Exit B
Pedestrian Entrance
Vehicular Entrance
Meals & Refreshments
Bus Stop
Light Bus Stop

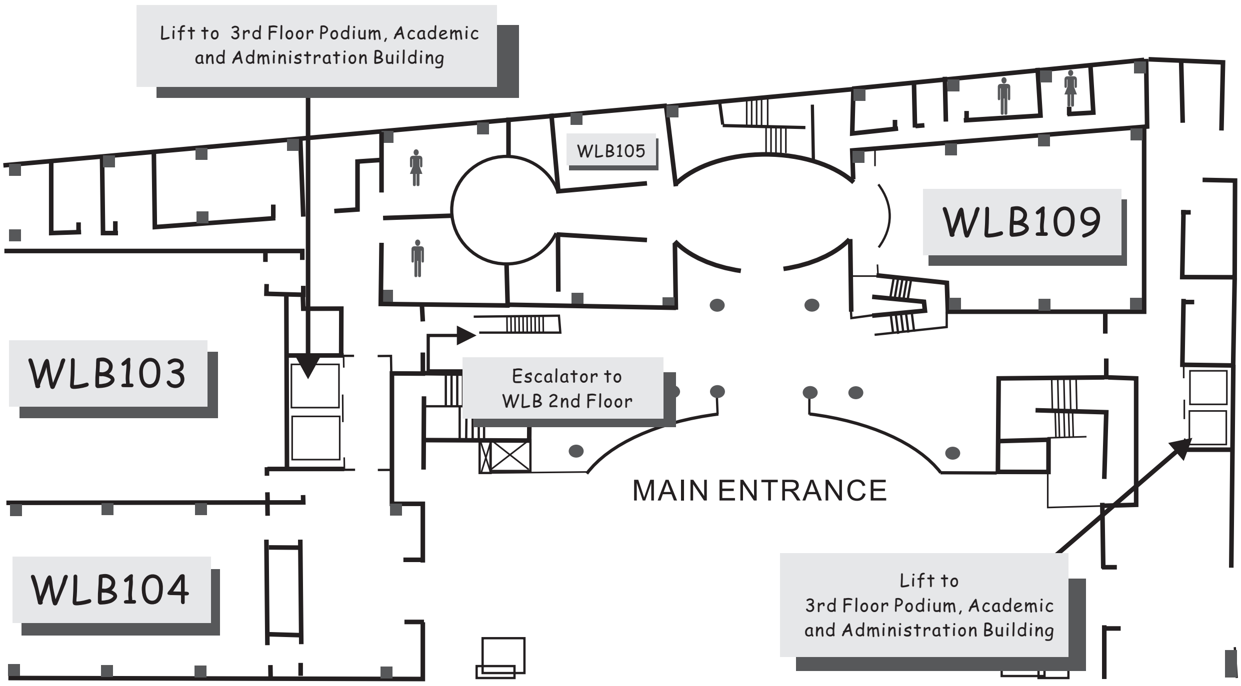
Shaw Campus and Baptist University Road Campus



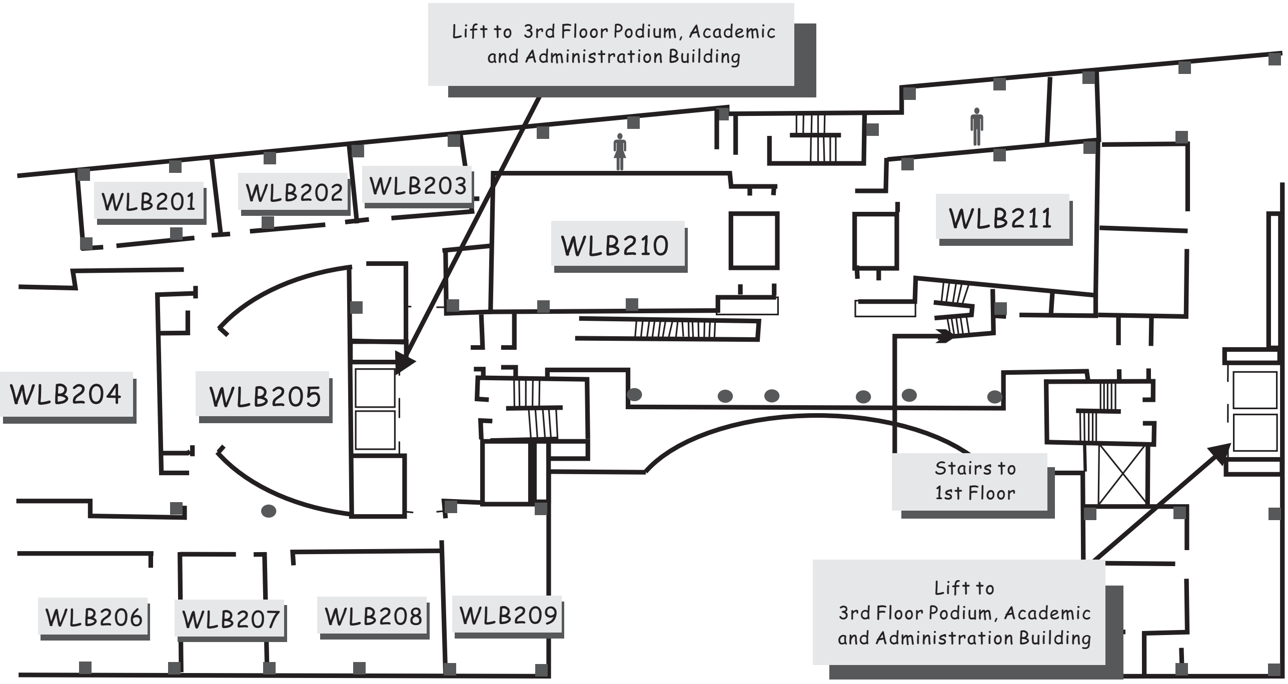
Academic and Administration Building (AAB) 2/F



Lam Woo International Conference Center / Wing Lung Building (WLB) 1/F



Wing Lung Building (WLB) 2/F



Conference Banquet Venue: Palace Wedding Banquet Specialist,
L13, The ONE, 100 Nathan Road, Tsim Sha Tsui

Invited Plenary Speakers

All Invited Plenary Presentations will take place in Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building.

Friday, May 4, 8:45 AM - 9:30 AM

IP1 Convergence Stories of Algebraic Iterative Reconstruction

Per Christian Hansen, Technical University of Denmark

Friday, May 4, 9:30 AM - 10:15 AM

IP2 Matrix Equation Techniques for a Class of PDE Problems with Data Uncertainty

Valeria Simoncini, Università di Bolognà

Friday, May 4, 1:45 PM - 2:30 PM

IP3 Interpolative Decomposition and Its Applications

Lexing Ying, Stanford University

Saturday, May 5, 8:45 AM - 9:30 AM

IP4 Comparative Spectral Decompositions for Personalized Cancer Diagnostics and Prognostics

Orly Alter, University of Utah

Saturday, May 5, 9:30 AM - 10:15 AM

IP5 Theory and Computation of 2D Eigenvalue Problems

Yangfeng Su, Fudan University

Sunday, May 6, 8:45 AM - 9:30 AM

IP6 On the Design of Algebraic Multigrid for High Performance Computers

Ulrike Meier Yang, Lawrence Livermore National Laboratory

Sunday, May 6, 9:30 AM - 10:15 AM

IP7 Nonlinear Eigenvalue Problems: Interpolatory Algorithms and Transient Dynamics

Mark Embree, Virginia Tech

Tuesday, May 8, 8:45 AM - 9:30 AM

IP8 Enlarged Krylov Subspace Methods and Robust Preconditioners

Laura Grigori, INRIA Paris

Tuesday, May 8, 9:30 AM - 10:15 AM

IP9 Null-space Based Block Preconditioners for Saddle-Point Systems

Chen Greif, The University of British Columbia

Tuesday, May 8, 1:45 PM - 2:30 PM

IP10 Fast Algorithms from Low-Rank Updates

Daniel Kressner, École Polytechnique Fédérale de Lausanne

SIAG/Linear Algebra Best Paper Prize[1]

The Prize Lecture will take place in Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building.

Monday, May 7, 8:45 AM - 9:30 AM

Prize Paper: J. Nie: "Generating Polynomials and Symmetric Tensor Decompositions", Foundations of Computational Mathematics 17(2): 423-465 (2017)

presented by

Jiawang Nie, University of California, San Diego

[1]The SIAM Activity Group on Linear Algebra Best Paper Prize (SIAG/LA Best Paper Prize), established in 1987, is awarded to the author(s) of the most outstanding paper, as determined by the prize committee, on a topic in applicable linear algebra published in English in a peer-reviewed journal.

SIAG/Linear Algebra Early Career Prize Lecture[2]

The Prize Lecture will take place in Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building.

Monday, May 7, 9:30 AM - 10:05 AM

The Ultraspherical Spectral Method

Alex Townsend, Cornell University

[2]The SIAM Activity Group on Linear Algebra Early Career Prize, established in 2017, is awarded to one outstanding early career researcher in the field of applicable linear algebra, for distinguished contributions to the field within six (6) years of receiving the PhD or equivalent degree as of January 1 of the year of the award.

MiniTutorial

The minitutorial will take place in Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building.

Sunday, May 6, 10:45 AM - 12:45 PM

Tensor Eigenvectors and Stochastic Processes

A. Benson, Cornell University

D. Gleich, Purdue University

SIAM ALA18 Program

Friday
May 4

Registration

8:00 AM - 11:30 AM
1:30 PM - 3:30 PM

Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

Welcoming Remarks

8:40 AM - 8:45 AM

Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

Friday
May 4

IP1

8:45 AM - 9:30 AM

Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

Chair: David Bindel, Cornell University

Convergence Stories of Algebraic Iterative Reconstruction

Per Christian Hansen, Technical University of Denmark

Kaczmarz's and Cimmino's methods are examples of algebraic iterative reconstruction methods, primarily used to solve discretized inverse problems in computed tomography. They are very flexible because the underlying system $Ax = b$ requires no assumption about the scanning geometry, and it is easy to incorporate convex constraints (e.g., box constraints). Their success in computing regularized solutions is due to a mechanism called semi-convergence.
While the asymptotic convergence for noise-free data is well understood, there are surprising few theoretical results related to the convergence for real-world problems with noisy data and model errors. For the same reason, we lack efficient and robust stopping rules that terminate the iterations at the point of semi-convergence.
In this talk I will survey some recent results related to the convergence and semi-convergence of various algebraic iterative reconstruction methods, both (block) row and (block) column versions, and I will illustrate the results with numerical results.

Friday
May 4

IP2

9:30 AM - 10:15 AM

Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

Chair: David Bindel, Cornell University

Matrix Equation Techniques for a Class of PDE Problems with Data Uncertainty

Valeria Simoncini, Universita di Bolognà

Linear matrix equations arise in an amazingly growing number of applications. Classically, they have been extensively encountered in Control theory and eigenvalue problems. More recently they have been shown to provide a natural platform in the discretization of certain partial differential equations (PDEs), both in the deterministic setting, and in the presence of uncertainty in the data.
We first review some numerical techniques for solving various classes of large scale linear matrix equations commonly occurring in applications. Then we focus on recent developments in the solution of (systems of) linear matrix equations associated with the numerical treatment of various stochastic PDE problems.

Coffee Break

10:15 AM - 10:45 AM

3/F Podium, Academic and Administration Building

Friday May 4

MS01
Advances in High-Performance Sparse Matrix Computation
10:45 AM - 12:45 PM
`WLB204`

This minisymposium will focus on advances in the solution of sparse systems of linear equations. We will consider both recent work in direct methods and iterative methods, with an emphasis on performance and scalability on current and future computer architectures. We will also discuss the roles of such solvers in the solution of large-scale scientific problems.

Organizers:
Mathias Jacquelin, Computational Research Division, Lawrence Berkeley National Laboratory, Berkeley, California, `mjacquelin@lbl.gov`
Esmond Ng, Computational Research Division, Lawrence Berkeley National Laboratory, Berkeley, California, `egng@lbl.gov`

10:45-11:15 Towards Highly Scalable Asynchronous Sparse Solvers for Symmetric Matrices
Esmond Ng, Lawrence Berkeley National Laboratory

11:15-11:45 Fine-Grained Parallel Incomplete LU Factorization
Edmond Chow, Georgia Institute of Technology

11:45-12:15 Approximate Sparse Matrix Factorization Using Low-Rank Compression
Pieter Ghysels, Lawrence Berkeley National Laboratory

12:15-12:45 Hiding Latencies and Avoid Communications in Krylov Solvers
Siegfried Cools, University of Antwerp

Friday May 4

MS05
Coupled Matrix and Tensor Decompositions: Theory and Methods
10:45 AM - 12:15 PM
`WLB205`

Matrices and higher-order arrays, also known as tensors, are natural structures for data representation, and their factorizations in low-rank terms are fundamental tools in data analysis. In recent years, there has been increasing interest in more elaborate data structures and coupled decompositions that provide more efficient ways to exploit the various types of diversity and structure in a single dataset or in an ensemble of possibly heterogeneous linked datasets. Such data arise in multidimensional harmonic retrieval, biomedical signal processing, and social network analysis, to name a few. However, understanding these new types of decompositions necessitates the development of new analytical and computational tools. In this minisymposium, we present several different frameworks that provide new insights into some of these types of coupled matrix and tensor decompositions. We show how the concept of irreducibility, borrowed from representation theory, is related to the uniqueness of coupled decompositions in low-rank terms, as well as to coupled Sylvester-type matrix equations. We compare the gain that can be achieved from computing coupled CP decompositions of tensors in a semi-algebraic framework, in several scenarios. Finally, we study connections between different tensorization approaches that are based on decoupling multivariate polynomials.
We discuss advantages and drawbacks of these approaches, as well as their potential applications.

Organizer:
Dana Lahat, GIPSA-Lab, Grenoble, `Dana.Lahat@gipsa-lab.grenoble-inp.fr`

10:45-11:15 Understanding the Uniqueness of Decompositions in Low-Rank Block Terms Using Schur's Lemma on Irreducible Representations
Dana Lahat, GIPSA-LAb, Grenoble

11:15-11:45 Decoupling Multivariate Polynomials: Comparing Different Tensorization Methods
Philippe Dreesen, Vrije Universiteit Brussel

11:45-12:15 Coupled and Uncoupled Sparse-Bayesian Non-Negative Matrix Factorization for Integrated Analyses in Genomics
Elana J. Fertig, Johns Hopkins University

Friday May 4

MS10 Part I

Generalized Inverses and the Linear Least Squares

10:45 AM - 12:45 PM

WLB104

Within this minisymposium we will consider some actual problems of the generalized inverses, generalized invertibility of operators, representations of the Drazin inverse, least squares problem, and computing generalized inverses using gradient neural networks and using database stored procedures. We will develop the relationship between generalized inverses and the linear least squares problem with applications in signal processing.

Organizers:
Dragana Cvetkovic Ilic, Facuty of Science and Mathematics, University of Nis, dragana@pmf.ni.ac.rs
Ken Hayami, Principles of Informatics Research Division, National Institute of Informatics, hayami@nii.ac.jp
Yimin Wei, School of Mathematical Sciences, Fudan University, ymwei@fudan.edu.cn

10:45-11:15 Recovery of Sparse Integer-Valued Signals
Xiao-Wen Chang, McGill University

11:15-11:45 Computing Time-Varying ML-Weighted Pseudoinverse by the Zhang Neural Networks
Sanzheng Qiao, McMaster University

11:45-12:15 GNN and ZNN Solutions of Linear Matrix Equations
Predrag S. Stanimirović, University of Niš

12:15-12:45 Randomized Algorithms for Total Least Squares Problems
Yimin Wei, Fudan University

Friday May 4

MS15 Part I

Low-Rank and Toeplitz-Related Structures in Applications and Algorithms

10:45 AM - 12:45 PM

WLB109

The mini-symposium is focused on Structured Matrix Analysis, with the special target of shedding light on Low-Rank and Toeplitz-related Structures. On sufficiently regular domains, certain combinations of such matrix objects weighted with proper diagonal sampling matrices are sufficient for describing in a great generality approximation of integro-differential operators with variable coefficient, by means of (virtually) any type of discretization technique (finite elements, finite differences, isogeometric analysis, finite volumes etc). The considered topics and the young age of the speakers are aimed at fostering the contacts between PhD students, postdocs and young researchers, with a balanced choice of talks addressing at improving collaborations between analysis and applied research,showing connections among different methodologies,using the applications as a challenge for the search of more advanced algorithms.

Organizers:
Stefano Serra-Capizzano, University of Insubria and Univeristy of Uppsala, s.serracapizzano@uninsubria.it
Eugene Tyrtyshnikov, Institute of Numerical Mathematics of Russian Academy of Sciences and Lomonosov Moscow State University, eugene.tyrtyshnikov@gmail.com

10:45-11:15 Multilinear and Linear Structures in Theory and Algorithms
Eugene Tyrtyshnikov, Institute of Numerical Mathematics of Russian Academy of Sciences

11:15-11:45 Generalized Locally Toeplitz Sequences: a Link Between Measurable Functions and Spectral Symbols
Giovanni Barbarino, Scuola normale Superiore, Pisa

11:45-12:15 On the Study of Spectral Properties of Matrix Sequences
Stanislav Morozov, Lomonosov Moscow State University

12:15-12:45 Cross Method Accuracy Estimates in Consistent Norms
Alexander Osinsky, Moscow Institute of Physics and Technology

Friday May 4

MS19 Part I

Nonlinear Eigenvalue Problems and Applications

10:45 AM - 12:45 PM

`WLB103`

Eigenvalue problems arise in many fields of science and engineering and their mathematical properties and numerical solution methods for standard, linear eigenvalue problems are well understood. Recent advances in several application areas resulted in a new type of eigenvalue problem—the nonlinear eigenvalue problem, $A(\lambda)x = 0$—which exhibits nonlinearity in the eigenvalue parameter. Moreover, the nonlinear eigenvalue problem received more and more attention from the numerical linear algebra community during the last decade. So far, the majority of the work has been focused on polynomial eigenvalue problems.

In this minisymposium we will address the general nonlinear eigenvalue problem involving nonlinear functions such as exponential, rational, and irrational ones. Recent literature on numerical methods for solving these general nonlinear eigenvalue problems can, roughly speaking, be subdivided into three main classes: Newton-based techniques, Krylov subspace methods applied to linearizations, and contour integration and rational filtering methods. Within this minisymposium we would like to address all three classes used to solve large-scale nonlinear eigenvalue problems in different application areas.

Organizers:
Meiyue Shao, Computational Research Division, Lawrence Berkeley National Laboratory,
`myshao@lbl.gov`
Roel Van Beeumen, Computational Research Division, Lawrence Berkeley National Laboratory,
`rvanbeeumen@lbl.gov`

10:45-11:15 Handling Square Roots in Nonlinear Eigenvalue Problems
Roel Van Beeumen, Lawrence Berkeley National Laboratory

11:15-11:45 Solving Nonlinear Eigenvalue Problems Using Contour Integration
Simon Telen, KU Leuven, University of Leuven

11:45-12:15 Automatic Rational Approximation and Linearization for Nonlinear Eigenvalue Problems
Karl Meerbergen, KU Leuven, University of Leuven

12:15-12:45 Robust Rayleigh Quotient Optimization and Nonlinear Eigenvalue Problems
Ding Lu, University of Geneva

Friday May 4

MS41 Part I

The Spectrum of Hypergraphs via Tensors

10:45 AM - 12:45 PM

`WLB210`

Many graph problems have been successfully solved with linear methods by employing the associated matrices for graphs. As generalized from graphs, hypergraphs are now studied through their representations by tensors, an extended concept of matrices. This minisymposium mainly focuses on recent results related to the spectrum of uniform hypergraphs via tensors, some relevent algorithms and their possible applications in the study of hypernetworks.

Organizer:
Xiying Yuan, Department of Mathematics, Shanghai University,
`xiyingyuan2007@hotmail.com`

10:45-11:15 On the Analytic Connectivity of Uniform Hypergraphs
Changjiang Bu, Harbin Engineering University

11:15-11:45 Some Recent Results on the Tensor Spectrum of Hypergraphs
An Chang, Fuzhou University

11:45-12:15 The Spectral Symmetry and Stabilizing Property of Tensors and Hypergraphs
Yizheng Fan, Anhui University

12:15-12:45 Sharp Upper and Lower Bounds for the Spectral Radius of a Nonnegative Weakly Irreducible Tensor and Its Application
Lihua You, School of Mathematical Sciences, South China Normal University

Friday May 4

CS01

Contributed Session 01
10:45 AM - 12:15 PM
WLB206

10:45-11:15 Choi-Davis-Jensen Type Inequalities Without Convexity
Jadranka Mićić Hot, University of Zagreb

11:15-11:45 Contractive Maps on Operator Ideals and Norm Inequalities III
Ancha Aggarwal, Sant Longowal Institute of Engineering and Technology

11:45-12:15 Contractive Maps on Operator Ideals and Norm Inequalities
Yogesh Kapil, Sant Longowal Institute of Engineering and Technology

Friday May 4

CS02

Contributed Session 02
10:45 AM - 12:15 PM
WLB208

10:45-11:15 Positivity Properties of Some Non-Negative Matrices
Isha Garg, National Institute of Technology, Jalandhar

11:15-11:45 Upper and Lower Bounds for Sines of Canonical Angles
Zoran Tomljanovic, J. J. Strossmayer University of Osijek

11:45-12:15 Spectral Decomposition of Selfadjoint Matrices in Positive Semi-Definite Inner Product Spaces and Its Applications
Pingping Zhang, Chongqing University of Posts and Telecommunications

Friday May 4

CS03

Contributed Session 03
10:45 AM - 12:45 PM
WLB211

10:45-11:15 Eigenvalues of Lévy Covariation Matrices
Gregory Zitelli, University of California, Irvine

11:15-11:45 An Inverse Eigenvalue Problem for Lower Hessenberg Matrices with Prescribed Entries
Kanae Akaiwa, Kyoto Sangyo University

11:45-12:15 Exploiting the Structure of the Bethe-Salpeter Eigenvalue Problem
Carolin Penke, Max-Planck-Institute for Dynamics of Complex Technical Systems

12:15-12:45 FEAST Algorithm for Self Adjoint Eigenvalue Problems
Luka Grubišić, University of Zagreb

Lunch Break

12:45 PM - 1:45 PM

Friday May 4

IP3

1:45 PM - 2:30 PM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Zlatko Drmač, University of Zagreb

Interpolative Decomposition and Its Applications

Lexing Ying, Stanford University

Interpolative decomposition is a simple and yet powerful tool for approximating low-rank matrices. After discussing the theory and algorithm, we will present a few new applications of interpolative decomposition in numerical linear algebra, partial differential equations, quantum chemistry, and machine learning.

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Coffee Break

2:30 PM - 3:00 PM

`3/F Podium, Academic and Administration Building`

Friday May 4

MS02

Advances in Preconditioning and Iterative Methods

3:00 PM - 5:00 PM

`WLB204`

As mathematical models become increasingly complex, efficiently solving large sparse linear systems remains a key concern in many applications. Iterative solvers are often the method of choice, in which case effective preconditioners are usually required. In this minisymposium, speakers will present recent advances in iterative methods and preconditioners.

Organizers:
Jennifer Pestana, Department of Mathematics and Statistics, University of Strathclyde, Glasgow, `jennifer.pestana@strath.ac.uk`
Alison Ramage, Department of Mathematics and Statistics, University of Strathclyde, Glasgow, `a.ramage@strath.ac.uk`

3:00-3:30 Conjugate Gradient for Nonsingular Saddle-Point Systems with a Highly Singular Leading Block
Michael Wathen, University of British Columbia

3:30-4:00 Symmetrizing Nonsymmetric Toeplitz Matrices in Fractional Diffusion Problems
Jennifer Pestana, University of Strathclyde

4:00-4:30 Commutator Based Preconditioning for Incompressible Two-Phase Flow
Niall Bootland, University of Oxford

4:30-5:00 The Efficient Solution of Linear Algebra Subproblems Arising in Optimization Methods
Tyrone Rees, Rutherford Appleton Laboratory

Friday May 4

MS10 Part II

Generalized Inverses and the Linear Least Squares

3:00 PM - 4:30 PM

`WLB104`

Within this minisymposium we will consider some actual problems of the generalized inverses, generalized invertibility of operators, representations of the Drazin inverse, least squares problem, and computing generalized inverses using gradient neural networks and using database stored procedures. We will develop the relationship between generalized inverses and the linear least squares problem with applications in signal processing.

Organizers:
Dragana Cvetkovic Ilic, Facuty of Science and Mathematics, University of Nis, `dragana@pmf.ni.ac.rs`
Ken Hayami, Principles of Informatics Research Division, National Institute of Informatics, `hayami@nii.ac.jp`
Yimin Wei, School of Mathematical Sciences, Fudan University, `ymwei@fudan.edu.cn`

3:00-3:30 Randomized Algorithms for Core Problem and TLS Problem
Liping Zhang, Zhejiang University of Technology

3:30-4:00 Condition Numbers of the Multidimensional Total Least Squares Problem
Bing Zheng, Lanzhou University

4:00-4:30 Fast Solution of Nonnegative Matrix Factorization via a Matrix-Based Active Set Method
Ning Zheng, National Institute of Informatics

Friday May 4

MS13

Large-Scale Matrix and Tensor Optimization

3:00 PM - 5:00 PM

WLB205

Matrix and tensor optimization problems naturally arise from applications that involve two-dimensional or multi-dimensional array data, such as social network analysis, neuroimaging, Netflix recommendation system, and so on. Unfolding the matrix and tensor variable and/or data into a vector may lose the intrinsic structure. Hence it is significant to keep the matrix and tensor format. This minisymposium includes talks about recently proposed models and algorithms with complexity analysis for large-scale matrix and tensor optimization.

Organizer:
Yangyang Xu, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, xuy21@rpi.edu

3:00-3:30 Greedy Method for Orthogonal Tensor Decomposition
Yangyang Xu, Rensselaer Polytechnic Institute

3:30-4:00 SDPNAL+: a MATLAB Software Package for Large-Scale SDPs with a User-Friendly Interface
Defeng Sun, Hong Kong Polytechnic University

4:00-4:30 Vector Transport-Free SVRG with General Retraction for Riemannian Optimization: Complexity Analysis and Practical Implementation
Bo Jiang, Nanjing Normal University

4:30-5:00 On Decompositions and Approximations of Conjugate Partial-Symmetric Complex Tensors
Bo Jiang, Shanghai University of Finance and Economics

Friday May 4

MS15 Part II

Low-Rank and Toeplitz-Related Structures in Applications and Algorithms

3:00 PM - 5:00 PM

WLB109

The mini-symposium is focused on Structured Matrix Analysis, with the special target of shedding light on Low-Rank and Toeplitz-related Structures. On sufficiently regular domains, certain combinations of such matrix objects weighted with proper diagonal sampling matrices are sufficient for describing in a great generality approximation of integro-differential operators with variable coefficient, by means of (virtually) any type of discretization technique (finite elements, finite differences, isogeometric analysis, finite volumes etc). The considered topics and the young age of the speakers are aimed at fostering the contacts between PhD students, postdocs and young researchers, with a balanced choice of talks addressing at improving collaborations between analysis and applied research,showing connections among different methodologies,using the applications as a challenge for the search of more advanced algorithms.

Organizers:
Stefano Serra-Capizzano, University of Insubria and University of Uppsala,
s.serracapizzano@uninsubria.it
Eugene Tyrtyshnikov, Institute of Numerical Mathematics of Russian Academy of Sciences and Lomonosov Moscow State University,
eugene.tyrtyshnikov@gmail.com

3:00-3:30 Spectral and Convergence Analysis of the Discrete Adaptive Local Iterative Filtering Method by Means of Generalized Locally Toeplitz Sequences
Antonio Cicone, INDAM and L'Aquila University

3:30-4:00 Asymptotic Expansion and Extrapolation Methods for the Fast Computation of the Spectrum of Large Structured Matrices
Sven-Erik Ekstrom, Uppsala University

4:00-4:30 Isogeometric Analysis for 2D and 3D Curl-Div Problems: Spectral Symbols and Fast Iterative Solvers
Hendrik Speleers, University of Rome "Tor Vergata"

4:30-5:00 Rissanen-Like Algorithm for Block Hankel Matrices in Linear Storage
Ivan Timokhin, Lomonosov Moscow State University

Friday May 4

MS19 Part II

Nonlinear Eigenvalue Problems and Applications

3:00 PM - 5:00 PM

`WLB103`

Eigenvalue problems arise in many fields of science and engineering and their mathematical properties and numerical solution methods for standard, linear eigenvalue problems are well understood. Recent advances in several application areas resulted in a new type of eigenvalue problem—the nonlinear eigenvalue problem, $A(\lambda)x = 0$—which exhibits nonlinearity in the eigenvalue parameter. Moreover, the nonlinear eigenvalue problem received more and more attention from the numerical linear algebra community during the last decade. So far, the majority of the work has been focused on polynomial eigenvalue problems.
In this minisymposium we will address the general nonlinear eigenvalue problem involving nonlinear functions such as exponential, rational, and irrational ones. Recent literature on numerical methods for solving these general nonlinear eigenvalue problems can, roughly speaking, be subdivided into three main classes: Newton-based techniques, Krylov subspace methods applied to linearizations, and contour integration and rational filtering methods. Within this minisymposium we would like to address all three classes used to solve large-scale nonlinear eigenvalue problems in different application areas.

Organizers:
Meiyue Shao, Computational Research Division, Lawrence Berkeley National Laboratory,
`myshao@lbl.gov`
Roel Van Beeumen, Computational Research Division, Lawrence Berkeley National Laboratory,
`rvanbeeumen@lbl.gov`

3:00-3:30 Conquering Algebraic Nonlinearity in Nonlinear Eigenvalue Problems
Meiyue Shao, Lawrence Berkeley National Laboratory

3:30-4:00 Solving Different Rational Eigenvalue Problems via Different Types of Linearizations
Froilán M. Dopico, Universidad Carlos III de Madrid

4:00-4:30 NEP-PACK a Julia Package for Nonlinear Eigenvalue Problems
Emil Ringh, KTH Stockholm

4:30-5:00 A Pade Approximate Linearization for Solving Nonlinear Eigenvalue Problems in Accelerator Cavity Design
Zhaojun Bai, University of California, Davis

Friday May 4

MS41 Part II

The Spectrum of Hypergraphs via Tensors

3:00 PM - 5:00 PM

`WLB210`

Many graph problems have been successfully solved with linear methods by employing the associated matrices for graphs. As generalized from graphs, hypergraphs are now studied through their representations by tensors, an extended concept of matrices. This minisymposium mainly focuses on recent results related to the spectrum of uniform hypergraphs via tensors, some relevent algorithms and their possible applications in the study of hypernetworks.

Organizer:
Xiying Yuan, Department of Mathematics, Shanghai University,
`xiyingyuan2007@hotmail.com`

3:00-3:30 Some Results on Spectrum of Graphs
Mei Lu, Tsinghua University

3:30-4:00 Spectral Radius of $\{0,1\}$-Tensor with Prescribed Number of Ones
Linyuan Lu, University of South Carolina

4:00-4:30 Some Results in Spectral (Hyper)Graph Theory
Xiaodong Zhang, Shanghai Jiaotong University

4:30-5:00 On Distance Laplacian Spectral Radius of Graphs
Bo Zhou, South China Normal University

Friday May 4

CS04
Contributed Session 04
3:00 PM - 5:00 PM
WLB211

3:00-3:30 Log-determinant Non-Negative Matrix Factorization via Successive Trace Approximation
Andersen Ang, Université de Mons

3:30-4:00 Optimization Methods on Problems with Generalized Orthogonality Constraints
Hong Zhu, Jiangsu University

4:00-4:30 A Low-Rank Approach to the Solution of Weak Constraint Variational Data Assimilation Problems
Daniel L.H. Green, University of Bath

4:30-5:00 Computing the Inverse and Pseudoinverse of Time-Varying Matrices by the Discretization of Continuous-Time ZNN Models
Marko D. Petković, University of Niš

Friday May 4

CS05
Contributed Session 05
3:00 PM - 5:00 PM
WLB206

3:00-3:30 GMRES in the ℓ^∞-Norm
Roland Herzog, Technische Universität Chemnitz

3:30-4:00 Smoothed Variants of Hybrid Bi-CG Methods for Solving Large Sparse Linear Systems
Kensuke Aihara, Tokyo City University

4:00-4:30 Stabilizing GMRES Using the Normal Equation Approach for Severely Ill-Conditioned Problems
Zeyu Liao, Sokendai

4:30-5:00 Numerical Stability of s-step Enlarged Conjugate Gradient Methods
Sophie Moufawad, American University of Beirut (AUB)

Friday May 4

SIAG/LA Business Meeting
5:15 PM - 6:00 PM

WLB103

Welcoming Reception
6:00 PM - 8:00 PM

Renfrew Restaurant, 2/F, David C Lam Building

Saturday May 5

Registration

8:30 AM - 11:30 AM
1:30 PM - 3:30 PM

`Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building`

Saturday May 5

IP4

8:45 AM - 9:30 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Raymond Chan, The Chinese University of Hong Kong

Comparative Spectral Decompositions for Personalized Cancer Diagnostics and Prognostics

Orly Alter, University of Utah

I will describe the development of novel, multi-tensor generalizations of the singular value decomposition, and their use in the comparisons of brain, lung, ovarian, and uterine cancer and normal genomes, to uncover patterns of DNA copy-number alterations that predict survival and response to treatment, statistically better than, and independent of, the best indicators in clinical use and existing laboratory tests. Recurring alterations have been recognized as a hallmark of cancer for over a century, and observed in these cancers' genomes for decades; however, copy-number subtypes predictive of patients' outcomes were not identified before. The data had been publicly available, but the patterns remained unknown until the data were modeled by using the multi-tensor decompositions, illustrating the universal ability of these decompositions — generalizations of the frameworks that underlie the theoretical description of the physical world — to find what other methods miss.

Saturday May 5

IP5

9:30 AM - 10:15 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Raymond Chan, The Chinese University of Hong Kong

Theory and Computation of 2D Eigenvalue Problems

Yangfeng Su, Fudan University

The 2D eigenvalue problem (2dEVP) is a class of the double eigenvalue problems first studied by Blum and Chang in 1970s. The 2dEVP seeks scalars λ, μ, and a corresponding vector x satisfying the following equations

$$\begin{aligned} Ax &= \lambda x + \mu C x, \\ x^H C x &= 0, \\ x^H x &= 1, \end{aligned}$$

where A and C are Hermitian and C is indefinite. We show the connections between 2dEVP with well-known numerical linear algebra and optimization problems such as quadratic programming, the distance to instability and H_∞-norm. We will discuss (1) fundamental properties of 2dEVP including well-posedness, types and regularity, (2) perturbation theory and (3) numerical algorithms with backward error analysis.

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Coffee Break

10:15 AM - 10:45 AM

`3/F Podium, Academic and Administration Building`

Saturday May 5

MS03

Asynchronous Iterative Methods in Numerical Linear Algebra and Optimization

10:45 AM - 12:45 PM

`WLB210`

In asynchronous iterative methods, a processing unit that normally depends on the data computed by other processing units is allowed to proceed even if not all these other processing units have completed their computations. Originally called Chaotic Relaxation for fixed-point iterations, asynchronous iterative methods have also now been developed for numerical optimization. In this minisymposium, recent research is presented both on the theory and implementation of asynchronous iterative methods.

Organizers:
Hartwig Anzt, Karlsruhe Institute of Technology, Karlsruhe, `Hartwig.Anzt@kit.edu`
Edmond Chow, School of Computational Science and Engineering, Georgia Institute of Technology, `echow@cc.gatech.edu`
Daniel B. Szyld, Department of Mathematics, Temple University, `szyld@temple.edu`

10:45-11:15 Arock: Asynchronous Parallel Coordinate Updates
Ming Yan, Michigan State University

11:15-11:45 Asynchronous Domain Decomposition Solvers
Christian Glusa, Sandia National Laboratories

11:45-12:15 Asynchronous Linear System Solvers on Supercomputers
Teodor Nikolov, University of Wuppertal and The Cyprus Institute

12:15-12:45 Asynchronous Optimized Schwarz Methods for Poisson's Equation in Rectangular Domains
José Garay, Temple University

Saturday May 5

MS06 Part I

Discovery from Data

10:45 AM - 12:45 PM

`AAB201`

The number of large-scale high-dimensional datasets recording different aspects of interrelated phenomena is growing, accompanied by a need for mathematical frameworks for discovery from data arranged in structures more complex than that of a single matrix. In the three sessions of this minisymposium we will present recent studies demonstrating "Discovery from Data," in "I: Systems Biology," and "II: Personalized Medicine," by developing and using the mathematics of "III: Tensors."

Organizers:
Sri Priya Ponnapalli, Scientific Computing and Imaging Institute, University of Utah, `priya@sci.utah.edu`
Katherine A. Aiello, Scientific Computing and Imaging Institute, University of Utah, `kaiello@sci.utah.edu`
Theodore E. Schomay, Scientific Computing and Imaging Institute, University of Utah, `tschomay@sci.utah.edu`
Orly Alter, Scientific Computing and Imaging Institute, University of Utah, `orly@sci.utah.edu`

10:45-11:15 Patterns of DNA Copy-Number Alterations Revealed by the GSVD and Tensor GSVD Encode for Cell Transformation and Predict Survival and Response to Platinum in Adenocarcinomas
Sri Priya Ponnapalli, University of Utah

11:15-11:45 Systems Biology of Drug Resistance in Cancer
Antti Hakkinen, University of Helsinki

11:45-12:15 Single-Cell Entropy for Estimating Differentiation Potency in Waddington's Epigenetic Landscape
Andrew E. Teschendorff, Shanghai CAS-MPG Computational Biology Institute and University College London

12:15-12:45 Dimension Reduction for the Integrative Analysis of Multilevel Omics Data
Gerhard G. Thallinger, Graz University of Technology

Saturday May 5

MS07 Part I
Domain Decomposition Methods for Heterogeneous and Large-Scale Problems
10:45 AM - 12:45 PM
WLB103

Many applications involve the solutions of coupled heterogeneous systems,and the resulting discretizations give huge linear or nonlinear systems of equations, which are in general expensive to compute. One popular and efficient approach is the domain decomposition method. While the method is successful for many problems, there are still many challenges in the application of the domain decomposition method for heterogeneous and multiscale problems. In this mini-symposium, we will review some recent advances in the use of domain decomposition and related methods to solve complex heterogeneous and large-scale problems.

Organizers:
Eric Chung, Department of Mathematics, The Chinese University of Hong Kong, tschung@math.cuhk.edu.hk
Hyea Hyun Kim, Department of Applied Mathematics, Kyung Hee University, hhkim@khu.ac.kr

10:45-11:15 Fast Solvers for Multiscale Problems: Overlapping Domain Decomposition Methods
Hyea Hyun Kim, Kyung Hee University

11:15-11:45 A Parallel Non-Iterative Domain Decomposition Method for Image Denoising
Xiao-Chuan Cai, University of Colorado, Boulder

11:45-12:15 Robust BDDC and FETI-DP Methods in PETSc
Stefano Zampini, King Abdullah University of Science and Technology

12:15-12:45 Goal-Oriented Adaptivity for a Class of Multiscale High Contrast Flow Problems
Sai-Mang Pun, Chinese University of Hong Kong

Saturday May 5

MS12 Part I
Large-Scale Eigenvalue Problems and Applications
10:45 AM - 12:45 PM
WLB104

Eigenvalue problem is the essential part and the computationally intensive part in many applications in a variety of areas, including, electron structure calculation, dynamic systems, machine learning, etc. In all these areas, efficient algorithms for solving large-scale eigenvalue problems are demanding. Recently many novel scalable eigensolvers were developed to meet this demand. The choice of an eigensolver highly depends on the properties and structure of the application. This minisymposium invites eigensolver developers to discuss the applicability and performance of their new solvers. The ultimate goal is to assist computational specialists with the proper choice of eigensolvers for their applications.

Organizers:
Haizhao Yang, Department of Mathematics, National University of Singapore, matyh@nus.edu.sg
Yingzhou Li, Department of Mathematics, Duke University, yingzhou.li@duke.edu

10:45-11:15 An $O(N^3)$ Scaling Algorithm to Calculate $O(N)$ Excited States Based on PP-RPA
Haizhao Yang, National University of Singapore

11:15-11:45 The ELSI Infrastructure for Large-Scale Electronic Structure Theory
Volker Blum, Duke University

11:45-12:15 Recent Progress on Solving Large-Scale Eigenvalue Problems in Electronic Structure Calculations
Chao Yang, Lawrence Berkeley National Laboratory

12:15-12:45 The Full Configuration Interaction Quantum Monte Carlo(FCIQMC) in the Lens of Inexact Power Iteration

Zhe Wang, Duke University

Saturday May 5

MS18 Part I
Matrix Optimization and Applications
10:45 AM - 12:45 PM
`WLB109`

In this session, we focus on optimization problems with matrix variables, including semidefinite programming problems, low rank matrix completion / decomposition problems, and orthogonal constrained optimization problems, etc. These problems arise in various applications such as bio-informatics, data analysis, image processing and materials science, and are also abundant in combinatorial optimization.

Organizers:
Xin Liu, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, `liuxin@lsec.cc.ac.cn`
Ting Kei Pong, Department of Applied Mathematics, Hong Kong Polytechnic University, `tk.pong@polyu.edu.hk`

10:45-11:15 Faster Riemannian Optimization Using Randomized Preconditioning
Haim Avron, Department of Applied Mathematics, Tel Aviv University

11:15-11:45 Smoothing Proximal Gradient Method for Nonsmooth Convex Regression with Cardinality Penalty
Wei Bian, Department of Mathematics, Harbin Institute of Technology

11:45-12:15 Implementation of an ADMM-Type First-Order Method for Convex Composite Conic Programming
Liang Chen, Department of Applied Mathematics, Hong Kong Polytechnic University

12:15-12:45 Relationship Between Three Sparse Optimization Problems for Multivariate Regression
Xiaojun Chen, Department of Applied Mathematics, Hong Kong Polytechnic University

Saturday May 5

MS22 Part I
Numerical Methods for Ground and Excited State Electronic Structure Calculations
10:45 AM - 12:45 PM
`WLB204`

Electronic structure theory and first principle calculations are among the most challenging and computationally demanding science and engineering problems. At their core, many of the methods used require the development of efficient and specialized linear algebraic techniques. This minisymposium aims to discuss new developments in the linear algebraic tools, numerical methods, and mathematical analysis used to achieve high levels of accuracy and efficiency in electronic structure theory. We bring together experts on electronic structure theory representing a broad set of computational approaches used in the field.

Organizers:
Anil Damle, Department of Computer Science, Cornell University, `damle@cornell.edu`
Lin Lin, Department of Mathematics, University of California, Berkeley, `linlin@math.berkeley.edu`
Chao Yang, Computational Research Division, Lawrence Berkeley National Laboratory, `cyang@lbl.gov`

10:45-11:15 A Unified Approach to Wannier Interpolation
Anil Damle, Cornell University

11:15-11:45 Potentialities of Wavelet Formalism Towards a Reduction of the Complexity of Large Scale Electronic Structure Calculations
Luigi Genovese, University of Grenoble

11:45-12:15 Convergence Analysis for the EDIIS Algorithm
Tim Kelley, North Carolina State University

12:15-12:45 A Semi-Smooth Newton Method for Solving Semidefinite Programs in Electronic Structure

Calculations
Zaiwen Wen, Beijing International Center for Mathematical Research, Peking University

Saturday May 5

MS35 Part I

Some Recent Applications of Krylov Subspace Methods
10:45 AM - 12:45 PM
`WLB205`

Krylov subspace methods are generally accepted as one of the most efficient methodsfor solving large sparse linear system of equations and eigenvalue problems. Traditionally, many famous Krylov subspace methods such as PCG, MINRES, GMRES, etc. for linear system of equations, and Lanczos and Arnoldi methods (also their variants) for eigenvalue problems, have been developed, and have been successfully solving numerous crucially important problems in science and engineering. One of recent trends of the Krylov subspace method is to extend its power to solve other important real-world applications. Along this line, we propose this mini-symposium by carefully choosing the following talks on some recent/new applications of Krylov subspace methods. These talks cover the applications of Krylov methods on optimization, tensor analysis, data mining, linear systems, eigenvalue problems, and preconditioning. Through this mini-symposium, we hope to reveal the power of Krylov subspace methods in solving these applications, and stimulate other more important developments.

Organizers:
Yunfeng Cai, School of Mathematical Sciences, Peking University,
`yfcai@math.pku.edu.cn`
Lei-Hong Zhang, School of Mathematics, Shanghai University of Finance and Economics,
`zhang.leihong@mail.shufe.edu.cn`

10:45-11:15 Preconditioning for Accurate Solutions of Linear Systems and Eigenvalue Problems
Qiang Ye, University of Kentucky

11:15-11:45 A Block Term Decomposition of High Order Tensors
Yunfeng Cai, Peking University

11:45-12:15 A Fast Implementation on the Exponential Marginal Fisher Analysis for High Dimensionality Reduction
Gang Wu, China University of Mining and Technology

12:15-12:45 Deflated Block Krylov Subspace Methods for Large Scale Eigenvalue Problems
Qiang Niu, Xi'an Jiaotong-Liverpool University

Saturday
May 5

CS06
Contributed Session 06
10:45 AM - 12:45 PM
WLB208

10:45-11:15 Computing the CPD of Unbalanced Tensors by Homotopy Method
Tsung-Lin Lee, National Sun Yat-sen University

11:15-11:45 A New Perron-Frobenius Theorem for Nonnegative Tensors
Francesco Tudisco, University of Strathclyde, Glasgow

11:45-12:15 A Modified Newton Iteration for Finding Nonnegative Z-Eigenpairs of a Nonnegative Tensor
Chun-Hua Guo, University of Regina

12:15-12:45 Algebraic Approach to Generalized Tensor Inversion
Predrag S. Stanimirović, University of Niš

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Lunch Break
12:45 PM - 1:45 PM

Saturday
May 5

MS07 Part II
Domain Decomposition Methods for Heterogeneous and Large-Scale Problems
1:45 PM - 3:45 PM
WLB103

Many applications involve the solutions of coupled heterogeneous systems, and the resulting discretizations give huge linear or nonlinear systems of equations, which are in general expensive to compute. One popular and efficient approach is the domain decomposition method. While the method is successful for many problems, there are still many challenges in the application of the domain decomposition method for heterogeneous and multiscale problems. In this mini-symposium, we will review some recent advances in the use of domain decomposition and related methods to solve complex heterogeneous and large-scale problems.

