THE FOURTEENTH INTERNATIONAL CONFERENCE ON MATRIX THEORY AND APPLICATIONS

Ocean University of China

Qingdao, Shandong, P.R. China

July 21-26, 2023

The Fourteenth International Conference on Matrix Theory and Applications

Ocean University of China, Qingdao
Shandong Province, P.R. China

July 21-26, 2023

The Fourteenth International Conference on Matrix Theory and Applications will be held at Ocean University of China, Qingdao City, Shandong Province, P.R. China, during July 21-26, 2023 (Registration: July 21, Departure: July 26). The main themes of this conference are pure linear algebra, numerical linear algebra and linear algebra education. The conference aims at enhancing academic communication and promoting research level among scholars in China and abroad interested in matrix theory, methods and computations as well as their applications, and pushing forward wider popularization and more thorough development of linear algebra education. It also aims at providing a friendly platform for senior researchers, professional educationist, and young teachers and scientists to exchange ideas on recent developments in the relevant areas. The conference is co-organized by Academy of Mathematics and Systems Science at Chinese Academy of Sciences (CAS), and Shanghai University, P.R. China. The local organizing institution is Ocean University of China.

Conference Chairs

Er-Xiong Jiang	**(Shanghai University, China)**
Zhong-Zhi Bai	**(Chinese Academy of Sciences, China)**

Invited Keynote Speakers

Chang-Jiang Bu	**(Harbin Engrg Univ, China)**
Yang Cao	**(Nantong Univ, China)**
Pei-Chang Guo	**(China Univ Geosci, China)**

Lu Lin	**(Xiamen Univ, China)**
Yu-Hong Ran	**(Northwest Univ, China)**
Qing-Wen Wang	**(Shanghai Univ, China)**
Zheng-Sheng Wang	**(Nanjing Univ Aeron Astron, China)**
Min-Li Zeng	**(Putian Univ, China)**

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Maya G. Neytcheva	**(Uppsala University, Sweden)**
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Important Notice

1. **The working language throughout the conference is English, except for the session "Linear Algebra Education" in which the talks can be orally presented either in Chinese or in English, but the submitted information associated with the abstract must be in English.**
2. **Participant who wants to deliver an oral presentation should submit the English title and abstract of a talk, and the full Chinese address of institution including email (within one A4 page) to Prof. Zhong-Zhi Bai (bzz@lsec.cc.ac.cn) before April 30, 2023. Please write a notice on the subject line of your email to indicate which topic your talk will belong to: "pure linear algebra", "numerical linear algebra" or "linear algebra education".**
3. **The acceptance of the talk will be informed before May 30, 2023.**
4. **Participant who only wants to attend the conference, but is not able to deliver an oral presentation, is also welcome to submit the above information of a talk. In this situation, the participant should clearly claim in the submission that he/she does NOT plan to deliver a talk.**

Program

July 21 (Friday)

15:00-18:00 Registration

July 22 (Saturday)

9:00-9:30 **Opening and Photo** **Chair: Xiao-Xia Guo**

9:30-10:15 **Invited Plenary Talk** **Chair: Zhong-Zhi Bai**

9:30-10:15 **Yang Cao**
Accelerated Modulus-Based Matrix Splitting Iteration Methods for Mixed-Size Cell Circuits Legalization

10:15-10:25 **Tea Break**

10:25-11:55 **Invited Plenary Talks** **Chair: Hua Dai**

10:25-11:10 **Qing-Wen Wang**
Making Linear Algebra Easier to Teach and Learn

11:10-11:55 **Yu-Hong Ran**
Block-Circulant with Circulant-Block Preconditioners for Two-Dimensional Spatial Fractional Diffusion Equations

12:00-13:30 **Lunch**

14:30-16:10 **Contributed Talks** **Chair: Li-Li Zhang**

14:30-14:55 **Fu-Rong Lin**
Fractional Centered Difference Schemes and Banded Preconditioners for Nonlinear Riesz Space Variable-Order Fractional Diffusion Equations

14:55-15:20 **Li Wang (Hunan)**
The New Solution Bounds of the Discrete Algebraic Riccati Equation and Their Applications in Redundant Control Inputs Systems

15:20-15:45 **Yu-Mei Huang**
TV Regularized Method for Multivariate Time Series Segmentation

15:45-16:10 **Kang-Ya Lu**
An Economic Implementation of the Optimal Rotated Block-Diagonal Preconditioning Method

16:10-16:20 Tea Break

16:20-18:25 Contributed Talks Chair: Yu-Mei Huang

16:20-16:45 Li-Li Zhang
Modulus-Based Multigrid Methods for Linear Complementarity Problems

16:45-17:10 Ai-Li Yang
Multi-Parameter Dimensional Split Preconditioner for Three-by-Three Block System of Linear Equations

17:10-17:35 Sheng-Xin Zhu
Importance of Matrix Computing Education in the AI Era

17:35-18:00 Lu Wang
On Relaxed Greedy Randomized Augmented Kaczmarz Methods for Solving Large Sparse Inconsistent Linear Systems

18:00-18:25 Jian-Hua Zhang
On Maximum Residual Nonlinear Kaczmarz-Type Algorithms for Large Nonlinear Systems of Equations

18:30-19:30 Dinner

July 23 (Sunday)

9:30-10:15 Invited Plenary Talk Chair: Gang Wu

9:30-10:15 Min-Li Zeng
Matrix-Splitting Iterative Methods for Nonlinear Saddle-Point Problems from Optimization Problems

10:15-10:25 Tea Break

10:25-11:55 Invited Plenary Talks Chair: Zhi-Ru Ren

10:25-11:10 Lu Lin
The Practice and Reflection of Linear Algebra Course Teaching

11:10-11:55 Chang-Jiang Bu
The Matrices, Tensors, the Spectra of Graphs and Hypergraphs

12:00-13:30 Lunch

14:30-16:10 Contributed Talks Chair: Jian-Jun Zhang

14:30-14:55 Lu-Xin Wang
Modulus-Based Matrix Splitting Iteration Methods for Horizontal Quasi-Complementarity Problem

14:55-15:20 Ting-Ting Feng
Randomized Kaczmarz Method for Solving Large-Scale Sylvester Matrix Equations

15:20-15:45 Xian-Ping Wu
Sharp Error Bounds of the Extended Vertical Linear Complementarity Problem

15:45-16:10 Fang Chen
Improved Splitting Preconditioner for Double Saddle Point Problems Arising from Liquid Crystal Director Modeling

16:10-16:20 Tea Break

16:20-18:00 Contributed Talks Chair: Fu-Rong Lin

16:20-16:45 Zhao-Zheng Liang
Fast Rotated SOR Method for Block Two-by-Two Linear Systems with Application to PDE-Constrained Optimal Control Problems

16:45-17:10 Yue-Hua Feng
On Computing HITS ExpertRank via Lumping the Hub Matrix

17:10-17:35 Chen-Can Zhou
A Modified Newton-Based Matrix Splitting Iteration Method for Generalized Absolute Value Equations

17:35-18:00 Li-Li Xing
A Class of Pseudoinverse-Free Greedy Block Nonlinear Kaczmarz Methods for Nonlinear Systems of Equations

18:10-20:30 Table Dinner

July 24 (Monday)

9:30-10:15 Invited Plenary Talk Chair: Wen Li

9:30-10:15 Zheng-Sheng Wang
Enriched Subspace Regularization for Large Discrete Ill-Posed Problems

10:15-10:25 Tea Break

10:25-11:10 Invited Plenary Talk Chair: Zheng-Da Huang

10:25-11:10 Pei-Chang Guo
On Regularization of Convolutional Kernel Tensors in Neural Networks

11:10-12:00 Contributed Talks Chair: Sheng-Xin Zhu

11:10-11:35 Lu-Bin Cui
A Projection Method Based on Discrete Normalized Dynamical System for Computing the C-Eigenpairs of a Piezoelectric Tensor