Organizers:
Eric Chung, Department of Mathematics, The Chinese University of Hong Kong, tschung@math.cuhk.edu.hk
Hyea Hyun Kim, Department of Applied Mathematics, Kyung Hee University, hhkim@khu.ac.kr

1:45-2:15 A Parareal Algorithm for Coupled Systems Arising from Optimal Control Problems
Felix Kwok, Hong Kong Baptist University

2:15-2:45 Convergence of Adaptive Weak Galerkin Finite Element Methods
Liuqiang Zhong, South China Normal University

2:45-3:15 A Nonoverlapping DD Method for an Interior Penalty Method
Eun-Hee Park, Kangwon National University

3:15-3:45 A Two-Grid Preconditioner for Flow Simulations in Highly Heterogeneous Media with an Adaptive Coarse Space
Shubin Fu, The Chinese University of Hong Kong

Saturday May 5

MS12 Part II
Large-Scale Eigenvalue Problems and Applications
1:45 PM - 3:45 PM
WLB104

Eigenvalue problem is the essential part and the computationally intensive part in many applications in a variety of areas, including, electron structure calculation, dynamic systems, machine learning, etc. In all these areas, efficient algorithms for solving large-scale eigenvalue problems are demanding. Recently many novel scalable eigensolvers were developed to meet this demand. The choice of an eigensolver highly depends on the properties and structure of the application. This minisymposium invites eigensolver developers to discuss the applicability and performance of their new solvers. The ultimate goal is to assist computational specialists with the proper choice of eigensolvers for their applications.

Organizers:
Haizhao Yang, Department of Mathematics, National University of Singapore, matyh@nus.edu.sg
Yingzhou Li, Department of Mathematics, Duke University, yingzhou.li@duke.edu

1:45-2:15 A FEAST Algorithm with Oblique Projection for Generalized Eigenvalue Problems
Guojian Yin, Hong Kong University of Science and Technology

2:15-2:45 Real Eigenvalues in Linear Viscoelastic Oscillators
Heinrich Voss, Hamburg University of Technology

2:45-3:15 Error Bounds for Ritz Vectors and Approximate Singular Vectors
Yuji Nakatsukasa, University of Oxford

3:15-3:45 Consistent Symmetric Greedy Coordinate Descent Method
Yingzhou Li, Duke University

Saturday May 5

MS18 Part II
Matrix Optimization and Applications
1:45 PM - 3:45 PM
WLB109

In this session, we focus on optimization problems with matrix variables, including semidefinite programming problems, low rank matrix completion / decomposition problems, and orthogonal constrained optimization problems, etc. These problems arise in various applications such as bio-informatics, data analysis, image processing and materials science, and are also abundant in combinatorial optimization.

Organizers:
Xin Liu, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, liuxin@lsec.cc.ac.cn
Ting Kei Pong, Department of Applied Mathematics, Hong Kong Polytechnic University, tk.pong@polyu.edu.hk

1:45-2:15 Euclidean Distance Embedding for Collaborative Position Localization with NLOS Mitigation
Chao Ding, Academy of Mathematics and Systems Science, Chinese Academy of Sciences

2:15-2:45 An Exact Penalty Method for Semidefinite-Box Constrained Low-Rank Matrix Optimization Problems
Tianxiang Liu, The Hong Kong Polytechnic University

2:45-3:15 A Parallelizable Algorithm for Orthogonally Constrained Optimization Problems
Xin Liu, Academy of Mathematics and Systems Science, Chinese Academy of Sciences

3:15-3:45 A Non-Monotone Alternating Updating Method for a Class of Matrix Factorization Problems
Ting Kei Pong, Department of Applied Mathematics, Hong Kong Polytechnic University

Saturday May 5

MS22 Part II
Numerical Methods for Ground and Excited State Electronic Structure Calculations
1:45 PM - 3:15 PM
WLB204

Electronic structure theory and first principle calculations are among the most challenging and computationally demanding science and engineering problems. At their core, many of the methods used require the development of efficient and specialized linear algebraic techniques. This minisymposium aims to discuss new developments in the linear algebraic tools, numerical methods, and mathematical analysis used to achieve high levels of accuracy and efficiency in electronic structure theory. We bring together experts on electronic structure theory representing a broad set of computational approaches used in the field.

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Lin Lin, Department of Mathematics, University of California, Berkeley, linlin@math.berkeley.edu
Chao Yang, Computational Research Division, Lawrence Berkeley National Laboratory, cyang@lbl.gov

1:45-2:15 Adaptive Compression for Hartree-Fock-Like Equations
Michael Lindsey, University of California, Berkeley

2:15-2:45 Projected Commutator DIIS Method for Linear and Nonlinear Eigenvalue Problems
Lin Lin, University of California, Berkeley

2:45-3:15 Parallel Transport Evolution of Time-Dependent Density Functional Theory
Dong An, University of California, Berkeley

Saturday May 5

MS27 Part I

Preconditioners for Ill-Conditioned Linear Systems in Large Scale Scientific Computing

1:45 PM - 3:45 PM

`WLB201`

The efficient solution to sparse linear systems is quite a common issue in several real world applications and often represents the main memory-and time-consuming task in a computer simulation. In many areas of large scale engineering and scientific computing, the solution to large, sparse and very ill-conditioned systems relies on iterative methods which need appropriate preconditioning to achieve convergence in a reasonable number of iterations. The aim of this minisymposium is to present state-of-the-art scalar and parallel preconditioning techniques with particular focus on

1. block preconditioners for indefinite systems
2. multilevel preconditioners
3. preconditionersfor least-squares problems
4. low-rank updates of preconditioners

Organizers:
Luca Bergamaschi, Massimiliano Ferronato, Carlo Janna, Department of Civil Environmental and Architectural Engineering, University of Padua,
`luca.bergamaschi@unipd.it`,
`massimiliano.ferronato@unipd.it`,
`carlo.janna@unipd.it`

1:45-2:15 Robust AMG Interpolation with Target Vectors for Elasticity Problems
Ruipeng Li, Lawrence Livermore National Laboratory

2:15-2:45 A Multilevel Preconditioner for Data Assimilation with 4D-Var
Alison Ramage, Department of Mathematics and Statistics, University of Strathclyde, Glasgow

2:45-3:15 Algebraic Multigrid: Theory and Practice
James Joseph Brannick, Mathematics Department, Pennsylvania State University

3:15-3:45 Preconditioning for Multi-Physics Problems: A General Framework
Massimiliano Ferronato, Department of Civil Environmental and Architectural Engineering, University of Padua

Saturday May 5

MS33 Part I

Recent Advances in Tensor Based Data Processing

1:45 PM - 3:45 PM

`WLB207`

As a natural representation for high-dimensional data (e.g., hyperspectral images and heterogeneous information network), tensor (i.e. multidimensional array) has recently become ubiquitous in data analytics at the confluence of statistics, image processing and machine learning. The related advances in applied mathematics motivate us to gradually move from classical matrix based methods to tensor based methods for data processing problems, which could offer new tools to exploit the intrinsic multilinear structure. In this inter-disciplinary research field, there are fast emerging works on tensor based theory, models, numerical algorithms, and applications on data processing. This mini-symposium aims at promoting discussions among researchers investigating innovative tensor based approaches to data processing problems in both theoretical and practical aspects.

Organizers:
Chuan Chen, School of Data and Computer Science, Sun Yat-Sen University,
`chenchuan@mail.sysu.edu.cn`
Yi Chang, School of Automation, Huazhong University of Science and Technology, `yichang@hust.edu.cn`
Yao Wang, School of Mathematics and Statistics, Xi'an Jiaotong University, `yao.s.wang@gmail.com`
Xi-Le Zhao, School of Mathematical Sciences, University of Electronic Science and Technology of China,
`xlzhao122003@163.com`

1:45-2:15 Block Term Decomposition for Multilayer Networks Clustering
Zi-Tai Chen, Sun Yat-Sen University

2:15-2:45 Hyperspectral Image Restoration via Tensor-Based Priors: From Low-Rank to Deep Model
Yi Chang, Huazhong University of Science and Technology

2:45-3:15 Compressive Tensor Principal Component Pursuit
Yao Wang, Xi'an Jiaotong University

3:15-3:45 Low-Rank Tensor Completion Using Parallel Matrix Factorization with Factor Priors
Xi-Le Zhao, University of Electronic Science and Technology of China

Saturday May 5

MS35 Part II
Some Recent Applications of Krylov Subspace Methods
1:45 PM - 3:45 PM
WLB205

Krylov subspace methods are generally accepted as one of the most efficient methods for solving large sparse linear system of equations and eigenvalue problems. Traditionally, many famous Krylov subspace methods such as PCG, MINRES, GMRES, etc. for linear system of equations, and Lanczos and Arnoldi methods (also their variants) for eigenvalue problems, have been developed, and have been successfully solving numerous crucially important problems in science and engineering. One of recent trends of the Krylov subspace method is to extend its power to solve other important real-world applications. Along this line, we propose this mini-symposium by carefully choosing the following talks on some recent/new applications of Krylov subspace methods. These talks cover the applications of Krylov methods on optimization, tensor analysis, data mining, linear systems, eigenvalue problems, and preconditioning. Through this mini-symposium, we hope to reveal the power of Krylov subspace methods in solving these applications, and stimulate other more important developments.

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yfcai@math.pku.edu.cn
Lei-Hong Zhang, School of Mathematics, Shanghai University of Finance and Economics,
zhang.leihong@mail.shufe.edu.cn

1:45-2:15 Lanczos Type Methods for the Linear Response Eigenvalue Problem
Zhongming Teng, Fujian Agriculture and Forestry University

2:15-2:45 Sparse Frequent Direction Algorithm for Low Rank Approximation
Delin Chu, National University of Singapore

2:45-3:15 On the Generalized Lanczos Trust-Region Method
Lei-Hong Zhang, Shanghai University of Finance and Economics

3:15-3:45 A Block Lanczos Method for the Extended Trust-Region Subproblems
Weihong Yang, Fudan University

Coffee Break
3:45 PM - 4:15 PM

Lobby of Lam Woo International Conference Centre

Saturday
May 5

MS12 Part III
Large-Scale Eigenvalue Problems and Applications
4:15 PM - 5:15 PM
`WLB104`

Eigenvalue problem is the essential part and the computationally intensive part in many applications in a variety of areas, including, electron structure calculation, dynamic systems, machine learning, etc. In all these areas, efficient algorithms for solving large-scale eigenvalue problems are demanding. Recently many novel scalable eigensolvers were developed to meet this demand. The choice of an eigensolver highly depends on the properties and structure of the application. This minisymposium invites eigensolver developers to discuss the applicability and performance of their new solvers. The ultimate goal is to assist computational specialists with the proper choice of eigensolvers for their applications.

Organizers:
Haizhao Yang, Department of Mathematics, National University of Singapore, `matyh@nus.edu.sg`
Yingzhou Li, Department of Mathematics, Duke University, `yingzhou.li@duke.edu`

4:15-4:45 On the Accuracy of Fast Structured Eigenvalue Solutions
Jimmy Vogel, Purdue University

4:45-5:15 Generation of Large Sparse Test Matrices to Aid the Development of Large-Scale Eigensolvers
Peter Tang, Intel

Saturday
May 5

MS18 Part III
Matrix Optimization and Applications
4:15 PM - 5:45 PM
`WLB109`

In this session, we focus on optimization problems with matrix variables, including semidefinite programming problems, low rank matrix completion / decomposition problems, and orthogonal constrained optimization problems, etc. These problems arise in various applications such as bio-informatics, data analysis, image processing and materials science, and are also abundant in combinatorial optimization.

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Ting Kei Pong, Department of Applied Mathematics, Hong Kong Polytechnic University, `tk.pong@polyu.edu.hk`

4:15-4:45 Quadratic Optimization with Orthogonality Constraint: Explicit Lojasiewicz Exponent and Linear Convergence of Retraction-Based Line-Search and Stochastic Variance-Reduced Gradient Methods
Anthony Man-Cho So, Department of Systems Engineering and Engineering Management, Chinese University of Hong Kong

4:45-5:15 Algebraic Properties for Eigenvalue Optimization
Yangfeng Su, School of Mathematical Sciences, Fudan University

5:15-5:45 Local Geometry of Matrix Completion
Ruoyu Sun, Department of Industrial and Enterprise Systems Engineering, University of Illinois at Urbana-Champaign

Saturday
May 5

MS20
Nonlinear Perron-Frobenius Theory and Applications
4:15 PM - 6:15 PM
`WLB103`

Nonlinear Perron-Frobenius theory addresses problems such as existence, uniqueness and maximality of positive eigenpairs of different types of nonlinear and order-preserving mappings.In recent years tools from this theory have been successfully exploited to address problems arising from a range of diverse applications and various areas, such as graph and hypergraph analysis, machine learning, signal processing, optimization and spectral problems for nonnegative tensors. This minisymposium sample some recent contributions in this field, covering advances in both the theory and the applications of Perron-Frobenius theory for nonlinear mappings.

Organizers:
Antoine Gautier, Department of Mathematics and Computer Science, Saarland University, `antoine.gautier@uni-saarland.de`
Francesco Tudisco, Department of Mathematics and Statistics, University of Strathclyde, Glasgow, `f.tudisco@strath.ac.uk`

4:15-4:45 Nonlinear Perron-Frobenius Theorem and Applications to Nonconvex Global Optimization
Antoine Gautier, Saarland University

4:45-5:15 Node and Layer Eigenvector Centralities for Multiplex Networks
Francesca Arrigo, University of Strathclyde

5:15-5:45 Inequalities for the Spectral Radius and Spectral Norm of Nonnegative Tensors
Shmuel Friedland, University of Illinois at Chicago

5:45-6:15 Some Results on the Spectral Theory of Hypergraphs
Jiang Zhou, Harbin Engineering University

Saturday May 5

MS26
Preconditioners for Fractional Partial Differential Equations and Applications
4:15 PM - 6:15 PM
`WLB204`

Fractional partial differential equations (FDEs) are a strongly emerging tool every day more present in models in many applicative fields where, e.g.,nonlocal dynamics and anomalous diffusion are present such as in viscoelastic and polymeric materials, in control theory, economy, etc.
In this minisymposium proposal we plan to give a short but quite illustrative overview of the potentialities and of the related convergence theory for some ah-hoc innovative preconditioning techniques for the iterative solution of the large (but full!) linear systems generated by the discretization of the underlying FDE models. The numerical solution of the underlying linear systems is an important research area as such equations pose substantial challenges to existing algorithms.

Organizer:
Daniele Bertaccini, Dipartimento di Matematica, Università di Roma Tor Vergata,
`bertaccini@mat.uniroma2.it`

4:15-4:45 Limited Memory Block Preconditioners for Fast Solution of Time-Dependent Fractional PDEs
Fabio Durastante, Università dell'Insubria

4:45-5:15 Spectral Analysis and Multigrid Preconditioners for Space-Fractional Diffusion Equations
Maria Rosa Mazza, Max-Planck Institute for Plasma Physics

5:15-5:45 Fast Tensor Solvers for Optimization Problems with FDE-Constraints
Martin Stoll, Max-Planck Institutefor Dynamics of Complex Technical Systems

5:45-6:15 Preconditioner for Fractional Diffusion Equations with Piecewise Continuous Coefficients
Hai-wei Sun, University of Macau

Saturday May 5

MS27 Part II
Preconditioners for Ill-Conditioned Linear Systems in Large Scale Scientific Computing
4:15 PM - 5:45 PM
`WLB201`

The efficient solution to sparse linear systems is quite a common issue in several real world applications and often represents the main memory-and time-consuming task in a computer simulation. In many areas of large scale engineering and scientific computing, the solution to large, sparse and very ill-conditioned systems relies on iterative methods which need appropriate preconditioning to achieve convergence in a reasonable number of iterations. The aim of this minisymposium is to present state-of-the-art scalar and parallel preconditioning techniques with particular focus on
1. block preconditioners for indefinite systems
2. multilevel preconditioners
3. preconditionersfor least-squares problems
4. low-rank updates of preconditioners

Organizers:
Luca Bergamaschi, Massimiliano Ferronato, Carlo Janna, Department of Civil Environmental and Architectural Engineering, University of Padua,
`luca.bergamaschi@unipd.it`, `massimiliano.ferronato@unipd.it`, `carlo.janna@unipd.it`

4:15-4:45 Preconditioners for Inexact-Newton Methods Based on Compactrepresentation of Broyden Class Updates
J. Marín, Polytechinc University of Valencia

4:45-5:15 Preconditioning for Time-Dependent PDE-Constrained Optimization
John Pearson, School of Mathematics, The University of Edinburgh

5:15-5:45 Spectral Preconditioners for Sequences of

Ill-Conditioned Linear Systems
Luca Bergamaschi, Department of Civil Environmental and Architectural Engineering, University of Padua

Saturday May 5

MS33 Part II

Recent Advances in Tensor Based Data Processing
4:15 PM - 6:15 PM
WLB207

As a natural representation for high-dimensional data (e.g., hyperspectral images and heterogeneous information network), tensor (i.e. multidimensional array) has recently become ubiquitous in data analytics at the confluence of statistics, image processing and machine learning. The related advances in applied mathematics motivate us to gradually move from classical matrix based methods to tensor based methods for data processing problems, which could offer new tools to exploit the intrinsic multilinear structure. In this inter-disciplinary research field, there are fast emerging works on tensor based theory, models, numerical algorithms, and applications on data processing. This mini-symposium aims at promoting discussions among researchers investigating innovative tensor based approaches to data processing problems in both theoretical and practical aspects.

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Yi Chang, School of Automation, Huazhong University of Science and Technology, yichang@hust.edu.cn
Yao Wang, School of Mathematics and Statistics, Xi'an Jiaotong University, yao.s.wang@gmail.com
Xi-Le Zhao, School of Mathematical Sciences, University of Electronic Science and Technology of China, xlzhao122003@163.com

4:15-4:45 Data Mining with Tensor Based Methods
Xu-Tao Li, Harbin Institute of Technology

4:45-5:15 Low-Rank Tensor Analysis with Noise Modeling
Zhi Han, Shenyang Institute of Automation, Chinese Academy of Sciences

5:15-5:45 Hyperspectral and Multispectral Image Fusion via Total Variation Regularized Nonlocal Tensor Train Decomposition
Kai-Dong Wang, School of Mathematics and Statistics, Xi'an Jiaotong University

5:45-6:15 A Novel Tensor-Based Video Rain Streaks Removal Approach via Utilizing Discriminatively Intrinsic Priors
Liang-Jian Deng, School of Mathematical Sciences, University of Electronic Science and Technology of China

Saturday May 5

MS35 Part III

Some Recent Applications of Krylov Subspace Methods
4:15 PM - 6:15 PM
`WLB205`

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Lei-Hong Zhang, School of Mathematics, Shanghai University of Finance and Economics, `zhang.leihong@mail.shufe.edu.cn`

4:15-4:45 Parametrized Quasi-Soft Thresholding Operator for Compressed Sensing and Matrix Completion
An-Bao Xu, Wenzhou University

4:45-5:15 Two-Level RAS Preconditioners of Krylov Subspace Methods for Large Sparse Linear Systems
Xin Lu, China University of Petroleum - Beijing

Sunday May 6

Registration

9:30 AM - 11:30 AM
1:30 PM - 3:30 PM

`Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building`

Sunday May 6

IP6

8:45 AM - 9:30 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Chao Yang, Lawrence Berkeley National Laboratory

On the Design of Algebraic Multigrid for High Performance Computers

Ulrike Meier Yang, Lawrence Livermore National Laboratory

Algebraic multigrid (AMG) is an efficient solver for large-scale scientific computing and an essential component of many simulation codes. However, with single-core speeds plateauing, future increases in computing performance have to rely on more complicated, often heterogenous computer architectures, which provide new challenges for efficient implementations of AMG. How one views the linear system, e.g. in terms of structured grids and stencils, or a traditional matrix-vector system, can significantly affect the design and performance of AMG. Structured AMG can take advantage of additional information in the structured matrix data structures, potentially leading to more efficient implementations but is confined to structured problems, whereas unstructured AMG can be applied to more general problems. We will discuss these methods, their implementation and performance and introduce a new semi-structured multigrid method that can take advantage of the structured parts of a problem, but is capable to solve more general problems.

Sunday May 6

IP7

9:30 AM - 10:15 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Chao Yang, Lawrence Berkeley National Laboratory

Nonlinear Eigenvalue Problems: Interpolatory Algorithms and Transient Dynamics

Mark Embree, Virginia Tech

Nonlinear eigenvalue problems pose intriguing challenges for analysis and computation. For starters, a finite-dimensional problem can give infinitely many eigenvalues, quantities that reveal the asymptotic behavior of associated dynamical systems. Delay differential equations provide an especially rich source of such problems. We describe several approaches for approximating solutions to nonlinear eigenvalue problems, based on ideas originally deployed for model-order reduction: a data-driven (Loewner) rational interpolation technique, and a structure-preserving interpolatory projection method. While eigenvalues describe asymptotic dynamics, the behavior of systems on transient time scales can be more subtle. We will describe how careful use of pseudospectra can give insight about the transient behavior of solutions to delay differential equations. This talk describes collaborative work with Michael Brennan, Alex Grimm, and Serkan Gugercin.

Coffee Break

10:15 AM - 10:45 AM

`3/F Podium, Academic and Administration Building`

Sunday May 6

Mini-Tutorial

10:45 AM - 12:45 PM

`AAB201`

Tensor Eigenvectors and Stochastic Processes

A. Benson, Cornell University and D. Gleich, Purdue University

The current generation of tensor analysis and computations has been a significant success story for studying datasets now routinely collected in diverse scientific disciplines such as signal processing, biology, and social networks. In this tutorial, the presenters will cover recent innovations and relationships between tensor eigenvectors and stochastic processes that present a challenging new set of computational motivations, generalizations, and trade-offs. Much of the ALA community is familiar with the close relationships between Markov chainsa simple type of stochastic processand matrix computations. For instance, stationary distributions of Markov chains can be formulated as the solution to a matrix eigenvector problem. By the end of this mini-tutorial, we will have “gone up” a dimension and surveyed relationships between tensors, higher-order Markov chains, and various types of tensor eigenvectors, as well as their applications in data analysis. To this end, the tutorial will involve new types of stochastic processes including vertex-reinforced random walks and spacey random walks. This line of research area has raised several possibilities for future research, and this tutorial will place a specific emphasis on providing well-defined open problems.

Sunday May 6

MS16
Machine Learning: Theory and Practice
10:45 AM - 12:45 PM
WLB204

Machine learning is experiencing a period of rising impact on many areas of the sciences and engineering such as imaging, advertising, genetics, robotics, and speech recognition. On the other hand, it has deep roots in various aspects in mathematics, from optimization, approximation theory, to statistics, etc. This mini-symposium aims to bring together researchers in different aspects of machine learning for discussions on the state-of-the-art developments in theory and practice. The mini-symposium has a total of four talks, which are about fast algorithms solving linear inequalities, genetic data analysis, theory and practice of deep learning.

Organizers:
Haixia Liu, Department of Mathematics, The Hong Kong University of Science and Technology, mahxliu@ust.hk
Yuan Yao, Department of Mathematics, The Hong Kong University of Science and Technology, yuany@ust.hk

10:45-11:15 Approximation of Inconsistent Systems of Linear Inequalities: Fast Solvers and Applications
Mila Nikolova, CMLA, CNRS, ENS Cachan, University Paris-Saclay

11:15-11:45 Theory of Distributed Learning
Ding-Xuan Zhou, City University of Hong Kong

11:45-12:15 Scattering Transform for the Analysis and Classification of Art Images
Roberto Leonarduzzi, Lab de Physique, Ecole Normale Superieure de Lyon, CNRS

12:15-12:45 TBA
Can Yang, The Hong Kong University of Science and Technology

Sunday May 6

MS24
Parallel Sparse Triangular Solve on Emerging Platforms
10:45 AM - 12:45 PM
WLB205

Sparse triangular solve (SpTRSV) is an important building block in a number of numerical linear algebra routines such as sparse direct solvers and preconditioned sparse iterative solvers. Compared to dense triangular solve and other sparse basic linear algebra subprograms, SpTRSV is more difficult to parallelize since it is inherently sequential. The set-based methods (i.e., level-set and color-set) brought parallelism but also demonstrated high costs for preprocessing and runtime synchronization. In this proposed minisymposium, we will discuss current challenges and novel algorithms for SpTRSV on shared memory processors with homogeneous architectures (such as GPU and Xeon Phi) and with heterogeneous architectures (such as Sunway and APU), and distributed memory clusters. The objective of this minisymposium is to explore and discuss how emerging parallel platforms can help next-generation SpTRSV algorithm design.

Organizers:
Weifeng Liu, Department of Computer Science, Norwegian University of Science and Technology, weifeng.liu@ntnu.no
Wei Xue, Department of Computer Science and Technology, Tsinghua University, xuewei@tsinghua.edu.cn

10:45-11:15 Scalability Analysis of Sparse Triangular Solve
Weifeng Liu, Norwegian University of Science and Technology

11:15-11:45 Solving sparse triangular systems in GPUs: what are the options and how do I choose the right one?
Ernesto Dufrechou, Universidad de la República

11:45-12:15 Refactoring Sparse Triangular Solve on Sunway Taihulight Many-Core Supercomputer
Wei Xue, Tsinghua University

12:15-12:45 Enhancing Scalability of Parallel Sparse Triangular Solve in SuperLU
Yang Liu, Lawrence Berkeley National Laboratory

Sunday May 6

MS28
Preconditioning for PDE Constrained Optimization
10:45 AM - 12:45 PM
`WLB211`

The field of PDE-constrained optimization provides a gateway to the study of many real-world processes from science and industry.As these problems typically lead to huge-scale matrix systems upon discretization, it is therefore crucial to develop fast and efficient numerical solvers tailored specifically to the application at hand.Significant progress has been made in recent years, and research is now shifting to more challenging problems, e.g., obtaining parameter robust iterations and solving coupled multi-physics systems.In this minisymposium we wish to draw upon state-of-the-art preconditioners to accelerate the convergence of iterative methods when applied to such problems.Speakers in this session will also provide an outlook to future challenges in the field.

Organizers:
Roland Herzog, Faculty of Mathematics, Technische Universität Chemnitz, `roland.herzog@mathematik.tu-chemnitz.de`
John Pearson, School of Mathematics, University of Edinburgh, `j.pearson@ed.ac.uk`

10:45-11:15 Preconditioners for PDE Constrained Optimization Problems with Coarse Distributed Observations
Kent-Andre Mardal, University of Oslo and Simula Research Laboratory

11:15-11:45 Preconditioning for Multiple Saddle Point Problems
Walter Zulehner, Johannes Kepler University Linz

11:45-12:15 New Poisson-Like Preconditioners for Fast and Memory-Efficient PDE-Constrained Optimization
Lasse Hjuler Christiansen, Technical University of Denmark

12:15-12:45 Preconditioning for Time-Dependent PDEs and PDE Control
Andrew Wathen, University of Oxford

Sunday May 6

MS32 Part I
Recent Advances in Linear Algebra for Uncertainty Quantification
10:45 AM - 12:45 PM
`WLB210`

The aim of this mini-symposium is to present recent development of advanced linear algebra techniques for uncertainty quantification including, but are not limited to, preconditioning techniques and multigrid methods for stochastic partial differential equations, multi-fidelity methods in uncertainty quantification, hierarchical matrices and low-rank tensor approximations, compressive sensing and sparse approximations, model reduction methods for PDEs with stochastic and/or multiscale features, random matrix models, etc.

Organizers:
Zhiwen Zhang, Department of Mathematics, The University of Hong Kong, `zhangzw@hku.hk`
Bin Zheng, Pacific Northwest National Laboratory, `bin.zheng@pnnl.gov`

10:45-11:15 Asymptotic Analysis and Numerical Method for Singularly Perturbed Eigenvalue Problems
Zhongyi Huang, Tsinghua University

11:15-11:45 An Adaptive Reduced Basis ANOVA Method for High-Dimensional Bayesian Inverse Problems
Qifeng Liao, Shanghai Tech University

11:45-12:15 Randomized Kaczmarz Method for Linear Inverse Problems
Yuling Jiao, Zhongnan University of Economics and Law

12:15-12:45 TBA
Ju Ming, Huazhong University of Science and Technology

Sunday May 6

MS36 Part I

Tensor Analysis, Computation, and Applications I
10:45 AM - 12:45 PM
`WLB103`

The term *tensor* has both meanings of a geometric object and a multi-way array. Applications of tensors include various disciplines in science and engineering, such as mechanics, quantum information, signal and image processing, optimization, numerical PDE, and hypergraph theory. There are several hot research topics on tensors, such as tensor decomposition and low-rank approximation, tensor spectral theory, tensor completion, tensor-related systems of equations, and tensor complementarity problems. Researchers in all these mentioned areas will give presentations to broaden our perspective on tensor research. This is one of a series minisymposia and focuses more on applications of tensors and structured tensors.

Organizer:
Weiyang Ding, Department of Mathematics, Hong Kong Baptist University, `wyding@hkbu.edu.hk`

10:45-11:15 Irreducible Function Bases of Isotropic Invariants of Third and Fourth Order Symmetric Tensors
Liqun Qi, The Hong Kong Polytechnic University

11:15-11:45 The Rank of $W \otimes W$ is Eight
Shmuel Friedland, University of Illinois at Chicago

11:45-12:15 Optimization Methods Using Matrix and Tensor Structures
Eugene Tyrtyshnikov, Russian Academy of Sciences

12:15-12:45 Exploitation of Structure in Large-Scale Tensor Decompositions
Lieven De Lathauwer, KU Leuven

Sunday May 6

MS40 Part I

The Perturbation Theory and Structure-Preserving Algorithms
10:45 AM - 12:45 PM
`WLB104`

The perturbation theory provides reliability and stability analysis of scientific systems and algorithms, and has been one of the most important topics in numerical analysis. Recently, the perturbation theory has been involved in various fields, including the nonlinear eigenvalue/eigenvector problem, the generalized least square problem, the tensor analysis, the random methods for big data analysis, etc. For example, one crucial subject is to analyze the backward and forward errors of the eigenvector-dependent eigenvalue problem from solving the discrete Kohn-Sham equations. With a rigorous selection, we propose this mini-symposium containing eight presentations on the recent development of the perturbation theory and related works. These presentations include the forward and backward errors of the nonlinear eigenvectors, the random perturbation intervals of symmetric eigenvalue problem, the statistical condition estimation, and the structure-preserving algorithms. The final aim of this mini-symposium is to reveal the new tools in the perturbation theory, and put forward the research of the new methods and subjects in this important field.

Organizers:
Zheng-Jian Bai, School of Mathematical Sciences, Xiamen University, `zjbai@xmu.edu.cn`
Tiexiang Li, School of Mathematics, South China University, `txli@seu.edu.cn`
Hanyu Li, College of Mathematics and Statistics, Chongqing University, `hyli@cqu.edu.cn`
Zhi-Gang Jia, School of Mathematics and Statistics, Jiangsu Normal University, `zhgjia@jsnu.edu.cn`

10:45-11:15 Perturbation Analysis of an Eigenvector-Dependent Nonlinear Eigenvalue Problem with Applications
Zhigang Jia, Jiangsu Normal University

11:15-11:45 Improved Random Perturbation Intervals of Symmetric Eigenvalue Problem
Hanyu Li, Chongqing University

11:45-12:15 Error Bounds for Approximate Deflating Subspaces of Linear Response Eigenvalue Problems
Wei-Guo Wang, Ocean University of China

12:15-12:45 Relative Perturbation Bounds for Eigenpairs of the Diagonalizable Matrices
Yanmei Chen, South China Normal University

Sunday May 6

CS07

Contributed Session 07
10:45 AM - 12:45 PM
`WLB109`

10:45-11:15 Spectral Clustering of Signed Graphs
Andrew Knyazev, Mitsubishi Electric Research Laboratories (MERL)

11:15-11:45 Density of States for Spectral Graph Analysis
Kun Dong, Cornell University

11:45-12:15 Resistance Characterizations of Resistance Distance Equivalence Graphs
Lizhu Sun, Harbin Engineering University

12:15-12:45 Numerical Analysis of Dynamic Centrality
Philip A. Knight, University of Strathclyde

Sunday May 6

CS08

Contributed Session 08
10:45 AM - 12:45 PM
`WLB206`

10:45-11:15 Implicit Hari–Zimmermann Method for the GEVD
Sanja Singer, University of Zagreb

11:15-11:45 Extended Generalized Fiedler Pencils for Matrix Polynomials and the Recovery of Eigenvectors and Minimal Bases
Ranjan Kumar Das, Indian Institute of Technology Guwahati

11:45-12:15 Vector Spaces of g-Linearizations for Rectangular Matrix Polynomials
Biswajit Das, Indian Institute of Technology Guwahati

12:15-12:45 Minimum Rank Problem for the Regular Class of (0,1)-Matrices
Chao Ma, Shanghai Maritime University

Lunch Break

12:45 PM - 1:45 PM

Sunday May 6

MS06 Part II

Discovery from Data
1:45 PM - 3:45 PM
`AAB201`

The number of large-scale high-dimensional datasets recording different aspects of interrelated phenomena is growing, accompanied by a need for mathematical frameworks for discovery from data arranged in structures more complex than that of a single matrix. In the three sessions of this minisymposium we will present recent studies demonstrating "Discovery from Data," in "I: Systems Biology," and "II: Personalized Medicine," by developing and using the mathematics of "III: Tensors."

Organizers:
Sri Priya Ponnapalli, Scientific Computing and Imaging Institute, University of Utah, `priya@sci.utah.edu`
Katherine A. Aiello, Scientific Computing and Imaging Institute, University of Utah, `kaiello@sci.utah.edu`
Theodore E. Schomay, Scientific Computing and Imaging Institute, University of Utah, `tschomay@sci.utah.edu`
Orly Alter, Scientific Computing and Imaging Institute, University of Utah, `orly@sci.utah.edu`

1:45-2:15 Mathematically Universal and Biologically Consistent Astrocytoma Genotype Encodes for Transformation and Predicts Survival Phenotype
Katherine A. Aiello, University of Utah

2:15-2:45 Statistical Methods for Integrative Clustering Analysis of Multi-Omics Data
Qianxing Mo, Baylor College of Medicine

2:45-3:15 Structured Convex Optimization Method for Orthogonal Nonnegative Matrix Factorization with Applications to Gene Expression Data
Junjun Pan, Hong Kong Baptist University

3:15-3:45 Mining the ECG Using Low Rank Tensor Approximations with Applications in Cardiac Monitoring
Sabine Van Huffel, KU Leuven

Sunday May 6

MS17 Part I

Matrix Functions and Their Applications

1:45 PM - 3:45 PM
`WLB210`

Matrix functions are an important tool in many areas of scientific computing. They arise in the solution of differential equations, as the exponential, sine, or cosine; in graph and network analysis, as measurements of communicability and betweenness; and in lattice quantum chromodynamics, as the sign of the Dirac overlap operator. They also have many applications in statistics, theoretical physics, control theory, and machine learning.
Methods for computing matrix functions times a vector encompass a variety of numerical linear algebra tools, such as Gauss quadrature, Krylov subspaces, rational and polynomial approximations, and singular value decompositions.
Furthermore, many numerical analysis tools are used for analyzing the convergence and stability of these methods, as well as the condition number of $f(A)$ and decay bounds of its entries.
Given the rapid expansion of the literature on matrix functions in the last few years, this seminar fills an ongoing need to present and discuss state-of-the-art techniques pertaining to matrix functions, their analysis, and applications.

Organizers:
Andreas Frommer, Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, Wuppertal, `frommer@uni-wuppertal.de`
Kathryn Lund, Department of Mathematics, Temple University, `katlund@temple.edu`
Massimiliano Fasi, School of Mathematics, The University of Manchester, `massimiliano.fasi@manchester.ac.uk`

1:45-2:15 A Harmonic Arnoldi Method for Computing the Matrix Function $f(A)v$
Zhongxiao Jia, Tsinghua University

2:15-2:45 A New Framework for Understanding Block Krylov Methods Applied to Matrix Functions
Kathryn Lund, Temple University and Bergische University

2:45-3:15 Bounds for the Decay of the Entries in Inverses and Cauchy-Stieltjes Functions of Certain Sparse Normal Matrices
Claudia Schimmel, University of Wuppertal

3:15-3:45 Matrix Means for Signed and Multi-Layer Graphs Clustering
Pedro Mercado, Saarland University

Sunday May 6

MS30 Part I

Rank Structured Methods for Challenging Numerical Computations

1:45 PM - 3:45 PM

WLB204

Rank-structured methods have demonstrated significant advantages in improving the efficiency and reliability of some large-scale computations and engineering simulations. These methods extend the fundamental ideas of multipole and panel-clustering methods to general non-local solution operators. While there exist various more or less closely related methods, the unifying aim of these methods is to explore efficient structured low-rank approximations, especially those exhibiting hierarchical or nested forms. These help the methods to achieve nearly linear complexity. In this minisymposium, we aim to present and exchange recent new developments on rank structured methods for some challenging numerical problems such as high frequencies, ill conditioning, eigenvalue perturbation, and stability. Studies of structures, algorithm design, and accuracy control will be discussed. The minisymposium will include experts working on a broad range of rank structured methods.

Organizers:
Sabine Le Borne, Institute of Mathematics, Hamburg University of Technology, leborne@tuhh.de
Jianlin Xia, Department of Mathematics, Purdue University, xiaj@math.purdue.edu

1:45-2:15 H-Matrices for Stable Computations in RBF Interpolation Problems
Sabine Le Borne, Hamburg University of Technology

2:15-2:45 How good are H-Matrices at high frequencies?
Timo Betcke, University College London

2:45-3:15 Local Low-Rank Approximation for the High-Frequency Helmholtz Equation
Steffen Boerm, University of Kiel

3:15-3:45 Efficiency and Accuracy of Parallel Accumulator-Based H-Arithmetic
Ronald Kriemann, Max-Planck-Institute for Mathematics in the Sciences, Leipzig

Sunday May 6

MS31 Part I

Rational Krylov Methods and Applications

1:45 PM - 3:45 PM

WLB205

Rational Krylov methods have become an indispensable tool of scientific computing. Invented by Axel Ruhe for the solution of large sparse eigenvalue problems, these methods have seen an increasing number of other applications over the last two decades or so. Applications of rational Krylov methods are connected with model order reduction, matrix function approximation, matrix equations, nonlinear eigenvalue problems, and nonlinear rational least squares fitting, to name a few. This minisymposium aims to bring together experts to discuss recent progress on theoretical and numerical aspects of these methods as well as novel applications.

Organizers:
Stefan Güttel, School of Mathematics, The University of Manchester, stefan.guettel@manchester.ac.uk
Patrick Kürschner, Computational Methods in Systems and Control Theory, Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg, kuerschner@mpi-magdeburg.mpg.de

1:45-2:15 The Block Rational Arnoldi Algorithm
Steven Elsworth, The University of Manchester

2:15-2:45 Rational Krylov Subspaces for Wavefield Applications
Jörn Zimmerling, TU Delft

2:45-3:15 Krylov Methods for Hermitian Nonlinear Eigenvalue Problems
Giampaolo Mele, KTH Royal Institute of Technology, Stockholm

3:15-3:45 Compressing Variable-Coefficient Helmholtz Problems via RKFIT
Stefan Güttel, The University of Manchester

Sunday May 6

MS34 Part I
Recent Applications of Rank Structures in Matrix Analysis
1:45 PM - 3:45 PM
WLB109

The development of applied science and engineering raised attention on large scale problems, generating an increasing demand of computational effort. In many practical situations, the only way to satisfy this request is to exploit obvious and hidden structures in the data. In this context, rank structures constitute a powerful tool for reaching this goal. Many real-world problems are analyzed by means of algebraic techniques that exploit low-rank structures: fast multipole methods, discretization of PDEs and integral equations, efficient solution of matrix equations, and computation of matrix functions.
The representation and the theoretical analysis of these algebraic objects is of fundamental importance to devise fast algorithms. Several representations have been proposed in the literature: $\mathcal{H}$, $\mathcal{H}^2$, and HSS matrices, quasiseparable and semiseparable structures. The design of fast methods relying on these representations is currently an active branch of numerical linear algebra. The talks in this minisymposium present some recent advances in this field.

Organizers:
Thomas Mach, Department of Mathematics, School of Science and Technology Nazarbayev University, thomas.mach@nu.edu.kz
Stefano Massei, EPF Lausanne, stefano.massei@epfl.ch
Leonardo Robol, ISTI, Area della ricerca CNR, Pisa, leonardo.robol@isti.cnr.it

1:45-2:15 Low Rank Updates and a Divide and Conquer Method for Matrix Equations
Stefano Massei, EPF Lausanne

2:15-2:45 RQZ: A Rational QZ Algorithm for the Generalized Eigenvalue Problem
Daan Camps, KU Leuven - University of Leuven

2:45-3:15 Fast Direct Algorithms for Least Squares and Least Norm Solutions for Hierarchical Matrices
Abhay Gupta, Indian Institute of Science

3:15-3:45 Computing the Inverse Matrix ϕ_1-Function for a Quasiseparable Matrix
Luca Gemignani, Università di Pisa

Sunday May 6

MS36 Part II
Tensor Analysis, Computation, and Applications I
1:45 PM - 3:45 PM
WLB103

The term *tensor* has both meanings of a geometric object and a multi-way array. Applications of tensors include various disciplines in science and engineering, such as mechanics, quantum information, signal and image processing, optimization, numerical PDE, and hypergraph theory. There are several hot research topics on tensors, such as tensor decomposition and low-rank approximation, tensor spectral theory, tensor completion, tensor-related systems of equations, and tensor complementarity problems. Researchers in all these mentioned areas will give presentations to broaden our perspective on tensor research. This is one of a series minisymposia and focuses more on applications of tensors and structured tensors.

Organizer:
Weiyang Ding, Department of Mathematics, Hong Kong Baptist University, wyding@hkbu.edu.hk

1:45-2:15 An Adaptive Correction Approach for Tensor Completion
Minru Bai, Hunan University

2:15-2:45 Generalized Polynomial Complementarity Problems with Structured Tensors
Chen Ling, Hangzhou Dianzi University

2:45-3:15 Copositive Tensor Detection and Its Applications in Physics and Hypergraphs
Haibin Chen, Qufu Normal University

3:15-3:45 The Bound of H-Eigenvalue of Some Structure Tensors with Entries in an Interval
Lubin Cui, Henan Normal University

Sunday May 6

MS40 Part II
The Perturbation Theory and Structure-Preserving Algorithms
1:45 PM - 3:45 PM
WLB104

The perturbation theory provides reliability and stability analysis of scientific systems and algorithms, and has been one of the most important topics in numerical analysis. Recently, the perturbation theory has been involved in various fields, including the nonlinear eigenvalue/eigenvector problem, the generalized least square problem, the tensor analysis, the random methods for big data analysis, etc. For example, one crucial subject is to analyze the backward and forward errors of the eigenvector-dependent eigenvalue problem from solving the discrete Kohn-Sham equations. With a rigorous selection, we propose this mini-symposium containing eight presentations on the recent development of the perturbation theory and related works. These presentations include the forward and backward errors of the nonlinear eigenvectors, the random perturbation intervals of symmetric eigenvalue problem, the statistical condition estimation, and the structure-preserving algorithms. The final aim of this mini-symposium is to reveal the new tools in the perturbation theory, and put forward the research of the new methods and subjects in this important field.

Organizers:
Zheng-Jian Bai, School of Mathematical Sciences, Xiamen University, zjbai@xmu.edu.cn
Tiexiang Li, School of Mathematics, South China University, txli@seu.edu.cn
Hanyu Li, College of Mathematics and Statistics, Chongqing University, hyli@cqu.edu.cn
Zhi-Gang Jia, School of Mathematics and Statistics, Jiangsu Normal University, zhgjia@jsnu.edu.cn

1:45-2:15 Mixed and Componentwise Condition Numbers for a Linear Function of the Solution of the Total Least Squares Problem
Huaian Diao, Northeast Normal University

2:15-2:45 Some Perturbation Results for Joint Block Diagonalization Problems
Decai Shi, Xidian University

2:45-3:15 A Structure-Preserving Γ-Lanczos Algorithm for Bethe-Salpeter Eigenvalue Problems
Tiexiang Li, Southeast University

3:15-3:45 A Structure-Preserving Jacobi Algorithm for Quaternion Hermitian Eigenvalue Problems
Ru-Ru Ma, Xiamen University

Sunday May 6

CS09
Contributed Session 09
1:45 PM - 3:45 PM
WLB211

1:45-2:15 Lowest Complexity, Self Recursive, Radix-2 Discrete Cosine Transform Algorithms
Sirani M. Perera, Embry-Riddle Aeronautical University

2:15-2:45 Solving 2D Fractional Differential Equations Using Rank-Structured Matrix Equations
Leonardo Robol, ISTI-CNR

2:45-3:15 Speeding up Sparse Grid Density Estimation with Matrix Factorizations
Kilian Röhner, Technical University of Munich

3:15-3:45 Recent Advances in the Development of Discrete Empirical Interpolation Method (DEIM)
Zlatko Drmač, University of Zagreb

Coffee Break
3:45 PM - 4:15 PM

Lobby of Lam Woo International Conference Centre

Sunday May 6

MS17 Part II

Matrix Functions and Their Applications
4:15 PM - 6:15 PM
WLB210

Matrix functions are an important tool in many areas of scientific computing. They arise in the solution of differential equations, as the exponential, sine, or cosine; in graph and network analysis, as measurements of communicability and betweenness; and in lattice quantum chromodynamics, as the sign of the Dirac overlap operator. They also have many applications in statistics, theoretical physics, control theory, and machine learning.
Methods for computing matrix functions times a vector encompass a variety of numerical linear algebra tools, such as Gauss quadrature, Krylov subspaces, rational and polynomial approximations, and singular value decompositions.
Furthermore, many numerical analysis tools are used for analyzing the convergence and stability of these methods, as well as the condition number of $f(A)$ and decay bounds of its entries.
Given the rapid expansion of the literature on matrix functions in the last few years, this seminar fills an ongoing need to present and discuss state-of-the-art techniques pertaining to matrix functions, their analysis, and applications.