11:35-12:00 Kang Zhao
Eigenvalue Embedding of Damped Vibroacoustic System with No-Spillover

12:00-13:30 Lunch

14:30-16:10 Contributed Talks Chair: Xu Li

14:30-14:55 Tao Li
Structure Preserving Quaternion Biconjugate Gradient Method

14:55-15:20 Qi-Lun Luo
Multi-Dimensional Data Processing with Bayesian Inference via Structural Block Decomposition

15:20-15:45 Peng-Peng Xie
A Randomized Singular Value Decomposition for Third-Order Oriented Tensors

15:45-16:10 Wei-Ru Xu

	A Divide-and-Conquer Method for Constructing a Pseudo-Jacobi Matrix from Mixed Given Data
16:10-16:20	**Tea Break**
16:20-18:00	**Contributed Talks Chair: Ai-Li Yang**
16:20-16:40	**Ying Gu** **A Semi-Randomized Sketch-and-Project Method with Simple Random Sampling for Large-Scale Linear Systems**
16:40-17:00	**Yong-Yan Guo** **A Restarted Large-Scale Spectral Clustering with Self-Guiding and Block Diagonal Representation**
17:00-17:20	**Shu-Ru He** **Practical RPCG Methods for Complex Symmetric Linear Systems**
17:20-17:40	**Zong-Yuan Han** **Logarithmic Determinant Calculation Based on Variance Reduction Technique**
17:40-18:00	**Bo Feng** **A Block Lanczos Method for Large-Scale Quadratic Minimization Problems with Orthogonality Constraints**
18:00-18:20	**Closing Chair: Wei-Guo Wang**
18:30-20:00	**Dinner**

July 25 (Tuesday)

9:30-12:00 Discussion

12:00-13:30 Lunch

14:30-18:00 Discussion

18:10-20:00 Dinner

July 26 (Wednesday)

Departure

Invited Plenary Talks

The Matrices, Tensors, the Spectra of Graphs and Hypergraphs

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Abstract

In this report, we introduce some results and developments from the matrix spectrum to the tensor spectrum, focusing on the generative relationship between eigenvalues (and traces) of the power hypergraph tensors and eigenvalues (and traces) of the signed graphs.

Accelerated Modulus-Based Matrix Splitting Iteration Methods for Mixed-Size Cell Circuits Legalization

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Abstract

Mixed-size cell circuits dominate in advanced technology node designs, with attendant increases in layout complexity. The introduction of multi-row-height cells requires additional constraints, such as power line alignment, to be considered in the legalization stage, in addition to eliminating overlap while maintaining the results of the global placement stage as much as possible. In this paper, a three-stage legalization methodology is presented. The first is cell preprocessing, namely cell diffusion based on the network flow algorithm. Then the legalization problem is modeled as a quadratic programming problem, which is converted into a linear complementarity problem and solved by accelerated modulus-based matrix splitting iteration methods. Finally, the illegal cells are reshaped. Experimental results reveal that our method achieves 11.8% and 0.4% reduction in total displacement, respectively, over existing two state-of-the-art works, and is 1.407x faster than the modulus-based matrix splitting iteration method. In particular, the proposed approach provides a reference for solving large-scale quadratic programming problems.

On Regularization of Convolutional Kernel Tensors in Neural Networks

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Abstract

Convolutional neural network is an important model in deep learning, where a convolution operation can be represented by a tensor. To avoid exploding/vanishing gradient problems and to improve the generalizability of a neural network, it is desirable to let the singular values of the transformation matrix corresponding to the tensor be bounded. We propose penalty functions to constrain the singular values of the transformation matrix. We derive the gradient descent algorithm for each penalty function in terms of the tensor. Numerical examples are presented to demonstrate the effectiveness of the method.

The Practice and Reflection of Linear Algebra Course Teaching

Lu Lin

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Abstract

This report focuses on the teaching reform and practice of the "Linear Algebra" course for adapting to the enrollment of major in mathematics and physics. Through measures such as reconstructing the teaching content, integrating mathematical ideas, and conducting blended teaching, both the requirements of the "Linear Algebra" course for physics students are taken into account, and the standard of algebraic learning for mathematics students is not lowered.