Organizers:
Andreas Frommer, Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, Wuppertal,
frommer@uni-wuppertal.de
Kathryn Lund, Department of Mathematics, Temple University,
katlund@temple.edu
Massimiliano Fasi, School of Mathematics, The University of Manchester,
massimiliano.fasi@manchester.ac.uk

4:15-4:45 A Daleckii–Krein Formula for the Fréchet Derivative of SVD-Based Matrix Functions
Vanni Noferini, University of Essex

4:45-5:15 Computing Matrix Functions in Arbitrary Precision
Massimiliano Fasi, The University of Manchester

5:15-5:45 Matrix Function Approximation for Computational Bayesian Statistics
Markus Hegland, Mathematical Sciences Institute, The Australian National University

5:45-6:15 Conditioning of the Matrix-Matrix Exponentiation
Joao R. Cardoso, Polytechnic Institute of Coimbra, and Institute of Systems and Robotics–Coimbra

Sunday May 6

MS29

Randomized Algorithms for Factorizing Matrices
4:15 PM - 5:45 PM
WLB211

Methods based on randomized projections have over the last several years proven to provide powerful tools for computing low-rank approximations to matrices. This minisymposium will explore recent research that demonstrates that the underlying ideas can also be used to solve other linear algebraic problems of high importance in applications. Problems addressed include how to compute *full* factorizations of matrices, how to compute matrix factorizations where the factors are required to have non-negative entries, how to compute matrix factorizations under constraints on how matrix entries can be accessed, solving linear systems, and more. The common theme is a focus on high practical efficiency.

Organizer:
Per-Gunnar Martinsson, Mathematical Institute, University of Oxford,
martinsson@maths.ox.ac.uk

4:15-4:45 Randomized Nonnegative Matrix Factorizations
Benjamin Erichson, University of Washington

4:45-5:15 Randomized Algorithms for Computing Full Rank-Revealing Factorizations
Abinand Gopal, University of Oxford

5:15-5:45 A Randomized Blocked Algorithm for Computing a Rank-Revealing UTV Matrix Decomposition
Nathan Heavner, University of Colorado at Boulder

Sunday May 6

MS30 Part II
Rank Structured Methods for Challenging Numerical Computations
4:15 PM - 6:15 PM
WLB204

Rank-structured methods have demonstrated significant advantages in improving the efficiency and reliability of some large-scale computations and engineering simulations. These methods extend the fundamental ideas of multipole and panel-clustering methods to general non-local solution operators. While there exist various more or less closely related methods, the unifying aim of these methods is to explore efficient structured low-rank approximations, especially those exhibiting hierarchical or nested forms. These help the methods to achieve nearly linear complexity. In this minisymposium, we aim to present and exchange recent new developments on rank structured methods for some challenging numerical problems such as high frequencies, ill conditioning, eigenvalue perturbation, and stability. Studies of structures, algorithm design, and accuracy control will be discussed. The minisymposium will include experts working on a broad range of rank structured methods.

Organizers:
Sabine Le Borne, Institute of Mathematics, Hamburg University of Technology, leborne@tuhh.de
Jianlin Xia, Department of Mathematics, Purdue University, xiaj@math.purdue.edu

4:15-4:45 Randomized Techniques for Fast Eigenvalue Solution
Jianlin Xia, Purdue University

4:45-5:15 The Perfect Shift and the Fast Computation of Roots of Polynomials
Nicola Mastronardi, Istituto per le Applicazioni del Calcolo "Mauro Picone"

5:15-5:45 Structured Matrices in Polynomial System Solving
Simon Telen, KU Leuven

5:45-6:15 Preserving Positive Definiteness in HSS Approximation and Its Application in Preconditioning
Xin Xing, Georgia Tech

Sunday May 6

MS31 Part II
Rational Krylov Methods and Applications
4:15 PM - 6:15 PM
WLB205

Rational Krylov methods have become an indispensable tool of scientific computing. Invented by Axel Ruhe for the solution of large sparse eigenvalue problems, these methods have seen an increasing number of other applications over the last two decades or so. Applications of rational Krylov methods are connected with model order reduction, matrix function approximation, matrix equations, nonlinear eigenvalue problems, and nonlinear rational least squares fitting, to name a few. This minisymposium aims to bring together experts to discuss recent progress on theoretical and numerical aspects of these methods as well as novel applications.

Organizers:
Stefan Güttel, School of Mathematics, The University of Manchester, stefan.guettel@manchester.ac.uk
Patrick Kürschner, Computational Methods in Systems and Control Theory, Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg, kuerschner@mpi-magdeburg.mpg.de

4:15-4:45 Rational Krylov Methods in Discrete Inverse Problems
Volker Grimm, Karlsruhe Institute of Technology

4:45-5:15 Inexact Rational Krylov Methods Applied to Lyapunov Equations
Melina Freitag, University of Bath

5:15-5:45 Numerical Methods for Lyapunov Matrix Equations with Banded Symmetric Data
Davide Palitta, Università di Bologna

5:45-6:15 A Comparison of Rational Krylov and Related Low-Rank Methods for Large Riccati Equations
Patrick Kürschner, Max Planck Institute for Dynamics of Complex

Technical Systems, Magdeburg

Sunday May 6

MS34 Part II
Recent Applications of Rank Structures in Matrix Analysis
4:15 PM - 6:15 PM
WLB109

The development of applied science and engineering raised attention on large scale problems, generating an increasing demand of computational effort. In many practical situations, the only way to satisfy this request is to exploit obvious and hidden structures in the data. In this context, rank structures constitute a powerful tool for reaching this goal. Many real-world problems are analyzed by means of algebraic techniques that exploit low-rank structures: fast multipole methods, discretization of PDEs and integral equations, efficient solution of matrix equations, and computation of matrix functions.
The representation and the theoretical analysis of these algebraic objects is of fundamental importance to devise fast algorithms. Several representations have been proposed in the literature: $\mathcal{H}$, $\mathcal{H}^2$, and HSS matrices, quasiseparable and semiseparable structures. The design of fast methods relying on these representations is currently an active branch of numerical linear algebra. The talks in this minisymposium present some recent advances in this field.

Organizers:
Thomas Mach, Department of Mathematics, School of Science and Technology Nazarbayev University, thomas.mach@nu.edu.kz
Stefano Massei, EPF Lausanne, stefano.massei@epfl.ch
Leonardo Robol, ISTI, Area della ricerca CNR, Pisa, leonardo.robol@isti.cnr.it

4:15-4:45 Superfast Direct Solvers for 3D MSN PDE Solvers
Shiv Chandrasekaran, UC Santa Barbara

4:45-5:15 Fast Direct Solvers for Boundary Value Problems on Globally Evolving Geometries
Adrianna Gillman, CAAM, Rice University

5:15-5:45 Matrix Aspects of Fast Multipole Method
Xiaofeng Ou, Department of Mathematics, Purdue University

5:45-6:15 Adaptive Cross Approximation for Ill-Posed Problems
Thomas Mach, Nazarbayev University

Sunday May 6

MS38
Tensor-Based Modelling
4:15 PM - 5:45 PM
WLB103

An important trend is the extension of applied linear algebra to applied multilinear algebra. The developments gradually allow a transition from classical vector and matrix based methods to methods that involve tensors of arbitrary order. Tensor decompositions open up various new avenues beyond the realm of matrix methods. This minisymposium presents tensor decompositions as new modelling tools. A range of applications in signal processing, data analysis, system modelling en computing is discussed.

Organizer:
Lieven De Lathauwer, Dept. of Electrical Engineering, KU Leuven, Lieven.DeLathauwer@kuleuven.be

4:15-4:45 Prewhitening Under Channel-Dependent Signal-to-Noise Ratios
Chuan Chen, Sun Yat-sen University

4:45-5:15 Tensor Decompositions in Reduced Order Models
Youngsoo Choi, Lawrence Livermore National Laboratory

5:15-5:45 Nonlinear System Identification with Tensor Methods
Kim Batselier, The University of Hong Kong

Sunday May 6

MS40 Part III
The Perturbation Theory and Structure-Preserving Algorithms
4:15 PM - 4:45 PM
WLB104

The perturbation theory provides reliability and stability analysis of scientific systems and algorithms, and has been one of the most important topics in numerical analysis. Recently, the perturbation theory has been involved in various fields, including the nonlinear eigenvalue/eigenvector problem, the generalized least square problem, the tensor analysis, the random methods for big data analysis, etc. For example, one crucial subject is to analyze the backward and forward errors of the eigenvector-dependent eigenvalue problem from solving the discrete Kohn-Sham equations. With a rigorous selection, we propose this mini-symposium containing eight presentations on the recent development of the perturbation theory and related works. These presentations include the forward and backward errors of the nonlinear eigenvectors, the random perturbation intervals of symmetric eigenvalue problem, the statistical condition estimation, and the structure-preserving algorithms. The final aim of this mini-symposium is to reveal the new tools in the perturbation theory, and put forward the research of the new methods and subjects in this important field.

Organizers:
Zheng-Jian Bai, School of Mathematical Sciences, Xiamen University, zjbai@xmu.edu.cn
Tiexiang Li, School of Mathematics, South China University, txli@seu.edu.cn
Hanyu Li, College of Mathematics and Statistics, Chongqing University, hyli@cqu.edu.cn
Zhi-Gang Jia, School of Mathematics and Statistics, Jiangsu Normal University, zhgjia@jsnu.edu.cn

4:15-4:45 On the Explicit Expression of Chordal Metric Between Generalized Singular Values of Grassmann Matrix Pairs with Applications
Wei-Wei Xu, Nanjing University of Information Science and Technology

Sunday May 6

CS10

Contributed Session 10
4:15 PM - 6:15 PM
WLB206

4:15-4:45 An Efficient Adaptive Solution Technique for Periodic Stokes' Flow
Yabin Zhang, Rice University

4:45-5:15 Algebraic Analysis for Long-Time Instabilities in Wave Simulations on Non-Conforming Grids
Longfei Gao, KAUST

5:15-5:45 Predicting Frequencies of Interest in Structural Dynamics Problems
Mante Zemaityte, The University of Manchester

5:45-6:15 Linear Rate-Model Simulations in a Spiking Neural Network Simulator
Jan Hahne, University of Wuppertal

Monday May 7

Registration

9:30 AM - 11:30 AM
1:30 PM - 3:30 PM

Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

Monday May 7

SIAG/Linear Algebra Best Paper Prize Lecture

8:45 AM - 9:30 AM
Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building

Chair: James Nagy, Emory University

Generating Polynomials and Symmetric Tensor Decompositions
Jiawang Nie, University of California, San Diego

This talk discusses how to compute symmetric tensor decompositions. There exist linear relations of recursive patterns among symmetric tensor entries. These relations can be represented by polynomials, which we call generating polynomials. The homogenization of a generating polynomial belongs to the apolar ideal. Generally, a symmetric tensor decomposition is uniquely determined by a set of consistent generating polynomials. We give conditions for such a set of polynomials to have a desired number of common zeros. Based on them, a new approach is proposed for computing symmetric tensor decompositions.

Monday May 7

SIAG/Linear Algebra Early Career Prize Lecture

9:30 AM - 10:05 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: James Nagy, Emory University

The Ultraspherical Spectral Method

Alex Townsend, Cornell University

Pseudospectral methods, based on high degree polynomials, have spectral accuracy but lead to dense and ill-conditioned matrices. The ultraspherical spectral method is a numerical technique to solve ordinary and partial differential equations, leading to almost banded well-conditioned linear systems while maintaining spectral accuracy. In this talk, we introduce the ultraspherical spectral method and discuss its applications and future.

Coffee Break

10:05 AM - 10:35 AM

`3/F Podium, Academic and Administration Building`

Monday May 7

MS06 Part III

Discovery from Data

10:35 AM - 12:35 PM

`AAB201`

The number of large-scale high-dimensional datasets recording different aspects of interrelated phenomena is growing, accompanied by a need for mathematical frameworks for discovery from data arranged in structures more complex than that of a single matrix. In the three sessions of this minisymposium we will present recent studies demonstrating "Discovery from Data," in "I: Systems Biology," and "II: Personalized Medicine," by developing and using the mathematics of "III: Tensors."

Organizers:
Sri Priya Ponnapalli, Scientific Computing and Imaging Institute, University of Utah, `priya@sci.utah.edu`
Katherine A. Aiello, Scientific Computing and Imaging Institute, University of Utah, `kaiello@sci.utah.edu`
Theodore E. Schomay, Scientific Computing and Imaging Institute, University of Utah, `tschomay@sci.utah.edu`
Orly Alter, Scientific Computing and Imaging Institute, University of Utah, `orly@sci.utah.edu`

10:35-11:05 Tensor Higher-Order GSVD: A Comparative Spectral Decomposition of Multiple Column-Matched But Row-Independent Large-Scale High-Dimensional Datasets

Theodore E. Schomay, University of Utah

11:05-11:35 The GSVD: Where are the ellipses?

Alan Edelman, Massachusetts Institute of Technology

11:35-12:05 Tensor Convolutional Neural Networks (TCNN): Improved Featurization Using High-Dimensional Frameworks

Elizabeth Newman, Tufts University

12:05-12:35 Three-Way Generalized Canonical Correlation Analysis

Arthur Tenenhaus, CentraleSupélec

Monday May 7

MS09 Part I

Exploiting Low-Complexity Structures in Data Analysis: Theory and Algorithms

10:35 AM - 12:35 PM

WLB104

Low-complexity structures are central to modern data analysis — they are exploited to tame data dimensionality, to rescue ill-posed problems, and to ease and speed up hard numerical computation. In this line, the past decade features remarkable advances in theory and practice of estimating sparse vectors or low-rank matrices from few linear measurements. Looking ahead, there are numerous fundamental problems in data analysis coming with more complex data formation processes. For example, the dictionary learning and the blind deconvolution problems have intrinsic bilinear structures, whereas the phase retrieval problem and variants pertain to quadratic measurements. Moreover, many of these applications can be naturally formulated as nonconvex optimization problems, which are ruled to be hard by the worst-case theory. In practice, however, simple numerical methods are surprisingly effective in solving them. Partial explanation of this curious gap has started to appear very recently.
This minisymposium highlights the intersection between numerical linear algebra/numerical optimization and the mathematics of modern signal processing and data analysis. Novel results on both theoretical and algorithmic sides of exploiting low-complexity structures will be discussed, with an emphasis on addressing the new challenges.

Organizers:
Ju Sun, Department of Mathematics, Stanford University,
sunju@stanford.edu
Ke Wei, School of Data Science, Fudan University,
weike1986@gmail.com

10:35-11:05 When are nonconvex optimization problems not scary?
Ju Sun, Stanford University

11:05-11:35 The Scaling Limit of Online Lasso, Sparse PCA and Related Algorithms
Yue M. Lu, Harvard University

11:35-12:05 Accelerated Alternating Projection for Robust Principle Component Analysis
Jian-Feng Cai, Hong Kong University of Science and Technology

12:05-12:35 Numerical Integrators for Rank-Constrained Differential Equations
Bart Vandereycken, University of Geneva

Monday May 7

MS14 Part I

Low Rank Matrix Approximations with HPC Applications

10:35 AM - 12:35 PM

WLB109

Low-rank matrix approximations have demonstrated attractive theoretical bounds, both in memory footprint and arithmetic complexity. In fact, they have even become numerical methods of choice when designing high performance applications, especially when looking at the forthcoming exascale era, where systems with billions of threads will be routine resources at hand. This minisymposium aims at bringing together experts from the field to assess the software adaptation of low-rank matrix computations into HPC applications.

Organizers:
Hatem Ltaief, Division of Computer, Electrical, and Mathematical Sciences and Engineering, Extreme Computing Research Center, King Abdullah University of Science and Technology,
Hatem.Ltaief@kaust.edu.sa
David Keyes, Division of Computer, Electrical, and Mathematical Sciences and Engineering, Extreme Computing Research Center, King Abdullah University of Science and Technology,
David.Keyes@kaust.edu.sa

10:35-11:05 Fast Low-Rank Solvers for HPC Applications on Massively Parallel Systems
Hatem Ltaief, King Abdullah University of Science and Technology

11:05-11:35 GOFMM: A Geometry-Oblivious Fast Multipole Method for Approximating Arbitrary SPD Matrices
George Biros, University of Texas at Austin

11:35-12:05 A Parallel Implementation of a High Order Accurate Variable Coefficient Helmholtz Solver
Natalie Beams, Rice University

12:05-12:35 Low-Rank Matrix

Approximations for Oil and Gas HPC Applications
Issam Said, NVIDIA

Monday May 7

MS23 Part I
Optimization Methods on Matrix and Tensor Manifolds
10:35 AM - 12:35 PM
`WLB204`

Riemannian optimization methods are a natural extension of Euclidean optimization methods: the search space is generalized from a Euclidean space to a manifold endowed with a Riemannian structure. This allows for many constrained Euclidean optimization problems to be formulated as unconstrained problems on Riemannian manifolds; the geometric structure can be exploited to provide mathematically elegant and computationally efficient solution methods by using tangent spaces as local linearizations.
Many important structures from linear algebra admit a Riemannian manifold structure, such as matrices with mutually orthogonal columns (Stiefel manifold), subspaces of fixed dimension (Grassmann manifold), positive definite matrices, or matrices of fixed rank.
The first session of this minisymposium will present some applications of the Riemannian optimization framework, such as blind deconvolution, computation of the Karcher mean, and low-rank matrix learning. It will also present novel results on subspace methods in Riemannian optimization.
The second session will be centered on the particular class of low-rank tensor manifolds, which make computations with multiway arrays of large dimension feasible and have attracted particular interest in recent research. It will present novel results on second-order methods on tensor manifolds, such as trust-region or quasi-Newton methods. It will also present results on dynamical approximation of tensor differential equations.

Organizers:
Gennadij Heidel, Department of Mathematics, Trier University,
`heidel@uni-trier.de`
Wen Huang, Department of Computational and Applied Mathematics, Rice University,
`wen.huang@rice.edu`

10:35-11:05 Blind Deconvolution by Optimizing Over a Quotient Manifold
Wen Huang, Rice University

11:05-11:35 Riemannian Optimization and the Computation of the Divergences and the Karcher Mean of Symmetric Positive Definite Matrices
Kyle A. Gallivan, Florida State University

11:35-12:05 A Manifold Approach to Structured Low-Rank Matrix Learning
Bamdev Mishra, Amazon.com

12:05-12:35 Subspace Methods in Riemannian Manifold Optimization
Weihong Yang, Fudan University

Monday May 7

MS25 Part I

Polynomial and Rational Matrices
10:35 AM - 12:35 PM
`WLB205`

Polynomial and rational matrices have attracted much attention in the last years. Their appearance in numerous modern applications requires revising and improving known as well as developing new theories and algorithms concerning the associated eigenvalue problems, error and perturbation analyses, efficient numerical implementations, etc. This Mini-Symposium aims to give an overview of the recent research on these topics, focusing on numerical stability of quadratic eigenvalue problem; canonical forms, that reveal transparently the complete eigenstructures; sensitivity of complete eigenstructures to perturbations; low-rank matrix pencils and matrix polinomials; block-tridiagonal linearizations.

Organizers:
Javier Pérez, Department of Mathematical Sciences, University of Montana, `javier.perez-alvaro@mso.umt.edu`
Andrii Dmytryshyn, Department of Computing Science, Umeå University, `andrii@cs.umu.se`

10:35-11:05 Stratifying Complete Eigenstructures: From Matrix Pencils to Polynomials and Back
Bo Kågström, Umeå University

11:05-11:35 Block-Symmetric Linearizations of Odd Degree Matrix Polynomials with Optimal Condition Number and Backward Error
Maria Isabel Bueno, University of California, Santa Barbara

11:35-12:05 Transparent Realizations for Polynomial and Rational Matrices
Steve Mackey, Western Michigan University

12:05-12:35 Generic Eigenstructures of Matrix Polynomials with Bounded Rank and Degree
Andrii Dmytryshyn, Umeå University

Monday May 7

MS37 Part I

Tensor Analysis, Computation, and Applications II
10:35 AM - 12:35 PM
`WLB211`

The term *tensor* has both meanings of a geometric object and a multi-way array. Applications of tensors include various disciplines in science and engineering, such as mechanics, quantum information, signal and image processing, optimization, numerical PDE, and hypergraph theory. There are several hot research topics on tensors, such as tensor decomposition and low-rank approximation, tensor spectral theory, tensor completion, tensor-related systems of equations, and tensor complementarity problems. Researchers in all these mentioned areas will give presentations to broaden our perspective on tensor research. This is one of a series minisymposia and focuses more on tensor analysis and algorithm design.

Organizer:
Shenglong Hu, School of Mathematics, Tianjin University, `timhu@tju.edu.cn`

10:35-11:05 The Fiedler Vector of a Laplacian Tensor for Hypergraph Partitioning
Yannan Chen, The Hong Kong Polytechnic University and Zhengzhou University

11:05-11:35 Solving Tensor Problems via Continuation Methods
Lixing Han, University of Michigan-Flint

11:35-12:05 Local Convergence Rate Analysis for the Higher-Order Power Method in Best Rank One Approximations of Tensors
Guoyin Li, The University of New South Wales

12:05-12:35 Tensor Splitting Methods for Solving the Multi-Linear System
Wen Li, South China Normal University

Monday May 7

CS11

Contributed Session 11
10:35 AM - 12:35 PM
WLB103

10:35-11:05 Preconditioners for the Iterative Solution of Large Linear Least-Squares Problems
Miroslav Tuma, Charles University and the Czech Academy of Sciences

11:05-11:35 Polynomial Preconditioners Based on GMRES for Solving Multi-Shifted Linear Systems
Xian-Ming Gu, Southwestern University of Finance and Economics

11:35-12:05 Convergence of the Right Preconditioned Range Restricted MINRES for Singular Systems
Kota Sugihara, National Institute of Informatics

12:05-12:35 Circulant Preconditioners for Systems Defined by Functions of Toeplitz Matrices
Sean Hon, University of Oxford

Monday May 7

CS12

Contributed Session 12
10:35 AM - 12:35 PM
WLB210

10:35-11:05 Continuous Analogues of Krylov-Based Methods for Differential Operators
Marc Aurele Gilles, Cornell University

11:05-11:35 A Distributed Algorithm for Computing Rational Krylov Subspaces
Mikhail Pak, Technical University of Munich

11:35-12:05 Generalizations of Roth's Criteria for Solvability of Matrix Equations
Klymchuk Tetiana, Taras Shevchenko National University of Kyiv, Universitat Politècnica de Catalunya

12:05-12:35 Perturbation Analysis of Linear Dynamical Systems with Ill-Conditioned Matrices
Peter Chang-Yi Weng, Institute of Statistical Science, Academia Sinica

Lunch Break

12:35 PM - 1:35 PM

Monday May 7

Poster Sessions

1:35 PM - 3:00 PM
Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building

1. SPMR: A Family of Saddle-Point Minimum Residual Methods
Ron Estrin, Stanford University

2. Spectral Computed Tomography with Linearization and Preconditioning
Yunyi Hu, Emory University

3. Efficient Implementations of the Modified Gram-Schmidt Orthogonalization with a Non-Standard Inner Product
Akira Imakura, University of Tsukuba

4. Removing Objects from Video Based on Tensor Completion
Sheheryar Khan, City University of Hong Kong

5. Rayleigh-Ritz Majorization Error Bounds of the Mixed Type
Andrew Knyazev, Mitsubishi Electric Research Laboratories (MERL)

6. Fitting Eigenvectors Given Partial Eigenvector Information
Eric Hans Lee, Cornell University

7. Truncated SVD Approximation via Kronecker Summations
Chang Meng, Emory University

8. Verified computation of partial eigenvalues using contour integrals
Keiichi Morikuni, University of Tsukuba

9. IR Tools MATLAB Package for Large-Scale Inverse Problems
James G. Nagy, Emory University

10. Messenger-Field and Conjugate Gradients in Cosmic Microwave Background Data Analysis
Jan Papež, INRIA Paris

11. A Distributed Database Providing Data Privacy Based on Lagrange Interpolation Polynomial

Hung-Min Sun, National Tsing Hua University

12. A Fast Direct Solver for Fractional Elliptic Problems on General Meshes in 2D and 3D
Nurbek Tazhimbetov, Stanford University

13. Sparse Recovery Algorithms for 3D Imaging Using Point Spread Function Engineering
Chao Wang, The Chinese University of Hong Kong

14. Elliptic Preconditioner for Accelerating the Self-Consistent Field Iteration in Kohn-Sham Density Functional Theory
Jin Xie, Stanford University

15. A Tensor Flatten Layer for Deep Neural Networks Based on Multilinear Subspace Learning
Xuefei Zhe, City University of Hong Kong

Coffee Break

3:00 PM - 3:30 PM

`3/F Podium, Academic and Administration Building`

Monday May 7

MS09 Part II

Exploiting Low-Complexity Structures in Data Analysis: Theory and Algorithms
3:30 PM - 5:30 PM
`WLB104`

Low-complexity structures are central to modern data analysis — they are exploited to tame data dimensionality, to rescue ill-posed problems, and to ease and speed up hard numerical computation. In this line, the past decade features remarkable advances in theory and practice of estimating sparse vectors or low-rank matrices from few linear measurements. Looking ahead, there are numerous fundamental problems in data analysis coming with more complex data formation processes. For example, the dictionary learning and the blind deconvolution problems have intrinsic bilinear structures, whereas the phase retrieval problem and variants pertain to quadratic measurements. Moreover, many of these applications can be naturally formulated as nonconvex optimization problems, which are ruled to be hard by the worst-case theory. In practice, however, simple numerical methods are surprisingly effective in solving them. Partial explanation of this curious gap has started to appear very recently.
This minisymposium highlights the intersection between numerical linear algebra/numerical optimization and the mathematics of modern signal processing and data analysis. Novel results on both theoretical and algorithmic sides of exploiting low-complexity structures will be discussed, with an emphasis on addressing the new challenges.

Organizers:
Ju Sun, Department of Mathematics, Stanford University,
`sunju@stanford.edu`
Ke Wei, School of Data Science, Fudan University,
`weike1986@gmail.com`

3:30-4:00 Foundations of Nonconvex and Nonsmooth Robust Subspace Recovery
Tyler Maunu, University of Minnesota

4:00-4:30 Geometry and Algorithm for Sparse Blind Deconvolution
Yuqian Zhang, Columbia University

4:30-5:00 Convergence of the Randomized Kaczmarz Method for Phase Retrieval
Halyun Jeong, Courant Institute of Mathematical Sciences

5:00-5:30 Nonconvex Optimization for High-Dimensional Learning
Mahdi Soltanolkotabi, University of Southern California

Monday May 7

MS14 Part II
Low Rank Matrix Approximations with HPC Applications
3:30 PM - 5:30 PM
WLB109

Low-rank matrix approximations have demonstrated attractive theoretical bounds, both in memory footprint and arithmetic complexity. In fact, they have even become numerical methods of choice when designing high performance applications, especially when looking at the forthcoming exascale era, where systems with billions of threads will be routine resources at hand. This minisymposium aims at bringing together experts from the field to assess the software adaptation of low-rank matrix computations into HPC applications.

Organizers:
Hatem Ltaief, Division of Computer, Electrical, and Mathematical Sciences and Engineering, Extreme Computing Research Center, King Abdullah University of Science and Technology,
Hatem.Ltaief@kaust.edu.sa
David Keyes, Division of Computer, Electrical, and Mathematical Sciences and Engineering, Extreme Computing Research Center, King Abdullah University of Science and Technology,
David.Keyes@kaust.edu.sa

3:30-4:00 Stars-H: A Hierarchical Matrix Market Within an HPC Framework
Alexandr Mikhalev, King Abdullah University of Science and Technology

4:00-4:30 Matrix-Free Construction of HSS Representations Using Adaptive Randomized Sampling
X. Sherry Li, Lawrence Berkeley National Laboratory

4:30-5:00 Low Rank Approximations of Hessians for PDE Constrained Optimization
George Turkiyyah, American University of Beirut

5:00-5:30 Simulations for the European Extremely Large Telescope Using Low-Rank Matrix Approximations
Damien Gratadour, Paris Observatory and LESIA

Monday May 7

MS23 Part II
Optimization Methods on Matrix and Tensor Manifolds
3:30 PM - 5:30 PM
WLB204

Riemannian optimization methods are a natural extension of Euclidean optimization methods: the search space is generalized from a Euclidean space to a manifold endowed with a Riemannian structure. This allows for many constrained Euclidean optimization problems to be formulated as unconstrained problems on Riemannian manifolds; the geometric structure can be exploited to provide mathematically elegant and computationally efficient solution methods by using tangent spaces as local linearizations.
Many important structures from linear algebra admit a Riemannian manifold structure, such as matrices with mutually orthogonal columns (Stiefel manifold), subspaces of fixed dimension (Grassmann manifold), positive definite matrices, or matrices of fixed rank.
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The second session will be centered on the particular class of low-rank tensor manifolds, which make computations with multiway arrays of large dimension feasible and have attracted particular interest in recent research. It will present novel results on second-order methods on tensor manifolds, such as trust-region or quasi-Newton methods. It will also present results on dynamical approximation of tensor differential equations.

Organizers:
Gennadij Heidel, Department of Mathematics, Trier University,
heidel@uni-trier.de
Wen Huang, Department of Computational and Applied

Mathematics, Rice University, wen.huang@rice.edu

3:30-4:00 Quasi-Newton Optimization Methods on Low-Rank Tensor Manifolds
Gennadij Heidel, Trier University

4:00-4:30 Robust Second Order Optimization Methods on Low Rank Matrix and Tensor Varieties
Valentin Khrulkov, Skoltech

4:30-5:00 A Riemannian Trust Region Method for the Canonical Tensor Rank Approximation Problem
Nick Vannieuwenhoven, KU Leuven

5:00-5:30 Dynamical Low-Rank Approximation of Tensor Differential Equations
Hanna Walach, University of Tübingen

Monday May 7

MS25 Part II

Polynomial and Rational Matrices
3:30 PM - 5:30 PM
WLB205

Polynomial and rational matrices have attracted much attention in the last years. Their appearance in numerous modern applications requires revising and improving known as well as developing new theories and algorithms concerning the associated eigenvalue problems, error and perturbation analyses, efficient numerical implementations, etc. This Mini-Symposium aims to give an overview of the recent research on these topics, focusing on numerical stability of quadratic eigenvalue problem; canonical forms, that reveal transparently the complete eigenstructures; sensitivity of complete eigenstructures to perturbations; low-rank matrix pencils and matrix polinomials; block-tridiagonal linearizations.

Organizers:
Javier Pérez, Department of Mathematical Sciences, University of Montana, javier.perez-alvaro@mso.umt.edu
Andrii Dmytryshyn, Department of Computing Science, Umeå University, andrii@cs.umu.se

3:30-4:00 A Backward Stable Quadratic Eigenvalue Solver
Françoise Tisseur, The University of Manchester

4:00-4:30 A Geometric Description of the Sets of Palindromic and Alternating Matrix Pencils with Bounded Rank
Fernando De Terán, Universidad Carlos III de Madrid

4:30-5:00 Strong Linearizations of Rational Matrices with Polynomial Part Expressed in an Orthogonal Basis
M. Carmen Quintana, Universidad Carlos III de Madrid

5:00-5:30 On the Stability of the Two-Level Orthogonal Arnoldi Method for Quadratic Eigenvalue Problems
Javier Pérez, University of Montana

Monday May 7

MS32 Part II

Recent Advances in Linear Algebra for Uncertainty Quantification

3:30 PM - 5:30 PM

WLB210

The aim of this mini-symposium is to present recent development of advanced linear algebra techniques for uncertainty quantification including, but are not limited to, preconditioning techniques and multigrid methods for stochastic partial differential equations, multi-fidelity methods in uncertainty quantification, hierarchical matrices and low-rank tensor approximations, compressive sensing and sparse approximations, model reduction methods for PDEs with stochastic and/or multiscale features, random matrix models, etc.

Organizers:
Zhiwen Zhang, Department of Mathematics, The University of Hong Kong, zhangzw@hku.hk
Bin Zheng, Pacific Northwest National Laboratory, bin.zheng@pnnl.gov

3:30-4:00 Sequential Data Assimilation with Multiple Nonlinear Models and Applications to Subsurface Flow
Peng Wang, Beijing University of Astronautics and Aeronautics

4:00-4:30 A New Model Reduction Technique for Convection-Dominated PDEs with Random Velocity Fields
Guannan Zhang, Oak Ridge National Laboratory

4:30-5:00 Gamblet Based Multilevel Decomposition/Preconditioner for Stochastic Multiscale PDE
Lei Zhang, Shanghai Jiaotong University

5:00-5:30 Scalable Generation of Spatially Correlated Random Fields
Panayot Vassilevski, Portland State University

Monday May 7

MS37 Part II

Tensor Analysis, Computation, and Applications II

3:30 PM - 5:30 PM

WLB211

The term *tensor* has both meanings of a geometric object and a multi-way array. Applications of tensors include various disciplines in science and engineering, such as mechanics, quantum information, signal and image processing, optimization, numerical PDE, and hypergraph theory. There are several hot research topics on tensors, such as tensor decomposition and low-rank approximation, tensor spectral theory, tensor completion, tensor-related systems of equations, and tensor complementarity problems. Researchers in all these mentioned areas will give presentations to broaden our perspective on tensor research. This is one of a series minisymposia and focuses more on tensor analysis and algorithm design.

Organizer:
Shenglong Hu, School of Mathematics, Tianjin University, timhu@tju.edu.cn

3:30-4:00 Sparse Tucker Decomposition Completion for 3D Facial Expression Recognition
Ziyan Luo, Beijing Jiaotong University

4:00-4:30 Tensor Ranks and Secant Varieties
Yang Qi, University of Chicago

4:30-5:00 S-lemma of the Fourth Order Tensor Systems
Qingzhi Yang, Nankai University

5:00-5:30 Hankel Tensor Decompositions and Ranks
Ke Ye, Chinese Academy of Science and University of Chicago

Monday May 7

CS13

Contributed Session 13

3:30 PM - 5:30 PM

WLB103

3:30-4:00 Complex Moment-Based Partial Singular Value Decomposition
Akira Imakura, University of Tsukuba

4:00-4:30 Condition Number and Equilibriation of Factors in the SR Decomposition
Miroslav Rozložník, Czech Academy of Sciences, Prague

4:30-5:00 Conditionally Negative Definite Functions
Mandeep Singh Rawla, Sant Longowal Institute of Engineering and Technology

5:00-5:30 Port-Hamiltonian Systems and Various Distances for Control Systems
Punit Sharma, University of Mons

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Conference Banquet

6:30 PM - 9:00 PM

Palace Wedding Banquet Specialist, L13, The ONE, 100 Nathan Road, Tsim Sha Tsui

Tuesday May 8

Registration

9:30 AM - 11:30 PM

`Tsang Chan Sik Yue Auditorium Lobby, 2/F Academic and Administration Building`

Tuesday May 8

IP8

8:45 AM - 9:30 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Hans de Sterck, Monash University

Enlarged Krylov Subspace Methods and Robust Preconditioners

Laura Grigori, INRIA Paris

This talk discusses robust preconditioners and iterative methods for solving large sparse linear systems of equations. The issues addressed include robustness as well as communication reduction for increasing the scalability of linear solvers on large scale computers. The focus is in particular on enlarged Krylov subspace methods and preconditioners based on low rank corrections, as well as associated computational kernels as computing a low rank approximation of a sparse matrix. The efficiency of the proposed methods is tested on matrices arising from linear elasticity problems as well as convection diffusion problems with highly heterogeneous coefficients.

Tuesday May 8

IP9

9:30 AM - 10:15 AM

`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Hans de Sterck, Monash University

Null-space Based Block Preconditioners for Saddle-Point Systems

Chen Greif, The University of British Columbia

The need to iteratively solve large and sparse saddle-point systems continues to be a challenging task in numerical linear algebra. In particular, it is important to design preconditioning techniques that take into account the numerical properties of the underlying discrete operators. In this talk we consider saddle-point matrices whose leading block has a low rank. We show that under specific assumptions on the rank and a few additional mild assumptions, the inverse has unique mathematical properties. It is possible to utilize null spaces of the leading block or the off-diagonal blocks as an alternative to Schur complements. Consequently, a family of indefinite block preconditioners can be developed. We also introduce a new minimum residual short-recurrence method for solving saddle-point systems, which is capable of handling singularity of the leading block.

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Coffee Break

10:15 AM - 10:45 AM

`3/F Podium, Academic and Administration Building`

Tuesday May 8

MS04 Part I
Constrained Low-Rank Matrix and Tensor Approximations
10:45 AM - 12:45 PM
`WLB103`

Constrained low rank matrix and tensor approximations are extremely useful in large-scale data analytics with applications across data mining, signal processing, statistics, and machine learning. Tensors are multidimensional arrays, or generalizations of matrices to more than two dimensions. The talks in this minisymposium will span various matrix and tensor decompositions and discuss applications and algorithms, as well as available software, with a particular focus on computing solutions that satisfy application-dependent constraints.

Organizers:
Grey Ballard, Wake Forest University, `ballard@wfu.edu`
Ramakrishnan Kannan, Oak Ridge National Laboratory, `kannanr@ornl.gov`
Haesun Park, Georgia Institute of Technology, `hpark@cc.gatech.edu`

10:45-11:15 Joint Nonnegative Matrix Factorization for Hybrid Clustering based on Content and Connection Structure
Haesun Park, Georgia Institute of Technology

11:15-11:45 Tensor Decompositions for Big Multi-Aspect Data Analytics
Evangelos Papalexakis, University of California Riverside

11:45-12:15 Speeding Up Tensor Contractions Through Extended BLAS Kernels
Yang Shi, University of California, Irvine

12:15-12:45 SUSTain: Scalable Unsupervised Scoring for Tensors and Its Application to Phenotyping
Ioakeim Perros, Georgia Institute of Technology

Tuesday May 8

MS08 Part I
Efficient Kernel Methods and Numerical Linear Algebra
10:45 AM - 12:45 PM
`WLB104`

Despite their theoretical appeal and grounding in tractable convex optimization techniques, kernel methods are often not the first choice for large-scale machine learning applications due to their significant memory requirements and computational expense.
Thus it is not surprising that mainly due to the advances of deep learning, the performances in various machine learning tasks have been progressing intensively. However, in recent years different elegant mechanisms (such as randomized approximate feature maps) to scale-up kernel methods emerged mainly from computational mathematics and applied linear algebra. So these are indications that kernel methods are not dead and that they could match or even outperform deep nets.
To tackle such challenging area, one appeals for new advanced approaches at the bridge of numerical linear algebra and kernels methods. Therefore, the purpose of the minisymposium is to bring together experts in modern machine learning and scientific computing to discuss current results in numerical approximation and its usage for scaling up kernel methods, as well as potential areas of application. The emphasis is put on original theoretical and algorithmic developments, however interesting application results are welcome as well.

Organizers:
Evgeny Burnaev, Center for Computational Data-Intensive Science and Engineering, Skolkovo Institute of Science and Technology, `E.Burnaev@skoltech.ru`
Ivan Oseledets, Center for Computational Data-Intensive Science and Engineering, Skolkovo Institute of Science and Technology, `I.Oseledets@skoltech.ru`

10:45-11:15 Overview of Large Scale Kernel Methods
Evgeny Burnaev, Skolkovo Institute of Science and Technology

11:15-11:45 Kernel Methods and Tensor Decompositions
Ivan Oseledets, Skolkovo Institute of Science and Technology

11:45-12:15 Quadrature-Based Features for Kernel Approximation
Ermek Kapushev, Skolkovo Institute of Science and Technology

12:15-12:45 Convergence Analysis of Deterministic Kernel-Based Quadrature Rules in Sobolev Spaces
Motonobu Kanagawa, Max Planck Institute for Intelligent Systems, Tuebingen

Tuesday May 8

MS11
Iterative Solvers for Parallel-in-Time Integration
10:45 AM - 12:45 PM
WLB109

Due to stagnating processor speeds and increasing core counts, the current paradigm of high performance computing is to achieve shorter computing times by increasing the concurrency of computations. Sequential time-stepping is a computational bottleneck when attempting to implement highly concurrent algorithms, thus parallel-in-time methods are desirable. This minisymposium will present recent advances in iterative solvers for parallel-in-time integration. This includes methods like parareal, multigrid reduction, and parallel space-time methods, with application to linear and nonlinear PDEs of parabolic and hyperbolic type.

Organizers:
Xiao-Chuan Cai, Department of Computer Science, University of Colorado at Boulder, cai@cs.colorado.edu
Hans De Sterck, School of Mathematical Sciences, Monash University, hans.desterck@monash.edu

10:45-11:15 Space-Time Schwarz Preconditioning and Applications
Xiao-Chuan Cai, University of Colorado at Boulder

11:15-11:45 Parallel-in-Time Multigrid with Adaptive Spatial Coarsening for the Linear Advection and Inviscid Burgers Equations
Hans De Sterck, Monash University

11:45-12:15 On the Convergence of PFASST
Matthias Bolten, Bergische Universitaet Wuppertal

12:15-12:45 Waveform Relaxation with Adaptive Pipelining (Wrap)
Felix Kwok, Hong Kong Baptist University

Tuesday May 8

MS21 Part I
Numerical Linear Algebra Algorithms and Applications in Data Science
10:45 AM - 12:15 PM
WLB204

Data science is currently one of the hottest research fields in many real applications such as medicine, business, finance, transportation, etc.. Lots of computational problems arise in the process of data modelling and data analysis. Due to the finite dimension property of the data samples, most computational problems can be transformed to linear algebra related problems. To date, numerical linear algebra has played important roles in data science.
With the fast development of experimental techniques and growth of internet communications, more and more data are generated nowadays. The availability of a huge amount of data brings big challenges for traditional computational methods. On one hand, to handle the big data matrices (high dimension, big sample size), algorithms having high computational speed and accuracy are in great need. This proposes the problem of improving the traditional methods such as SVD methods, conjugate gradient method, matrix preconditioning methods, and so on. On the other hand, with the generation of more data, many new models are proposed. This brings the chances for developing novel algorithms. Taking into account the properties of data to build good models and propose fast and accurate algorithms will accelerate the development of data science greatly. Numerical linear algebra as the essential technique for numerical algorithm development should be paid more attention.
The speakers in this minisymposium will discuss work that arises in data modelling including multiview data learning, data dimension reduction, data approximation, and stochastic data analysis. The numerical linear algebra methods cover low-dimension projection, matrix splitting, parallel SVD, conjugate gradient method, matrix preconditioning and so on. This minisymposium brings together researchers from different data analysis fields focusing on numerical linear algebra related algorithm development. It will emphasize the importance and strengthen the role of linear algebra in data science, thereby advances the collaborations for researchers from different fields.

Organizers:
Shuqin Zhang, School of Mathematical Sciences, Fudan University, zhangs@fudan.edu.cn
Limin Li, School of Mathematics and Statistics, Xi'an Jiaotong University, liminli@mail.xjtu.edu.cn

10:45-11:15 Simultaneous Clustering of Multiview Data
Shuqin Zhang, Fudan University

11:15-11:45 Averaged Information Splitting for Heterogeneously High-Throughput Data Analysis
Shengxin Zhu, Xi'an Jiaotong-Liverpool University

11:45-12:15 A Modified Seasonal Grey System Model with Fractional Order Accumulation for Forecasting Traffic Flow
Yang Cao, Nantong University

Tuesday May 8

MS39 Part I
Tensors and Multilinear Algebra
10:45 AM - 12:45 PM
WLB205

Tensors in the form of multidimensional arrays have seen an increasing interest in recent years in the context of modern data analysis and high-dimensional equations in numerical analysis. Higher-order tensors are a natural generalization of matrices and, just as for matrices, their low-rank decompositions and spectral properties are important for applications. In the multilinear setting of tensors, however, analyzing such structures is challenging and requires conceptually new tools. Many techniques investigate and manipulate unfoldings (flattenings) of tensors into matrices, where linear algebra operations can be applied. In this respect, the subject of tensors and multilinear algebra fits a conference on applied linear algebra in two ways, as it occurs in many modern applications, and requires linear algebra for its treatment.
In this minisymposium, we wish to bring the latest developments in this area to attention, and promote it as an active and attractive research field to people interested in linear algebra. Contrary to the other sessions on tensors, this session will focus on algebraic foundations and spectral properties of tensors that are important in understanding their low-rank approximations.

Organizers:
Anna Seigal, Department of Mathematics, University of California, Berkeley,
seigal@berkeley.edu
André Uschmajew, Max Planck Institute MIS, Leipzig,
uschmajew@mis.mpg.de
Bart Vandereycken, Section of Mathematics, University of Geneva,
bart.vandereycken@unige.ch

10:45-11:15 Adaptive Tensor Optimization for the Log-Normal Parametric Diffusion Equation
Max Pfeffer, Max Planck Institute for Mathematics in the Sciences

11:15-11:45 Geometrical Description of Feasible Singular Values in Tree Tensor Formats
Sebastian Kraemer, RWTH Aachen

11:45-12:15 The Positive Cone to Algebraic Varieties of Hierarchical Tensors
Benjamin Kutschan, Technical University Berlin

12:15-12:45 Nuclear Decomposition of Higher-Order Tensors
Lek-Heng Lim, University of Chicago

Tuesday May 8

MS42 Part I
Tridiagonal Matrices and Their Applications in Physics and Mathematics
10:45 AM - 12:45 PM
WLB210

Tridiagonal matrices emerge in plenty of applications in science and engineering. They are used for solving a variety of problems in disparate contexts. Beyond their several applications seldom discussed, the methods, techniques, and theoretical framework used in this research field make it very interesting and challenging. In this minisymposium we attract people from different areas of mathematics who use tridiagonal matrices in their study to discuss recent developments, new approaches and perspectives as well as new applications of tridiagonal matrices.

Organizers:
Natalia Bebiano, Department of Mathematics, University of Coimbra,
bebiano@mat.uc.pt
Mikhail Tyaglov, School of Mathematical Sciences, Shanghai Jiao Tong University,
tyaglov@sjtu.edu.cn

10:45-11:15 On von Neumann and Rényi Entropies of Rings and Paths
Natália Bebiano, CMUC, University of Coimbra

11:15-11:45 Tridiagonal Matrices with Only One Eigenvalue and Their Relations to Polynomials Orthogonal with Non-Hermitian Weight
Mikhail Tyaglov, Shanghai Jiao Tong University

11:45-12:15 Positivity and Recursion Formula of the Linearization Coefficients of Bessel Polynomials
M. J. Atia, M. J. A. Qassim University and Gabès University

12:15-12:45 Ultra-Discrete Analogue of the QD Algorithm for Min-Plus Tridiagonal Matrix
Akiko Fukuda, Shibaura Institute of Technology

Tuesday May 8

CS14

Contributed Session 14
10:45 AM - 12:45 PM
`WLB211`

10:45-11:15 Convergence of the Complex Cyclic Jacobi Methods and Applications
Erna Begovic, University of Zagreb

11:15-11:45 Generalized Davidson and Multidirectional-Type Methods for the GSVD
Ian N. Zwaan, Bergische Universität Wuppertal

11:45-12:15 Inner Deflation and Computation of the Eigenvectors of Symmetric Tridiagonal Matrices
Harold Taeter, University of Bari

12:15-12:45 Contour Integral Methods for Partial Eigenproblems of Linear Rectangular Matrix Pencils
Keiichi Morikuni, University of Tsukuba

Lunch Break

12:45 PM - 1:45 PM

Tuesday May 8

IP10

1:45 PM - 2:30 PM
`Tsang Chan Sik Yue Auditorium, 2/F Academic and Administration Building`

Chair: Eugene Tyrtyshnikov, Russian Academy of Science

Fast Algorithms from Low-Rank Updates
Daniel Kressner, École Polytechnique Fédérale de Lausanne

The development of efficient numerical algorithms for solving large-scale linear systems is one of the success stories of numerical linear algebra that has had a tremendous impact on our ability to perform complex numerical simulations and large-scale statistical computations. Many of these developments are based on multilevel and domain decomposition techniques, which are intimately linked to Schur complements and low-rank updates of matrices. These tools do not carry over in a direct manner to other important linear algebra problems, including matrix functions and matrix equations. In this talk, we describe a new framework for performing low-rank updates of matrix functions. This allows to address a wide variety of matrix functions and matrix structures, including sparse matrices as well as matrices with hierarchical low rank and Toeplitz-like structures. The versality of this framework will be demonstrated with several applications and extensions. This talk is primarily based on joint work with Bernhard Beckermann and Marcel Schweitzer.

Coffee Break

2:30 PM - 3:00 PM

`3/F Podium, Academic and Administration Building`

Tuesday May 8

MS04 Part II

Constrained Low-Rank Matrix and Tensor Approximations
3:00 PM - 5:00 PM
`WLB103`

Constrained low rank matrix and tensor approximations are extremely useful in large-scale data analytics with applications across data mining, signal processing, statistics, and machine learning. Tensors are multidimensional arrays, or generalizations of matrices to more than two dimensions. The talks in this minisymposium will span various matrix and tensor decompositions and discuss applications and algorithms, as well as available software, with a particular focus on computing solutions that satisfy application-dependent constraints.

Organizers:
Grey Ballard, Wake Forest University, `ballard@wfu.edu`
Ramakrishnan Kannan, Oak Ridge National Laboratory, `kannanr@ornl.gov`
Haesun Park, Georgia Institute of Technology, `hpark@cc.gatech.edu`

3:00-3:30 Accelerating the Tucker Decomposition with Compressed Sparse Tensors
George Karypis, University of Minnesota

3:30-4:00 Efficient CP-ALS and Reconstruction from CP Form
Jed Deursch, Sandia National Laboratories

4:00-4:30 Non-Negative Sparse Tensor Decomposition on Distributed Systems
Jiajia Li, Georgia Institute of Technology

4:30-5:00 Communication-Optimal Algorithms for CP Decompositions of Dense Tensors
Grey Ballard, Wake Forest University

Tuesday May 8

MS08 Part II
Efficient Kernel Methods and Numerical Linear Algebra
3:00 PM - 5:00 PM
WLB104

Despite their theoretical appeal and grounding in tractable convex optimization techniques, kernel methods are often not the first choice for large-scale machine learning applications due to their significant memory requirements and computational expense.
Thus it is not surprising that mainly due to the advances of deep learning, the performances in various machine learning tasks have been progressing intensively. However, in recent years different elegant mechanisms (such as randomized approximate feature maps) to scale-up kernel methods emerged mainly from computational mathematics and applied linear algebra. So these are indications that kernel methods are not dead and that they could match or even outperform deep nets.
To tackle such challenging area, one appeals for new advanced approaches at the bridge of numerical linear algebra and kernels methods. Therefore, the purpose of the minisymposium is to bring together experts in modern machine learning and scientific computing to discuss current results in numerical approximation and its usage for scaling up kernel methods, as well as potential areas of application. The emphasis is put on original theoretical and algorithmic developments, however interesting application results are welcome as well.

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E.Burnaev@skoltech.ru
Ivan Oseledets, Center for Computational Data-Intensive Science and Engineering, Skolkovo Institute of Science and Technology,
I.Oseledets@skoltech.ru

3:00-3:30 Sequential Sampling for Kernel Matrix Approximation and Online Learning
Michal Valko, Inria Lille, Nord Europe

3:30-4:00 Tradeoffs of Stochastic Approximation in Hilbert Spaces
Aymeric Dieuleveut, École Normale Supérieure

4:00-4:30 Scalable Deep Kernel Learning
Andrew Gordon Wilson, Cornell University

4:30-5:00 Kernel Methods for Causal Inference
Krikamol Muandet, Mahidol University

Tuesday May 8

MS21 Part II
Numerical Linear Algebra Algorithms and Applications in Data Science
3:00 PM - 4:30 PM
WLB204

Data science is currently one of the hottest research fields in many real applications such as medicine, business, finance, transportation, etc.. Lots of computational problems arise in the process of data modelling and data analysis. Due to the finite dimension property of the data samples, most computational problems can be transformed to linear algebra related problems. To date, numerical linear algebra has played important roles in data science.
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Limin Li, School of Mathematics and Statistics, Xi'an Jiaotong University, liminli@mail.xjtu.edu.cn

3:00-3:30 A Distributed Parallel SVD Algorithm Based on the Polar Decomposition via Zolotarev's Function
Shengguo Li, National University of Defense Technology

3:30-4:00 A Riemannian Variant of Fletcher-Reeves Conjugate Gradient Method for Stochastic Inverse Eigenvalue Problems with Partial Eigendata
Zheng-Jian Bai, Xiamen University

4:00-4:30 A Splitting Preconditioner for Implicit Runge-Kutta Discretizations of a Differential-Algebraic Equation
Shuxin Miao, Northwest Normal Univeristy

Tuesday May 8

MS39 Part II
Tensors and Multilinear Algebra
3:00 PM - 4:30 PM
WLB205

Tensors in the form of multidimensional arrays have seen an increasing interest in recent years in the context of modern data analysis and high-dimensional equations in numerical analysis. Higher-order tensors are a natural generalization of matrices and, just as for matrices, their low-rank decompositions and spectral properties are important for applications. In the multilinear setting of tensors, however, analyzing such structures is challenging and requires conceptually new tools. Many techniques investigate and manipulate unfoldings (flattenings) of tensors into matrices, where linear algebra operations can be applied. In this respect, the subject of tensors and multilinear algebra fits a conference on applied linear algebra in two ways, as it occurs in many modern applications, and requires linear algebra for its treatment.
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André Uschmajew, Max Planck Institute MIS, Leipzig, uschmajew@mis.mpg.de
Bart Vandereycken, Section of Mathematics, University of Geneva, bart.vandereycken@unige.ch

3:00-3:30 Duality of Graphical Models and Tensor Networks
Anna Seigal, UC Berkeley

3:30-4:00 Orthogonal Tensors and Rank-One Approximation Ratio
Andre Uschmajew, MPI MIS Leipzig

4:00-4:30 A Condition Number for the Tensor Rank Decomposition
Nick Vannieuwenhoven, KU Leuven

Tuesday May 8

MS42 Part II
Tridiagonal Matrices and Their Applications in Physics and Mathematics
3:00 PM - 5:00 PM
WLB210

Tridiagonal matrices emerge in plenty of applications in science and engineering. They are used for solving a variety of problems in disparate contexts. Beyond their several applications seldom discussed, the methods, techniques, and theoretical framework used in this research field make it very interesting and challenging. In this minisymposium we attract people from different areas of mathematics who use tridiagonal matrices in their study to discuss recent developments, new approaches and perspectives as well as new applications of tridiagonal matrices.

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Natalia Bebiano, Department of Mathematics, University of Coimbra, bebiano@mat.uc.pt
Mikhail Tyaglov, School of Mathematical Sciences, Shanghai Jiao Tong University, tyaglov@sjtu.edu.cn

3:00-3:30 A Generalized Eigenvalue Problem with Two Tridiagonal Matrices
Alagacone Sri Ranga, DMAp/IBILCE, UNESP - Universidade Estadual Paulista

3:30-4:00 Eigenvalue Problems of Structured Band Matrices Related to Discrete Integrable Systems
Masato Shinjo, Kyoto University

4:00-4:30 On Instability of the Absolutely Continuous Spectrum of Dissipative Schrödinger Operators and Jacobi Matrices
Roman Romanov, Saint Petersburg State University

4:30-5:00 Block-Tridiagonal Linearizations of Matrix Polynomials
Susana Furtado, Faculdade de Economia da Universidade do Porto

Tuesday May 8

CS15
Contributed Session 15
3:00 PM - 5:00 PM
WLB211

3:00-3:30 Fully-Coupled and Block/Schur Complement Based Algebraic MultiGrid-Based Preconditioners for Implicit Continuum Plasma Simulations
Paul Lin, Sandia National Laboratories

3:30-4:00 Geometric Multigrid for Graphene
Nils Kintscher, University of Wuppertal

4:00-4:30 Machine Learning in Algebraic Multigrid
Matthias Rottmann, University of Wuppertal

4:30-5:00 An Eigensolver for the Hermitian Dirac Operator with Multigrid Acceleration
Artur Strebel, Bergische Universitaet Wuppertal

Tuesday May 8

CS16
Contributed Session 16
3:00 PM - 5:00 PM
WLB109

3:00-3:30 Partial Solutions to Riccati Equations for Feedback Gains Using the Staircase Form
Eric King-Wah Chu, School of Mathematics, Monash University

3:30-4:00 A New Solution Method for the Linear Systems of 3-D Radiation Hydrodynamics
Xudeng Hang, Institute of Applied Physics and Computational Mathematics

4:00-4:30 Closed-Form Projection Method for Regularizing a Function Defined by a Discrete Set of Noisy Data and for Estimating its Derivative and Fractional Derivative
Timothy J. Burns, NIST

4:30-5:00 Manifold Preserving: An Intrinsic Approach for Distance Metric Learning and Data Retrieval
Yaxin Peng, Shanghai University

Abstracts of Minisymposia Talks

MS01
Towards Highly Scalable Asynchronous Sparse Solvers for Symmetric Matrices

Sparse direct solvers are important in the solution of scientific problems but their parallel implementations typically exhibit poor scalability. They suffer from a very high communication to computation ratio. Reducing synchronization and communication along the critical path is crucial to achieve good performance. In this context, we are investigating a parallel implementation of sparse Cholesky factorization using the Fan-Both approach based on novel lightweight asynchronous communication framework, and we will present our findings.

Esmond Ng, Lawrence Berkeley National Laboratory,
EGNg@lbl.gov
Mathias Jacquelin, Lawrence Berkeley National Laboratory

MS01
Fine-Grained Parallel Incomplete LU Factorization

We discuss some recent developments on fine-grainedparallel incomplete LU factorization. In particular, we will demonstrate the effect of synchronous vs. asynchronous fixed-pointiterations; variant factorizations that improve generality and robustness; and adapting the sparsity pattern to improve the quality of the preconditioner.

Edmond Chow, Georgia Institute of Technology,
echow@cc.gatech.edu

MS01
Approximate Sparse Matrix Factorization Using Low-Rank Compression

We present an improved parallel and fully algebraic sparse direct linear solver using data-sparse approximations. We consider multiple hierarchical matrix formats. For the low-rank compression, we use randomized algorithms, as this can lead, for model problems, to linear complexity. We study the impact of the clustering of the degrees of freedom on the efficiency of the resulting preconditioner. We focus on parallel performance and compare with state of the art preconditioners.

Pieter Ghysels, Lawrence Berkeley National Laboratory,
pghysels@lbl.gov

MS01
Hiding Latencies and Avoid Communications in Krylov Solvers

On large parallel machines global reductions such as dot products are suffering from long latencies. Pipelining hides these latencies. Krylov methods can be reorganized such that the dot products, sparse matrix-vector products and the application of the preconditioner are executed in an simultaneously rather then sequentially. However, this reorganization leads to different accumulation of rounding errors and countermeasures need to be introduced to achieve a similar accuracy as classical krylov methods.

Siegfried Cools, University of Antwerp,
siegfried.cools@uantwerp.be
Wim Vanroose, University of Antwerp
Jeffrey Cornelis, University of Antwerp

MS02
Conjugate Gradient for Nonsingular Saddle-Point Systems with a Highly Singular Leading Block

We consider iterative solvers for large, sparse, symmetric linear systems with a saddle-point structure. Since such systems are indefinite, the conjugate gradient (CG) method cannot typically be used. However, in the case of a maximally rank-deficient leading block, we show that there are two necessary and sufficient conditions that allow for CG to be used. We show that the conditions are satisfied for a model mixed Maxwell problem. To support our analysis, we present several three-dimensional numerical experiments on complicated computational domains or with variable coefficients.

Michael Wathen, University of British Columbia,
mwathen@cs.ubc.ca

MS02
Symmetrizing Nonsymmetric Toeplitz Matrices in Fractional Diffusion Problems

Fractional diffusion equations are increasingly used in applications. Discretising these equations by shifted Grünwald-Letnikov finite difference approximations on uniform meshes lead to Toeplitz, block Toeplitz, and related matrices, all of which may be nonsymmetric. In this talk we will discuss how to symmetrize these nonsymmetric matrices, and the benefits of doing so. We will also propose preconditioning strategies for the symmetrized problems.

Jennifer Pestana, University of Strathclyde,
jennifer.pestana@strath.ac.uk

MS02
Commutator Based Preconditioning for Incompressible Two-Phase Flow

Modelling two-phase incompressible flow gives rise to variable coefficient Navier–Stokes equations that can be challenging to solve computationally. This talk explores the effectiveness of novel commutator based preconditioners that provide approximate Schur complements within block preconditioned iterative methods to solve such systems. The applications we are interested in come from models of hydrological flows yielding air-water systems which have significance in, for example, the study of coastal structures and dam-break scenarios.

Niall Bootland, University of Oxford,
bootland@maths.ox.ac.uk
Alistair Bentley, Clemson University
Christopher Kees, US Army Engineer Research and Development Center
Andrew Wathen, University of Oxford

MS02
The Efficient Solution of Linear Algebra Subproblems Arising in Optimization Methods

The need to minimize (or maximize) a function subject to some constraints is ubiquitous in scientific computing. Many modern algorithms developed to solve such optimization problems require, at their heart, the solution of a series of linear systems with a saddle point structure. In this talk I will describe the efficient iterative solution of such systems, based on specialised null-space preconditioners that exploit the structure. Both theoretical justification and numerical results will be presented.

Tyrone Rees, Rutherford Appleton Laboratory,
tyrone.rees@stfc.ac.uk

MS03

Arock: Asynchronous Parallel Coordinate Updates

In this talk, I will present ARock, an asynchronous parallel algorithmic framework for finding a fixed point to a nonexpansive operator. In the framework, a set of agents (machines, processors, or cores) updates a sequence of randomly selected coordinates of the unknown variable in a parallel asynchronous fashion. As special cases of ARock, novel algorithms in linear algebra, convex optimization, machine learning, distributed and decentralized optimization are introduced. We show that if the nonexpansive operator has a fixed point, then with probability one the sequence of points generated by ARock converges to a fixed point. Very encouraging numerical performance of ARock is observed on solving linear equations, sparse logistic regression, and other large-scale problems in recent data sciences.

Ming Yan, Michigan State University, myan@msu.edu
Zhimin Peng, UCLA
Yangyang Xu, Rensselaer Polytechnic Institute
Wotao Yin, UCLA

MS03

Asynchronous Domain Decomposition Solvers

Parallel implementations of linear iterative solvers generally alternate between phases of data exchange and phases of local computation. Increasingly large problem sizes on more heterogeneous systems make load balancing and network layout very challenging tasks. In particular, global communication patterns such as inner products become increasingly limiting at scale. In this talk, we explore the use of asynchronous domain decomposition solvers based on one-sided MPI primitives. We will discuss practical issues encountered in the development of a scalable solver and show experimental results obtained on a variety of state-of-the-art supercomputer systems.

Christian Glusa, Sandia National Laboratories, caglusa@sandia.gov
Erik Boman, Sandia National Laboratories
Edmund Chow, Georgia Tech
Jose Garay, Temple University
Mireille El Haddad, Temple University
Kathryn Lund-Nguyen, Temple University
Sivasankaran Rajamanickam, Sandia National Laboratories
Paritosh Ramanan, Georgia Tech
Daniel Szyld, Temple University
Jordi Wolfson-Pou, Georgia Tech
Ichitaro Yamazaki, University of Tennesse, Knoxville

MS03

Asynchronous Linear System Solvers on Supercomputers

In parallel environments, asynchronous solvers sacrifice convergence and generality for scalability, fault and latency tolerance. At current scales these methods are viable as preconditioners. They are especially useful when there is inherent load imbalance as they eliminate processor idle time. Their intrinsic latency tolerance makes them particularly suited for heterogeneous environments as well as future exascale machines.
In this work we present an open-source hybrid parallel library written in C++(11/14). The library implements asynchronous variants of Jacobi and Block-Jacobi methods, both as stand-alone solvers and as preconditioners. A general D-dimensional asynchronous distributed stencil matrix-vector product is implemented in the library allowing to test the solvers on variety of systems. The solvers are executed on a number of supercomputers equipped with cutting-edge hardware at the Juelich Supercomputing Center. Various approaches to implementing asynchronous methods on distributed memory machines will be discussed.

Teodor Nikolov, University of Wuppertal and The Cyprus Institute, teodor.nikolov22@gmail.com
Andreas Frommer, University of Wuppertal

MS03

Asynchronous Optimized Schwarz Methods for Poisson's Equation in Rectangular Domains

Optimized Schwarz methods (OSM) are Domain Decomposition methods in which the artificial boundary conditions are chosen in a way that the convergence speed is enhanced with respect to classical Schwarz Methods. OSM are fast methods in terms of iteration counts, and can can be implemented asynchronously. A convergence analysis of Asynchronous Optimized Schwarz methods when applied as outer solvers for Poisson's Equation in rectangular domains with Dirichlet (physical) boundary conditions and artificial boundary conditions of the family OO0, for the case when the subdomains form a 2D array, is presented. Numerical experiments illustrate the theoretical results.

José Garay, Temple University, jose.garay@temple.edu

MS04

Joint Nonnegative Matrix Factorization for Hybrid Clustering based on Content and Connection Structure

A hybrid method called JointNMF is presented for latent information discovery from data sets that contain both text content and connection structure information. The method jointly optimizes an integrated objective function, which is a combination the Nonnegative Matrix Factorization (NMF) objective function for handling text content and the Symmetric NMF (SymNMF) objective function for handling relation/connection information. An effective algorithm for the joint NMF objective function is proposed utilizing the block coordinate descent (BCD) framework. The proposed hybrid method simultaneously discovers content associations and related latent connections without any need for post-processing or additional clustering. It is shown that JointNMF can also be applied when the text content is associated with hypergraph edges. An additional capability is prediction of unknown connection information which is illustrated using some real world problems such as citation recommendations of papers and leader detection in organizations.
This is a joint work with Rundong Du, Barry Drake.

Haesun Park, Georgia Institute of Technology, hpark@cc.gatech.edu

MS04

Tensor Decompositions for Big Multi-Aspect Data Analytics

Tensors and tensor decompositions have been very popular and effective tools for analyzing multi-aspect data in a wide variety of fields, ranging from Psychology to Chemometrics, and from Signal Processing to Data Mining and Machine Learning.
Using tensors in the era of big data poses the challenge of scalability and efficiency. In this talk, I will discuss recent techniques on tackling this challenge by parallelizing and speeding up tensor decompositions, especially for very sparse datasets (such as the ones encountered for example in online social network analysis).

In addition to scalability, I will also touch upon the challenge of unsupervised quality assessment, where in absence of ground truth, we seek to automatically select the decomposition model that captures best the structure in our data.
The talk will conclude with a discussion on future research directions and open problems in tensors for big data analytics.

Evangelos Papalexakis, University of California Riverside,
epapalex@cs.ucr.edu

MS04
Speeding Up Tensor Contractions Through Extended BLAS Kernels

Tensor contractions constitute a key computational ingredient of numerical multi-linear algebra. However, as the order and dimension of tensors grow, the time and space complexities of tensor-based computations grow quickly. Existing approaches for tensor contractions typically involves explicit copy and transpose operations. In this paper, we propose and evaluate a new BLAS-like primitive StridedBatchedGemm that is capable of performing a wide range of tensor contractions on CPU and GPU efficiently. Through systematic benchmarking, we demonstrate the advantages of our approach over conventional approaches. Concretely, we implement the Tucker decomposition and show that using our kernels yields 100x speedup as compared to the implementation using existing state-of-the-art libraries.

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MS04
SUSTain: Scalable Unsupervised Scoring for Tensors and Its Application to Phenotyping

We present a new method, which we call `SUSTain`, that extends real-valued matrix and tensor factorizations to data where values are integers. Such data are common when the values correspond to event counts or ordinal measures. The conventional approach is to treat integer data as real, and then apply real-valued factorizations. However, doing so fails to preserve important characteristics of the original data, thereby making it hard to interpret the results.
`SUSTain` outperforms several baselines on both synthetic and real Electronic Health Records (EHR) data, showing either a better fit or orders-of-magnitude speedups at a comparable fit. We apply `SUSTain` to EHR datasets to extract patient phenotypes (i.e., clinically meaningful patient clusters). Furthermore, 87% of them were validated as clinically meaningful phenotypes related to heart failure by a cardiologist.

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MS04
Accelerating the Tucker Decomposition with Compressed Sparse Tensors

The Tucker decomposition is a higher-order analogue of the singular value decomposition and is a popular method of performing analysis on multi-way data (i.e., tensors). Computing the Tucker decomposition of a sparse tensor is demanding in terms of both memory and computational resources. The primary kernel of the factorization is a chain of tensor-matrix multiplications (TTMc). State-of-the-art algorithms accelerate the underlying computations by trading off memory to memoize the intermediate results of TTMc in order to reuse them across iterations. We present an algorithm based on a compressed data structure for sparse tensors and show that many computational redundancies during TTMc can be identified and pruned without the memory overheads of memoization. In addition, our algorithm can further reduce the number of operations by exploiting an additional amount of user-specified memory. We evaluate our algorithm on a collection of real-world and synthetic datasets and demonstrate up to 20.7x speedup while using 28.5x less memory than the state-of-the-art parallel algorithm.

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MS04
Efficient CP-ALS and Reconstruction from CP Form

The Canonical Polyadic (CP) decomposition is an essential tool in the analysis of multi-way datasets. Just as the singular value decomposition (SVD) can be used to analyze and approximate matrices, the CP decomposition generalizes the SVD to multi-dimensional arrays. It can be used for data compression, for feature extraction, and to fill in missing entries. The alternating least-squares algorithm CP-ALS is the standard means of computing the CP decomposition. We present a high-performance reformulation of CP-ALS that substantially reduces memory requirements and improves performance on large dense tensors. This is accomplished by reformulating a critical kernel called matricized-tensor times Khatri-Rao product (MTTKRP). This operation is restructured to avoid large intermediate Khatrio-Rao products. We then exploit the restructured formulation to reuse partial computations as the algorithm alternates through factor matrix updates. This new approach runs up to 20 times faster. We apply the same technique to reconstruct the full tensor from the CP formulation. The new reconstruction mechanism also reduces both memory requirements and run time by an order of magnitude over the previous approach.

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MS04
Non-Negative Sparse Tensor Decomposition on Distributed Systems

Sparse tensor decompositions have emerged as a promising analysis technique in a variety of applications for real-world sparse data. This work focuses on modeling of sparse count data which is described by Poisson distribution. Two distributed parallel sparse CANDECOMP/PARAFAC alternating Poisson regression (CP-APR) implementations are developed based on two sparse tensor formats: coordinate (COO) and our recently proposed hierarchical coordinate (HiCOO) formats. We achieve up to 95x speedup on 320 IBM POWER8 cores over the sequential code.

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MS04
Communication-Optimal Algorithms for CP Decompositions of Dense Tensors

The CP decomposition is a generalization of the matrix SVD to tensors, or multidimensional data arrays. We will present communication lower bounds and optimal algorithms for the fundamental computations used within algorithms for computing CP decompositions. We will consider both sequential and parallel memory models, and we will discuss the communication costs of existing algorithms for variations of the matricized-tensor times Khatri-Rao product (MTTKRP) computation.

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MS05

Understanding the Uniqueness of Decompositions in Low-Rank Block Terms Using Schur's Lemma on Irreducible Representations

In this work, we characterize the set of non-trivial solutions to a system of coupled homogeneous Sylvester-type matrix equations, given rank and irreducibility constraints. We show how the non-trivial solutions to this system are associated with the uniqueness of a coupled decomposition of a set of matrices in a sum of low-rank elements. We argue that this problem can be regarded as a generalization of a variant of Schurś lemma on irreducible representations.

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MS05

Decoupling Multivariate Polynomials: Comparing Different Tensorization Methods

Decoupling multivariate polynomials is a useful tool for obtaining an insight into the workings of a nonlinear mapping, to perform parameter reduction, or to approximate nonlinear functions. It is well-known that multivariate polynomials have a close connection to symmetric tensors, and it turns out that a decoupled representation can be obtained by performing the symmetric canonical polyadic decomposition. When considering a multivariate polynomial vector function, this leads to a coupled symmetric CPD. Another well-studied tensor-based method proceeds by collecting the first-order information of the polynomials in a set of operating points, which is captured by the Jacobian matrix evaluated at the operating points. The polyadic canonical decomposition of the three-way tensor of Jacobian matrices directly returns the desired information. We will describe and study the connections between the different tensorization approaches. The particular choice of tensorization approach has practical repercussions, and favors or disfavors easier computations or the implementation of certain aspects.

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MS05

Coupled and Uncoupled Sparse-Bayesian Non-Negative Matrix Factorization for Integrated Analyses in Genomics

Sparse, Bayesian non-negative matrix factorization (SB-NMF) algorithms infer overlapping patterns in large datasets, applicable to genomics. Data for biological systems in multiple platforms measure distinct molecular components (e.g., DNA, RNA, protein). These data can be integrated with coupled SB-NMF. We present the success of coupled SB-NMF in clustering analyses to learn sample groupings for cancer subtypes. We also demonstrate their limitations for time course data and the need to model time delays.

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MS06

Patterns of DNA Copy-Number Alterations Revealed by the GSVD and Tensor GSVD Encode for Cell Transformation and Predict Survival and Response to Platinum in Adenocarcinomas

GSVD and tensor GSVD comparisons of patient-matched lung, ovarian, and uterine adenocarcinoma and normal genomes reveal technology-independent tumor-exclusive patterns of DNA copy-number alterations that predict survival, both in general and in response to platinum. A quarter or more of these tumors are resistant to platinum, the first-line systemic treatment, yet no other diagnostic distinguishes resistant from sensitive tumors. This demonstrates the mathematically universal ability of comparative spectral decompositions to find in data what other methods miss.

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MS06

Systems Biology of Drug Resistance in Cancer

Development of cell populations resistant to existing treatment regimens is a burning challenge in cancer research and patient care. Drug resistance is induced by a number cellular mechanisms that are activated by genetic or epigenetic alterations. In this presentation I focus on ovarian cancer chemoresistance in general, and using mathematical models for integration and analysis of patient-derived next-generation sequencing data at genomic, epigenomic, and RNA levels to guide the effort of overcoming the resistance.

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MS06

Single-Cell Entropy for Estimating Differentiation Potency in Waddington's Epigenetic Landscape

Single cell omics has ushered in a new era in molecular biology, offering an unprecedented opportunity to improve our fundamental understanding of cell biology. Here, I will describe some recent progress in using single-cell data to model Waddington's epigenetic landscape, representing a simplified model of cell differentiation. I will describe a network theoretical framework which uses the concept of signaling entropy to approximate the potency of single cells, be they normal or cancer cells.

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MS06

Dimension Reduction for the Integrative Analysis of Multilevel Omics Data

Biological systems are increasingly studied at multiple omics levels simultaneously. Sequential analysis of the individual omics levels does not take the interconnected nature of the data into account. Integrative analysis of the multilevel data using dimension reduction techniques facilitate the identification of a larger number and more relevant features than sequential methods. We apply principal component-, correspondence- and multiple co-inertia analysis to transcriptome and proteome data from 57 cancer cell lines and show that MCIA allows identification of a more complete set of relevant features and more accurate classification of the cancer types.

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MS06

Mathematically Universal and Biologically Consistent Astrocytoma Genotype Encodes for Transformation and Predicts Survival Phenotype

DNA alterations have been observed in astrocytoma genomes for decades. A copy-number genotype predictive of survival phenotype was only detected by using the GSVD. In comparisons of sets of patient-matched astrocytoma tumor and normal genomes, profiled by different technologies, the GSVD separates the biologically consistent genotype and phenotype from changing experimental variations. This demonstrates the mathematically universal ability of the GSVD, formulated as a comparative spectral decomposition, to find in data what other methods miss.

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MS06

Statistical Methods for Integrative Clustering Analysis of Multi-Omics Data

We developed integrative clustering methods to jointly model multi-omics data for identification of tumor subtypes and driver omics features. These methods use a few latent variables to capture the inherent structure of multi-omics data to achieve joint dimension reduction. As a result, the samples are clustered in the latent variable space and driver features contributing to the sample clustering are identified through variable selection algorithms. TCGA multi-omics data will be used to illustrate the methods.

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MS06

Structured Convex Optimization Method for Orthogonal Nonnegative Matrix Factorization with Applications to Gene Expression Data

Orthogonal nonnegative matrix factorization (ONMF) plays an important role for data clustering and machine learning. We propose a new optimization model for ONMF based on the structural properties of orthogonal nonnegative matrix. The new model can be solved by a novel convex relaxation technique which can be employed quite efficiently. Numerical examples on hyperspectral imaging data and gene expression data are presented to illustrate the effectiveness of the proposed algorithm.

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MS06

Mining the ECG Using Low Rank Tensor Approximations with Applications in Cardiac Monitoring

The power of low rank tensor approximations using multilead Electrocardiography (ECG) is shown in T-wave alternans and irregular heartbeat detection. Although Canonical Polyadic Decompositions (CPD) and Multilinear Singular Value Decompositions (MLSVD) are most popular, their extensions, e.g. Block Term Decompositions (BTD) and multiscale MLSVD, are emerging in clinical applications. Their benefits in biomedical data processing are shown. Nevertheless, their use in smart diagnostics is still largely unexplored.

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MS06

Tensor Higher-Order GSVD: A Comparative Spectral Decomposition of Multiple Column-Matched But Row-Independent Large-Scale High-Dimensional Datasets

The number of interrelated large-scale high-dimensional datasets is growing, accompanied by a need for decompositions that can simultaneously identify the similar and dissimilar among multiple tensors. We define a tensor higher-order GSVD (HO GSVD), which preserves the exactness of the GSVD. We prove that the tensor HO GSVD exists, generalizes the uniqueness properties of, and reduces to the GSVD. We also prove that the common tensor HO GSVD subspace, like the GSVD, maintains orthogonality of the corresponding column basis vectors.

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MS06

The GSVD: Where are the ellipses?

The SVD ellipse picture is a familiar visual for the action of A on the unit ball. We are not aware of any ellipse pictures in the literature nor even a notion that a natural ellipse picture exists for the generalized SVD of two matrices A and Bor the closely related CS Decomposition of an orthogonal matrix. In this talk, we reveal the trigonometry, the ellipse picture, and further geometry of the GSVD.

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MS06

Tensor Convolutional Neural Networks (TCNN): Improved Featurization Using High-Dimensional

Frameworks

The tensor convolutional neural networks (tCNNs) we have developed provide an exciting new direction in machine learning. Our tCNNs have the potential to improve featurization, manage storage costs, and develop a deeper understanding of machine learning algorithms. From our tensor framework, we can extract multidimensional correlations otherwise lost in matrix-based approaches. In this talk, we will demonstrate the flexibility of our tCNNs and present results comparable to matrix-based CNNs, but with more efficient featurization.

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Lior Horesh, IBM TJ Watson Research Center
Haim Avron, Tel Aviv University
Misha Kilmer, Tufts University

MS06
Three-Way Generalized Canonical Correlation Analysis

Regularized generalized canonical correlation analysis (RGCCA) is a rich technique that encompasses several important multivariate analysis methods such as partial least squares, principal components analysis, and (generalized) canonical correlation analysis. RGCCA is currently devoted to the analysis of a set of two-way data matrices. In this work, multiway RGCCA (MGCCA) extends RGCCA to the configuration where data matrices can have a multiway structure.

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MS07
Fast Solvers for Multiscale Problems: Overlapping Domain Decomposition Methods

Two-level overlapping domain decomposition methods are considered for fast solvers for elliptic problems with coefficients of highly varying and random values. The main ingredient is how to enrich the coarse component of the domain decomposition methods. The coarse component is obtained from the constrained energy minimizing multiscale finite element methods applied to off-line basis functions, which are formed by solving a certain generalized eigenvalue problem on each subdomain. The proposed method is shown to be less sensitive to the overlapping width of the subdomain partition in contrast to the previously developed methods. Numerical results are included.

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MS07
A Parallel Non-Iterative Domain Decomposition Method for Image Denoising

Total variation denoising (TVD) is an effective technique for image denoising, but it is quite expansive, computationally speaking, for large images, especially in 3D. In this talk, we discuss a highly parallel version of the algorithm formulated based on a non-iterative overlapping domain decomposition approach. We show by a theory and also by some two- and three-dimensional numerical experiments that the new approach has similar numerical accuracy as the classical TVD, but is much more efficient in terms of the parallel efficiency. This is a joint work with R. Chen and J. Huang.

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MS07
Robust BDDC and FETI-DP Methods in PETSc

Novel classes of solvers based on the Balancing Domain Decomposition by Constraints (BDDC) and the Finite Element Tearing and Interconnecting Dual-Primal (FETI-DP) methods are available in the PETSc library. Such methods provide sophisticated and almost black-box Domain Decomposition solvers which are able to deal with elliptic PDEs with coefficients' heterogeneities and discretized by means of non-standard finite element discretizations. The talk introduces the algorithms and their current implementation in PETSc. Large scale numerical results for different type of PDEs and finite elements discretizations prove the effectiveness of the methods.

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MS07
Goal-Oriented Adaptivity for a Class of Multiscale High Contrast Flow Problems

Goal-oriented adaptivity is introduced within the framework of the Generalized Multiscale Finite Element Method (GMsFEM) for a class of multiscale high contrast flow problems. GMsFEM is a system-atic approach for approximation to multiscale problems. The methodology is based on a coarse mesh for global solution and a subordinate fine mesh over which local problems are considered. Goal-oriented indicators are introduced to enhance both the accuracy and efficiency for seeking the approximation in the sense of a given quantity of interest, which is generally a localized functional of the weak solution of the PDEs. Our results show that the goal-oriented adaptivity outperforms standard adaptivity when approximating the quantity of interest. In this talk, we will discuss the formulation of goal-oriented a posteriori error indicators within GMsFEM. These error indicators are of residual-based and dual-weighted residual type. The techniques will be illustrated with numerical examples.

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MS07
A Parareal Algorithm for Coupled Systems Arising from Optimal Control Problems

We present a parareal method for solving coupled nonlinear systems arising from optimal control problems. Just like parareal for initial value problems (IVP), we integrate with coarse time steps to predict values at intermediate states, so that the time-consuming fine integration step can be performed in parallel on different time intervals. However, the system is globally coupled, unlike for IVPs. We discuss preconditioning issues and show numerical examples to illustrate the effectiveness of our approach.

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Julien Salomon, INRIA-Paris

MS07
Convergence of Adaptive Weak Galerkin Finite

Element Methods

In this talk, we prove the convergence of Adaptive Weak Galerkin Finite Element Methods (AWGFEM) for the second order elliptic problems. At first, we present the definitions for both the weak gradient and the corresponding weak gradient space, and review the standard adaptive procedure. Secondly, we present Weak Galerkin Finite Element Methods for the second order elliptic problems, the corresponding a posteriori error estimator and the algorithm of AWGFEM. At last, by using the conservation property of the WG approximation, global upper bound of error and the reduction of the error of estimator, we obtain the recursion formula for the sum of the norm of error function and the scaled error estimator, between two consecutive adaptive loops. Furthermore, according to the contraction of oscillation, we obtain the algorithm AWGFEM will terminate in finite steps for a given tolerance.

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MS07
A Nonoverlapping DD Method for an Interior Penalty Method

In this talk we will discuss a nonoverlapping domain decomposition (DD) method for heterogeneous elliptic problems. There are two key ingredients in the proposed method: one is a subspace decomposition of the finite element space and the other is a procedure based on the dual-primal finite element tearing and interconnecting approach. Numerical results are presented, which illustrate the performance of the proposed DD method.

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Susanne C. Brenner, Louisiana State University
Li-yeng Sung, Louisiana State University

MS07
A Two-Grid Preconditioner for Flow Simulations in Highly Heterogeneous Media with an Adaptive Coarse Space

We propose a two-grid preconditioner for flow simulations in highly heterogeneous media using the Raviart-Thomas finite element spaces. This preconditioner is based on a overlapping domain decomposition local smoother and a coarse preconditioner with an adaptive coarse space. The coarse space is formed by adaptive chosen eigenfunctions of a spectral problem. We show that the condition number of the preconditioned systems is almost independent of the media contrast. We also apply this preconditioner for two phase flow simulations with the SPE10 benchmark model.

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MS08
Overview of Large Scale Kernel Methods

TBA

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MS08
Kernel Methods and Tensor Decompositions

Kernel methods are very efficient tool in machine learning. Tensor decompositions are quite popular to approximate multimodal data, but they typically rely on the standard Euclidean structure of the data. In this talk, we review different approaches how kernel and tensor methods can be used together, for function interpolation, classification and regression tasks.

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MS08
Quadrature-Based Features for Kernel Approximation

We consider the problem of improving kernel approximation via randomized feature maps.These maps arise as Monte Carlo approximation to integral representations of kernel functions and scale up kernel methods for larger datasets. We propose to use more efficient numerical integration technique to obtain better estimates of the integrals compared to the state-of-the-art methods. Our approach allows the use of information about the integrand to enhance approximation and facilitates fast computations. We derive the convergence behavior and conduct an extensive empirical study that supports our hypothesis.

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Evgeny Burnaev, Skolkovo Institute of Science and Technology

MS08
Convergence Analysis of Deterministic Kernel-Based Quadrature Rules in Sobolev Spaces

Kernel-based quadrature rules are a promising approach to numerical integration, as they can exploit prior knowledge on the integrand through the choice of a positive definite kernel, and thus can achieve convergence rates much faster than standard Monte Carlo methods. In this talk I present convergence results for this approach, focusing on a Sobolev space as an RKHS. In particular I show that minimal optimal rates may be achieved both in well-specified and misspecified settings.

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Bharath K. Sriperumbudur, The Pennsylvania State University
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MS08
Sequential Sampling for Kernel Matrix Approximation and Online Learning

TBA

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MS08
Tradeoffs of Stochastic Approximation in Hilbert Spaces

TBA

Aymeric Dieuleveut, École Normale Supérieure, `aymeric.dieuleveut@ens.fr`

MS08
Scalable Deep Kernel Learning

Gaussian processes are flexible distributions over functions, which can learn interpretable structure through covariance kernels. In this talk, I introduce a Gaussian process framework which is capable of learning expressive kernel functions on massive datasets, through creating and then exploiting algebraic structure, followed by local interpolation. I will show how this framework generalizes a wide family of scalable machine learning approaches, and combines the non-parametric flexibility of kernel methods, and the probabilistic representation of a Gaussian process, with the inductive biases of deep learning architectures. I will then discuss how we can use this framework for a wide range of applications: reverse engineering human learning biases, crime prediction using point processes, spatiotemporal regression, image inpainting, video extrapolation, modelling change points and the impacts of vaccine introduction, autonomous vehicles, and discovering the structure and evolution of stars. I will also introduce a new computational platform for scalable deep kernel methods, based on iterative algorithms that only make use of matrix vector multiplies (MVMs) and structure exploiting algebra.

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MS08
Kernel Methods for Causal Inference

TBA

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MS09
When are nonconvex optimization problems not scary?

General nonconvex optimization problems could possess many spurious local minimizers, whereas heuristic optimization methods often work surprisingly well and return high-quality solutions on practical problems. In this talk, I will describe a benign global structure of nonconvex problems that allows simple iterative methods to efficiently find a global minimizer, irrespective of initialization. The described global structure has been verified on a number of practical problems, including sparsifying dictionary learning and generalized phase retrieval, and hence spawned novel and often more practical solutions to these problems.

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Qing Qu, Columbia University
John Wright, Columbia University

MS09
The Scaling Limit of Online Lasso, Sparse PCA and Related Algorithms

We analyze the dynamics of a family of online learning algorithms in the high-dimensional scaling limit. As the ambient dimension tends to infinity, and with proper time scaling, we show that the time-varying joint empirical measure of the target vector and the estimates provided by the algorithm will converge weakly to a deterministic measured-valued process that can be characterized as the unique solution of a nonlinear PDE. In addition to providing a tool for understanding the performance of the algorithm, our PDE analysis also provides useful insight. In particular, in the high-dimensional limit, the original coupled dynamics associated with the algorithm will be asymptotically "decoupled", with each coordinate independently solving a 1-D effective minimization problem via stochastic gradient descent. Exploiting this insight to design new algorithms for achieving optimal trade-offs between computational and statistical efficiency may prove an interesting line of future research.

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Jonathan Mattingly, Duke University
Chuang Wang, Harvard University

MS09
Accelerated Alternating Projection for Robust Principle Component Analysis

In this talk, I will present a non-convex optimization algorithm for robust principle component analysis, where a given data matrix is decomposed into the sum of a low-rank matrix and a sparse matrix. Our algorithm is an alternating projection algorithm accelerated by the projection onto the tangent space of the manifold of all low-rank matrices. With the tangent space projection, SVDs of large size can be avoided, and therefore our algorithm is computationally efficient. Our theoretical result reveals that the proposed algorithm with a special initialization is guaranteed to find the correct low-rank plus sparse decomposition, provided the sparse component is sparse enough.

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MS09
Numerical Integrators for Rank-Constrained Differential Equations

We present discrete methods for computing low-rank approximations of time-dependent tensors that can be the solution of a differential equation. The format for the low-rank approximation can be Tucker, tensor trains, MPS or hierarchical tensors. We will consider two types of discrete integrators: projection methods based on quasi-optimal metric projection, and splitting methods based on inexact solutions of substeps. For both approaches we show numerically and theoretically that their behavior is superior compared to standard methods applied to the so-called gauged equations. In particular, the error bounds are robust in the presence of small singular values of the tensor matricisations.

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Christian Lubich, University of Tübingen
Hanna Walach, University of Tübingen

MS09
Foundations of Nonconvex and Nonsmooth Robust Subspace Recovery

We present a mathematical analysis of a non-convex energy landscape for Robust Subspace Recovery. We develop generic conditions that ensures recovery of an underlying subspace in corrupted datasets. We further show that if the generic condition is satisfied, a geodesic gradient descent method over the Grassmannian manifold can exactly recover the underlying subspace.

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Gilad Lerman, University of Minnesota
Teng Zhang, University of Central Florida

MS09
Geometry and Algorithm for Sparse Blind Deconvolution

Blind deconvolution is a ubiquitous problem aiming to recover a convolution kernel $a_0 \in \Re^k$ and an activation signal $x_0 \in \Re^m$ from their convolution $y \in \Re^m$. This is an ill-posed problem in general. This talk focuses on the *short and sparse* blind deconvolution problem, where the convolution kernel is

short ($k \ll m$) and the activation signal is sparsely and randomly supported ($normx_00 \ll m$). This variant captures the structure of the convolutional signals in several important application scenarios.
The observation y is invariant up to some mutual scaling and shift of the convolutional pairs. Such *scaled-shift symmetry* is intrinsic to the convolution operator and imposes challenges for reliable algorithm design. We normalize the convolution kernel to have unit Frobenius norm and then cast the blind deconvolution problem as a nonconvex optimization problem over the kernel sphere. We demonstrate that (i) under conditions, every local optimum is close to some shift truncation of the ground truth, and (ii) for a generic filter $a_0 \in S^{k-1}$, when the sparsity of activation signal satisfies $\theta \lesssim k^{-2/3}$ and number of measurements $m \gtrsim polyparenk$, provable recovery of some shift truncation of the ground truth kernel can be obtained.

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MS09
Convergence of the Randomized Kaczmarz Method for Phase Retrieval

The classical Kaczmarz iteration and its randomized variants are popular tools for fast inversion of linear overdetermined systems. This method extends naturally to the setting of the phase retrieval problem via substituting at each iteration the phase of any measurement of the available approximate solution for the unknown phase of the measurement of the true solution. Despite the simplicity of the method, rigorous convergence guarantees that are available for the classical linear setting have not been established so far for the phase retrieval setting. In this short note, we provide a convergence result for the randomized Kaczmarz method for phase retrieval in $\mathbb{R}^d$. We show that with high probability a random measurement system of size $m \simeq d$ will be admissible for this method in the sense that convergence in the mean square sense is guaranteed with any prescribed probability. The convergence is exponential and comparable to the linear setting.

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MS09
Nonconvex Optimization for High-Dimensional Learning

Many problems of contemporary interest in signal processing and machine learning involve highly non-convex optimization problems. While nonconvex problems are known to be intractable in general, simple local search heuristics such as (stochastic) gradient descent are often surprisingly effective at finding global optima on real or randomly generated data. In this talk I will discuss some results explaining the success of these heuristics in the context of learning shallow neural networks.

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MS10
Recovery of Sparse Integer-Valued Signals

In some applications the signal vector in a linear model is sparse and its entries are drawn from a finite alphabet following some distribution. To recover the signal vector from the observations one can apply the maximum a posteriori (MAP) estimation method. Under a reasonable assumption about the distribution of the signal vector, the MAP estimate of the signal vector is the solution of an l_0-norm regularized constrained integer least squares problem. Due to the high computational complexity, we propose to find some suboptimal solutions to the optimization problem. Some theory and algorithms are presented. Numerical examples are given to illustrate the effectiveness of the proposed algorithms.

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MS10
Computing Time-Varying ML-Weighted Pseudoinverse by the Zhang Neural Networks

The ML-weighted generalized inverse is a useful tool in solving and analyzing the constrained least squares problems. The Zhang neural network (ZNN), a recurrent neural network, proposed in 2001, is particularly effective in solving time-varying problems. We propose a ZNN model for computing the ML-weighted generalized inverse of a time-varying matrix. We show that our model converges globally and exponentially to the solution and our system is robust at the presence of small errors.

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MS10
GNN and ZNN Solutions of Linear Matrix Equations

We investigate the solution to the general time-invariant matrix equation $AXB = D$ by means of gradient based neural network model, denoted by GNN(A,B,D). The resulting matrix generated by the GNN(A,B,D) model is defined by the choice of the initial state and coincides with the general solution of the matrix equation $AXB = D$. The explicit ZNN based dynamical system is denoted by ZNN(A,B,D). Several particular appearances of this matrix equation and their applications in approximating various inner and outer inverses are considered. General algorithm is based on the following. Solution $\tilde{V}$ to $BXCAB = B$ defined by the GNN(B,CAB,B) or by the ZNN(B,CAB,B) model gives $\tilde{V} \in (CAB)\{1\}$.Then $X = B\tilde{V}C$ gives various representations of outer inverses, according to Urguhart formula.Developed algorithms are applicable to both the time-varying and time-invariant real matrices.

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MS10
Randomized Algorithms for Total Least Squares Problems

Motivated by the recently popular probabilistic methods for low-rank approximations and randomized algorithms for the least squares problems, we develop randomized algorithms for the total least squares (TLS) problem with single right-hand side. For the medium-sized problems we present the randomized strategy and Nystrom method. For the large-scale and ill-conditioned cases we introduce the randomized truncated TLS (RTTLS) with the known or estimated rank as regularization parameter, and also propose an adaptive method. We analyze the accuracy of the typical algorithm RTTLS, and perform numerical experiments to check the efficiency of the randomized algorithms.

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Hua Xiang, Wuhan University
Pengpeng Xie, Ocean University of China

MS10

Randomized Algorithms for Core Problem and TLS Problem

In this talk, we apply the randomized algorithms to the core problem and the total least squares (TLS) problem $Ax \approx b$ in the large-scale discrete ill-posed problems. The randomized projection is proposed, based on the rank-k approximation of A. In the error analysis, we provide an upper bound that requires the computation of the $(k+1)$-th singular value of A. Illustrative numerical examples and comparisons are presented.

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Liping Zhang, Department of Mathematics, Zhejiang University of Technology
Yimin Wei, Fudan University

MS10

Condition Numbers of the Multidimensional Total Least Squares Problem

We present the Kronecker-product-based formulae for the normwise, mixed and componentwise condition numbers of the multidimensional total least squares (TLS) problem. For easy estimation, we also exhibit Kronecker-product-free upper bounds for these condition numbers. The upper bound for the normwise condition number is proved to be optimal, greatly improve the results by Gratton et al. for the truncated solution of the ill-conditioned basic TLS problem. As a special case, we also provide a lower bound for the normwise condition number of the classic TLS problem when having a unique solution. These bounds are analyzed in detail. Furthermore, we prove that the tight estimates of mixed and componentwise condition numbers recently given by other authors for the basic TLS problem are exact. Some numerical experiments are performed to illustrate our results.

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MS10

Fast Solution of Nonnegative Matrix Factorization via a Matrix-Based Active Set Method

For the solution of nonnegative matrix factorization, which is a low rank matrix approximation problem with nonnegative constraints, we propose an alternating nonnegative least squares method by utilizing modulus-type inner outer iteration to solve the nonnegative constrained least squares problem with multiple right hand sides at each iteration. We also propose a fast matrix-based active set method to improve the convergence. Numerical experiments show that the proposed methods converges faster than the state-of-the-art methods.

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MS11

Space-Time Schwarz Preconditioning and Applications

We discuss a multilevel space-time additive Schwarz method for solving linear system of equations arising from the discretization of parabolic equations. With this method, the problem is solved in parallel on both space and time dimensions. After establishing two important properties of the space and time decomposition; i.e., a strengthened Cauchy-Schwarz type inequality and a stable multilevel decomposition under a space-time energy norm, we introduce an optimal convergence theory and show how the convergence rate depends on the mesh sizes, the number of subdoamins, the window size and the number of levels. Some numerical experiments carried out on a parallel computer with thousands of processors confirm the theory in terms of the number of iterations, as well as the strong and weak scalabilities. This is a joint work with S. Li and X. Shao.

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MS11

Parallel-in-Time Multigrid with Adaptive Spatial Coarsening for the Linear Advection and Inviscid Burgers Equations

We apply multigrid reduction-in-time (MGRIT) to 1D hyperbolic PDEs, adding spatial coarsening to the temporal coarsening of the MGRIT process. For explicit time-stepping, spatial coarsening helps to satisfy stability conditions on all levels, and for implicit time-stepping it may produce cheaper multigrid cycles. We show that adaptive spatial coarsening is required to obtain fast convergence when local wave speeds are close to zero. Parallel scaling tests indicate good scalability and run-time improvements over serial time-stepping.

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MS11

On the Convergence of PFASST

The "Parallel Full Approximation Scheme in Space and Time" (PFASST) can be used to solve time-dependent partial differential equations using parallelization in time. PFASST shows promising results for many use cases. However, a solid and reliable mathematical foundation is still missing. Under certain assumptions the PFASST algorithm can be stated as a multigrid-in-time method. Using this formulation PFASST can be analyzed using block-wise local Fourier analysis.

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Dieter Moser, RWTH Aachen
Robert Speck, Forschungszentrum Jülich

MS11

Waveform Relaxation with Adaptive Pipelining (Wrap)

Waveform relaxation methods are domain decomposition methods for time-dependent PDEs in which subdomain problems are posed in space and time. In this talk, we introduce temporal parallelism in these methods, with different processors working on different time windows. Because the convergence rate of the new method is independent of the overall time horizon length, we obtain significant speedup relative to sequential time-stepping. Numerical examples are presented to illustrate the effectiveness of our approach.

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Benjamin W. Ong, Michigan Technological University

MS12

An $O(N^3)$ Scaling Algorithm to Calculate $O(N)$ Excited States Based on PP-RPA

The particle-particle random phase approximation (pp-RPA) has been shown to be capable of describing double, Rydberg, and charge transfer excitations, for which the conventional time-dependent density functional theory (TDDFT) might not be suitable. It is thus desirable to reduce the computational cost of pp-RPA so that it can be efficiently applied to larger molecules and even solids. This paper introduces an $O(N^3)$ algorithm, where N is the number of orbitals, based on an interpolative separable density fitting technique and the Jacobi-Davidson eigensolver to calculate $O(N)$ low-lying excitations in the pp-RPA framework.

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MS12

The ELSI Infrastructure for Large-Scale Electronic Structure Theory

This talk outlines the ELSI infrastructure (http://elsi-interchange.org), an open-source framework that abstracts the generic task of deriving single-particle eigenvalues/eigenvectors or density matrices from the Hamilton and overlap matrices of large-scale density-functional theory. ELSI converts different parallel distributed matrix formats to those needed by efficient solvers such as the O(N^3) eigensolver ELPA or the lower-scaling PEXSI method, and offers a simple interface to choose appropriate solvers for different system types, density functionals, and discretization types.

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Raul Laasner, Duke University
Yingzhou Li, Duke University
Lin Lin, University of California, Berkeley
Jianfeng Lu, Duke University
Alvaro Vazquez-Mayagoitia, Argonne National Laboratory
Chao Yang, Lawrence Berkeley National Laboratory
Haizhao Yang, National University Singapore

MS12

Recent Progress on Solving Large-Scale Eigenvalue Problems in Electronic Structure Calculations

One of the major challenges in the Kohn-Sham density functional theory based electronic structure calcluation is the solution of a linear eigenvalue problem in each step of the self-consistent field (SCF) iteration used to find the ground state electron density. The number of eigenpairs to be computed can reach tens or hundreds of thousands. For systems of this size, the Rayleigh-Ritz procedure used in many standard iterative solvers becomes prohibitively expensive. We will examine a number of techniques to overcome this difficulty.

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MS12

The Full Configuration Interaction Quantum Monte Carlo(FCIQMC) in the Lens of Inexact Power Iteration

In this talk, I will present a general analysis framework of inexact power iteration for high dimensional eigenvalue problems arising from quantum many-body problems. Under this framework, I will compare and establish convergence analysis for several recently proposed stochastic eigenvalue algorithms, including the full configuration interaction quantum Monte Carlo (FCIQMC) and the fast randomized iteration (FRI) algorithms. The analysis is confirmed with numerical experiments for physical systems such as Hubbard model and molecules.

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MS12

A FEAST Algorithm with Oblique Projection for Generalized Eigenvalue Problems

The FEAST algorithm is a recent effort for computing the eigenvalues inside a given region in the complex plane. It is stable, accurate and is easily parallelizable. However, it was observed that the FEAST algorithm may fail when applied to non-Hermitian problems. In this talk, we will introduce a non-Hermitian FEAST algorithm, as well as the related implementation details. Numerical experiments will be reported to illustrate that our method is stable and efficient.

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Raymond H. Chan, The Chinese University of Hong Kong
Man-Chung Yeung, University of Wyoming

MS12

Real Eigenvalues in Linear Viscoelastic Oscillators

This paper presents the dynamic analysis of a system involving various nonviscous damping models. The free motion equation can be transformed to a system containing only exponentially decaying damping. Its real eigenvalues can be characterized as maxmin values of a Rayleigh functional and can be determined by the quadratically convergent save guarded iteration. A numerical example demonstrates the efficiency of the approach.

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MS12

Error Bounds for Ritz Vectors and Approximate Singular Vectors

We derive sharp and computable bounds for the accuracy of approximate eigenvectors (Ritz vectors) obtained by the standard Rayleigh-Ritz process for symmetric eigenvalue problems. While this is a well-studied problem for which classical results are available based on the Davis-Kahan theory, our bounds can give nontrivial information even when classical bounds suggest that a Ritz vector would have no digits of accuracy, that is, when the residual norm is larger than the eigenvalue gap. We also derive the counterpart for the SVD: namely the accuracy of singular vectors computed via a (Petrov-Galerkin) projection method.

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MS12

Consistent Symmetric Greedy Coordinate Descent Method

We propose a consistent symmetric greedy coordinate descent method for solving leading eigenvalue problems from an optimization viewpoint. Since different coordinates converge to the optimal value at different speeds, coordinate-wise method has been shown to outperform the full updating method. Our proposed algorithm is able to select and update the most important coordinates in $O(kn)$ time at each iteration, where k is the number of coordinates and n is the matrix size. Although the objective function in the optimization problem is non-convex, we prove that any local minimum is the global minimum and a stochastic version of the algorithm helps the iteration escaping from every single saddle point. Experimental results show that our methods achieve a great speedup over the basic power method. Meanwhile, due to its coordinate-wise nature, our methods can be implemented in an synchronized manner and is very suitable for the cases when data cannot fit into memory.

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MS12
On the Accuracy of Fast Structured Eigenvalue Solutions

It was previously shown that the class of symmetric hierarchical semiseparable (HSS) matrices and matrices that can be well approximated as such admit a near-linear complexity divide and conquer eigenvalue algorithm. We show the stability of this algorithm and present some accuracy analysis results that invite the use of aggressive truncation and thus even faster eigenvalue solutions to certain classes of hierarchical matrices without sacrificing prescribed accuracy. We also present some applications of this algorithm.

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Jianlin Xia, Purdue University

MS12
Generation of Large Sparse Test Matrices to Aid the Development of Large-Scale Eigensolvers

Large-scale eigenvalue problems play an important role in many scientific computational applications. Many existing eigensolvers for large-scale problems are continued to be refined and new solvers are being developed. Test problems to aid these software developments are thus valuable. While common large test matrices - such as those found in the University of Florida Collection are usually derived from actual scientific applications, they seldom come with full knowledge of eigen decompositions. This talk presents a mechanism that generates synthetic large sparse matrices whose eigen decomposition is known a priori. The mechanism consists of applying polynomials to seed matrices, composition of matrices by tensor products, and permutations. Results by running some solvers on these test matrices will be presented as well.

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MS13
Greedy Method for Orthogonal Tensor Decomposition

Atensor can be decomposed to the summation of rank-one tensors such as the Canonical Polyadic (CP) and Tucker tensor decomposition. Both decompositions mimic the singular value decomposition of a matrix. However, CP decomposition does not preserve orthogonality property, and Tucker decomposition is too restrictive: every two vectors in the same mode either orthogonal or parallel to each other. This talk will introduce a greedy algorithm for orthogonal tensor decomposition, which enforces orthogonality between any two rank-one tensors. Numerical results will also be shown to demonstrate the correctness and efficiency of the algorithm.

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MS13
SDPNAL+: a MATLAB Software Package for Large-Scale SDPs with a User-Friendly Interface

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 design it within an inexact symmetric Gauss-Seidel based semi-proximal ADMM/ALM (alternating direction method of multipliers/augmented Lagrangian method) framework for the purpose of deriving simpler stopping conditions. The basic code is written in MATLAB, but some subroutines in C language are incorporated via Mex files. We also design a convenient interface for users to input their SDP models into the solver. Numerous problems arising from combinatorial optimization and binary integer quadratic programming problems have been tested to evaluate the performance of the solver. Extensive numerical experiments conducted in [Yang, Sun, and Toh, Mathematical Programming Computation, 7 (2015), pp. 331–366] show that the proposed method is quite efficient and robust.

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Xin-Yuan Zhao, Beijing University of Technology

MS13
Vector Transport-Free SVRG with General Retraction for Riemannian Optimization: Complexity Analysis and Practical Implementation

We propose a vector transport-free stochastic variance reduced gradient (SVRG) method with general retraction for empirical risk minimization over Riemannian manifold. The vector transport-free SVRG with general retraction we propose do not need additional computational costs in previous works. We analyze its iteration complexity for obtaining an ϵ-stationary point and local linear convergence by assuming the Łojasiewicz inequality. We also incorporate the Barzilai-Borwein step size and design a very practical method.

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Anthony Man-Cho So, The Chinese University of Hong Kong
Shuzhong Zhang, University of Minnesota

MS13
On Decompositions and Approximations of Conjugate Partial-Symmetric Complex Tensors

Conjugate partial-symmetric (CPS) tensors are the high-order generalization of Hermitian matrices. As the role played by Hermitian matrices in matrix theory and quadratic optimization, CPS tensors have shown growing interest recently in tensor theory and optimization, particularly in many application-driven complex polynomial optimization problems. In this talk, we study CPS tensors with a focus on ranks, rank-one decompositions and approximations, as well as their applications. The analysis is conducted along side with a more general class of complex tensors called partial-symmetric tensors. We prove constructively that any CPS tensor can be decomposed into a sum of rank-one CPS tensors, which provides an alternative definition of CPS tensors via linear combinations of rank-one CPS tensors.

Three types of ranks for CPS tensors are defined and shown to be different in general. This leads to the invalidity of the conjugate version of Comonś conjecture. We then study rank-one approximations and matricizations of CPS tensors. By carefully unfolding CPS tensors to Hermitian matrices, rank-one equivalence can be preserved. This enables us to develop new convex optimization models and algorithms to compute best rank-one approximation of CPS tensors. Numerical experiments from various data are performed to justify the capability of our methods.

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MS14
Fast Low-Rank Solvers for HPC Applications on Massively Parallel Systems

By exploiting the low-rank off-diagonal block structure, we design and implement fast linear algebra operations on massively parallel hardware architectures. The main idea is to refactor the numerical algorithms and the corresponding implementations by aggregating similar numerical operations in terms of highly optimized batched kernels. Applications in weather prediction, seismic imaging and material science are employed to assess the trade-off between numerical accuracy and parallel performance of these fast matrix computations compared to more traditional approaches.

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MS14
GOFMM: A Geometry-Oblivious Fast Multipole Method for Approximating Arbitrary SPD Matrices

The Fast multipole method (FMM) is ubiquitous in science and engineering. Roughly speaking, it accelerates computations with dense matrices. For example, for a square dense matrix of size N matrix vector multiplication requires $O(N^2)$ work. FMM can accelerate this operation to $O(N)$ work. FMM methods where originally defined using analytical expansion methods but over the years they have been “algebrized” to an increasing degree. Current state-of-the art FMM methods are only applicable to problems endowed with geometrical information, typically point coordinates. underlying geometric information (typically point coordinates).
Here we generalize the FMM method to arbitrary symmetric positive definite matrices–no geometric information is necessary.
We present GOFMM (geometry-oblivious fast-multipole methods), a novel method that creates a hierarchical low-rank approximation, or “sketching”, of an N-by-N arbitrary SPD matrix. For many applications, GOFMM enables an approximate matrix-vector multiplication in O(N logN) or even O(N) time. Sketching requires O(N log N) storage and work. In general, our scheme belongs to the hierarchical matrix approximation methods. In particular, it generalizes the fast multipole method (FMM) to a purely algebraic setting by only requiring the ability to sample matrix entries. Neither geometric information (i.e., point coordinates) nor knowledge of how the matrix entries have been generated is required, thus the term ”geometry oblivious”. Also,we introduce a shared-memory parallel scheme for hierarchical matrix computations that reduces synchronization barriers. We present results on the Intel Knights Landing and Haswell architectures, and on the NVIDIA’s Pascal architecture for a variety of matrices.

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Chenhan Yu, The University of Texas at Austin
James Levitt, The University of Texas at Austin
Severin Reiz, Technical University of Munich

MS14
A Parallel Implementation of a High Order Accurate Variable Coefficient Helmholtz Solver

The Hierarchical Poincaré-Steklov (HPS) method can efficiently, accurately and robustly solve variable coefficient Helmholtz problems without the pollution effect. This discretization technique comes with a direct solver, inspired by nested dissection, making it ideal for problems with multiple right hand sides. A parallel implementation is important to make the method useful for large computations. This talk presents the parallelization technique. Numerical results illustrate the performance of the method.

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Adrianna Gillman, Rice University
Russell Hewett, Total E&P Research & Technology USA

MS14
Low-Rank Matrix Approximations for Oil and Gas HPC Applications

In this talk we demonstrate how task-based programming model maximizes the performance of the Reverse Time Migration (RTM) on large GPU clusters. By relying on a dynamic runtime system to schedule the various tasks of the RTM (e.g., stencil computation kernel, Perfectly Matched Layer computations, I/O operations, image condition calculations, etc.), the overall application translates into an out-of-order execution. This opens up new opportunities to further overlap expensive and non-critical operations, such as I/O, with tasks which belong to the critical path, such as the high performance GPU stencil kernel computations during the forward/backward modeling. Idle time is then reduced through load balancing using work stealing on each node. Once the RTM stencil kernel has been optimized, profiling results show then that the I/O operations become the most time-consuming part of the RTM. To further reduce the overhead of the I/O operations, numerical compression algorithms are investigated, in addition to the asynchronous execution. This enables the prevention of running in an out-of-core mode of operation using CPU memory (or even disks), while maximizing occupancy on GPUs.
This talk touches base with most of HPC concepts and performance optimizations for extreme-scale RTM simulation: low-level CUDA optimization for stencil GPU kernel, asynchronous execution, overlapping communication with computation, compression techniques, load balancing and dynamic runtime systems.

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MS14
Stars-H: A Hierarchical Matrix Market Within an HPC Framework

STARS-H is a high performance parallel open-source Software for Testing Accuracy, Reliability and Scalability of Hierarchical computations. Hierarchical matrices arise in many PDEs and use much less memory, while requiring fewer flops for computations, thanks to low-rank approximations. STARS-H intends to provide a standard for assessing accuracy and performance of hierarchical matrix libraries, for compression and computation operations, on a given hardware architecture environment. For that purpose, it implements a hierarchical matrix market computed from various real scientific applications. STARS-H currently supports the tile low-rank (TLR) data format for approximation on shared and distributed-memory systems.

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Hatem Ltaief, King Abdullah University of Science and Technology
David Keyes, King Abdullah University of Science and Technology

MS14
Matrix-Free Construction of HSS Representations Using Adaptive Randomized Sampling

Although the theoretical foundation for the hierarchical matrix algebra has been solidified, there is lack of robust algorithm and software that can handle many practical issues. For example, randomized sampling has been shown to be an effective tool to reveal the low rank structure, but choosing the right number of samples is difficult. In this talk we present new results for HSS compression using an adaptive randomized sampling strategy. We developed robust stopping criteria based on a stochastic error estimation. We present results in the matrix-free context, show some practical difficulties and our proposed solutions.

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Chris Gorman, University of California, Santa Barbara
Pieter Ghysels, Lawrence Berkeley National Laboratory
Gustavo Chavez, Lawrence Berkeley National Laboratory
Francois-Henry Rouet, Livermore Software Technology Corporation

MS14
Low Rank Approximations of Hessians for PDE Constrained Optimization

TBA

George Turkiyyah, American University of Beirut, gt02@aub.edu.lb

MS14
Simulations for the European Extremely Large Telescope Using Low-Rank Matrix Approximations

To design, simulate and eventually deploy complex and critical large scale adaptive optics (AO) instruments on the next generation of extremely large telescopes, the implementation of efficient numerical strategies has become essential. Low rank matrix approximations techniques can potentially be leveraged since the physical model of AO systems, relying on multiple sensors distributed over regular patterns, intrinsically contains some level of data sparsity. In this talk we will review the core AO pipeline and present the results we have obtained so far in applying low rank matrix approximation.

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MS15
Multilinear and Linear Structures in Theory and Algorithms

Linear structures in matrices are described by linear algebraic equations.Typical examples are various kinds of sparsity, included bandedness, and Toeplitz and Hankel matrices. Multiplication and inversion of such matrices generally leads to matrices with polynomial (multilinear) relations between their elements. Other typical examples of multilinear structure are Cauchy and Vandermonde matrices, rank structures and various tensor decompositions. In this talk we survey general results and outline some open research questions for most popular and pervasive linear and multilinear structures.

Eugene Tyrtyshnikov, Institute of Numerical Mathematics of Russian Academy of Sciences, eugene.tyrtyshnikov@gmail.com

MS15
Generalized Locally Toeplitz Sequences: A Link Between Measurable Functions and Spectral Symbols

An asymptotic approximation theory for sequences of matrices with increasing size has recently been developed, providing tools for computing their asymptotic singular value and eigenvalue distribution. Using the notions of Approximating Classes of Sequences and spectral symbols, several pseudometric structures can be induced on the space of matrix sequences, giving rise to a natural isometry and isomorphism of algebras between the space of Generalized Locally Toeplitz sequences and the space of measurable functions.

Giovanni Barbarino, Scuola normale Superiore, Pisa giovanni.barbarino@sns.it

MS15
On the Study of Spectral Properties of Matrix Sequences

We show that in the study spectral properties of sequences of matrices obtained by discretization of elliptic operators on the plane it turns out that in many cases such sequences of matrices cannot be GLT. However, these sequences can be transformed to GLT by using some transformation of similarity. Eventually we come up with a new class of matrix sequences that naturally arise in the applications, possess spectral distribution symbols, but are not GLT.

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Eugene Tyrtyshnikov, Institute of Numerical Mathematics of Russian Academy of Sciences

MS15
Cross Method Accuracy Estimates in Consistent Norms

Two new accuracy estimates are discussed, concerning column-based (CW) and skeleton ($C\hat{A}^+R$) matrix approximations.
At first, a random error is considered. It is shown that the choice of columns, associated with the maximum volume principle, on the average gives an error that coincides with the best-known existence estimate for a fixed matrix. The estimate is then generalized to the case of $C\hat{A}^+R$ approximation.
In the second part of the talk the existence of a skeleton approximation that differs from the best low-rank approximation only by a factor $(r+1)$ is proven. This factor can be made a constant with a small increase in the size of the submatrix.
It is important that the new estimates do not depend on the matrix size and that both optimal and skeleton approximations are compared in the same norm. This distinguishes the current work from the previous ones, based on the maximum volume principle, where either the estimates depend on matrix size or different norms are used to reach a constant factor.

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MS15

Spectral and Convergence Analysis of the Discrete Adaptive Local Iterative Filtering Method by Means of Generalized Locally Toeplitz Sequences

In this talk we introduce a newly developed algorithm, the Adaptive Local Iterative Filtering (ALIF). This is an alternative technique to the well known Empirical Mode Decomposition method for the decomposition of nonstationary real life signals. This last algorithm has been successfully applied in many fields of research in the last two decades.
The mathematical convergence analysis of all the aforementioned algorithms is still lacking. For this reason, focusing the attention on the discrete version of ALIF, we show how recent results about sampling matrices and, in particular, the theory of Generalized Locally Toeplitz sequences allow to perform a spectral analysis of the matrices involved in the iterations. In particular we are able to study the eigenvalue clustering and the eigenvalue distribution for such matrices; we provide a necessary condition for the convergence of the Discrete ALIF method and we derive a simple criterion to construct filters, needed in the ALIF algorithm, that guarantee the fulfilment of the aforementioned necessary condition. We show some numerical examples and discuss about important open problems that are waiting to be tackled.
This is a joint work with Carlo Garoni and Stefano Serra-Capizzano.

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MS15

Asymptotic Expansion and Extrapolation Methods for the Fast Computation of the Spectrum of Large Structured Matrices

We often need an estimate of the spectrum of a matrix, for example when constructing a preconditioner.
For a (real) banded symmetric Toeplitz matrix $T_n(f)$, the eigenvalues can be approximated by sampling the symbol, $f(\theta)$, using an equispaced grid $\theta_n \in [0, \pi]$. However, the error is typically rather large, $\mathcal{O}(h)$, where $h = 1/(n+1)$.
We show that when the symbol is monotone, which is the case for many PDE discretizations such as FDM, IgA, and FEM, we can approximate an asymptotic expansion of the error $\lambda_j(T_n(f)) - f(\theta_{j,n}) = \sum_{k=1}^{\alpha} c_k(\theta_{j,n})h^k + E_{j,n,\alpha}$,
at a low computational cost. Then, the eigenvalues for a large matrix, of the same type, can be significantly better approximated using the precomputed approximations of $c_k(\theta)$.
Various aspects of the methods and procedures are described, discussed, and highlighted by numerical experiments.
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MS15

Isogeometric Analysis for 2D and 3D Curl-Div Problems: Spectral Symbols and Fast Iterative Solvers

In plasma physics, magnetohydrodynamics is used to study the macroscopic behavior of plasma. In this talk, we focus on a parameter-dependent curl-div subproblem, and we discretize it using isogeometric analysis. Since the involved linear systems are very ill-conditioned, we follow a two-step strategy to solve this problem. First, we conduct a detailed spectral study of the coefficient matrices. Second, we exploit such spectral information to design fast iterative solvers. Several numerical examples are provided.

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MS15

Rissanen-Like Algorithm for Block Hankel Matrices in Linear Storage

This work is devoted to the problem of solving linear systems with block Hankel matrices, in particular in the case of finite fields. Existing algorithms for this purpose typically have complexity proportional to the square of the size of the matrix in blocks (and the cube of the size of the block); however, they are not without deficiencies, which limit their applicability to the problem at hand. The aim of the present work is to develop an algorithm of similar complexity that would operate directly on the given matrix, be applicable to the case of finite fields, have only modest requirements on the matrix (if any), and, most importantly, require the amount of memory proportional to that required to set the problem (so, the number of blocks stored should be linear in the size of the matrix).
To this end, a modification of an algorithm proposed earlier by Cherepnev, which is itself a modification of Rissanen's algorithm, is developed. The Rissanen's method is aimed at the scalar case, boasting no requirements on the matrix and quadratic complexity; unfortunately, storage requirements are also quadratic. Cherepniov's modification of it is applicable to block matrices, but introduces additional requirements on the matrixnamely, that $(m+1)s \times ms$ leading submatrices have full rank, where s is the block size-and also retains the quadratic storage requirement. The crucial insight that allows to reduce storage requirements to linear is that the relevant structure is preserved by transposition, and the

transposed decomposition can be utilized to solve the system as it is being constructed, thus removing the need to store it in its entirety. Combined with a simple and straightforward generalisation, this yields an algorithm for finite-field systems, with additional requirement that all leading $ms \times (m+k)s$ submatrices have full rank for any fixed positive k, with only linear storage requirements and $O(n^2p^3k)$ complexity.

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MS16
Approximation of Inconsistent Systems of Linear Inequalities: Fast Solvers and Applications

TBA

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MS16
Theory of Distributed Learning

Analyzing and processing big data has been an important and challenging task in various fields of science and technology. Distributed learning based on a divide-and-conquer approach is an important topic in learning theory and is a powerful method to handle big data, with the advantages of reducing storage and computing costs.This talk describes some analysis viewpoints of distributed learning, and demonstrates error bounds for some distributed learning algorithms generated by regularization schemes in reproducing kernel Hilbert spaces.

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MS16
Scattering Transform for the Analysis and Classification of Art Images

Recently, the scattering transform was proposed as a signal processing tool aimed at providing a theoretical understanding of deep neural networks and state-of-the-art performance in image classification. It uses a cascade of wavelet filters and nonlinear (modulus) operations to build representations translation-invariant and deformation-stable representations. We explore the performance of this tool for art authentication purposes, focusing on the impact of different layers of the cascade structure.

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MS16
TBA

TBA

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MS17
A Harmonic Arnoldi Method for Computing the Matrix Function $f(A)v$

Based on GMRES for large linear systems, we propose a harmonic Arnoldi method for computing $f(A)v$. We make a convergence analysis, showing that the restarted harmonic Arnoldi algorithm is always guaranteed to converge for a properly given target point that can be determined easily. Numerical experiments illustrate that the proposed algorithm converges more smoothly and can be more effective than the restarted standard Arnoldi algorithm.
This is a joint work with Dr Hui Lv, supported in part by the National Science Foundation of China (No. 11771249).

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MS17
A New Framework for Understanding Block Krylov Methods Applied to Matrix Functions

Hinging on a generalized framework for block Krylov subspaces, we define a restarted block full orthogonalization method for matrix functions applied to multiple vectors. This method converges for Stieltjes functions of Hermitian positive definite matrices, and a block harmonic version for positive real matrices. We demonstrate the performance and versatility of our methods in a variety of applications and also examine the matrix polynomials corresponding to the block Krylov approximations.

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MS17
Bounds for the Decay of the Entries in Inverses and Cauchy-Stieltjes Functions of Certain Sparse Normal Matrices

We present new decay bounds for the inverse and Cauchy-Stieltjes functions of certain normal matrices, for which fewer and typically less satisfactory results exist so far. In the banded case, these and all the widely known results lead to a Toeplitz matrix of bounds. We construct an example of a Hermitian, tridiagonal matrix with non-Toeplitz structured inverse and present new, more appropriate bounds, where we take into account the distribution of the eigenvalues of A.

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MS17
Matrix Means for Signed and Multi-Layer Graphs Clustering

We study suitable matrix functions to merge information that comes from different kinds of interactions encoded in multilayer graphs, and its effects in cluster identification. We consider a family of matrix functions, known as power means, and show that different means identify clusters under different settings of the stochastic block model. For instance, we show that a limit case identifies clusters if at least one layer is informative and remaining layers are potentially just noise.

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MS17
A Daleckii–Krein Formula for the Fréchet Derivative of SVD-Based Matrix Functions

Matrix maps based on the singular value decomposition, called “generalized matrix functions”, have recently been argued to be relevant in several applications. I will obtain an explicit formula for their Fréchet derivative: an analogue of the Daleckii-Krein theorem. I will also discuss the issue of real versus complex differentiability, and the application of the result to the study of the condition number of generalized matrix functions.

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MS17
Computing Matrix Functions in Arbitrary Precision

Some state-of-the-art algorithms for the evaluation of matrix functions are tuned to work in double precision arithmetic. They typically carry out expensive precomputations that require knowledge of the precision at which the final computation will be performed. In this talk we investigate how these algorithms can be adapted to arbitrary precision environments, where the working precision is known only at runtime and can be treated as an input argument to the algorithm.

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MS17
Matrix Function Approximation for Computational Bayesian Statistics

TBA

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MS17
Conditioning of the Matrix-Matrix Exponentiation

If A has no eigenvalues on the closed negative real axis, and B is arbitrary square complex, the matrix-matrix exponentiation is defined as $A^B := e^{\log(A)B}$. It arises, for instance, in Von Newmann's quantum-mechanical entropy, which in turn finds applications in other areas of science and engineering. In this talk, we revisit this function and derive new related results. Particular emphasis is devoted to its Fréchet derivative and conditioning. We propose a new definition of bivariate matrix function and derive some general results on their Fréchet derivatives, which hold, not only to the matrix-matrix exponentiation, but also to other known functions, such as means of two matrices, second order Fréchet derivatives and some iteration functions arising in matrix iterative methods. The numerical computation of the Fréchet derivative is discussed and an algorithm for computing the relative condition number of A^B is proposed. Some numerical examples are given.

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MS18
Faster Riemannian Optimization Using Randomized Preconditioning

We consider optimization problems of the form
$\max f(x) st x^T matBx = 1$
where $matB$ is a symmetric positive definite matrix. This problem naturally occurs in quite a few application, such as finding the largest or smallest eigenvalues, linear discriminant analysis and canonical correlation analysis. Since the constraint set is a manifold, Riemannian optimization is natural tool for tackling such problems.
In order to use Riemannian optimization, one has to define a Riemannian metric on the constraint manifold. The prevalent choice in the literature is to use the metric $(u, v)_x = u^T matBv$. This choice of metric requires computing $matB^{-1}z$ for various vectors z formed through the execution of the algorithm. The starting point for our work is the observation that in many of the aforementioned applications $matB$ is presented as a Gram matrix of a large data matrix, i.e. $matB = matX^T matX$ for some $matX \in \mathbb{R}^{n\times d}$, where the input is given as $matX$. Since typically $n \gg d$, we seek to minimize the running time dependence on n. The use of the metric $(u, v)_x = u^T matBv$ necessitated either $O(nd^2)$ pre-processing operation (if $matB$ is formed and factorized), or $O(nd\kappa(matB))$ operations per iterations (if an iterative method is used to solve for $matB$). Our goal in this work is to improve on these dependences on n.
We propose to use an alternative metric:
$(u, v)_x = u^T matMv$, where $matM$ is an approximation of $matB$ formed using randomized preconditioning techniques (e.g. the construction used in Blendenpik). We shall present theoretical and empirical results that demonstrate the benefit of the proposed method.

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MS18
Smoothing Proximal Gradient Method for Nonsmooth Convex Regression with Cardinality Penalty

This presentation studies a class of constrained sparsity regression problem. We focus on the case where the loss function is convex but nonsmooth, and the penalty (regularization) term is defined by a cardinality function. The contributions of this paper are fundamental and important for this problem on both the theoretical and algorithmic aspects.First, we prove that the shifted stationary points of the suggested continuous approximation model with capped-l1 penalty not only preserve all the global minimizers, but also correspond to the local minimizers of the original noncontinuous problem. Most importantly, some unwanted local minimizers of original problem can be abandoned by solving the shifted stationary points of continuous approximation model. Then, solving the original regression problem with cardinality penalty is equivalent, in a sense, to solving the corresponding problem with the capped-l1 penalty, which not only enjoys stronger optimal capability, but also owns some better functional properties on the objective function, such as the continuity, DC representation and piecewise linear penalty. Second, we propose a *smoothing proximal gradient* (SPG) algorithm for solving the shifted stationary points of the new continuous model, which is an effective method for finding the better local minimizers of the studied regression model with l0 penalty. Our SPG algorithm is a novel combination of the classical proximal gradient algorithm and the smoothing method. The proposed SPG algorithm due to the special structure of the optimization model and the skilled design for the smoothing parameter achieves the only known global convergence and the best known convergence rate for this kind of problem. Finally, we provide numerical evidence with two examples to illustrate the validity and good performance of the results in this paper.

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MS18
Implementation of an ADMM-Type First-Order Method for Convex Composite Conic Programming

In this talk, we introduce the implementation of an inexact multi-block ADMM-type first order method for solving a class of high-dimensional convex composite conic optimization problems to moderate accuracy. The design of this method combines an inexact 2-block majorized semi-proximal ADMM and the recent advances in the inexact block symmetric Gauss-Seidel (sGS) technique. The proposed method only needs one cycle of an inexact sGS method, instead of an unknown number of cycles, to solve each of the subproblems involved. With some simple and implementable error tolerance criteria, the cost for solving the subproblems can be greatly reduced, and many steps in the forward sweep of each sGS cycle can often be skipped, which further contributes to the efficiency of the proposed method.

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MS18
Relationship Between Three Sparse Optimization Problems for Multivariate Regression

In multivariate regression analysis, a coefficient matrix is used to relate multiple response variables to regressor variables in a noisy linear system from given data. Optimization is a natural approach to find such coefficient matrix with few nonzero rows.
However, the relationship between solutions of most sparse optimization models are not clear. In this paper, we give a comprehensive description of the relationship between three widely used sparse optimization problems: i) the number of nonzero rows is minimized subject to an error tolerance for regression; ii) the error for regression is minimized subject to a row sparsity constraint; iii) the sum of number of nonzero rows and error for regression is minimized. The first two problems have convex constraints and cardinality constraints respectively, while the third one is an unconstrained optimization problem with a penalty parameter. We provide sufficient conditions under which the three optimization problems have the same global minimizers. Moreover, we analyze the relationship of stationary points and local minimizers of the three problems. The stationary points are characterized by using the regular, limiting and horizon subdifferentials of the function defined by the number of nonzero rows at a matrix, and the Frechet, Mordukhovich and Clarke normal cones. Finally, we use two examples to illustrate our theoretical results.

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MS18
Euclidean Distance Embedding for Collaborative Position Localization with NLOS Mitigation

One of the challenging problems in collaborative position localization arises when the distance measurements contain Non-Line-Of-Sight (NLOS) biases. Convex optimization has played a major role in modelling such problems and numerical algorithm developments. One of the successful examples is the Semi-Definite Programming (SDP), which translates Euclidean distances into the constraints of positive semidefinite matrices, leading to a large number of constraints in the case of NLOS biases. In this talk, we propose a new convex optimization model that is built upon the concept of Euclidean Distance Matrix (EDM). We establish a non-asymptotic error bound for the random graph model with sub-Gaussian noise, and prove that our model produces a high accuracy estimator when the order of the uniform sample size is roughly the degree of freedom up to a logarithmic factor. The resulting EDM optimization also has an advantage that its Lagrangian dual problem is well structured and hence is conducive to algorithm developments. In particular, the EDM model significantly outperforms the existing SDP model and several others.

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MS18
An Exact Penalty Method for Semidefinite-Box Constrained Low-Rank Matrix Optimization Problems

In this talk, we consider a matrix optimization problem involving a semidefinite-box constraint and a rank constraint. We penalize the rank constraint by a non-Lipschitz function and prove that the corresponding penalty problem is exact with respect to the original problem. Next, we present an efficient NPG algorithm to solve the penalty problem and furthermore propose an adaptive penalty method (APM) for solving the original problem. Finally, the efficiency of APM is shown via numerical simulations.

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Yu-Hong Dai, Chinese Academy of Sciences

MS18
A Parallelizable Algorithm for Orthogonally Constrained Optimization Problems

To construct a parallel approach for solving orthogonally constrained optimization problems is usually regarded as an extremely difficult mission, due to the low scalability of orthogonalization procedure. In this talk, we propose an infeasible algorithm for solving optimization problems with orthogonality constraints, in which orthogonalization is no longer needed at each iteration, and hence the algorithm can be parallelized. We also establish a global subsequence convergence and a worst-case complexity for our proposed algorithm. Numerical experiments illustrate that the new algorithm attains a good performance and a high scalability in solving discretized Kohn-Sham total energy minimization problems.

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MS18
A Non-Monotone Alternating Updating Method for a Class of Matrix Factorization Problems

We develop an algorithm for solving a large class of matrix factorization problems, including nonnegative matrix factorization (NMF) as a special case. Our method is based on finding a stationary point of a suitable potential function related to the original objective. In this potential function, the matrix product is "decoupled" from other operations. Consequently, one can readily adapt techniques such as the hierarchical updating strategies used extensively in the NMF literature. We also incorporate a line-search strategy in our method for empirical acceleration, and establish its convergence under mild conditions. This is joint work with Xiaojun Chen and Lei Yang.

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MS18

Quadratic Optimization with Orthogonality Constraint: Explicit Lojasiewicz Exponent and Linear Convergence of Retraction-Based Line-Search and Stochastic Variance-Reduced Gradient Methods

The problem of optimizing a quadratic form over an orthogonality constraint (QP-OC for short) is one of the most fundamental matrix optimization problems and arises in many applications. In this work, we characterize the growth behavior of the objective function around the critical points of the QP-OC problem and demonstrate how such characterization can be used to obtain strong convergence rate results for iterative methods that exploit the manifold structure of the orthogonality constraint (i.e., the Stiefel manifold) to find a critical point of the problem. Specifically, our primary contribution is to show that the Łojasiewicz exponent at any critical point of the QP-OC problem is 1/2. Such a result is significant, as it expands the currently very limited repertoire of optimization problems for which the Łojasiewicz exponent is explicitly known. Moreover, it allows us to show, in a unified manner and for the first time, that a large family of retraction-based line-search methods will converge linearly to a critical point of the QP-OC problem. Then, as our secondary contribution, we propose a stochastic variance-reduced gradient (SVRG) method called Stiefel-SVRG for solving the QP-OC problem and present a novel Łojasiewicz inequality-based linear convergence analysis of the method. An important feature of Stiefel-SVRG is that it allows for general retractions and does not require the computation of any vector transport on the Stiefel manifold. As such, it is computationally more advantageous than other recently-proposed SVRG-type algorithms for manifold optimization.
Joint work with Huikang Liu and Weijie Wu.

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MS18

Algebraic Properties for Eigenvalue Optimization

TBA

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MS18

Local Geometry of Matrix Completion

Matrix completion is the problem of recovering a low-rank matrix from a few entries.
A popular approach is to solve the following matrix factorization formulation $\min_{X,Y} bP_\Omega(M - XY^T)\|_F^2$, where $bP_\Omega(Z)$ represents a sampled submatrix of a matrix Z. It is a generalization of the classical low-rank approximation formulation $\min_{X,Y} \|M - XY^T\|_F^2$.
The matrix completion formulation can be solved (to stationary points) very efficiently through standard optimization algorithms. However, due to the non-convexity caused by the factorization model, it is not clear whether these algorithms will generate a good solution.
In this talk, we first discuss the local geometry of the matrix factorization for low-rank approximation, and then discuss how to generalize the local geometrical result to matrix completion. We show that under standard conditions for matrix completion, many standard optimization algorithms converge to the global optima of a regularized formulation and recover the original matrix. One major technical approach is perturbation analysis for matrix factorization.

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MS19

Handling Square Roots in Nonlinear Eigenvalue Problems

Most nonlinear eigensolvers proposed in the recent literature require the region of the complex plane in which we want to compute eigenvalues to be analytic. This restriction is often a limitation when we aim for eigenvalues in the neighborhood of branch points and branch cuts. In this talk, we propose a way to efficiently handle algebraic branch cuts in nonlinear eigenvalue problems and illustrate it for a problem with multiple square roots.

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Chao Yang, Lawrence Berkeley National Laboratory

MS19

Solving Nonlinear Eigenvalue Problems Using Contour Integration

Based on contour integration, nonlinear eigenvalue problems involving analytic matrix functions can be transformed into generalized eigenvalue problems. The contour integrals are approximated numerically by a quadrature formula, which corresponds to a filter function. In this talk the properties of such a filter function as well as its implications on the nonlinear eigenvalue approximation problem will be investigated.

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MS19

Automatic Rational Approximation and Linearization for Nonlinear Eigenvalue Problems

We present a method for solving nonlinear eigenvalue problems using rational approximation. The method uses the AAA method by Nakatsukasa, Sète and Trefethen to approximate the nonlinear eigenvalue problem by a rational eigenvalue problem and is embedded in the state space representation of a rational polynomial by Su and Bai.
The advantage of the method compared to related techniques such as NLEIGS and infinite Arnoldi is that the rational interpolant is computed efficiently by an automatic procedure. In addition, a set-valued approach is developed that allows for building a low degree rational approximation of a nonlinear eigenvalue problem, and the method perfectly fits within the framework of the Compact rational Krylov methods (CORK and TS-CORK), which allow for the efficient solution of large scale nonlinear eigenvalue problems. Numerical examples show that the presented framework is competitive with NLEIGS, usually produces smaller linearizations with the same accuracy but with little effort by the user.

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MS19

Robust Rayleigh Quotient Optimization and Nonlinear Eigenvalue Problems

In this talk, we consider the robust Rayleigh quotient optimization problem.We will discuss the possibilities in solving such problems by the nonlinear eigenvalue problem with eigenvector nonlinearity. Our analysis can shed light on the potential divergence issue of a commonly applied simple iterative method for the robust solution. In particular, two schemes are proposed to address this issue by reformulating the objective nonlinear eigenvalue problem. Numerical examples, with applications in data sciences, are provided to demonstrate the effectiveness of our approaches.

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MS19
Conquering Algebraic Nonlinearity in Nonlinear Eigenvalue Problems

We present a linearization scheme for solving algebraic nonlinear eigenvalue problem $T(\lambda)x = 0$. By algebraic, we mean each entry of $T(\lambda)$ is an algebraic function of λ. In contrast to existing approximation based approaches, which typically aim at finding only a few eigenvalues, our linearization scheme can be used to compute all eigenvalues counting algebraic multiplicity. As an example, we apply this linearization scheme to analyze the gun problem from the NLEVP collection.

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MS19
Solving Different Rational Eigenvalue Problems via Different Types of Linearizations

Rational eigenvalue problems arise expressed in different forms, since there are many ways to write a rational matrix. Moreover, it has been shown that any rational matrix can be "linearized" in many ways, i.e., that there exist many matrix pencils that contain the complete information of poles and zeros (including those at infinity) of any rational matrix. We discuss which are the most adequate linearizations of rational eigenvalue problems depending on how they are expressed.

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MS19
NEP-PACK a Julia Package for Nonlinear Eigenvalue Problems

We present an open-source library for nonlinear eigenvalue problems (NEPs), designed for scientists working on method development, high-performance computing, as well as specific NEP-applications.The package is constructed to provide easy access to may state-of-the-art methods, exploiting multiple dispatch and parametric types for efficiency.Moreover, the multiple dispatch allows us to incorporate problem specific structures in the methods, e.g. with the use of matrix functions applied to matrices with particular structure.

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Giampaolo Mele, KTH Royal Institute of Technology
Parikshit Upadhyaya, KTH Royal Institute of Technology

MS19
A Pade Approximate Linearization for Solving Nonlinear Eigenvalue Problems in Accelerator Cavity Design

We discuss a Padé approximate linearization (PAL) method for solving nonlinear eigenvalue problems. We show the effectiveness of PAL by comparing it with the NLEIGS and CORK methods to solve nonlinear eigenvalue problems arising from SLAC's Omega3P, a parallel eigenmode calculation code for accelerator cavities modeling in frequency domain analysis using finite-element methods.

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MS20
Nonlinear Perron-Frobenius Theorem and Applications to Nonconvex Global Optimization

Let $\mathbb{R}^n_+ = \{x \in \mathbb{R}^n \mid x_i \geq 0, \forall i\}$ and $f : \mathbb{R}^{n_1}_+ \times \ldots \times \mathbb{R}^{n_d}_+ \to \mathbb{R}$. We discuss how the Perron-Frobenius theory provides assumptions on f which guarantee that the following problem can be solved efficiently to global optimality: $\max_{\|x^1\|_{p_1} = \ldots = \|x^d\|_{p_d} = 1} f(x^1, \ldots, x^d)$.
We propose a method with a linear convergence rate for finding the global maximizer. We discuss applications including the computation of nonnegative matrix and tensor norms and the training of a class of generalized polynomial neural networks.

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MS20
Node and Layer Eigenvector Centralities for Multiplex Networks

Eigenvector-based centrality measures are among the most popular centrality measures in network science in the framework of standard, mono-layer networks. Indeed, the underlying idea is intuitive, the mathematical description is simple, and they can be computed very efficiently even for large networks.
In this talk we describe what happens when we move up in dimensionality, by defining a new eigenvector centrality for both nodes and layers in multiplex networks.

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MS20
Inequalities for the Spectral Radius and Spectral Norm of Nonnegative Tensors

We extend some characterizations and inequalities for the eigenvalues of nonnegative matrices, such as Donsker-Varadhan, Friedland-Karlin, Karlin-Ost, and Kingman inequalities, to nonnegative tensors. We discuss the tropical spectral radius of nonnegative tensors and characterize it combinatorically. We bound the spectral radius of a nonnegative tensor in terms of its tropical spectral radius. These properties are related to a representation of the spectral radius of a nonnegative tensor as the value of a risk-sensitive type ergodic control problem.

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MS20
Some Results on the Spectral Theory of Hypergraphs

In this talk, we report some recent results on the spectral theory of hypergraphs via tensors, including the spectral radius, Perron vector and cospectrality of uniform hypergraphs.

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MS21

Simultaneous Clustering of Multiview Data

The availability of different types of data makes integrative study possible. As the basic problem, clustering for multiview data has attracted much attention. In this talk, we introduce one model and algorithm for multiview data clustering. The method can be applied to the multiview data with the same and different underlying clusters. Experimental results show the performance of the proposed method.

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Lei-Hong Zhang, Shanghai University of Finance and Economics

MS21

Averaged Information Splitting for Heterogeneously High-Throughput Data Analysis

The restricted log-likelihood function involves log determinants of products of complicated co-variance matrices. Standard methods to compute these terms are computationally prohibitive for heterogeneously high-throughput data sets. In this talk, we will explore how to leverage an averaged information splitting technique and dedicate matrix transform to significantly reduce computations for heterogeneously high-throughput data analysis, and how to use the multi-frontal solvers on linear systems with multiple right-hand sides to accelerate computing.

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MS21

A Modified Seasonal Grey System Model with Fractional Order Accumulation for Forecasting Traffic Flow

As the core of intelligent transportation system applications, accurate real-time traffic flow prediction plays an important role in traffic management and control. Due to its complex stochastic, nonlinear and seasonality characteristics, the traffic flow can not be accurately predicted by the conventional grey system model. In this talk, based on the fractional order accumulation technique, we propose a modified seasonal grey system model to study the traffic flow forecasting problem. Time response sequence of the new model is derived. Based on matrix perturbation theory, we study the error estimate of the new model. Finally, two numerical examples are used to show the efficiency of the proposed modified seasonal grey system model.

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MS21

A Distributed Parallel SVD Algorithm Based on the Polar Decomposition via Zolotarev's Function

Computing the SVD of a matrix is an important problem in scientific computing and many applications such as information retrieval, PCA and signal processing, etc.In order to computing SVD fast on supercomputers, we implement and test some algorithms on Tianhe2, one of the fastest computers in the world. We find the polar decomposition (PD) recently exhibits much advantage in computing the singular value decomposition (SVD). This work introduces a high performance implementation of Zolo-SVD algorithm on the distributed memory systems, which is based on the PD algorithm via the Zolotarev's function (Zolo-PD), originally proposed by Nakatsukasa and Freund [SIAM Review, 2016]. Our implementation highly relies on the routines of ScaLAPACK and therefore it is portable. Comparing with other PD algorithms such as the QR-based dynamically weighted Halley method (QDWH-PD), Zolo-PD is naturally parallelizable and has better scalability though performs more floating-point operations. When using more processes, Zolo-PD can be up to three times faster than QDWH-PD algorithm, and Zolo-SVD can be two times faster than the ScaLAPACK routine PDGESVD. These numerical experiments are performed on Tianhe2 supercomputer, and the tested matrices include some sparse matrices from particular applications and some randomly generated dense matrices with different dimensions.

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MS21

A Riemannian Variant of Fletcher-Reeves Conjugate Gradient Method for Stochastic Inverse Eigenvalue Problems with Partial Eigendata

We consider the inverse problem of constructing a stochastic matrix from the prescribed partial eigendata. A Riemannian variant of Fletcher-Reeves conjugate gradient method is proposed for solving this inverse problem. Under some mild conditions, the global convergence of our method is established. Our method is also extended to the case of prescribed entries and the case of column stochastic matrix. Finally, we report some numerical tests to illustrate the effectiveness of our method.

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MS21

A Splitting Preconditioner for Implicit Runge-Kutta Discretizations of a Differential-Algebraic Equation

In each step of the time integration of fully implicit Runge-Kutta method is used to discretise a class of differential-algebraic equations leads to a block two-by-two linear system. In this talk, a preconditioning strategy based on a splitting of the coefficient matrix is proposed to solve such linear system. Some spectral properties of the preconditioned matrix are discussed. Numerical experiments are presented to demonstrate the effectiveness of the proposed approach.

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MS22

A Unified Approach to Wannier Interpolation

The so-called Wannier localization problem in quantum physics is analogous to finding a localized representation of a subspace associated with a nonlinear eigenvalue problem. While this problem is well understood for insulating systems, less is known for metallic systems with entangled eigenvalues. We propose a new method to solve the Wannier localization problem; our method is robust, efficient, and provides a unified framework for dealing with isolated and entangled eigenvalues.

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MS22

Potentialities of Wavelet Formalism Towards a Reduction of the Complexity of Large Scale Electronic Structure Calculations

Since a few years ago, the BigDFT software package implements a linear scaling Kohn-Sham density functional theory optimization algorithm based on Daubechies wavelets, where a minimal set of localized support functions are optimized in situ and therefore adapted to the physico-chemical properties of the system under investigation. We illustrate, from a general perspective, a quantitative method to identify and assess the partitioning of a large quantum-mechanical system into fragments. Our approach reduces arbitrariness in the fragmentation procedure and enables the possibility of assessing quantitatively whether the corresponding fragment multipoles can be interpreted as observable quantities associated with a system moiety. Such an approach is based on general grounds and its implementation is unrelated to the wavelet formalism. However, we show that the use of a minimal set of in situ-optimized basis functions allows at the same time a proper fragment definition and an accurate description of the electronic structure.

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MS22

Convergence Analysis for the EDIIS Algorithm

The EDIIS algorithm was designed to globalize Anderson acceleration in the context of electronic structure computations. In this paper we prove a convergence result for that algorithm and discuss its efficient implementation.

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MS22

A Semi-Smooth Newton Method for Solving Semidefinite Programs in Electronic Structure Calculations

The ground state energy of a many-electron system can be approximated by an variational approach in which the total energy of the system is minimized with respect to one and two-body reduced density matrices (RDM) instead of many-electron wavefunctions. This problem can be formulated as a semidefinite programming problem. Due the large size of the problem, the well-known interior point method can only be used to tackle problems with a few atoms. First-order methods such as the the alternating direction method of multipliers (ADMM) have much lower computational cost per iteration. However, their convergence can be slow, especially for obtaining highly accurate approximations. In this paper, we present a practical and efficient second-order semi-smooth Newton type method for solving the SDP formulation of the energy minimization problem. We discuss a number of techniques that can be used to improve the computational efficiency of the method and achieve global convergence. Extensive numerical experiments show that our approach is competitive to the state-of-the-art methods in terms of both accuracy and speed.

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MS22

Adaptive Compression for Hartree-Fock-Like Equations

The adaptively compressed exchange (ACE) method provides an efficient way for solving Hartree-Fock-like equations in quantum physics, chemistry, and materials science. The key step of the ACE method is to adaptively compress an operator that is possibly dense and full-rank. We present a detailed study of the adaptive compression operation and establish rigorous convergence properties of the adaptive compression method for linear eigenvalue problems.

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MS22

Projected Commutator DIIS Method for Linear and Nonlinear Eigenvalue Problems

The commutator direct inversion of the iterative subspace (commutator DIIS or C-DIIS) method developed by Pulay in the 1980s is an efficient and the most widely used scheme for solving nonlinear eigenvalue problems in quantum chemistry. However, for large matrices this method is not practical due to the need of explicit construction of the projector and the commutator. I will discuss a newly developed Projected Commutator DIIS method (PC-DIIS) method to accelerate nonlinear eigenvalue problems and even certain linear eigenvalue problems with much reduced cost. The PC-DIIS method has been successfully applied to accelerate hybrid functional density functional theory calculations in quantum chemistry. (Joint work with Wei Hu and Chao Yang)

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MS22

Parallel Transport Evolution of Time-Dependent Density Functional Theory

Real time time-dependent density functional theory calculations (RT-TDDFT) typically suffer from very small time step sizes, due to the quickly rotating phase factors. We will discuss a new parallel transport formulation to smooth out the phase factor and significantly increase the step size when the dynamics is close to be an adiabatic evolution, and demonstrate its applications to nonlinear Schrodinger equations and time-dependent density functional theory (joint with Weile Jia and Lin Lin).

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MS23

Blind Deconvolution by Optimizing Over a Quotient Manifold

We consider the problem of separating two unknown signals given their circular convolution. We formulate this problem as a nonconvex optimization problem on a quotient manifold and propose Riemannian optimization algorithms for solving the problem. We prove that the proposed algorithm with an appropriate initialization will recover the exact solution with high probability when the number of measurements is, up to log-factors, the information-theoretical minimum scaling. The quotient structure in our formulation yields a simpler penalty term in the cost function compared to the Wirtinger gradient descent method, which eases the convergence analysis and yields a natural implementation. Empirically, the proposed algorithm has better performance than the Wirtinger gradient descent algorithm and an alternating minimization algorithm in the sense that i) it needs fewer operations, such as DFTs and matrix-vector multiplications, to reach a similar accuracy, and ii) it has a higher probability of successful recovery in synthetic tests.

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MS23
Riemannian Optimization and the Computation of the Divergences and the Karcher Mean of Symmetric Positive Definite Matrices

Riemannian optimization approaches to the computation of divergences and Karcher means of symmetric positive definite matrices are discussed. Theoretical and computational aspects of the problem are considered. The Riemannian objects required are presented along with an analysis of the expected behavior of Euclidean and Riemannian approaches. Empirical evidence of the robust and efficient performance of Riemannian quasi-Newton methods is presented.

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MS23
A Manifold Approach to Structured Low-Rank Matrix Learning

In this talk, we look at a unified framework for structured matrix learning. We propose a novel fixed-rank decomposition that allows to model low-rank and linear subspace constraints simultaneously. Specifically, the fixed-rank decomposition of a structured matrix W is $W = UU^T(Z + A)$, where UU^T models the low-rank constraint, Z models the loss function, and A models the subspace constraint. This decomposition results from a particular dual framework that leads to an optimization problem on the spectrahedron manifold. Leveraging the versatile Riemannian optimization framework, we develop large-scale conjugate gradient and trust-region algorithms. Numerical experiments show that our algorithms outperform state-of-the-art algorithms in various different applications – matrix completion, non-negative matrix completion, Hankel matrix learning, and robust matrix learning. Building on the matrix case, we further extend our framework to the large-scale tensor completion problem and show the initial results.

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MS23
Subspace Methods in Riemannian Manifold Optimization

We present a subspace method for the unbalanced Procrustes problem, which minimizes a quadratic function defined on a Stiefel manifold. We first add a subspace to the constraints of the problem to form a small-scale problem, and then use a SCF iteration to solve the small-scale problem. We prove that our method converges for any initial point. Numerical experiments demonstrate that our method is effective and can achieve high accuracy for large-scale ETR subproblems.

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MS23
Quasi-Newton Optimization Methods on Low-Rank Tensor Manifolds

In recent years, computationally efficient and provably convergent extensions of quasi-Newton methods to Riemannian manifolds have been developed. We develop a novel Riemannian BFGS method on tensor manifolds of fixed Tucker and TT rank, using an intrinsic tangent vector representation.We compare it to existing methods from the literature for tensor completion, including CG and trust-region methods and also methods based on convex relaxations. Our applications include tensor completion for image recovery and functional data.

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MS23
Robust Second Order Optimization Methods on Low Rank Matrix and Tensor Varieties

Optimization problems on matrix and tensor sets appear in many practical applications. Imposing an additional assumption of a low-rank structure of the solution allows one to greatly reduce the number of degrees of freedom and simplify the problem. However, sets of matrices and tensors represented using certain tensor decompositions e.g. the Tensor Train (TT) format are strictly speaking not manifolds but algebraic varieties with singular points. This creates certain problems for optimization algorithms based on Riemannian optimization framework. We will discuss an attempt to resolve these issues based on the called desingularization technique inspired by methods from algebraic geometry.

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MS23
A Riemannian Trust Region Method for the Canonical Tensor Rank Approximation Problem

The CP decomposition generalizes low-rank matrix factorizations, expressing a tensor as $\mathcal{A} = \sum_{i=1}^{r} \mathbf{a}_i^1 \otimes \mathbf{a}_i^2 \otimes \cdots \otimes \mathbf{a}_i^d \in \mathbb{R}^{n_1 \times n_2 \times \cdots \times n_d}$. We seek to approximate a tensor by a low-rank CP decomposition. This *tensor canonical rank approximation problem* (TAP) is naturally formulated as a nonlinear least squares problem whose constraint set is semi-algebraic. In this talk, we propose a Riemannian Gauss–Newton method with trust region for solving TAPs. Numerical experiments reveal speedups of upwards of two orders of magnitude over state-of-the-art non-Riemannian Gauss–Newton methods.

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Paul Breiding, MPI MiS Leipzig

MS23
Dynamical Low-Rank Approximation of Tensor Differential Equations

We present a discrete method for approximating time-dependent tensors, which are the unknown solutions of tensor differential equations. The approximation tensors are of a prescribed (low) rank and can be represented in several

tensor formats, such as the Tucker tensor format. The approximation follows the setting of the dynamical tensor approximation, which yields a differential equation for the approximation tensor on the manifold of tensors of multilinear rank. This differential equation needs to be solved numerically.
We give a new derivation of an integrator that solves the differential equation for the approximation tensor in the Tucker format. The ideas can be traced back to the recently proposed matrix projector-splitting integrator with inexact solution of the appearing substeps in matricised form. In cases, where the tensor, that needs to be approximated, is given explicitly the numerical integrator reproduces the known tensor. The exactness property also holds for the two-dimensional matrix case and this result is fundamental for the error analysis of the integration method for the Tucker tensor case. The error bounds of the integrator are robust in the presence of small singular values of the Tucker tensors' matricisations.
We extend this integration scheme and its analysis to tensors in the Hierarchical Tucker format.

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MS24
Scalability Analysis of Sparse Triangular Solve

Sparse triangular solve exists in a number of computational problems in scientific and engineering. Recently, the emergence of many-core processors has introduced more conflicts between algorithm efficiency and scalability. On one hand, many-core processors require a large amount of fine-grained tasks to saturate their resources, on the other, the irregular structure of sparse matrix brings difficulties to the task partitioning. This talk will discuss scalability of existing work on sparse triangular solve. Several key challenges in this area will be presented as well.

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MS24
Solving sparse triangular systems in GPUs: what are the options and how do I choose the right one?

A myriad of problems in science and engineering, involve the solution of sparse triangular linear systems. They arise frequently as part of direct and iterative solvers for linear systems and eigenvalue problems, and hence can be considered as a key building block of sparse numerical linear algebra. This is why, since the early days, their parallel solution has been exhaustively studied, and efficient implementations of this kernel can be found for almost every hardware platform.
In the GPU context, the most widespread implementation of this kernel is the one distributed in NVIDIA cuSparse library, which relies on a preprocessing stage to aggregate the unknowns of the triangular system into level sets. This determines an execution schedule for the solution of the system, where the level sets have to be processed sequentially while the unknowns that belong to one level set can be solved in parallel. One of the disadvantages of the cuSparse implementation is that this preprocessing stage is often extremely slow in comparison to the runtime of the solving phase.
We have developed a parallel GPU algorithm that is able to compute the same level sets as cuSparse but takes significantly less runtime. Our experiments on a set of matrices from the SuiteSparse collection show acceleration factors of up to 44x. Furthermore, a linear system can be solved toghether with the analysis at relatively little extra cost.
The availability of level information at a lower computational cost gives us an opprotunity to attempt a characterization and use this information to select between different strategies to solve the subsequent linear systems.

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MS24
Refactoring Sparse Triangular Solve on Sunway Taihulight Many-Core Supercomputer

Currently, much research on parallel sparse triangular solve focuses on level-set construction for reducing the number of inter-level synchronizations. However, the out-of-control data reuse and high cost for memory access in inter-level synchronization have been largely neglected. In this talk, we will present our novel data layout and algorithms to address the above problems and demonstrate experimental results from an SW26010 many-core processor, the main building-block of the current fastest supercomputer Sunway Taihulight.

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Xinliang Wang, Tsinghua University

MS24
Enhancing Scalability of Parallel Sparse Triangular Solve in SuperLU

Sparse triangular solve is an important compute-kernel in direct and preconditioned iterative methods for solving linear systems. This kernel has become a performance bottleneck for many distributed-memory linear solvers, particularly those applied to problems involving many iterations, due to its sequential nature and low flop-to-memory ratio. Our study shows in SuperLU the triangular solve is highly communication bound and we leverage a tree-based asynchronous communication algorithm and hybrid OpenMP/MPI programming models to improve the communication load balance.

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MS25
Stratifying Complete Eigenstructures: From Matrix Pencils to Polynomials and Back

The classical approach to analyze and determine the complete eigenstructure of matrix polynomials is to study their linearizations, which, in turn, requires some analysis and methods for matrix pencils. In this presentation, we study how small perturbations of matrix polynomials may change their elementary divisors and minimal indices by constructing the closure hierarchy graphs (stratifications) of orbits and bundles of matrix polynomial Fiedler linearizations. The stratifications of the Fiedler linearizations are constructed using the stratifications of general matrix pencils. The results are illustrated by examples using the software tool StratiGraph.

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Andrii Dmytryshyn, Umeå University
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Paul Van Dooren, Catholic University of Louvain

MS25

Block-Symmetric Linearizations of Odd Degree Matrix Polynomials with Optimal Condition Number and Backward Error

The standard way to solve the polynomial eigenvalue problem is to use a linearization. When a matrix polynomial $P(\lambda)$ has some structure (Hermitian, palindromic, T-even,...), it is convenient to use linearizations of $P(\lambda)$ with the same structure as $P(\lambda)$ to preserve the symmetries in the spectrum. If the polynomial is symmetric (Hermitian), it is well-known that the block-symmetric pencils $D_1(\lambda, P)$ and $D_k(\lambda, P)$, that is, the first and the last pencils in the standard basis of the vector space $\mathbb{DL}(P)$, introduced by Mackey et al. (2006), have almost optimal numerical behavior in terms of conditioning and backward error within $\mathbb{DL}(P)$. However, there are some constraints in the use of these two pencils. To start with, $D_1(\lambda, P)$ (resp. $D_k(\lambda, P)$) is only a linearization of $P(\lambda) = \sum_{i=0}^{k} A_i\lambda^i$ if A_0 (resp. A_k) is nonsingular. Moreover, when $P(\lambda)$ has eigenvalues of modulus less than 1 and larger than 1, the use of both linearizations is necessary. In this paper, we consider a block-symmetric pencil in the family of generalized Fiedler pencils, introduced by Antoniou and Vologiannidis in 2004, that we denote by $\mathcal{T}_P(\lambda)$. This pencil has several appealing properties, namely, for every $P(\lambda)$, the pencil $\mathcal{T}_P(\lambda)$ is a strong linearization of $P(\lambda)$, it is easy to construct from the coefficients of $P(\lambda)$, the eigenvectors of $P(\lambda)$ can be recovered easily from those of $\mathcal{T}_P(\lambda)$, it is symmetric (resp. Hermitian) when $P(\lambda)$ is, and it preserves the (classical) sign characteristic of $P(\lambda)$ when $P(\lambda)$ is Hermitian. Here we show that, when $P(\lambda)$ has odd degree, $\mathcal{T}_P(\lambda)$ also presents optimal numerical behavior in terms of conditioning and backward error and, therefore, it is an ideal alternative to the combined use of $D_1(\lambda, P)$ and $D_k(\lambda, P)$.

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MS25

Transparent Realizations for Polynomial and Rational Matrices

Given a list $\mathcal{L}$ of structural data, i.e., a list of finite and infinite elementary divisors together with left and right minimal indices, the fundamental inverse problem for polynomial matrices is to determine whether there exists a polynomial matrix of degree d (or grade d) that realizes exactly the structural data list $\mathcal{L}$. For matrix pencils (i.e., for $d = 1$), the Kronecker canonical form provides a “transparent” solution for this inverse problem, in the sense that the structural data can be immediately “read off” from the pencil realization itself, without any numerical computation. De Terán, Dopico, and Van Dooren recently [2015] found a simple characterization of all realizable structural data lists for any $d > 1$, but their method for constructing a realization for any given list $\mathcal{L}$ produces a polynomial matrix that does *not* transparently reveal the structural data $\mathcal{L}$. This talk will discuss our recent work on finding transparent solutions to the polynomial matrix inverse problem. As time permits, the corresponding inverse problem for rational matrices will also be discussed.

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MS25

Generic Eigenstructures of Matrix Polynomials with Bounded Rank and Degree

We show that the set $m \times n$ complex matrix polynomials of grade d, i.e., of degree at most d, and rank at most r ($r = 1, \ldots, \min\{m, n\} - 1$) is the union of the closures of the $rd + 1$ sets of matrix polynomials with rank r, degree d, and explicitly described complete eigenstructures. These $rd + 1$ complete eigenstructures correspond to generic $m \times n$ matrix polynomials of grade d and rank at most r. The analogous problem is also considered for complex skew-symmetric matrix polynomials of odd grade. In this case, there is only one generic complete eigenstructure, which shows a drastic effect of imposing the structure on matrix polynomials.

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Froilán M. Dopico, Universidad Carlos III de Madrid

MS25

A Backward Stable Quadratic Eigenvalue Solver

The eigensolver `quadeig` for the complete solution of the quadratic eigenvalue problem $Q(\lambda)x = 0$ with $Q(\lambda) = \lambda^2 M + \lambda D + K$ is backward stable when Q is not too heavily damped, i.e., $\|D\|_2^2 \leq \|M\|_2 |K\|_2$. For heavily damped quadratics, we show that a special linearization combined with a scaling strategy and appropriate recovery of the eigenvectors leads to computed eigenpairs with small backward errors. Here perturbations are measured relative to each coefficient matrix.

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Laurence Grammont, Université Jean Monnet, Saint-Etienne
Marc Van Barel, KU Leuven

MS25

A Geometric Description of the Sets of Palindromic and Alternating Matrix Pencils with Bounded Rank

The sets of $n \times n$ $\top$-palindromic, $\top$-anti-palindromic, $\top$-even, and $\top$-odd matrix pencils with rank at most $r < n$ are algebraic subsets of the set of $n \times n$ matrix pencils. In this talk, we will show some interesting features of these sets. In particular, we will obtain their dimension and we will see that they are all irreducible. We will compare with the non-structured case, which presents an striking difference, since it is known that the set of $n \times n$ matrix pencils with rank at most $r < n$ is an algebraic set with $r + 1$ irreducible components. We will also determine the generic canonical form of structured $n \times n$ matrix pencils with rank at most r, for any of the previous structures. For this, we show that these sets of structured pencils with bounded rank are the closure of the congruence orbit of pencils having this canonical form.

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MS25

Strong Linearizations of Rational Matrices with Polynomial Part Expressed in an Orthogonal Basis

In this talk we present new classes of strong linearizations of a rational matrix $G(\lambda)$ constructed from carefully combining strong linearizations of its polynomial part $D(\lambda)$ and state-space realizations of its strictly proper part $G_{sp}(\lambda)$. More precisely, we consider strong linearizations of the polynomial part that belong to the ansatz spaces $\mathbb{M}_1(D)$ and $\mathbb{M}_2(D)$, recently developed by Faßbender and Saltenberger. Moreover, if $G(\lambda)$ is symmetric, we present strong linearizations that preserve its structure.

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Froilán M. Dopico, Universidad Carlos III de Madrid
Silvia Marcaida, Universidad del País Vasco

MS25

On the Stability of the Two-Level Orthogonal Arnoldi Method for Quadratic Eigenvalue Problems

We revisit the numerical stability of the two-level orthogonal Arnoldi (TOAR) method for computing an orthonormal basis of a second-order Krylov subspace associated with two given matrices. We show that the computed basis is close to a basis for a second-order Krylov subspace associated with nearby matrices, provided that the norms of the given matrices are not too large or too small. Thus, we provide conditions that guarantee the numerical stability of the TOAR method in computing orthonormal bases of second-order Krylov subspaces. We also study scaling the quadratic problem for improving the numerical stability of the TOAR procedure when the norms of the matrices are too large or too small.

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Karl Meerbergen, KU Leuven

MS26

Limited Memory Block Preconditioners for Fast Solution of Time-Dependent Fractional PDEs

We propose an innovative block structured with sparse blocks multi-iterative preconditioner for linear multistep formulas in boundary value form to accelerate Krylov subspace methods as, e.g., GMRES, FGMRES, and BiCGstab(ℓ). The preconditioner is based on blockω – circulant matrices and a short memory approximation of the underlying Jacobian matrix of the fractional partial differential equations. Convergence results, numerical tests and comparisons with other techniques confirm the effectiveness of the proposed approach.

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MS26

Spectral Analysis and Multigrid Preconditioners for Space-Fractional Diffusion Equations

We focus on both 1D and 2D time-dependent space-FDE problems discretized by means of finite differences. By fully exploiting the Toeplitz-like structure of the resulting linear systems, we provide a detailed spectral analysis of the coefficient matrices, both in the case of constant and variable diffusion coefficients. The retrieved spectral information guides the design of new preconditioning and multigrid strategies. Several numerical results confirm the theoretical analysis and the effectiveness of our proposals.

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MS26

Fast Tensor Solvers for Optimization Problems with FDE-Constraints

Fractional differential equations have recently received much attention within computational mathematics and applied science, and their numerical treatment is an important research area as such equations pose substantial challenges to existing algorithms. In our talk an optimization problem with constraints given by fractional differential equations is considered, which in its discretized form leads to a high-dimensional tensor equation. To reduce the computation time and storage, the solution is sought in the tensor-train format. We illustrate solution strategies such as sophisticated iterative techniques using either preconditioned Krylov solvers or tailored alternating schemes. The competitiveness of these approaches is presented using several examples.

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John W. Pearson, University of Edinburgh
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MS26

Preconditioner for Fractional Diffusion Equations with Piecewise Continuous Coefficients

We study the discretized linear systems arising from the space-fractional diffusion equations with piecewise continuous coefficients. Using the implicit finite difference scheme with the shifted Grünwald discretization, the resulting linear systems are Toeplitz-like which can be written as the sum of a scaled identity matrix and two diagonal-times-Toeplitz matrices. Standard circulant preconditioners and the existing approximate circulant-inverse preconditioner do not work for such Toeplitz-like linear systems since the discontinuous diffusion coefficients cannot be well approximated by interpolation polynomials. We propose a new approximate circulant-inverse preconditioner to handle the fractional diffusion equations with piecewise continuous coefficients. Theoretically, the spectra of the resulting preconditioned matrices are shown to be clustered around one, which can guarantee the fast convergence rate of the proposed preconditioner. Numerical examples are provided to demonstrate the effectiveness of our method.

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MS27

Robust AMG Interpolation with Target Vectors for Elasticity Problems

TBA

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MS27

A Multilevel Preconditioner for Data Assimilation with 4D-Var

The 4D-Var method is frequently used for variational data assimilation problems in applications like numerical weather prediction and oceanographic modelling. One key challenge is that the state vectors used in realistic applications contain a very large number of unknowns so it can be impossible to assemble, store or manipulate the matrices involved explicitly. We present a multilevel limited-memory approximation to the inverse Hessian and illustrate its effectiveness as a preconditioner within a Gauss-Newton iteration.

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MS27

Algebraic Multigrid: Theory and Practice

This talk gives an overview of recent progress made in the design and analysis of algebraic multigrid methods. The focus is on the setup algorithm that automatically constructs the multilevel hierarchy used in the solve phase. A sharp two-grid theory is introduced and then used to derive various quality measures of the coarse spaces constructed by the setup algorithm, based on the ideas of compatible relaxation. We consider measures that assume the use of the so-called ideal interpolation operator as well as a new optimal form of classical algebraic multigrid interpolation that gives the best possible two-grid convergence rate. Various numerical results are presented to illustrate these theoretical results. As test problems, we focus on discretizations of a scalar diffusion problem with highly varying (discontinuous) diffusion coefficient and linear elasticity.

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MS27
Preconditioning for Multi-Physics Problems: A General Framework

We discuss a general approach for preconditioning the block Jacobian matrix arising from the discretization of coupled multiphysics problem. The basic idea relies on approximately computing an operator able to decouple the different processes by extending the theory of block sparse approximate inverses. The proposed approach is specialized for two multiphysics applications, namely the simulation of poromechanical systems and the mechanics of fractured media. The numerical results are used to discuss the preconditioner properties.

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Andrea Franceschini, University of Padova
Carlo Janna, University of Padova
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MS27
Preconditioners for Inexact-Newton Methods Based on Compact representation of Broyden Class Updates

In this paper we study preconditioners for the solution of systems of nonlinear equations with inexact Newton methods. The linear systems in each nonlinear iteration are solved with the preconditioned conjugate gradient method. The preconditioner is based on different compact representations of the limited memory BFGS matrices (LBFGS) that approximate the Hessian or Jacobian matrix. The results of numerical experiments for problems arising in different scientific applications including unconstrained optimization will be presented.

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A. Martínez, University of Padua

MS27
Preconditioning for Time-Dependent PDE-Constrained Optimization

We consider the development of preconditioned iterative methods to tackle the large-scale matrix systems that arise from the discretization of a number of time-dependent PDE-constrained optimization problems. In particular, we discuss the use of interior point methods to handle additional inequality constraints on the state and control variables, the solution of problems involving fractional differential equation constraints, and the application of deferred correction schemes to reduce the discretization error in the time variable.

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MS27
Spectral Preconditioners for Sequences of Ill-Conditioned Linear Systems

Fast solution of large and sparse SPD linear systems $Ax = b$ by Krylov subspace methods is usually prevented by the presence of near zero eigenvalues of A. Given P_0, an initial preconditioner for A, we discuss how cost-effective spectral information on either A or P_0A can be used to construct a low-rank modification of P_0. We give evidence of the important acceleration provided by such spectral preconditioners either within iterative eigensolvers or to address very ill-conditioned sequences of linear systems.

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MS28
Preconditioners for PDE Constrained Optimization Problems with Coarse Distributed Observations

Modern medical imaging often provides coarse distributed observations. Minimization constrained by partial differential equations then provides a mean to enhance the image and augment the image with additional physical quantities. In this talk we will discuss preconditioners for problems where observations are everywhere, but coarse with respect to the resolution of the numerical methods used for solving the partial differential equations. Order optimal algorithms are derived for some simplified problems.

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MS28
Preconditioning for Multiple Saddle Point Problems

We discuss preconditioners for multiple saddle point problems in Hilbert spaces $X_1 \times X_2 \times \cdots \times X_n$. Under appropriate assumptions on the structure of the Hessian of such a problem sharp bounds for the condition number are derived.If applied to specific classes of optimal control problems the abstract analysis leads to new existence results as well as to the construction of efficient preconditioners for the associated discretized optimality systems.

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Jarle Sogn, Johannes Kepler University Linz

MS28
New Poisson-Like Preconditioners for Fast and Memory-Efficient PDE-Constrained Optimization

This talk introduces a new class of Poisson-like preconditioners tailored for fast and memory-efficient iterative solution of PDE-constrained optimization problems governed by time-dependent convection-diffusion-reaction equations. At their core, the preconditioners rely on fast direct solvers for constant-coefficient problems of diffusion-reaction type. The direct methods exploit the structure of a new set of customized high-order polynomial bases to reduce large-scale problems to a sequence of independent subsystems that only involve small-scale sparse matrices.

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John Bagterp Jørgensen, Department of Applied Mathematics and Computer Science & Center for Energy Resources Engineering, Technical University of Denmark

MS28
Preconditioning for Time-Dependent PDEs and PDE Control

We present a novel approach to the solution of time-dependent PDEs via the so-called monolithic or all-at-once formulation. This approach will be explained for simple parabolic problems and its utility in the context of PDE constrained optimization problems will be elucidated. The underlying linear algebra includes circulant matrix approximations of nonsymmetric Toeplitz-structured matrices and may be suitable for parallel implementation (over time). This is joint work with Elle McDonald and Jen Pestana

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MS29
Randomized Nonnegative Matrix Factorizations

Nonnegative matrix factorization (NMF) is a powerful tool for data mining. However, the emergence of large-scale datasets has severely challenged our ability to compute this fundamental decomposition using deterministic algorithms. We present a randomized hierarchical alternating least squares (HALS) algorithm to compute the NMF. By deriving a smaller matrix from the nonnegative input data, a more efficient nonnegative decomposition can be computed. Our algorithm scales to big data applications while attaining a near-optimal factorization, i.e., the algorithm scales with the target rank of the data rather than the ambient dimension of measurement space.

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MS29
Randomized Algorithms for Computing Full Rank-Revealing Factorizations

TBA

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MS29
A Randomized Blocked Algorithm for Computing a Rank-Revealing UTV Matrix Decomposition

Current popular methods for computing rank-revealing matrix factorizations, namely column pivoted QR and the SVD, are not efficient enough in communication to perform optimally in modern high performance computational settings. However, a rank-revealing UTV decomposition can be efficiently constructed using techniques based on randomized projections, casting most of the work in the highly efficient matrix matrix multiplication operation. The result is a factorization method that in tested cases yields low-rank approximations approaching those of the SVD in quality, but whose computational costs are competitive with, and in certain cases faster than, a column pivoted QR factorization.

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MS30
H-Matrices for Stable Computations in RBF Interpolation Problems

The most straightforward way, RBF-Direct, to calculate Gaussian based RBF interpolants leads to dense, ill-conditioned systems of equations. Both the iterative solution process as well as the quality of the resulting interpolant are negatively affected by the ill-conditioning. In this talk, we apply low-rank matrix formats to the numerically more stable algorithms RBF-QR and RBF-GA. We analyze the condition numbers of the interpolation matrices and the performance of various preconditioners for the subsequent iterative solution process.

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MS30
How good are H-Matrices at high frequencies?

$\mathcal{H}$-Matrices are a widely used an easy to implement tool for the fast discretization of boundary integral equation problems. While for non-oscillatory problems $\mathcal{H}$-Matrices achieve an almost optimal complexity of $O(N \log N)$, where N is the number of elements, the picture looks different in the high-frequency limit for $k \to \infty$, where k is the wave number of the problem. Here, traditional $\mathcal{H}$-matrix approximations break down and we expect their asymptotic complexity to be no better than dense discretizations. However, in practice, for realistic wave number ranges we do not observe this behavior and still often achieve very robust $\mathcal{H}$-matrix approximations for problems involving over hundred wavelengths in three dimensions.In this talk we want to discuss the mid-frequency behavior of $\mathcal{H}$-matrices in more detail and present a range of experiments and some explanations of why classical $\mathcal{H}$-matrix techniques remain a simple and viable tool even at high wave numbers.

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Steffen Boerm, Christian-Albrechts University
Christina Boerst, Christian-Albrechts University

MS30
Local Low-Rank Approximation for the High-Frequency Helmholtz Equation

Boundary element methods lead to dense matrices that have to be approximated efficiently in order to allow us to treat complicated three-dimensional geometries.
The oscillatory behaviour of the kernel function associated with the high-frequency Helmholtz equation poses a challenge that can be overcome by suitably modified approximation schemes. We introduce the $\mathcal{DH}^2$-matrix method that can be proven to be exponentially convergent at complexity $\mathcal{O}(n \log^\alpha n)$.

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MS30
Efficiency and Accuracy of Parallel Accumulator-Based H-Arithmetic

In the classical formulation of algorithms for hierarchical matrix arithmetic, sub block operations, e.g., updates, are performed as soon as they are computed and independent on the position of the subblock in the hierarchy. A reformulation of these arithmetical procedures was recently introduced, which collects updates for each subblock in an accumulator and where the application of updates strictly follows the hierarchy of the H-matrix. Due to this, the number of low-rank truncations per sub block is significantly reduced, which leads to a reduction of the runtime of H-arithmetic. Since the different arithmetic operations are applied in a different order and intermediate results on different levels are first accumulated, the accuracy of the H-arithmetic is affected. Furthermore, different implementations, e.g., eager vs. lazy evaluation or sorting of updates, will further influence the accuracy (and runtime) of arithmetical operations. We will discuss the properties of these various forms of H-arithmetic for the algorithmical formulation and the influence on the approximation.

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MS30
Randomized Techniques for Fast Eigenvalue Solution

We discuss how randomized techniques can be used in the design and analysis of fast eigenvalue solvers. With low-accuracy matrix approximations based on structured matrices, we can quickly perform some computations in iterative eigenvalue solvers such as contour-integral methods. We will justify the reliability of the randomized methods, show the accuracy control, and also illustrate the efficiency benefit. Part of the work was joint with Raymond Chan and Xin Ye.

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MS30
The Perfect Shift and the Fast Computation of Roots of Polynomials

In this talk we revisit the Implicit–Q Theorem and analyze the the problem of performing a QR–step on an unreduced Hessenberg matrix H when we know an "exact" eigenvalue λ_0 of H. In exact arithmetic, this eigenvalue will appear on diagonal of the transformed Hessenberg matrix H_1 and will be decoupled from the remaining part of the Hessenberg matrix, thus resulting in a deflation. But it is well known that in finite precision arithmetic the so-called perfect shift could get blurred and the eigenvalue λ_0 can not be deflated and/or is perturbed significantly. In this talk we develop a new strategy for computing such a QR step so that the deflation is indeed successful. The method is based on the preliminary computation of the corresponding eigenvector x such that the residual $(H - \lambda_0)x$ is sufficiently small.The eigenvector is then transformed to a unit vector by a sequence of Givens transformations, which are also performed on the Hessenberg matrix. Such a QR step is the basic ingredient of the QR method to compute the Schur form, and hence the eigenvalues of an arbitrary matrix. But it also is a crucial step in the reduction of a general matrix A to its Weyr form. It is in fact this last problem that lead to the development of this new technique.As an application an algorithm for compute the eigenvalues of companion matrices will be described.A deflation technique that can be embedded in the implicitly restarted Arnoldi algorithm will be also considered.

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Paul Van Dooren, Catholic University of Louvain–la–Neuve

MS30
Structured Matrices in Polynomial System Solving

This talk is about the problem of solving systems of polynomial equations. More specifically, let $f_1, \ldots, f_n$ be polynomials in $k[x_1, \ldots, x_n]$, with k an algebraically closed field. These polynomials define the system of equations $f_1 = \ldots = f_n = 0$ and generically, there are finitely many solutions in k^n. The problem of finding these solutions, although it seems strongly nonlinear, is related to linear algebra in many ways. In this talk, we formulate the problem as a linear algebra problem, involving matrices with a specific structure, and present some new numerical linear algebra techniques to stabilize the computations.

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MS30
Preserving Positive Definiteness in HSS Approximation and Its Application in Preconditioning

Given a symmetric positive definite (s.p.d.) matrix, two methods are proposed for directly constructing hierarchically semiseparable (HSS)matrix approximations that are guaranteed to be positive definite. The methods are based on a new, recursive description of the HSS approximation process where projection is used to compress the off-diagonal blocks.The recursive description also leads to a new error analysis of HSS approximations. Numerical tests using the approximations as preconditioners are presented.

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Edmond Chow, School of Computational Science and Engineering, Georgia Institute of Technology

MS31
The Block Rational Arnoldi Algorithm

The block rational Arnoldi algorithm naturally yields block-versions of rational Krylov decompositions. We discuss various algebraic properties of such decompositions and present a corresponding implicit Q theorem for block rational Krylov spaces. Two deflation approaches are discussed, leading to so-called fat and slim block decompositions, respectively. We demonstrate how to use our implementation of the block rational Arnoldi algorithm in the Rational Krylov Toolbox and apply it to a problem from time series analysis.

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Stefan Güttel, The University of Manchester

MS31
Rational Krylov Subspaces for Wavefield Applications

The spatial discretization of the Helmholtzś equation leads to sparse parametrized systems if a PML is used to simulate open domains. These systems depend nonlinearly on the frequency. In this talk, we discuss the use of rational Krylov subspace techniques to efficiently solve these types of problems. Applications include model reduction as fast approximate solvers for optical imaging of gratings or approximation of open resonance modes, the eigenvectors of the nonlinear eigenvalue problem.

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Vladimir Druskin, Schlumberger-Doll Research
Mikhail Zaslavsky, Schlumberger-Doll Research
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MS31
Krylov Methods for Hermitian Nonlinear Eigenvalue Problems

We consider the Hermitian nonlinear eigenvalue problem: let $M: \mathbb{C} \rightarrow \mathbb{C}^{n\times n}$ be a holomorphic function such that $M(\lambda)^H = M(\bar{\lambda})$, determine $(\lambda, v) \in \mathbb{C} \times (\mathbb{C}^n \setminus \{0\})$ such that$M(\lambda)v = 0$.Hermitian polynomial (and rational) eigenvalue problems have been successfully solved by constructing linearizations that preserve this structure. Analogous to this, we here propose a Krylov-like method based on iteratively expanding an Hermitian linearization. We derive a short-term recurrence and illustrate how the performances benefit by exploiting this feature of the problem.

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MS31
Compressing Variable-Coefficient Helmholtz Problems via RKFIT

The efficient discretization of Helmholtz problems on unbounded domains is a challenging task, in particular, when the wave medium is nonhomogeneous. We present a new numerical approach for compressing finite difference discretizations of such problems, thereby giving rise to efficient perfectly matched layers (PMLs) for nonhomogeneous media. This approach is based on the solution of a nonlinear rational least squares problem using the RKFIT method proposed in [M. Berljafa and S. Güttel, *SIAM J. Matrix Anal. Appl.*, 36(2):894–916, 2015]. We show how the solution of this least squares problem can be converted into an accurate finite difference grid within a rational Krylov framework. Numerical experiments indicate that RKFIT computes PMLs more accurate than previous analytic approaches and even works in regimes where the Dirichlet-to-Neumann functions to be approximated are highly irregular. Spectral adaptation effects allow for accurate finite difference grids with point numbers below the Nyquist limit.

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Vladimir Druskin, Schlumberger–Doll Resarch, Boston
Leonid Knizhnerman, Central Geophysical Expedition, Moscow

MS31
Rational Krylov Methods in Discrete Inverse Problems

Polynomial Krylov methods are known to be very efficient regularisation methods for discrete inverse problems. This is especially true for conjugate gradient type methods stopped by the discrepancy principle. We will discuss some ideas whether rational Krylov methods might provide new regularisation schemes. The rational schemes can be seen as an acceleration of known iterative regularisation methods. Standard examples in image reconstruction will serve as an application in order to numerically compare the discussed methods.

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MS31
Inexact Rational Krylov Methods Applied to Lyapunov Equations

Rational Krylov subspace (RKS) methods are a useful and powerful tool for the numerical solution of large-scale Lyapunov equations. In order to generate the basis vectors for the RKS, the solution to a shifted linear system is necessary. For very large systems this solve is usually implemented using iterative methods, leading to inexact solves. In this talk we will provide theory for a relaxation strategy within these inexact solves, supported by numerical examples.

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Patrick Kuerschner, Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg

MS31
Numerical Methods for Lyapunov Matrix Equations with Banded Symmetric Data

We consider the large-scale Lyapunov equation
$A\mathbf{X} + \mathbf{X}A^T = C$,
where $A, C \in \mathbb{R}^{n\times n}$ are both large and banded matrices. We suppose that A is SPD and $C = C^T$.While the case of low-rank C has been successfully addressed in the literature, the more general banded setting has not received much attention, in spite of its possible occurrence in applications. In this talk we aim to fill this gap. It has been recently shown that if A is well conditioned, the entries of the solution matrix $\mathbf{X}$ decay in absolute value as their indexes move away from the sparsity pattern of C. This property can be used in a memory-saving matrix-oriented CG method to obtain a banded approximate solution. For A not well conditioned, the entries of $\mathbf{X}$ do not sufficiently decay to derive a good banded approximation. Nonetheless, we show that it is possible to split $\mathbf{X}$ as $\mathbf{X} = \mathbf{Z}_b + \mathbf{Z}_r$, where $\mathbf{Z}_b$ is banded and $\mathbf{Z}_r$ is numerically low rank. A novel strategy that efficiently approximates both these terms with acceptable memory requirements is proposed and numerical experiments are reported to illustrate the potential of the discussed methods.

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MS31
A Comparison of Rational Krylov and Related Low-Rank Methods for Large Riccati Equations

Projection methods using rational Krylov subspaces are being used successfully to compute low-rank approximate solutions of large-scale, continuous-time algebraic Riccati equations. Further classes of algorithms for this purpose include ADI-like iterations as well as low-rank Newton-Kleinman methods. All these methods generate at some point rational Krylov subspaces, but utilize them in different ways to build low-rank solutions.After discussing these constructions and further key aspects of the algorithms, we survey which methods achieve the fastest convergence, require the smallest computation time, and consume the smallest amount of memory. For this, we will compare the expected numerical effort in state-of-the-art implementations of the algorithms. A series of numerical experiments is carried out to evaluate all approaches, for instance, how certain key properties of the underlying Riccati equation influence the performance.

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Zvonimir Bujanović, University of Zagreb
Jens Saak, Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg

MS32
Asymptotic Analysis and Numerical Method for Singularly Perturbed Eigenvalue Problems

In this talk, we study the asymptotic analysis and numerical method for singularly perturbed eigenvalue problems (SPEP). We first make a close asymptotic analysis on the SPEP, and prove the main theorems about the asymptotic behavior of the eigenvalues and eigenfunctions. Then we introduce a new tailored finite point method (TFPM) for numerical solutions of SPEP with higher accuracy. Our numerical examples verify our theory and show the feasibility and efficiency of our method.

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MS32
An Adaptive Reduced Basis ANOVA Method for High-Dimensional Bayesian Inverse Problems

TBA

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MS32
Randomized Kaczmarz Method for Linear Inverse Problems

In this talk we will discuss a randomized Kaczmarz method for linear inverse problems. We will explain why randomized Kaczmarz is suitable for linear inverse problem by providing pre-asymptotic analysis and studying the structure of some specific problems. Numerical examples validated our analysis.

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MS32
TBA

TBA

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MS32
Sequential Data Assimilation with Multiple Nonlinear Models and Applications to Subsurface Flow

Complex systems are often described with competing models. Such divergence of interpretation on the system may stem from model fidelity, mathematical simplicity, and more generally, our limited knowledge of the underlying processes. Meanwhile, available but limited observations of system state could further complicates one's prediction choices. Over the years, data assimilation techniques, such as the Kalman filter, have become essential tools for improved system estimation by incorporating both models forecast and measurement; but its potential to mitigate the impacts of aforementioned model-form uncertainty has yet to be developed. Based on an earlier study of Multi-model Kalman filter, we propose a novel framework to assimilate multiple models with observation data for nonlinear systems, using extended Kalman filter, ensemble Kalman filter and particle filter, respectively. Through numerical examples of subsurface flow, we demonstrate that the new assimilation framework provides an effective and improved forecast of system behaviour.

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MS32
A New Model Reduction Technique for Convection-Dominated PDEs with Random Velocity Fields

We developed a new model-order reduction technique for PDEs with random field input. In our approach, domain decomposition is used to reduce the parametric dimension in local physical domains; proper orthogonal decomposition is used to reduce the degree of freedom along the interfaces and within subdomains, and sparse approximation is used to construct surrogate to the local stiffness matrices obtained from Schur complement. The main advantages of our method are: (i) the complexity of the surrogate model is independent the FEM mesh size (online-offline decomposition); (ii) being able to handle both colored noise and discrete white noise (i.e., piecewise constant random fields); and (iii) promising accuracy in solving convection-dominated transport with random velocity fields.

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MS32
Gamblet Based Multilevel Decomposition/Preconditioner for Stochastic Multiscale PDE

TBA

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MS32
Scalable Generation of Spatially Correlated Random Fields

We use a domain embedding technique between two nonmatching meshes used for generating realizations of spatially correlated random fields with applications to large-scale sampling-based uncertainty quantification. The samples are used in the multilevel Monte Carlo (MLMC) method for the quantification of output uncertainties of PDEs with random input coefficients. The studied highly scalable, hierarchical sampling method to generate realizations of a Gaussian random field on a given unstructured mesh is based on solving a reactiondiffusion PDE with a stochastic right-hand side. The stochastic PDE is discretized using the mixed finite element method on an embedded domain with a structured mesh, and then, the solution is projected onto the unstructured mesh of main interest. This is also done on a hierarchy of algebraically constructed coarse meshes. We demonstrate the efficiency and parallel scalability of the technique in three dimensions with application in subsurface flow problems with up to 1.9·109 unknowns.
The presentation is based on:
[1] S. Osborn, P. Zulian, T. Benson, U. Villa, R. Krause, and P. S. Vassilevski, "Scalable Hierarchical PDE Sampler for Generating Spatially Correlated Random Fields Using Non-Matching Meshes.," *Numerical Linear Algebra with Applications 2018; e2146. https://doi.org/10.1002/nla.2146

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MS33
Block Term Decomposition for Multilayer Networks Clustering

Multilayer networks clustering is an essential method for mining multi-source data, which avoids incompleteness and unreliability from single source. In this talk, we proposed a novel approach which differentiates irrelative sources and integrates unanimous information to cluster instances simultaneously. Tensor representation of networks and rank-$(L_r, L_r, 1)$ block term decomposition are employed to discover the latent clusters. The efficiency and robustness of the proposed method against both noise and irrelevant data are investigated through the simulations.

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MS33
Hyperspectral Image Restoration via Tensor-Based Priors: From Low-Rank to Deep Model

In this talk, we will focus on tensor-based prior modeling for hyperspectral image (HSI) restoration, in which both the unsupervised optimization and discriminative learning based tensor models are discussed. For the optimization-based model, it is very common to see an elongated cost function that incorporates several priors, yet hard to tell which contributes how much. We figure out which component contributes most from the low-rank tensor perspective. For the learning-based model, it is very natural to fine-tune the classical deep convolutional neural network (CNNs) with only slightly modifying the channels of the first layer filters. The learned multi-channel filters exactly capture the spirit of tensor-based methods for preserving the structure integrity.

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MS33
Compressive Tensor Principal Component Pursuit

TBA

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MS33
Low-Rank Tensor Completion Using Parallel Matrix Factorization with Factor Priors

In this talk, we discuss the low-rank tensor completion (LRTC) problem. To tackle the LRTC problem, we propose the parallel matrix factorization with factor priors (e.g., smoothness). We develop an efficient block successive upper-bound minimization method to solve the proposed model. The convergence of the numerical scheme is theoretically guaranteed under some mild conditions. Numerical examples of synthetic and real data are reported to demonstrate the effectiveness of the proposed model and the efficiency of the proposed numerical scheme.

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MS33
Data Mining with Tensor Based Methods

In this talk, I will introduce a serial of tensor based methods for data mining. In terms of the methodologies, the tensor methods are categorized into two parts: multilinear Markov chain models and low-rank factorization models. I will introduce the basic principles and theories of the models, and explain how they are applied to data mining tasks, e.g., information retrieval, recommender systems, missing value completion, and multi-view clustering etc. Experimental results will be reported to demonstrate the effectiveness of the developed models in the corresponding data mining tasks.

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MS33
Low-Rank Tensor Analysis with Noise Modeling

Because of the limitations of matrix factorization, such as losing spatial structure information, the concept of tensor factorization has been applied for the recovery of a low dimensional subspace from high dimensional visual data. Generally, the recovery is achieved by minimizing the loss function between the observed data and the factorization representation. Under different assumptions of the noise distribution, the loss functions are in various forms, like L1 and L2 norms. However, real data are often corrupted by noise with an unknown distribution. Then any specific form of loss function for one specific kind of noise often fails to tackle such real data with unknown noise. To overcome such drawbacks, we propose new tensor factorization and tensor RPCA algorithm, meanwhile the noise is modeled by a Mixture of Gaussians (MoG), as MoG has the ability of universally approximating any hybrids of continuous distributions. We test our algorithms through synthetic and real data experiments on various topics, such as RGB image recovery, multispectral/hyperspectral image denoising, foreground/background separation, etc.

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MS33
Hyperspectral and Multispectral Image Fusion via Total Variation Regularized Nonlocal Tensor Train Decomposition

TBA

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MS33
A Novel Tensor-Based Video Rain Streaks Removal Approach via Utilizing Discriminatively Intrinsic Priors

Rain streaks removal is an important issue of the outdoor vision system and has been recently investigated extensively. In this paper, we propose a novel tensor-based video rain streaks removal approach by fully considering the discriminatively intrinsic characteristics of rain streaks and clean videos, which needs neither rain detection nor time-consuming dictionary learning stage. In specific, on the one hand, rain streaks are sparse and smooth along the raindrops' direction, and on the other hand, the clean videos possess smoothness along the rain-perpendicular direction and global and local correlation along time direction. We use the l1 norm to enhance the sparsity of the underlying rain streaks, two unidirectional Total Variation (TV) regularizers to guarantee the different discriminative smoothness, and a tensor nuclear norm and a time directional difference operator to characterize the exclusive correlation of the clean video along time. Alternation direction method of multipliers (ADMM) is employed to solve the proposed concise tensor-based convex model. Experiments implemented on synthetic and real data substantiate the effectiveness and efficiency of the proposed method. Under comprehensive quantitative performance measures, our approach outperforms other state-of-the-art methods.

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MS34
Low Rank Updates and a Divide and Conquer Method for Matrix Equations

In this work we study how the solutions of certain linear matrix equations behave when the original coefficients are modified with low-rank perturbations. More precisely, given the solution X of the Sylvester equation $AX + XB = C$, and 3 low-rank matrices $\delta A, \delta B$ and δC, we are interested in characterizing the update δX that verifies

$(A + \delta A)(X + \delta X) + (X + \delta X)(B + \delta B) = C + \delta C.$
Under reasonable assumptions, δX turns out to have a low numerical rank and allows to be efficiently approximated by means of Krylov subspace techniques. We show how to exploit this property to design divide and conquer methods for solving large-scale Sylvester equations whose coefficients are represented in the HODLR and HSS formats. This comprises the case of banded and quasiseparable coefficients.

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Daniel Kressner, EPF Lausanne
Leonardo Robol, ISTI-CNR Pisa

MS34
RQZ: A Rational QZ Algorithm for the Generalized Eigenvalue Problem

The multishift QZ method by Moler and Stewart implicitly applies subspace iteration driven by a polynomial. We have generalized this to the RQZ method, operating on two Hessenberg matrices, and employing subspace iteration driven by a rational function. This is done implicitly without computing matrix inverses. In this talk we introduce the RQZ method and explore some possibilities to utilize pole selection as an additional degree of freedom.

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Raf Vandebril, KU Leuven - University of Leuven

MS34
Fast Direct Algorithms for Least Squares and Least Norm Solutions for Hierarchical Matrices

TBA

Abhay Gupta, Indian Institute of Science

MS34
Computing the Inverse Matrix ϕ_1-Function for a Quasiseparable Matrix

In this talk we introduce a family of rational approximations of the inverse of a ϕ function. It is shown that for a symmetric banded matrix these novel approximations exhibit better decaying properties than other computable polynomial approximations. Also, when the matrix is quasiseparable the action of the matrix function on a vector can be computed efficiently using some direct fast solvers for shifted linear systems recently proposed.

Luca Gemignani, Università di Pisa, l.gemignani@di.unipi.it
Paola Boito, Université de Limoges
Yuli Eidelman, Tel-Aviv University

MS34
Superfast Direct Solvers for 3D MSN PDE Solvers

The FMM structure can capture the fill-in that arises during the LU factorization of the discrete representations of elliptic PDE operators. However, the compression levels that are required for efficiency are close to the smallest singular value making it difficult to establish trade-offs between accuracy and speed. We show that by exploiting the flexibility in grid positioning offered by the Minimum Sobolev Norm discretization technique many of these shortcomings can be overcome.

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Chris Gorman, University of California at Santa Barbara
Hrushikesh Mhaskar, Claremont Graduate School

MS34
Fast Direct Solvers for Boundary Value Problems on Globally Evolving Geometries

Problems involving evolving geometries arise in many applications.Unfortunately in most applications there are not many solves associated with each geometry; thus rendering the high overhead for precomputation of a fast direct solver useless. This talk presents a new fast direct solver which build a direct solver for the new geometry from the solver for a previous geometry. The cost of the creating the new solver is significantly less than building a solverfrom scratch.

Adrianna Gillman, CAAM, Rice University, adrianna.gillman@rice.edu
Yabin Zhang, Rice University

MS34
Matrix Aspects of Fast Multipole Method

The fast multipole method has a strong physics background, so it is hard for non-physics people to understand its essence. This talk aims to reveal the essence of 2D-FMM in matrix language. Also its connection with the hierarchical semiseparable matrices(HSS) will be explored. We can show that FMM matrix admits a HSS representation. Hence we can perform common operations in linear complexity, such as the matrix vector product and ULV factorization.

Xiaofeng Ou, Department of Mathematics, Purdue University, ou17@purdue.edu
Jianlin Xia, Purdue University

MS34
Adaptive Cross Approximation for Ill-Posed Problems

Consider integral equations of the first kind with a smooth kernel and perturbed right-hand side, i.e. based on contaminated data. Discretization leads to linear systems of equations with singular values clustering near zero. The solution of these systems requires regularization damping or ignoring the small singular values. With adaptive cross approximation we approximate a small number of the largest singular values that are sufficient for an approximation of the solution.

Thomas Mach, Nazarbayev University, thomas.mach@nu.edu.kz
Lothar Reichel, Kent State University
Marc Van Barel, KU Leuven
Raf Vandebril, KU Leuven

MS35
Preconditioning for Accurate Solutions of Linear Systems and Eigenvalue Problems

We present the preconditioning technique as a method to address the accuracy issue caused by ill-conditioning. Given a preconditioner for an ill-conditioned linear system, we show that, if the inverse of the preconditioner can be applied to vectors accurately, then the linear system can be solved accurately. As an application, we use the preconditioning approach to accurately compute a few smallest eigenvalues of certain ill-conditioned matrices.

Qiang Ye, University of Kentucky, qye3@uky.edu

MS35
A Block Term Decomposition of High Order Tensors

For an $I_1 \times I_2 \times \ldots \times I_N$ tensor $\mathcal{T}$,we consider a block term decomposition of it:
$\mathcal{T} = \sum_{r=1}^{R} \mathcal{S}_r \times_1 A_r^{(1)} \ldots \times_N A_r^{(N)},$

where the sizes of the tensors on the diagonal $\mathcal{S}_r$ś are unknown and the number of the tensors on the diagonal R needs to be as large as possible. The existence and uniqueness conditions for such a decomposition are established. A Krylov subspace type method is proposed to compute such a decomposition, and numerical experiments show the efficiency and stability of the method.

Yunfeng Cai, Peking University, yfcai@math.pku.edu.cn
Jiang Qian, South University of Science and Technology

MS35

A Fast Implementation on the Exponential Marginal Fisher Analysis for High Dimensionality Reduction

We consider how to enhance the performance of the Exponential Marginal Fisher Analysis (EMFA) method. The idea is to equivalently transform the large matrix computation problems of size d into small ones of size n. A fast implementation on the Exponential Discriminant Analysis (EDA) method is also investigated.

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Youwei Luo, China University of Mining and Technology

MS35

Deflated Block Krylov Subspace Methods for Large Scale Eigenvalue Problems

We discuss a class of deflated block Krylov subspace methods for solving large scale matrix eigenvalue problems. The efficiency of an Arnoldi-type method is examined in computing partial or closely clustered eigenvalues of large matrices. As an improvement, we also propose a refined variant of the Arnoldi-type method. Comparisons show that the refined variant can further improve the Arnoldi-type method and both methods exhibit very regular convergence behavior.

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MS35

Lanczos Type Methods for the Linear Response Eigenvalue Problem

The linear response eigenvalue problem arising from computational quantum chemistry and physics needs to compute a small portion of eigenvalues around zero together with the associated eigenvectors. Lanczos type methods are particularly suitable for such a task. We consider the single-vector Lanczos methods and the block Lanczos methods for the linear response eigenvalue problem. Convergence results are established and reveal the accuracy of the approximations of both eigenvalues and eigenspace. A practical thick-restart procedure is also introduced to alleviate the increasing numerical difficulties of the Lanczos method in computational costs, memory demands and numerical stability. Numerical examples are presented to support the effectiveness of the thick-restart Lanczos method.

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MS35

Sparse Frequent Direction Algorithm for Low Rank Approximation

TBA

Delin Chu, National University of Singapore, matchudl@nus.edu.sg

MS35

On the Generalized Lanczos Trust-Region Method

The so-called Trust-Region Subproblem gets its name in the trust-region method in optimization and also plays a vital role in various other applications. Several numerical algorithms have been proposed in the literature for solving small-to-medium size dense problems as well as for large scale sparse problems. The Generalized Lanczos Trust-Region (GLTR) method proposed by [Gould, Lucidi, Roma and Toint, SIAM J. Optim., 9:504-525 (1999)] is a natural extension of the classical Lanczos method for the linear system to the trust-region subproblem. In this talk, we will present the convergence of GLTR to reveal its convergence behavior in theory, and then propose new stopping criteria that can be integrated into GLTR for better numerical performance of the trust-region solver TRU in the Fortran routine GLTR in the library GALAHAD.

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Chungen Shen, College of Science, University of Shanghai for Science and Technology
Ren-Cang Li, Department of Mathematics, University of Texas at Arlington

MS35

A Block Lanczos Method for the Extended Trust-Region Subproblems

We present a block Lanczos method for solving the large-scale extended trust-region (ETR) subproblem. During the algorithm, the original ETR subproblem is projected to a small-scale one, and then the active-set method is employed to solve this small-scale ETR subproblem to get a solution, which can be used to derive an approximate solution of the original ETR subproblem. Error bounds for the optimal value, the optimal solution and multipliers is proved. Numerical experiments demonstrate that the block Lanczos method is effective and can achieve high accuracy for large-scale ETR subproblems.

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MS35

Parametrized Quasi-Soft Thresholding Operator for Compressed Sensing and Matrix Completion

Compressed sensing and matrix completion are two new theories of signal acquisition and processing. Both of them deal with two different problems, however they have close connection with each other. In compressed sensing, based on four basic operators, we give a parametrized quasi-soft thresholding operator and its induced algorithm. Further, by updating parametrized quasi-soft thresholding operator in every iteration, a varied parametric quasi-soft thresholding algorithm is obtained. Then we generalize both algorithms to suit matrix completion. Finally, the convergence of all algorithms are proved, and the numerical results given show that the new algorithms can effectively improve the accuracy to achieve compressed sensing and matrix completion.

An-Bao Xu, Wenzhou University, xuanbao777@163.com

MS35

Two-Level RAS Preconditioners of Krylov Subspace Methods for Large Sparse Linear Systems

Two kinds of two-level restricted additive Schwarz (RAS) preconditioners of Krylov subspace methods for large sparse linear systems are proposed based on the multi-level architecture of the parallel computer. Both kinds of preconditioners use the RAS preconditioner on CPU as the first level; and for the second level among cores in each CPU,

one kind uses the block Jacobi preconditioner and the other kind uses the RAS preconditioner.
Numerical experiments show that these two-level preconditioners are both more efficient than one level preconditioner and have good scalability. Convergence analysis is also given for both two-level preconditioners.

Xin Lu, China University of Petroleum - Beijing, xinlu@cup.edu.cn

MS36
Irreducible Function Bases of Isotropic Invariants of Third and Fourth Order Symmetric Tensors

Representation theorems for both isotropic and anisotropic functions are of prime importance in both theoretical and applied mechanics. For third and fourth order tensors in the three-dimensional physical space, existing results are restricted to integrity bases. In this paper, as the first step to explore irreducible function bases of isotropic invariants of third and fourth order three-dimensional (completely) symmetric tensors, we show that the four invariant Smith-Bao minimal isotropic integrity basis of a third order three-dimensional symmetric and traceless tensor is also an irreducible function basis of that tensor. Then we present isotropic function bases of a third order three-dimensional symmetric tensor, a fourth order three-dimensional symmetric and traceless tensor and a fourth order three-dimensional symmetric tensor. These function bases are proper subsets of minimal integrity bases of these three tensors.

Liqun Qi, The Hong Kong Polytechnic University, liqun.qi@polyu.edu.hk

MS36
The Rank of $W \otimes W$ is Eight

Let W be a symmetric complex valued $2 \times 2 \times 2$ tensor with rank three. In this talk we outline the proof that the rank of $W \otimes W$ is eight and discuss related problems of ranks of tensor products.

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MS36
Optimization Methods Using Matrix and Tensor Structures

Several optimization problems for matrices assume a huge number of variables but, despite that, are very efficiently solved using the theory and constructions of matrix analysis. However,increasing the size of matrices we still get moving towards intractability, and have to look better for more structures in our data. We consider low-rank structures that appear after tensorization of data and new optimization techniques capitalizing on those structures.We also consider some new heuristic global search methods using the search over tensor-structured manifolds.

Eugene Tyrtyshnikov, Russian Academy of Sciences, eugene.tyrtyshnikov@gmail.com

MS36
Exploitation of Structure in Large-Scale Tensor Decompositions

Decomposing tensors into simple terms is often crucial in knowledge discovery and compression. To alleviate the cost of large-scale decompositions, we present structure-exploiting algorithms that reduce the complexity from O(tensor entries) to O(parameters). Sparse or factored tensors, or implicitly tensorized data are examples of such structures. The presented approach allows constraints and coupling to be incorporated trivially. We illustrate the performance for Hankelization and large-scale nonnegative tensor factorization using compression.

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Nico Vervliet, KU Leuven
Otto Debals, KU Leuven

MS36
An Adaptive Correction Approach for Tensor Completion

In this talk, we study the tensor completion problem on recovery of the multilinear data under limited sampling. A popular convex relaxation of this problem is to minimize the nuclear norm of the more square matrix produced by matricizing a tensor. However, it may fail to produce a high accurate solution under low sample ratio. In order to get a recovery with high accuracy, we propose an adaptive correction approach for tensor completion. Firstly, a corrected model for matrix completion with bound constraint is proposed and its error bound is established. Then, we extend it to tensor completion with bound constraint and propose a corrected model for tensor completion. The adaptive correction approach consists of solving a series of corrected models with an initial estimator where the initial estimator used for the next step is computed from the value of the current solution. Moreover, the error bound of the corrected model for tensor completion is also established. A convergent 3-block alternating direction method of multipliers (ADMM) is applied to solve the dual problem of the corrected model. Numerical experiments on both random data and real world data validate the efficiency of our proposed correction approach.

Minru Bai, Hunan University, minru-bai@163.com

MS36
Generalized Polynomial Complementarity Problems with Structured Tensors

In this talk, we consider the *generalized polynomial complementarity problem* (GPCP), which is an interesting generalization of *polynomial complementarity problem* (PCP), and is also a special instance of *generalized nonliear complementarity problem* (GNCP). We first show that, when a pair of leading tensors is cone ER, the solution set of GPCPs is nonempty and compact. Then, we study some basic topological properties of the solution set of GPCPs under the condition that the leading tensor pair is cone R^0. Finally, we study the global Lipshitzian error bound of the solution set of GPCP. It is noteworthy that, due to the special structure of GPCPs, our error bounds seem better than the results obtained in the current PCPs and *tensor complementarity problem* literature.

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MS36
Copositive Tensor Detection and Its Applications in Physics and Hypergraphs

Copositivity of tensors plays an important role in vacuum stability of a general scalar potential, polynomial optimization, tensor complementarity problem and tensor generalized eigenvalue complementarity problem. In this talk, we propose a new algorithm for testing copositivity of high order tensors, and then present applications of the algorithm in physics and hypergraphs. For this purpose, we first give several new conditions for copositivity of tensors based on the representative matrix of a simplex. Then a new algorithm is proposed with the help of a proper convex subcone of the copositive tensor cone, which is defined via the copositivity of Z-tensors. Furthermore, by considering a sum-of-squares program problem, we define two new subsets of the copositive tensor cone and discuss their convexity. As an application of the proposed algorithm, we prove that the coclique number of a uniform hypergraph is equivalent to an optimization problem over the completely positive tensor cone, which implies that the proposed algorithm can be applied to compute an upper bound of the coclique number of a uniform hypergraph. Then we study another application of the proposed algorithm on particle physics in testing copositivity of some potential fields. At last, various numerical examples are given to show the performance of the algorithm.

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MS36
The Bound of H-Eigenvalue of Some Structure Tensors with Entries in an Interval

The tensor eigenvalue problem have been widely studied in the recent years. In this paper, we proposed a new constructive way to estimate the bound of a well-defined eigenvalue problem called H-eigenvalue for two kinds of structured tensors including nonnegative tensor and real symmetric tensor. As applications, the permutation analysis of both nonnegative tensor and real symmetric tensor are numerically studied.

Lubin Cui, Henan Normal University, cuilubinrx@163.com

MS37
The Fiedler Vector of a Laplacian Tensor for Hypergraph Partitioning

We explore the Fiedler vector of an even-uniform hypergraph, which is the Z-eigenvector associated with the second smallest Z-eigenvalue of a normalized Laplacian tensor arising from the hypergraph. We develop a novel tensor-based spectral method for partitioning vertices of the hypergraph. Then, we establish a feasible optimization algorithm to compute the Fiedler vector. Finally, preliminary numerical experiments illustrate that the new approach based on a hypergraph-based Fiedler vector is effective and promising.

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Liqun Qi, The Hong Kong Polytechnic University
Xiaoyan Zhang, Nanjing Normal University

MS37
Solving Tensor Problems via Continuation Methods

Many problems in tensors involve solving a system of polynomial equations. Various algorithms have been proposed for solving polynomial systems resulted from tensor computation. In this talk, we will survey a particular class of such algorithms: The continuation methods. These methods not only possess global and fast convergence, but also utilize the special structure of tensors. We will describe continuation methods for solving multilinear systems, tensor eigenvalue problems, and tensor complementarity problems.

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MS37
Local Convergence Rate Analysis for the Higher-Order Power Method in Best Rank One Approximations of Tensors

TBA

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MS37
Tensor Splitting Methods for Solving the Multi-Linear System

In this talk, firstly, we introduce the variant tensor splitting, and present some equivalent conditions for a strong $\mathcal{M}$-tensor based on the tensor splitting. Secondly, the existence and uniqueness conditions of the solution for multi-linear systems are given. Thirdly, we propose some tensor splitting algorithms for solving multi-linear systems with coefficient tensor being a strong $\mathcal{M}$-tensor. As an application, a tensor splitting algorithm for solving the multi-linear model of higher order Markov chains is proposed. Numerical examples are given to demonstrate the efficiency of the proposed algorithms.

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MS37
Sparse Tucker Decomposition Completion for 3D Facial Expression Recognition

In this talk, a new approach for multi-modal facial expression recognition via low-rank tensor completion (MFERLRTC) is proposed. By introducing a low-rank tensor completion scheme based on Tucker decomposition with some boundary constraint, a 4D tensor model is constructed to utilize multi-modal data (e.g. both 2D face images and 3D face models) to better capture the spectral correlation and excavate complementarity among different modalities simultaneously. The tensor low-rank and sparse representation are adopted to characterize the involved similarities of the 4D tensor data in terms of the low-rank structure of factor matrices and the sparsity of the core tensor in the Tucker decomposition of the 4D tensor model. This approach opens a promising direction for higher performance of 2D+3D multi-modal FER based on Tucker decomposition. The ADMM method is designed to efficiently solve the proposed model. Experiments are conducted with a full implementation on gender-independent and person-independent cases on the BU-3DFE and Bosphorus databases, and the results show that our approach outperforms the state-of-art approaches.

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MS37
Tensor Ranks and Secant Varieties

Secant varieties are closely related to tensors. For example, the affine cone of the rth secant variety of a Segre variety is the set of tensors whose border ranks are $\leq r$. By studying the geometric property of the rth secant variety of a projective variety X, we can obtain interesting information of X-ranks.

In this talk, we study linear sections of the rth secant variety of a Segre variety, in particular we focus on the influence of linear sections on the defining equations of the secant varieties, and give some applications on the ranks of a general tensor.

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MS37
S-lemma of the Fourth Order Tensor Systems

TBA

Qingzhi Yang, Nankai University,qz-yang@nankai.edu.cn

MS37
Hankel Tensor Decompositions and Ranks

Hankel tensors are generalizations of Hankel matrices. In this talk I will discuss the relations among various ranks of Hankel tensors. I will also give an algorithm that can compute the Vandermonde ranks and decompositions for all Hankel tensors. For a generic n-dimensional Hankel tensor of even order or order three, I will show that the the cp rank, symmetric rank, border rank, symmetric border rank, and Vandermonde rank all coincide with each other. In particular, this implies that the Comon's conjecture is true for generic Hankel tensors when the order is even or three. This talk is based on a joint work with Jiawang Nie.

Ke Ye, Chinese Academy of Science and University of Chicago, kennyyeke@gmail.com

MS38
Prewhitening Under Channel-Dependent Signal-to-Noise Ratios

We present a new approach for Principal Component Analysis/prewhitening when the noise covariance matrix is arbitrary diagonal. Utilizing the low-rank structure of the signal, the problem is converted into a variant of Multilinear Singular Value Decomposition/Low Multilinear Rank Approximation. For this variant, we have developed a Non-linear Least Squares algorithm. We further discuss the case where the noise covariance is piece-wise constant diagonal. Simulations demonstrate the significant improvement of our approach over classical prewhitening.

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Nico Vervliet, ESAT & Kulak, KU Leuven
Lieven De Lathauwer, ESAT & Kulak, KU Leuven

MS38
Tensor Decompositions in Reduced Order Models

Reduced order models (ROMs) are essential tools to accelerate large expensive simulations without losing much accuracy. They are desirable in multiple query simulations, such as design optimization and uncertainty quantification. The performance of ROMs highly depends on compression techniques that are used to represent solution fields (and other relevant fields such as residual and forcing terms). Popular compression techniques in ROMs have been mainly matrix decompositions such as eigen or singular value decompositions. However, many problems involve more than one field, which leads to multidimensional array data. For example, time-dependent problems have spatial and temporal fields, which lead to three-dimensional array data. Spatially one dimensional compressible Euler equations in fluid dynamics have one temporal and three distict spatial fields (i.e., mass, momentum, and energy), which lead to five-dimensional array data. Therefore, tensor decompositions are natural techniques to consider.
In this talk, several tensor decompositions are considered in ROMs with multidimensional array data. Their performances are compared with traditional matrix decomposition techniques and show great benifits of using tensor decompositions in ROMs.

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MS38
Nonlinear System Identification with Tensor Methods

A common method to model nonlinear dynamical systems is through multivariate polynomials. These models however suffer from the curse of dimensionality through a combinatorial explosion of the number of parameters that need to be estimated. In this talk, we will discuss and demonstrate how tensor methods can effectively lift this curse of dimensionality, resulting in algorithms that for the very first time are capable of estimating accurate highly nonlinear models in a few seconds on a standard desktop computer.

Kim Batselier, The University of Hong Kong, kimb@eee.hku.hk

MS39
Adaptive Tensor Optimization for the Log-Normal Parametric Diffusion Equation

Parametric PDEs often lead to high dimensional problems. In the *log-normal* diffusion equation, the logarithm of the coefficient admits a series expansion with normally distributed parameters. This is difficult to tackle, as the parameter cannot be uniformly bounded away from zero and infinity. We propose a Galerkin method using finite elements and a discrete approximation of the diffusion coefficient. This allows for efficient treatment with hierarchical tensor methods and an adaptive solver.

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Martin Eigel, WIAS Berlin
Manuel Marshall, WIAS Berlin
Reinhold Schneider, TU Berlin

MS39
Geometrical Description of Feasible Singular Values in Tree Tensor Formats

The tuples of singular values, associated with a tree tensor format, of a tensor are given through different matricizations of it -raising the question: for which prescribed tuples exist correspondent tensors?
This problem can be decoupled, and concerning the TT-format, it is connected to eigenvalues of sums of hermitian matrices.Using *honeycombs* [Knutson, Tao], we find that at least in this case, the topology of squared feasible singular values is geometrically described by polyhedral cones.

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MS39
The Positive Cone to Algebraic Varieties of Hierarchical Tensors

Hierarchical tensors (mathematical formulation of MPS, DMRG and certain graphical models) are used to approximate tensors of high order with relatively few variables.The set of hierarchical tensors of bounded rank is an algebraic variety. It is natural to ask for the tangent cones and their parametrization in singular points. The tangent cone is the set of all tangent directions, i.e. the set of all permitted search directions for local optimization.

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MS39
Nuclear Decomposition of Higher-Order Tensors

TBA

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MS39

Duality of Graphical Models and Tensor Networks

We give a duality between graphical models and tensor networks. Graphical models are a statistical tool for representing multivariate probability distributions in terms of conditional independence relations. Tensor networks are a graphical way to represent tensors. We also explore how certain algorithms translate under the duality correspondence.

Anna Seigal, UC Berkeley, seigal@berkeley.edu
Elina Robeva, MIT

MS39

Orthogonal Tensors and Rank-One Approximation Ratio

In many tensor spaces the minimal ratio between spectral and Frobenius norm is unknown. However, introducing a suitable notion of orthogonal tensors, the minimal ratio can be determined for spaces in which such tensors exist and is, in fact, attained by them. Existence of real orthogonal third-order tensors is equivalent to composition formulas for bilinear forms (Hurwitz problem). Construction of higher-order examples is possible inductively. Interestingly, these objects do not exist in higher-order complex spaces.

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MS39

A Condition Number for the Tensor Rank Decomposition

The CP decomposition expresses a tensor as $\mathcal{A} = \sum_{i=1}^{r} a_i^1 \otimes a_i^2 \otimes \cdots \otimes a_i^d \in \mathbb{R}^{n_1 \times n_2 \times \cdots \times n_d}$.
The sensitivity of the summands in this decomposition to perturbation of the tensor $\mathcal{A}$ can be quantified by the so-called condition number of the corresponding decomposition problem. In this talk, we compute this condition number, investigate some of its properties, and show that it naturally appears in a local convergence analysis of certain Riemannian manifold optimization methods for solving the decomposition problem.

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Paul Breiding, MPI MiS Leipzig

MS40

Perturbation Analysis of an Eigenvector-Dependent Nonlinear Eigenvalue Problem with Applications

The eigenvector-dependent nonlinear eigenvalue problem (NEPv) $A(P)V = V\Lambda$,where the columns of $V \in \mathbb{C}^{n\times k}$ are orthonormal, $P = VV^{\mathrm{H}}$, $A(P)$ is Hermitian, and $\Lambda = V^{\mathrm{H}}A(P)V$, arises in many important applications, such as the discretized Kohn-Sham equation in electronic structure calculations and the trace ratio problem in linear discriminant analysis. In this paper, we perform a perturbation analysis for the NEPv, which gives upper bounds for the distance between the solution to the original NEPv and the solution to the perturbed NEPv. A condition number for the NEPv is introduced, which reveals the factors that affect the sensitivity of the solution. Furthermore, two computable error bounds are given for the NEPv, which can be used to measure the quality of an approximate solution. The theoretical results are validated by numerical experiments for the Kohn-Sham equation and the trace ratio optimization.

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Yunfeng Cai, Peking University
Zheng-Jian Bai, Xiamen University

MS40

Improved Random Perturbation Intervals of Symmetric Eigenvalue Problem

In this talk, we will introduce two improved random perturbation intervals of symmetric eigenvalue problem. Under the random perturbation in these intervals, the probability of the simple eigenvalue of original matrix being still simple is not less than a given confidence level. Numerical experiments are also presented to illustrate these new results.

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Chuanfu Xiao, Chongqing University

MS40

Error Bounds for Approximate Deflating Subspaces of Linear Response Eigenvalue Problems

Consider the linear response eigenvalue problem (LREP) for $H = \begin{pmatrix} 0 & K \\ M & 0 \end{pmatrix}$, where K and M are positive semidefinite and one of them is definite.Given a pair of approximate deflating subspaces of $\{K, M\}$, it can be shown that LREP can be transformed into onefor $\widetilde{H}$that is nearly decoupled into two smaller LREPs upon congruence transformations on K and M that preservethe eigenvalues of H. We establish a bound on how far the pair of approximate deflating subspacesis from a pair of exact ones, using the closeness of $\widetilde{H}$ from being decoupled.

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Lei-Hong Zhang, Shanghai University of Finance and Economics
Ren-Cang Li, University of Texas at Arlington

MS40

Relative Perturbation Bounds for Eigenpairs of the Diagonalizable Matrices

In this lecture we present some uniform relative perturbation bounds for eigenvalues and eigenspaces of the diagonalizable matrices under the additive and the multiplicative perturbations. Some existing bounds can be derived or can be improved by the proposed bounds. Numerical experiments are given to demonstrate the advantage of the proposed bounds..

Yanmei Chen, South China Normal University, chch1980@163.com
Wen Li, South China Normal University
Xiaofei Peng, South China Normal University

MS40

Mixed and Componentwise Condition Numbers for a Linear Function of the Solution of the Total Least Squares Problem

In this talk, we consider the mixed and componentwise condition numbers for a linear function Lx of the solution to the total least squares (TLS) problem. We derive the explicit expressions of the mixed and componentwise condition numbers through the dual techniques under both unstructured and structured componentwise perturbations. The sharp upper bounds for condition numbers are obtained. An efficient condition estimation algorithm is proposed, which can be integrated into the iterative method for solving large scale TLS problems. Moreover, the new derived condition number expressions can recover the previous results on the condition analysis for the TLS problem when $L = I_n$. Numerical experiments show the effectiveness of the introduced condition numbers and condition estimation algorithm.

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Yang Sun, Northeast Normal University

MS40
Some Perturbation Results for Joint Block Diagonalization Problems

Joint block diagonalization (JBD) of a given matrix set $\{A_i\}_{i=0}^{p}$ is to find a nonsingular matrix W such that $W^T A_i W$ for $i = 0, 1, \ldots, p$ are all block diagonal matrices with the same prescribed block diagonal structure. It includes the joint diagonalization (JD) problem as a special case for which all $W^T A_i W$ are all diagonal. In this report, we discuss the perturbation theory for JD/JBD problems. First, we discuss the perturbation theory for JD problem as an optimization problem. We obtain an upper bound for the distance between an approximated solution of the perturbed optimal problem and the set of exact joint diagonalizers. As corollaries, a perturbation bound and an error bound are also given. Second, with the help of a necessary and sufficient condition for solution uniqueness of JBD problems, we establish the error bound, perform backward error analysis, and propose a condition number for JBD problems. Numerical tests validate the theoretical results.

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MS40
A Structure-Preserving Γ-Lanczos Algorithm for Bethe-Salpeter Eigenvalue Problems

In this work, we present an efficient structured-preserving algorithm Γ-Lanczos to solve the Bethe-Salpeter eigenvalue problems $\mathscr{H}x = \lambda x$ with distinct sizes, where $\mathscr{H} = \begin{pmatrix} A & B \\ -\bar{B} & -\bar{A} \end{pmatrix}$ with $A^H = A$, $B^T = B$. Based on newly introduced Γ-orthogonal transformation, our algorithm will preserve the special structure of the initial matrix $\mathscr{H}$ throughout the whole process and thus guarantees the computed eigenvalues to appear pairwise $(\lambda, -\lambda)$ as they should. Theorems are given to demonstrate the validity of the proposed algorithm in theory and the numerical results are presented to illustrate the effectiveness of the algorithm.

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MS40
A Structure-Preserving Jacobi Algorithm for Quaternion Hermitian Eigenvalue Problems

A new real structure-preserving Jacobi algorithm is proposed for solving the eigenvalue problem of quaternion Hermitian matrix. By employing the generalized JRS-symplectic Jacobi rotations, the new quaternion Jacobi algorithm can preserve the symmetry and JRS-symmetry of the real counterpart of quaternion Hermitian matrix. Moreover, the proposed algorithm only includes real operations without dimension-expanding. Numerical experiments are reported to indicate its efficiency and accuracy.

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Zhi-Gang Jia, Jiangsu Normal University
Zheng-Jian Bai, Xiamen University

MS40
On the Explicit Expression of Chordal Metric Between Generalized Singular Values of Grassmann Matrix Pairs with Applications

In this talk we provide the explicit expression of the chordal metric between generalized singular values of Grassmann matrix pairs, which improves the Hoffman-Wielandt type theorem proposed by Sun [SIAM J. Matrix Anal. Appl., 20 (1983), pp. 611-625] in theory. The new results involve the constrained optimization problem of the form $\max_{U \in \mathbb{U}_n} f(U)$ with $\mathbb{U}_n$ being the set of $n \times n$ unitary matrices and the optimal solution is also given. In applications, we apply the new results in comparative analysis of gene mRNA expression data for mice macrophage under different conditions in the actual clinical experiments in mice. They are helpful to guide further experimental research for seeking key determined certain genes, which will be illustrated by numerical experiments.

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Xue-Ping Huang, Bielefeld University
Wen-Jie Guo, Nanjing University

MS41
On the Analytic Connectivity of Uniform Hypergraphs

In 2014, Qi defined the analytic connectivity of a k-uniform hypergraph G, and show that G is connected if and only if its analytic connectivity is larger than zero. In this talk, we report some recent results on the analytic connectivity of uniform hypergraphs.

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MS41
Some Recent Results on the Tensor Spectrum of Hypergraphs

In the last decade, the tensor spectra theory of hypergraphs has been well developed due to its theoretical significance and applications in many disciplines. In this talk, we present some new results on the relation between structure properties of hypergraphs and their spectrum of the adjacency or Laplace tensor. In particular, we will pay more attention to the extremal tensor spectral properties of hypergraphs. This is the joint work with Yuan Hou and Lei Zhang.

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MS41
The Spectral Symmetry and Stabilizing Property of Tensors and Hypergraphs

The Perron-Frobenius theorem for nonnegative tensors gives us the symmetric property and stabilizing property of the spectrum of a weakly irreducible nonnegative tensor $\mathcal{A}$ of order m and dimension n, which are defined as follows respectively.
Let Spec$\mathcal{A}$ be the spectrum of $\mathcal{A}$.
The cyclic index $c(\mathcal{A})$ of $\mathcal{A}$ is defined to be the maximum positive integer ℓ such that Spec$\mathcal{A}$ keeps invariant under a rotation of angle $\frac{2\pi}{k}$ of the complex plane, which reflects the spectral symmetry of $\mathcal{A}$.
The stabilizing index $s(\mathcal{A})$ of $\mathcal{A}$ is defined to be the number of eigenvectors of $\mathcal{A}$ associated with the spectral radius up to a scalar, or equivalently the number of normalized diagonal matrices D such that $\mathcal{A}$ is similar to itself via D.
We give an explicit formula for the cyclic index $c(\mathcal{A})$ by using the generalized traces, and proved that for any positive integer ℓ such that $\ell \mid m$, there always exists an m-uniform

hypergraph G such that its adjacency tensor has the cyclic index ℓ. If $\mathcal{A}$ is further symmetric, then the projective eigen variety of $\mathcal{A}$ associated with the spectral radius admits a module structure, which is determined by the sign pattern of the tensor and can be characterized explicitly by solving the Smith norm form of the incidence matrix of the tensor. So we can get the stabilizing index of $\mathcal{A}$ via the Smith norm.
This is joint work with Yan-Hong Bao, Tao Huang, Chen-Lu Zhuan-Sun and Ya-Ping Li.

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MS41
Sharp Upper and Lower Bounds for the Spectral Radius of a Nonnegative Weakly Irreducible Tensor and Its Application

In this paper, we obtain the sharp bound and lower bounds for the spectral radius of a nonnegative weakly irreducible tensor. We also apply these bounds to the adjacency spectral radius and signless Laplacian spectral radius of a uniform hypergraph.

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MS41
Some Results on Spectrum of Graphs

Let G be a simple graph of order n. Let $D(G) = diag(d_1, d_2, \ldots, d_n)$ be the diagonal matrix of vertex degrees, and let $A(G) = (a_{ij})$ be the adjacency matrix of G, that is, a_{ij} equals 1 if v_i is adjacent to v_j and equals 0, otherwise. The matrix $Q(G) = D(G) + A(G)$ is called the signless Laplacian matrix of G. The eigenvalues of $Q(G)$ are denoted by $q_1(G), q_2(G), \cdots, q_n(G)$, and assume that $q_1(G) \geq q_2(G) \geq \ldots \geq q_n(G)$. Since $Q(G)$ is nonnegative, $q_1(G)$ is equal to the spectral radius of $Q(G)$ and is referred to as the *signless Laplacian spectral radius* or the *signless Laplacian index* of G. In 2010, Hansen and Lucas proposed some conjectures of the form

$$l(n) \leq q_1(G) \oplus i(G) \leq u(n),$$

where $\oplus$ is one the four operations $+, -, \times, /$ and $i(G)$ is another invariant chosen among diameter, radius, girth and so on. In this tall, we will disprove three conjectures of them. Also some other results about the signless Laplacian index will be given. The work was Joint with Huiqing Liu.

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MS41
Spectral Radius of $\{0,1\}$-Tensor with Prescribed Number of Ones

For any r-th order $\{0,1\}$-tensor A with e ones, we prove that the spectral radius of A is at most $e^{\frac{r-1}{r}}$ with the equality holds if and only if $e = k^r$ for some integer k and all ones forms a principle sub-tensor $\mathbf{1}_{k\times\cdots\times k}$. We also prove a stability result for general A with e ones where $e = k^r + l$ with relatively small l. Using the stability result, we completely characterize the tensors which achieve the maximum spectral radius among all r-th order $\{0,1\}$-tensor A with $k^r + l$ ones, with $-r \leq l \leq r + 1$, for sufficiently large k. (Joint work with Shuliang Bai)

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MS41
Some Results in Spectral (Hyper)Graph Theory

In 1941, Turan proved the famous Turan theorem, i.e., If G is a graph whichdoes not contain K_{r+1} as its subgraph, then the edge number of G is no more than $T_{n,r}$, Turan graph, which started the extremal theory of graphs. In this talk, wewill introduce the spectral Turan-Type results which are incident with the adjacent matrix (tensor), signless Laplacian matrix(tensor) of (hyper) graphs. Moreover, some open problems in this field are proposed.

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MS41
On Distance Laplacian Spectral Radius of Graphs

Let G be a connected graph on n vertices. The distance matrix of G is the $n \times n$ matrix $D = (d_{uv})_{u,v\in V(G)}$, where d_{uv} for $u, v \in V(G)$ is the distance (i.e., number of edges of a shortest path) between u and v in G. The distance Laplacian matrix of G defined as $\mathcal{L}(G) = Tr(G) - D(G)$, where $Tr(G)$ is the diagonal matrix of vertex transmissions of G. The eigenvalues of $\mathcal{L}(G)$ are called the distance Laplacian eigenvalues of G. The largest distance Laplacian eigenvalue of G is known as the distance Laplacian spectral radius of G. Among others, we discuss properties of distance spectral radius, and particularly, extremal results in various classes of graphs.

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MS42
On von Neumann and Rényi Entropies of Rings and Paths

There have been many attempts of understanding graph structure by investigating graph entropy. We study von Neumann and Rényi-α entropies of paths and rings, in connection with Conjectures on the entropies of connected graphs recently formulated.

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MS42
Tridiagonal Matrices with Only One Eigenvalue and Their Relations to Polynomials Orthogonal with Non-Hermitian Weight

Given a symmetric positive measure σ on an interval $[-a, a]$, $0 < a \leq +\infty$, one can construct two one-parametric families of orthogonal polynomials by real and pure imaginary one-dimensional perturbations of the tridiagonal matrix corresponding to the measure σ. In the present talk, we consider an example of such perturbations of a given finite discrete measure and construct polynomials orthogonal with respect to a discrete measure with one multiple point of spectrum.

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Carlos da Fonseca, Kuweit University

MS42
Positivity and Recursion Formula of the Linearization Coefficients of Bessel Polynomials

Positivity results about linearization coefficients for Bessel polynomials is proved in a more general case. The proof is based not on a recursion formula (a formula similar to one given by Berg and Vignat) but on an explicit triple sum formula. Moreover, this triple sum is simplified and a double sum formula for these linearization coefficients is given. In two general cases this formula reduces indeed to either Atia and Zeng's formula (Ramanujan Journal, Doi 10.1007/s11139-011-9348-4) or Berg and Vignat's formulas in their proof of the positivity results about these coefficients (Constructive Approximation, **27** (2008), 15-32).

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MS42

Ultra-Discrete Analogue of the QD Algorithm for Min-Plus Tridiagonal Matrix

Recursion formula of the qd algorithm, which is for computing eigenvalues of tridiagonal matrices, is known as the integrable discrete Toda equation. Ultra-discretization, which is also known as the tropicalization, of the discrete Toda equation yields the ultra-discrete Toda equation. In this talk, we give an ultra-discrete analogue of the qd algorithm for tridiagonal matrices over the Min-Plus algebra. We also discuss their characteristic polynomials and relationship to weighted directed graph.

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Hitomi Shigitani, Kyoto Prefectural University
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MS42

A Generalized Eigenvalue Problem with Two Tridiagonal Matrices

Jacobi matrices, which are tridiagonal matrices, have been very useful in the study of orthogonal polynomials on the real line. Let $\mathbf{A} = (a_{j,k})$ and $\mathbf{B} = (b_{j,k})$ be **tridiagonal** matrices, where the matrix $\mathbf{B}$ is real symmetric and positive definite with all $b_{jj} = 1$ and the matrix $\mathbf{A}$ is Hermitian with all a_{jj} real and further $-a_{j+1,j} = a_{j,j+1} = i\, b_{j,j+1}$. It has been shown recently (see http://arxiv.org/abs/1606.08055) that the generalized eigenvalue problem $\mathbf{Au} = \lambda\mathbf{Bu}$ can be of use in the study of orthogonal polynomials on the unit circle. In this talk we look into further applications and also numerical implications of this generalized eigenvalue problem.

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MS42

Eigenvalue Problems of Structured Band Matrices Related to Discrete Integrable Systems

Eigenvalue problems of tridiagonal matrices are closely related to the discrete Toda equation and Lotka-Volterra system which belong to discrete integrable systems. Some of products of bidiagonal matrices appearing in the LU decompositions of tridiagonal matrices are structured band matrices such as totally nonnegative matrices and M-matrices. In this talk, from the viewpoint of discrete integrable systems, we clarify some aspect of eigenvalue problems of the structured band matrices.

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MS42

On Instability of the Absolutely Continuous Spectrum of Dissipative Schrödinger Operators and Jacobi Matrices

TBA

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MS42

Block-Tridiagonal Linearizations of Matrix Polynomials

In this talk we study properties of some block-tridiagonal linearizations of a matrix polynomial known in the literature. In particular, we show that, when the matrix polynomial has odd degree, these linearizations present some advantages when compared with other known linearizations.

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Abstracts of Contributed Talks

CS 01

Choi-Davis-Jensen Type Inequalities Without Convexity

Choi-Davis-Jensen type inequalities for real valued twice differentiable functions are given. Applying these results, some known inequalities are improved. Also some inequalities for relative operator entropies and among quasi-arithmetic means are shown.

References
[1] J. Mićić, J. Pečarić and M. Praljak, *Levinson's inequality for Hilbert space operators*, Journal Math. Ineq., **9** (2015), 1271-1285.
[2] J. Mićić, H. R. Moradi and S. Furuichi, *Improved inequalities complementary to Jensen's operator inequality*, submitted (2017).

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CS 01

Contractive Maps on Operator Ideals and Norm Inequalities III

Let $(\mathcal{I}, |||.|||)$ be a norm ideal of operators equipped with a unitarily invariant norm $|||.|||$. We discuss some generalized Lyapunov type norm inequalities for operators, which are motivated by the work of Bhatia and Drissi [1], Hiai and Kosaki [2] and Jocić [3]. We exploit integral representations and series expansions of certain functions to prove that certain ratios of linear operators acting on operators in $\mathcal{I}$ are contractive. This leads to several new and old norm inequalities for operators which were earlier in the matrix settings.

References:
[1] R. Bhatia and D. Drissi, *Generalized Lyapunov equations and positive definite functions*, SIAM J. Matrix Anal. Appl. 27, 1 (2005), 103-114.
[2] F. Hiai and H. Kosaki, *Means of matrices and comparison of their norms*, Indiana University Math. J. 48, 3 (1999), 899-936.
[3] D. R. Jocić, *Cauchy-Schwarz norm inequalities for weak*-integrals of operator valued functions*, J. Funct. Anal. 218 (2005), 318-346.

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CS 01

Contractive Maps on Operator Ideals and Norm Inequalities

Let $(\mathcal{I}, |||.|||)$ be a norm ideal of operators equipped with a unitarily invariant norm $|||.|||$. We employ a technique introduced by K. H. Neeb [4], and used later by H. Kosaki [2] and G. Larotonda [3] to prove that certain ratios of linear operators acting on operators in $\mathcal{I}$ are contractive. This leads to new inequalities which are sharper than those proved by F. Kittaneh [1], and by L. Zou and C. He [5]. We also lift a variety of inequalities to the operator setting, which were proved in the matrix setting earlier.

References:
[1] F. Kittaneh, *On convexity of the Heinz means*, Integral Equations Operator Theory 68 (2010), 519-527.
[2] H. Kosaki, *On infinite divisibility of positive definite functions arising from operator means*, J. Funct. Anal. 254 (2008), 84-108.
[3] G. Larotonda, *Norm inequalities in operator ideals*, J. Funct. Anal. 255 (2008), 3208-3228.
[4] K. H. Neeb, *A Cartan-Hadamard theorem for Banach-Finsler manifolds*, Procedings of the Conference on Geometric and Combinatorial Group Theory, Part-II, Haifa, 2000, Geom. Dedicata 95 (2002), 115-156.
[5] L. Zou, C. He, *On some inequalities for unitarily invariant norms and singular values*, Linear Algebra Appl. 436 (2012), 3354-3361.

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CS 02

Positivity Properties of Some Non-Negative Matrices

In the present talk, we will discuss positivity properties of matrices $[f(p_i + p_j)]$ and $[f(\mid p_i - p_j \mid)]$, where f is a non-negative operator concave or operator convex function on $(0, \infty)$ and $p_1, p_2, \ldots, p_n$ are distinct positive real numbers. The results for these matrices for power function $t \mapsto t^r$ for $r > 0$ are proved by Bhatia and Jain in 2015 and Dyn, Goodman and Michelli in 1986. Our results generalize these results and lead to many known and new results.

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CS 02

Upper and Lower Bounds for Sines of Canonical Angles

We present an upper and a lower bound for the $\|\sin \Theta(\mathcal{X}_1, \widetilde{\mathcal{X}}_1)\|_F$,where Θ is a matrix of canonical angles for the eigensubspaces $\mathcal{X}_1$ and $\widetilde{\mathcal{X}}_1$, for two problems. The first one is a perturbation of a regular Hermitian matrix pairs and the second is a perturbation of a regular quadratic eigenvalue problem. Although the bounds in both cases looks similar they are essentially different, because they bound a different subspaces.

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CS 02

Spectral Decomposition of Selfadjoint Matrices in Positive Semi-Definite Inner Product Spaces and Its Applications

Given a positive semidefinite matrix A, we present spectral decomposition of A-selfadjoint matrices. These matrices act on positive semidefinite inner product space which is defined by A. As applications, we improve the singular value decomposition of these matrices in positive semi-definite inner product spaces in [1] and give polar decomposition of these matrices. Furthermore, singular value decomposition and polar decomposition of rectangular matrices are also derived.

Reference:
[1] Zheng C, Li HY. Singular value decomposition of matrices in positive semi-definite inner product spaces. Journal of Shangdong University (Natural Science), 2014; 49: 81-86. (in Chinese)

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CS 03

Eigenvalues of Lévy Covariation Matrices

The Marčenko–Pastur law for the empirical spectral distribution of large rectangular matrices has been used to model bias when statistics are computed using a small number of samples. Unfortunately, the leptokurtic structure of financial data presents unique problems when applying these models. We examine the structure of limiting distributions when the underlying matrices arise from refined observations of non-Gaussian Lévy processes.

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CS 03
An Inverse Eigenvalue Problem for Lower Hessenberg Matrices with Prescribed Entries

An inverse eigenvalue problem (IEP) is one of important subjects in numerical linear algebra. Characterizations of an IEP are given by some spectral and structural constraints. An IEP to construct a matrix which has prescribed eigenvalues and entries is called the PEIEP. In this talk, we show an exact solution to a kind of the PEIEP for lower Hessenberg matrices by using a discrete dynamical system. We also give some numerical examples of constructed matrices.

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Koichi Kondo, Doshisha University

CS 03
Exploiting the Structure of the Bethe-Salpeter Eigenvalue Problem

The Bethe-Salpeter eigenvalue problem arises in quantum chemistry and is characterized by a peculiar block structure that involves complex conjugated transposes as well as regular non-conjugated complex transposes. We evaluate to what extent structure preserving methods for other structured matrices, e.g. Hamiltonian, can be applied here and what effect they have on the structure. Further approaches are discussed with regard to their ability to serve as a basis for high performance implementations.

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CS 03
FEAST Algorithm for Self Adjoint Eigenvalue Problems

Filtered subspace iteration with Rayleigh-Ritz eigenvalue extraction is a recently reviewed method in the form of the FEAST algorithm. In this talk we present a method motivated by the FEAST iteration and apply it directly on the operator level. The core of the algorithm is a numerical resolvent calculus based on contour quadratures coupled with discontinuous Petrov-Galerkin discretization of the resolvent. We prove mesh independent convergence rate and present comprehensive numerical experiments.

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Jay Gopalakrishnan, Portland State University
Jeffrey Ovall, Portland State University

CS 04
Log-determinant Non-Negative Matrix Factorization via Successive Trace Approximation

We consider a regularized non-negative matrix factorization with a log-determinant (logdet) term on the Gramian of the matrix W for achieving minimum volume of the convex hull spanned by columns of W. We propose a method called successive trace approximation (STA). Based on a logdet-trace inequality, STA replaces the logdet regularizer by a parametric trace functional that decouples the columns on W. Experiment on synthetic and real data show that STA outperforms state-of-the-art algorithms.

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CS 04
Optimization Methods on Problems with Generalized Orthogonality Constraints

Based on analyze the generalized gradient flow defined on the tangent space of the Stiefel manifold, an alternating variable method is proposed to solve generalized orthogonality constrained optimization problems. The alternating variable method is capable of solving positive semi-definite matrices involved in generalized orthogonality constrained optimization problems, which was not considered in the previous papers.

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Zhaojun Bai, University of California, Davis

CS 04
A Low-Rank Approach to the Solution of Weak Constraint Variational Data Assimilation Problems

The linearised system arising within the minimisation process of weak constraint 4DVar data assimilation can be formulated as a saddle point problem. A disadvantage of this formulation is the large storage requirements. Here we present a low-rank approach which exploits the structure of the saddle point system using techniques and theory from solving large scale matrix equations. Numerical experiments demonstrate the effectiveness of a low-rank approximate Krylov subspace solver compared to a standard one.

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CS 04
Computing the Inverse and Pseudoinverse of Time-Varying Matrices by the Discretization of Continuous-Time ZNN Models

We consider discretizations of continuous-time Zhang Neural Network (ZNN) for computing time-varying matrix inverse and/or pseudoinverse. These discretizations incorporate scaled Hyperpower methods as well as the Newton method. We apply the most general linear multi-step method based scheme, including all known discretization schemes. Particularly, 4th order Adams-Bashforth method based scheme is proposed and numerically compared with known iterative schemes. In addition, the ZNN model for matrix inversion is extended to the pseudoinverse computation. Convergence properties of these extensions are also investigated.

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CS 05
GMRES in the ℓ^∞-Norm

The generalized minimal residual method (GMRES) is a popular Krylov subspace iteration for the solution of general linear systems. In the original method, the Euclidean norm of the residual (or more generally, a norm induced by some inner product) is being minimized at each step. By contrast, we consider minimization of the ℓ^∞-norm of the residual. This raises a number of questions concerning efficient implementation, which will be addressed, together with applications of the method.

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CS 05
Smoothed Variants of Hybrid Bi-CG Methods for Solving Large Sparse Linear Systems

Hybrid Bi-CG methods often have large oscillations in the residual norms, that affect the maximum attainable accuracy of the approximate solutions. The residual smoothing technique is useful to obtain a smooth convergence behavior, but it does not help to improve the attainable accuracy. In this talk, we propose smoothed variants of hybrid Bi-CG methods using an alternative scheme of the smoothing technique. Numerical experiments show that our proposed variants attain more accurate approximate solutions.

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CS 05
Stabilizing GMRES Using the Normal Equation Approach for Severely Ill-Conditioned Problems

Consider using GMRES to solve severely ill-conditioned problems, where the condition number of the Hessenburg matrix and the resulting upper triangular system becomes huge, so that the back substitution process becomes unstable and the convergence of GMRES deteriorates. We propose solving the normal equation corresponding to the above triangular system using standard Cholesky decomposition. This has the effect of 'hiding' tiny singular values, making the process stable, rendering better convergence and a more accurate solution.

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CS 05
Numerical Stability of s-step Enlarged Conjugate Gradient Methods

In the aim of speeding-up the convergence of Krylov subspace methods on modern architectures, we present s-step enlarged Krylov subspace methods, whereby s iterations of enlarged Krylov subspace methods are merged; leading to faster convergence than Krylov methods in terms of iterations. Moreover, computing st basis vectors of enlarged Krylov subspace $\mathscr{K}_{ks,t}(A, r_0)$ at each s-step iteration further reduces communication in parallel. We present several s-step enlarged CG versions (SRE-CG, MSDO-CG) and discuss their numerical stability.

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CS 06
Computing the CPD of Unbalanced Tensors by Homotopy Method

The CPD of the tensor whose maximal dimension is greater than its rank is considered. Computing the CPD is equivalent to solving a structured polynomial system that is determined by the full rank factorization of the matricization of the tensor. Under the generic uniqueness conditions, the CPD solutions of the system are isolated so that these solutions can be achieved by homotopy method.

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CS 06
A New Perron-Frobenius Theorem for Nonnegative Tensors

Based on the concept of dimensional partition we consider a general tensor spectral problem that includes all known tensor spectral problems as special cases. We formulate irreducibility and symmetry properties in terms of the dimensional partition and use the theory of multi-homogeneous order-preserving maps to derive a general and unifying Perron-Frobenius theorem for nonnegative tensors that either includes previous results of this kind or improves them by weakening the assumptions there considered.

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Matthias Hein, Saarland University, Saarbruecken

CS 06
A Modified Newton Iteration for Finding Nonnegative Z-Eigenpairs of a Nonnegative Tensor

We propose a modified Newton iteration for finding some nonnegative Z-eigenpairs of a nonnegative tensor. When the tensor is irreducible, all nonnegative eigenpairs are known to be positive. The new iteration has local quadratic convergence to any positive eigenpair of a nonnegative tensor, and seems capable of finding a nonnegative eigenpair starting with any positive unit vector.

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Ching-Sung Liu, National University of Kaohsiung

CS 06
Algebraic Approach to Generalized Tensor Inversion

Some basic properties of the range and null space of multidimensional arrays (tensors) with respect to Einstein tensor product are investigated. Further, computation of outer and inner inverses with prescribed image and kernel of higher order tensors is considered. Starting from an algebraic approach, some new relationships between the problems of solving tensor equations and computation of generalized inverses of tensors are established. In addition, results related with the (b, c)-inverses on semigroups are examined in details in a specific semigroup of tensors with a binary associative operation defined as the Einstein tensor product. Conditions for the existence, representation and computation of the Moore-Penrose inverse, the weighted Moore-Penrose inverse, the Drazin inverse and the usual inverse of tensors are derived as corollaries. In this way, we derive extensions of known representations of various classes of matrix generalized inverses to multidimensional arrays.

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CS 07
Spectral Clustering of Signed Graphs

Spectral clustering uses eigendecompositions of graph

Laplacians, obtained from typically positive graph edge weights. In signed graphs, the edge weights can be negative, describing disparities of graph vertices, e.g., negative correlations in the data, resulting in negative eigenvalues. Popular signed Laplacians are defined with inflated matrix diagonals to enforce spectral positivity, but result in meaningless clustering in our examples. We argue that negative eigenvalues in the original Laplacians are natural and beneficial for spectral clustering.

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CS 07
Density of States for Spectral Graph Analysis

Modern methods of complex network analysis relate extremal eigenvalues and eigenvectors to important graph properties. The interior part of the spectrum is rarely explored, as it seems expensive to compute and difficult to interpret. Motivated by condensed matter physics, we introduce computational tools for computing the interior spectral density for a graph, and discuss its implications in graph analysis.

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David Bindel, Cornell University

CS 07
Resistance Characterizations of Resistance Distance Equivalence Graphs

In this talk, we give some resistance characterizations of equiarboreal weighted and unweighted graphs, and obtain the necessary and sufficient conditions for k-subdivision graphs, iterated double graphs, line graphs of regular graphs and duals of planar graphs to be equiarboreal. Applying these results, we obtain new infinite families of equiarboreal graphs, including iterated double graphs of 1-walk-regular graphs, line graphs of triangle-free 2-walk-regular graphs, and duals of equiarboreal planar graphs.

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CS 07
Numerical Analysis of Dynamic Centrality

Centrality measures are an effective tool for analysing static networks. In recent years, many of these measures have been extended for use on dynamic networks. In particular, certain spectral measures can take into account time's arrow. We show that great care must be taken in applying such measures due to the inherent ill-conditioning in the associated matrices. We investigate some pre-conditioning techniques to alleviate the ill-conditioning, while attempting to keep the costs of computation low.

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CS 08
Implicit Hari–Zimmermann Method for the GEVD

In this work we present an algorithm for the solution of the generalized Hermitian eigenproblem (GEVD) given implicitly by
$A = \sum_{k=1}^{n} A_k^* T_k A_k, \quad B = \sum_{k=1}^{n} B_k^* B_k,$
where T_k are Hermitian indefinite, and A_k^*, B_k^* are tall and skinny. The problem is transformed into the generalized SVD. We show how to modify the Hari–Zimmermann method for the generalized eigenproblem to work implicitly on (A, B).

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Edoardo di Napoli, RWTH Aachen and Jülich Supercomputing Centre
Vedran Novaković, Department of Mathematics, University of Zagreb
Gayatri Čaklović, Department of Mathematics, University of Zagreb

CS 08
Extended Generalized Fiedler Pencils for Matrix Polynomials and the Recovery of Eigenvectors and Minimal Bases

Fiedler pencils, generalized Fiedler pencils and generalized Fiedler pencils with repetition (GFPRs) are well know classes of strong linearizations of matrix polynomials. The class of GFPRs is a rich source of structure-preserving strong linearizations of structured matrix polynomials. We introduce a new class of Fiedler-like pencils called "*extended generalized Fiedler pencils (EGFPs)*" which enlarges the class of GFPRs. The class of EGFPs expands the arena in which to look for structured and unstructured strong linearizations of matrix polynomials. We also describe the recovery of eigenvectors, minimal bases and minimal indices of matrix polynomials from those of the EGFPs and show that the recovery is operation-free.

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CS 08
Vector Spaces of g-Linearizations for Rectangular Matrix Polynomials

We define generalized linearizations (g-linearizations) for rectangular matrix polynomials and study them in a vector space framework. This generalizes similar work in literature for linearizations of square matrix polynomials. G-linearizations can be 'trimmed' to extract conventional linearizations of rectangular matrix polynomials that are smaller than many other such linearizations in literature. Finally, we show that the g-linearizations or their trimmed versions generically provide complete spectral information about the corresponding rectangular matrix polynomial.

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CS 08
Minimum Rank Problem for the Regular Class of (0,1)-Matrices

Let $\mathscr{B}(n,k)$ be the set of $(0,1)$-matrices of order n with constant line sum k, and let $\tilde{\nu}(n,k)$ be the minimum rank over $\mathscr{B}(n,k)$. It is interesting but difficult to find general formulae for $\tilde{\nu}(n,k)$. Some known results: (i) $\lceil n/k \rceil \le \tilde{\nu}(n,k) \le \lfloor n/k \rfloor + k$, $\tilde{\nu}(n,k) = \lceil n/k \rceil$ if and only if $k|n$; (ii) the exact values of $\tilde{\nu}(n,2)$ and $\tilde{\nu}(n,3)$. Our main results: (i) a sufficient and necessary condition for $\tilde{\nu}(n,k) = \lfloor n/k \rfloor + k$; (ii) the exact values of $\tilde{\nu}(n,4)$.

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Jin Zhong, Jiangxi University of Science and Technology

CS 09
Lowest Complexity, Self Recursive, Radix-2 Discrete Cosine Transform Algorithms

Applications of the Discrete Fourier Transform (DFT) can be

seen in applied mathematics and electrical engineering. The Discrete Cosine Transform (DCT) is a real analogue of DFT. Types of DCT varies based on boundary conditions. In this talk, we factor DCT matrices having self-contained, sparse, and orthogonal matrices. We show that the proposed algorithms have the lowest complexity compared to the known DCT algorithms. Signal flow graphs and image compression results are presented based on the proposed algorithms.
This work was supported by the Faculty Innovative Research in Science and Technology Grant (2016-2017) at Embry-Riddle Aeronautical University.

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CS 09
Solving 2D Fractional Differential Equations Using Rank-Structured Matrix Equations

Fractional matrix equations arise in many fields, from plasma physics to finance. We discuss the solution of 2D equations using matrix equations, and we prove that often the coefficients enjoy particular rank structures. When the right hand side of the PDE is regular or sparse, the known term of the matrix equation has low-rank properties, and this allows to design methods with a lower complexity than the ones currently available in the literature.

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Stefano Massei, EPFL
Mariarosa Mazza, Max-Planck Institute for Plasma Physics

CS 09
Speeding up Sparse Grid Density Estimation with Matrix Factorizations

Sparse grids are a numerical method to approximate high dimensional data. To speed up the sparse grid density estimation, we factorize the data independent system matrix in an offline step in order to reduce the computational effort upon data arrival. To adapt the model with regularization and grid refinement to the data, the regularization needs to be updated in the online step. Therefore, we present two matrix factorizations (orthogonal and cholesky) and applications (classification, clustering).

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Hans-Joachim Bungartz, Technical University of Munich

CS 09
Recent Advances in the Development of Discrete Empirical Interpolation Method (DEIM)

DEIM is a powerful model reduction tool, in particular when combined with the Galerkin projection and the POD. To preserve physical properties of the reduced model, the projection must be with respect to a particular weighted inner product. We present fine numerical details of the weighted DEIM, that can also be interpreted as a numerical implementation of the Generalized Empirical Interpolation Method and the more general Parametrized-Background Data-Weak approach. Further, we discuss new point selection strategies in the oversampled DEIM.

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Serkan Gugercin, Virginia Polytechnic Institute and State University
Arvind Krishna Saibaba, North Carolina State University
Benjamin Peherstorfer, University of Wisconsin-Madison

CS 10
An Efficient Adaptive Solution Technique for Periodic Stokes' Flow

The numerical modeling of objects flowing in periodic pipe results in a loss of accuracy when vesicles approach the walls of the pipe. To remedy this problem, this talk presents an adaptive discretization technique that comes with a fast direct solver. The discretization technique refines in the regions of the pipe where vesicles are getting close while the solver utilizes the fact that this is a low rank update to the original system.

Yabin Zhang, Rice University, yabin.zhang@rice.edu
Adrianna Gillman, Rice University

CS 10
Algebraic Analysis for Long-Time Instabilities in Wave Simulations on Non-Conforming Grids

Simulation results of time-domain linear wave equations on non-conforming grids can exhibit undesirable long-time instability issues that appear only at the late stage of the simulations and have no visible influence at the early stage. We analyze the algebraic system discretized from the acoustic wave equation to better understand the cause of the long-time instability and to devise proper numerical treatment, which involves application of discrete energy analysis and eigenvalue perturbation results.

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David Ketcheson, KAUST
David Keyes, KAUST

CS 10
Predicting Frequencies of Interest in Structural Dynamics Problems

To accurately describe the behaviour of a structure under dynamic loading, engineers require the smallest number of eigenvectors of the corresponding GEP that contribute by 90% to its total response. Usually only a few eigenvectors are required to achieve this target, but without the knowledge of the dominant eigenvalues, this results in a computation of a large number of eigenpairs. We present a method for estimating the frequency intervals of interest, reducing this number significantly.

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Françoise Tisseur, The University of Manchester
Ramaseshan Kannan, Arup

CS 10
Linear Rate-Model Simulations in a Spiking Neural Network Simulator

Contemporary modeling approaches to the dynamics of neural networks include two important classes of models: biologically grounded spiking neuron models and functionally inspired rate-based units. In this talk we analyze to which extent linear rate-model simulations can be integrated in a simulator designed for spiking neural networks. We investigate the stability and scalability for different linear rate-models described by stochastic differential equations with respect to the employed numerical method and the connectivity matrix W.

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CS 11
Preconditioners for the Iterative Solution of Large Linear Least-Squares Problems

The efficient solution of large linear least-squares problems is challenging. When attempting to use preconditioned iterative solvers significant obstacles are often encountered. For example, the row densities of the matrix can vary significantly and the underlying factorization may have to be computed implicitly. In this talk, new approaches employing a separate treatment of dense rows and sparsification by stretching are presented.

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Jennifer Scott, STFC Rutherford Appleton Laboratory and the University of Reading

CS 11
Polynomial Preconditioners Based on GMRES for Solving Multi-Shifted Linear Systems

Many Krylov subspace methods (KSMs) were proposed for solving multi-shifted systems by the shift-invariance property (SIP) of Krylov subspaces. However, the preconditioning for multi-shifted systems is always a difficult problem, because many preconditioning techniques cannot maintain the SIP. In our talk, we propose a kind of polynomial preconditioners based on GMRES for multi-shifted systems. These preconditioners keep the SIP and accelerate multi-shifted KSMs well. Finally, numerical experiments show the effectiveness of our proposed preconditioned methods.

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Ting-Zhu Huang, University of Electronic Science and Technology of China
Bruno Carpentieri, Libera Università di Bolzano

CS 11
Convergence of the Right Preconditioned Range Restricted MINRES for Singular Systems

Consider solving large sparse symmetric singular linear systems using the Range Restricted MINRES method. We formulate the right preconditioned Range Restricted MINRES and analyze its convergence theoretically. Further, we implement the right preconditioned Range Restricted MINRES using SSOR with Eisenstat's trick, and compare its performance with the corresponding MINRES type method by numerical experiments on ill-conditioned semi-definite systems.

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Ning Zheng, National Institute of Informatics

CS 11
Circulant Preconditioners for Systems Defined by Functions of Toeplitz Matrices

Circulant preconditioning for Hermitian Toeplitz systems has been well developed over the past few decades. For a large class of such systems, descriptive bounds on the convergence of the conjugate gradient method can be obtained. For nonsymmetric Toeplitz systems, most work had been focused on normalising the original systems until [J. Pestana and A. J. Wathen. SIAM J. MATRIX ANAL. APPL. Vol. 36, No. 1, pp. 273-288, 2015] recently showed that theoretic guarantees on the convergence of the minimal residual method can be established via a simple use of reordering. The authors further proved that a suitable absolute value circulant preconditioner can be used to ensure rapid convergence rate. In this talk, we show that the authors' ideas can also be applied to systems defined by functions of Toeplitz matrices. In particular, we show that the eigenvalues of such matrices are clustered at ± 1 when preconditioned by certain circulant matrices, acceleration in the convergence rate of Krylov subspace methods can be expected. Numerical examples are given to support our theoretical results.

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Andy Wathen, Mathematical Institute, University of Oxford

CS 12
Continuous Analogues of Krylov-Based Methods for Differential Operators

The conjugate gradient method is the algorithm of choice for solving large symmetric positive definite linear systems. Although self-adjoint elliptic PDEs are the differential analogues of SPD systems, their spectral discretizations typically lead to non-normal, ill conditioned systems on which CG cannot operate. In this talk, we present an extension of CG that applies to self-adjoint elliptic operators, and leads to an optimal complexity solver for the spectral solutions of some PDEs in rectangular domains.

Marc Aurèle Gilles, Cornell University, mtg79@cornell.edu
Alex Townsend, Cornell University

CS 12
A Distributed Algorithm for Computing Rational Krylov Subspaces

Recently, a novel approach to solving linear equations was developed by the distributed control community. The idea is to reformulate a linear equation $Ax = b$ as a distributed consensus problem, with a network of agents converging to the solution. We propose a similar distributed method for computing rational Krylov subspaces and prove its linear convergence. We discuss the strenghts of the proposed algorithm and its application to model order reduction of extremely large systems.

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CS 12
Generalizations of Roth's Criteria for Solvability of Matrix Equations

W.E. Roth (1952) proved that the matrix equation $AX - XB = C$ has a solution if and only if the matrices $\begin{bmatrix} A & C \\ 0 & B \end{bmatrix}$ and $\begin{bmatrix} A & 0 \\ 0 & B \end{bmatrix}$ are similar. A. Dmytryshyn and B. Kågström (2015) extended Roth's criterion to systems of matrix equations $A_i X_{i'} M_i - N_i X_{i''}^{\sigma_i} B_i = C_i$ $(i = 1, \dots, s)$ with unknown matrices $X_1, \dots, X_t$, in which every X^σ is X, $X^\top$, or X^*. We extend their criterion to systems of complex matrix equations that include the complex conjugation of unknown matrices. We also prove an analogous criterion for systems of quaternion matrix equations.

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CS 12
Perturbation Analysis of Linear Dynamical Systems with Ill-Conditioned Matrices

In this talk, we solve generalized Riccati differential equations and generalized algebraic Riccati equations with finite and infinite times using generalized Hamiltonian transformation and Newton's method, respectively. Some assumptions for the existence and uniqueness of solutions of Riccati equations are provided. Furthermore, we modify the condition theory according to only one perturbation matrix to get perturbation bounds. This work is applied to discrete-time systems. Numerical results are presented to show that perturbation bounds are tight.

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Frederick Kin Hing Phoa, Institute of Statistical Science, Academia Sinica

CS 13
Complex Moment-Based Partial Singular Value Decomposition

The complex moment-based eigensolvers have been recently developed and used in several application areas thanks to their high parallel efficiency. In this talk, we propose a complex moment-based method for computing partial singular value decomposition. We also develop the method using a nonlinear transformation to improve the accuracy of the computed singular triplets.

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Tetsuya Sakurai, University of Tsukuba

CS 13
Condition Number and Equilibriation of Factors in the SR Decomposition

In this contribution we analyze the freedom of choice in the symplectic and triangular factors and give suggestions on how to choose the free parameters in the SR decomposition so that the row norms of the triangular factor or the column norms in the symplectic factor are equal. Balancing is based on equilibriation of rows or columns in block diagonal scaling of factors in the Bunch decomposition of the associated skew-symmetric Gram matrix.

Miroslav Rozložník, Czech Academy of Sciences, Prague, miro@math.cas.cz
Heike Fassbender, Technische Universität Braunschweig

CS 13
Conditionally Negative Definite Functions

Let $f : [0, \infty) \to [0, \infty)$ be an operator monotone function and $g : \mathbb{R} \to [0, \infty)$ be a conditionally negative definite(in short cnd) function. We obtain $f \circ g : \mathbb{R} \to [0, \infty)$ is also conditionally negative definite . This generalizes and subsumes several existing results. A versatile direct connection between cnd functions and functions having Weierstrass factorization has also been established and consequently a reasonable account for cnd functions is presented.

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CS 13
Port-Hamiltonian Systems and Various Distances for Control Systems

Port-Hamiltonian systems are an important concept in the energy-based modeling of dynamical systems. We show that a linear time-invariant (LTI) port-Hamiltonian system can be used in computing various distances for control systems. This includes distance to stability (the converse problem of the stability radius problem) and distance to passivity (the converse problem of the passivity radius problem) for standard and descriptor LTI systems.

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Nicolas Gillis, University of Mons
Volker Mehrmann, Technical University Berlin

CS 14
Convergence of the Complex Cyclic Jacobi Methods and Applications

We prove global convergence of the complex Jacobi method for a large class of the generalized serial cyclic pivot strategies. We find a constant $\gamma < 1$ such that for a given Hermitian matrix A we have $S(A') \leq \gamma S(A)$, where A' is obtained from A by applying one cycle of the Jacobi method and $S(\cdot)$ stands for the off-norm. The theory of the Jacobi operators is used. The obtained results are applied to the generalized eigenvalue problem.

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Vjeran Hari, University of Zagreb

CS 14
Generalized Davidson and Multidirectional-Type Methods for the GSVD

We propose two new iterative methods for computing nontrivial extremal generalized singular values and vectors. The first method is a generalized Davidson-type algorithm and the second method employs a multidirectional subspace expansion technique. Essential to the latter is a fast truncation step designed to remove a low quality search direction and to ensure moderate growth of the search space. Numerical experiments indicate that both methods are competitive.

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Michiel E. Hochstenbach, TU Eindhoven

CS 14
Inner Deflation and Computation of the Eigenvectors of Symmetric Tridiagonal Matrices

There are different ways to deflate a symmetric tridiagonal matrix T of order n, known an eigenvalue λ of T. Algorithms based on the twisted factorization determine the index k, $1 \leq k \leq n$, where the upper and lower factorizations match. We propose a different way to determine k, an alternative deflation of T and the computation of the eigenvector corresponding to λ based on a modification of the perfect shift technique.

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Nicola Mastronardi, Consiglio Nazionale delle Ricerche
Paul Van Dooren, Catholic University of Leuven

CS 14
Contour Integral Methods for Partial Eigenproblems of Linear Rectangular Matrix Pencils

Consider solving generalized eigenproblems of linear rectangular matrix pencils for the eigenvalues inside a prescribed region in the complex plane and the corresponding eigenvectors. We show that contour integrals can compute the eigenpairs under certain conditions. One of the methods reduces the problem to the generalized Hankel eigenproblem, and the other takes a Rayleigh–Ritz-like procedure. Numerical experiments on test problems show that the methods give the desired eigenpairs.

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CS 15
Fully-Coupled and Block/Schur Complement Based Algebraic Multigrid-Based Preconditioners for

Implicit Continuum Plasma Simulations

Continuum modeling for plasma physics requires the solution of the governing PDEs describing conservation of mass, momentum, and total energy, along with various forms of Maxwell's equations for the electromagnetic fields. We consider finite element methods and employ fully-coupled and block/Schur complement based preconditioners for our algebraic multigrid-based preconditioned Newton-Krylov solution approach. We examine solver scaling and performance on both CPU and Intel Xeon Phi Knights Landing platforms.

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John Shadid, Sandia National Laboratories
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CS 15
Geometric Multigrid for Graphene

In order to calculate the electronic properties of graphene structures a tight-binding approach can be used. The tight-binding formulation leads to linear systems of equations which are maximally indefinite. We present a geometric multigrid method for this problem and the results of the two-level convergence analysis obtained by local Fourier analysis. Furthermore we show needed modifications of the method in the case of open periodic boundary conditions as they introduce additional near-kernel eigenvectors.

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Karsten Kahl, University of Wuppertal

CS 15
Machine Learning in Algebraic Multigrid

We present a novel adaptive coarsening scheme for algebraic multigrid which interprets the construction of interpolation as a machine learning problem, i.e., a problem of learning a model of smooth error. We introduce a penalty term to least squares interpolation which can be solved efficiently by least-angle regression. We show that the overall coarsening process is able to construct suitable coarsenings for unstructured problems including anisotropy and block smoothers within the bootstrap algebraic multigrid framework.

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Karsten Kahl, University of Wuppertal

CS 15
An Eigensolver for the Hermitian Dirac Operator with Multigrid Acceleration

In this presentation we introduce a Jacobi-Davidson type eigensolver which uses a multigrid preconditioned FGMRES solver as inner method. This is used in lattice QCD, where eigenvalues of the Hermitian Dirac operator are needed to accelerate expensive stochastic approaches. The main focus is the synergy between the outer and the inner method, as well as several other strategies to make our approach scalable with respect to the lattice size and number of eigenvalues.

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Andreas Frommer, Bergische Universitaet Wuppertal
Karsten Kahl, Bergische Universitaet Wuppertal
Matthias Rottmann, Bergische Universitaet Wuppertal

CS 16
Partial Solutions to Riccati Equations for Feedback Gains Using the Staircase Form

Solving a Riccati equation in $X \in \mathbb{R}^{n\times n}$ for the feedback gain $F \equiv -R^{-1}B^{\top}X \in \mathbb{R}^{m\times n}$ is wasteful when $m \ll n$. Is there a more efficient way to compute F? The answer is positive for the differential Riccati equation from Chandrasekhar's method. We answer the challenge affirmatively, in spirit, when the controllable subsystem is relatively small, as in partial pole assignment. The technique, with $O(n)$ computational complexity, can be applied to various algebraic, differential and generalized Riccati equations.

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Liping Zhang, Department of Mathematics, Zhejiang University of Technology
Hung-Yuan Fan, Department of Mathematics, National Taiwan Normal University
Ting-Ting Feng, Department of Mathematics, East China Normal University

CS 16
A New Solution Method for the Linear Systems of 3-D Radiation Hydrodynamics

In the simulation of 3D radiation hydrodynamics, a great part of time is spent on the solution of linear systems. We will introduce the discretization method, and show some properties of the systems. Based on the discretization, we introduce a new solution method, which utilizes a split matrix form. The new solution method is more efficient than the traditional ones both in storage and computation. An improved preconditioner is proposed for the new method.

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CS 16
Closed-Form Projection Method for Regularizing a Function Defined by a Discrete Set of Noisy Data and for Estimating its Derivative and Fractional Derivative

We present a finite-dimensional closed-form projection method for regularizing a smooth function that has been defined by a discrete set of measurement data, which have been contaminated by random, zero mean errors, and for determining smooth closed-form estimates of the derivative and fractional derivative of this function.

Timothy J. Burns, NIST, burns@nist.gov
Bert W. Rust, NIST

CS 16
Manifold Preserving: An Intrinsic Approach for Distance Metric Learning and Data Retrieval

In this talk, we address the semi-supervised distance metric learning problem and its applications in classification and image retrieval. First, we formulate a semi-supervised distance metric learning model by considering the metric information of inner-and inter-classes. In this model an adaptive parameter is designed to balance the inner-and inter-metrics by using data structure. Second, we convert the model to a minimization problem whose variable is symmetric positive definite matrix. Third, in implementation we deduce an intrinsic steepest descent method which assures that the metric matrix is strictly symmetric positive definite at each iteration, with the manifold structure of the symmetric positive definite matrix manifold. Finally, in this talk we also present other applications in point cloud and image processing.

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Abstracts of Posters

Poster 1

SPMR: A Family of Saddle-Point Minimum Residual Methods

We introduce SPMR, a new family of iterative methods for solving nonsymmetric saddle-point systems using a minimum or quasi-minimum residual approach. The basic mechanism underlying the method is a novel simultaneous bidiagonalization procedure that yields a simplified saddle-point matrix on a projected Krylov-like subspace, and allows for a monotonic short-recurrence iterative scheme. We develop a few variants, show connections to existing methods, and demonstrate their merits on some numerical examples.

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Chen Greif, University of British Columbia

Poster 2

Spectral Computed Tomography with Linearization and Preconditioning

In this poster, we present a linearization technique to transform the nonlinear matrix equation that models spectral computed tomography (CT) into an optimization problem that is based on a weighted least squares term and nonnegative bound constraints. To solve this optimization problem, we propose a new preconditioner that can reduce the condition number significantly, and with this preconditioner, we implement FISTA with projections to achieve remarkable improvements on convergence speed and image quality.

Yunyi Hu, Emory University, yhu85@emory.edu
James G. Nagy, Emory University
Martin S. Andersen, Technical University of Denmark

Poster 3

Efficient Implementations of the Modified Gram-Schmidt Orthogonalization with a Non-Standard Inner Product

The modified Gram-Schmidt (MGS) orthogonalization is one of the most well-used algorithms for the thin QR factorization and is straightforwardly extended to a non-standard inner product with respect to a symmetric positive definite matrix A. For an $m \times n$ matrix, a naive implementation of MGS with the non-standard inner product requires $2n$ matrix-vector multiplications (MVs) with respect to A.In this poster, we propose efficient implementations of MGS with only n MVs.

Akira Imakura, University of Tsukuba, imakura@cs.tsukuba.ac.jp
Yusaku Yamamoto, The University of Electro-Communications

Poster 4

Removing Objects from Video Based on Tensor Completion

Removing undesired object from video is an essential task for post-video processing. A tensor CUR decomposition is presented to sample the frames by leaving out the undesired objects. A fourth-order tensor with pre-registered frames is constructed and then careful sampling is performed following object's location. The low-rank reconstruction and the spatio-temporal coherence in video sequences allow data completion which is available on other non-occluded regions. The visual results demonstrate the effectiveness of tensor CUR decomposition.

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Xuefei Zhe, City University of Hong Kong
Hong Yan, City University of Hong Kong

Poster 5

Rayleigh-Ritz Majorization Error Bounds of the Mixed Type

The absolute change in the Rayleigh quotient (RQ) for a Hermitian matrix with respect to vectors is bounded by norms of residual vectors and angles between vectors in [https://doi.org/10.1137/120884468]. [https://doi.org/10.1137/16M1058121] introduces bounds of eigenvalues of the matrix RQ via singular values of residual matrices and principal angles between the subspaces, using majorization. We also cover discarding off-diagonal blocks and additive perturbations.

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Peizhen Zhu, Missouri University of Science and Technology

Poster 6

Fitting Eigenvectors Given Partial Eigenvector Information

Many engineering tasks extract modal data of control systems; these empirical modes are subsets of some system eigenvector corrupted with model error and sensor noise. We want to correlate an analytical model and an empirical mode — that is, a matrix and a perturbed subset of its eigenvector. We propose a correlation measure fitting the system eigenvector via a least-squares computation. We survey applications of this method and provide experimental results in power system contingency identification.

Eric Hans Lee, Cornell University, erichanslee@cs.cornell.edu
David Bindel, Cornell University

Poster 7

Truncated SVD Approximation via Kronecker Summations

In this poster we describe an approach to approximate the truncated SVD of a large matrix by decomposing the matrix into a sum of Kronecker products. Our approach can be used to more efficiently approximate a large number of singular values and vectors than other well-known schemes. We provide theoretical results and numerical experiments to demonstrate accuracy of our approximation, and show how the approximation can be used to solve large scale ill-posed inverse problems.

Chang Meng, Emory University, chang.meng@emory.edu
Clarissa Garvey, Emory University
James Nagy, Emory University

Poster 8

Verified Computation of Partial Eigenvalues Using Contour Integrals

We propose using the block Hankel-type Sakurai-Sugiura method for verified partial eigenvalue computations for a real symmetric matrix. Upper bounds of the truncated and rounding errors of a numerical quadrature give the rigorous enclosure of the entries of Hankel matrices. By rigorously enclosing eigenvalues of the Hankel matrices, our method yields verified partial eigenvalues of the given matrix. The method requires the solutions of the linear systems at quadrature points, which are computed in parallel.

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Akira Imakura, University of Tsukuba

Akitoshi Takayasu, University of Tsukuba

Poster 9

IR Tools MATLAB Package for Large-Scale Inverse Problems

In this poster we describe and demonstrate capabilities of a new MATLAB software package that consists of state-of-the-art iterative methods to solve large scale discretizations of inverse problems. The package allows users to easily experiment with different iterative methods and regularization strategies with very little programming effort. The package includes several test problems and examples to illustrate how the iterative methods can be used on a variety of large-scale inverse problems.

James G. Nagy, Emory University, jnagy@emory.edu
Silvia Gazzola, University of Bath
Per Christian Hansen, Technical University of Denmark

Poster 10

Messenger-Field and Conjugate Gradients in Cosmic Microwave Background Data Analysis

Cosmic Microwave Background is currently one of the most efficient probes of the early Universe. Among its keystone problems, there is an estimation of a signal from a very large noisy data. The size of CMB datasets is expected to reach 10^{15} in a near future.
We present a recent approach (called messenger-field method) for solving this problem and discuss its relationship with preconditioned conjugate gradient method that is used commonly in this context.

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Laura Grigori, INRIA Paris
Radek Stompor, Université Paris 7 Denis Diderot

Poster 11

A Distributed Database Providing Data Privacy Based on Lagrange Interpolation Polynomial

The (k, n) threshold scheme by applying Lagrange Interpolation Polynomial is to divide a secret S into n pieces such that:
1. Knowledge of any k or more pieces can recover the polynomial and S easily.
2. Knowledge fewer than k pieces obtain no information about the polynomial and S.
In this paper, we apply (k, n) threshold scheme in distributed systems to provide integral data privacy and solve the problem of storing private data on third-party cloud storage systems.

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Poster 12

A Fast Direct Solver for Fractional Elliptic Problems on General Meshes in 2D and 3D

One alternative approach to represent fractional Laplacian $(-\Delta)^s w = g$ relies on the Dunford integral formula for spectral representation. Since a complex valued function $f(x) = x^s$ is analytic over the complex domain with a branch cut on the negative real axis, we can solve the discretized fractional Laplacian by computing the matrix function $f(\Delta)$ using the contour integral representation and conformal mapping, where the closed contour Γ lies in the region of analyticity of f and encloses spectrum of Δ.

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Poster 13

Sparse Recovery Algorithms for 3D Imaging Using Point Spread Function Engineering

We consider the high-resolution imaging problem of 3D point source image recovery from 2D data using methods based on point spread function (PSF) design. Finding the locations of point sources is a large-scale sparse 3D inverse problem and we have studied solution algorithms based on sparse recovery in compressed sensing using non-convex optimization. Applications to high-resolution single molecule localization microscopy are described, and numerical tests are presented.

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Poster 14

Elliptic Preconditioner for Accelerating the Self-Consistent Field Iteration in Kohn-Sham Density Functional Theory

Designed algorithm to implement Elliptic Preconditioner into DFT package KSSOLV and improved convergence rate of the SCF iteration through diagonal approximation of polarizability matrix, which allowed solving PDEs of large scale 3D models of complex materials. Conducted numerical stability analysis of the algorithm and found that parameters learned for same material in different material settings are very similar, which makes it possible to design effective preconditioners for large and complicated materials.

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Poster 15

A Tensor Flatten Layer for Deep Neural Networks Based on Multilinear Subspace Learning

In this paper, we present a novel tensor flatten layer for deep neural networks (DNNs) based on multilinear subspace learning, which can replace the combination of a global average pooling or flatten-layer with a fully-connected layer. Our approach can project tensor data in DNNs to vectors of desired dimension with two advantages. First, our approach utilizes the tensor structure information better. Second, our method significantly reduces the number of parameters.

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