In terms of teaching content, all topics related to traditional linear algebra are prioritized and taught in one semester. More difficult topics on subspace theory, linear transformations, polynomial theory, similar standard forms, Euclidean spaces, etc., are arranged in the second semester. This ensures the linear algebra requirements for physics students without adding extra burden.

Attention is paid to highlighting the fundamental ideas and methods of algebra, revealing the essential connection within the course, enhancing the understanding of knowledge, and promoting a higher level of comprehension.

In teaching practice, blended teaching is conducted using online resources and intelligent teaching tools for multi-level training, and peer mentors are leveraged to influence and assist students.

Block-Circulant with Circulant-Block Preconditioners for Two-Dimensional Spatial Fractional Diffusion Equations

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Abstract

The implicit finite difference scheme with the shifted Grünwald formula for discretizing the two-dimensional spatial fractional diffusion equations can result in discrete linear systems whose coefficient matrices are the sum of the identity matrix and a block-Toeplitz with Toeplitz-block matrix. For these discrete spatial fractional diffusion matrices, we construct block-circulant with circulant-block preconditioners to further accelerate the convergence rate of the Krylov subspace iteration methods. We analyze the eigenvalue distributions for the corresponding preconditioned matrices. Theoretical results show that most eigenvalues of the preconditioned matrices are located within a complex disk centered at 1. Numerical experiments demonstrate that these structured preconditioners can significantly improve the convergence behavior of the Krylov subspace iteration method.

Making Linear Algebra Easier to Teach and Learn

Qing-Wen Wang

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Abstract

Taking linear algebra as an example, in this talk, I introduce the experience and experience of building national first-class curriculum teaching materials under the guidance of educational mathematics. In particular, I give a new proofs of Sylvester's inertia law, and a new method for solving systems of homogeneous linear equations and one of non-homogeneous linear equations. It fully embodies the innovation, high level and challenge of textbook construction.

Enriched Subspace Regularization for Large Discrete Ill-Posed Problems

Zheng-Sheng Wang

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Abstract

Large discrete ill-posed problems are commonly solved by subspace projection regularization, that is, by first reducing them to small size by application of a few steps of a Krylov subspace method, and then applying Tikhonov regularization to the reduced problem. However, the Krylov subspace is not always the case that it provides a good basis for a projection method due to the noise and some basis vectors that are not so important for the regularized solution. In this talk, we consider some strategies to enrich the Krylov space such that the enriched subspace can captures the dominating components of the solution and produce a good regularized solution. Based on the improvement by generating a suitable basis, the enriched subspace regularization method for large discrete ill-posed problems is proposed. We analyze some theoretical results and numerical performance of the enriched subspace projection regularization. The corresponding numerical experiments are reported to confirm presented results and the effectiveness of the proposed method.

Matrix-Splitting Iterative Methods for Nonlinear Saddle-Point Problems from Optimization Problems

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Abstract

In this talk, we will focus on the efficient algorithms for solving nonlinear saddle-point problems from optimization problems. For solving the nonlinear saddle-point problems from PDE optimal control problems with box-constraint, we construct a new Uzawa-based matrix splitting iteration method. For solving the nonlinear saddle-point problems from linearly constrained convex optimization problems, we construct a nonlinear regularized HSS iteration method, which can be seen as a generalization of the regularised HSS (RHSS) iteration method proposed by Bai and Benzi [BIT 2017, 57(2): 287-311]. We will show the convergence properties and numerical performances for the new methods by detailed theoretical analyze and numerical experiments.

Contributed Talks

Improved Splitting Preconditioner for Double Saddle Point Problems Arising from Liquid Crystal Director Modeling

Fang Chen

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Abstract

To improve the performance of alternating positive semi-definite splitting (APSS) preconditioner, we present an improved APSS (IAPSS) preconditioner for the double saddle point problem arising from liquid crystal director modeling. Theoretical analysis shows that all eigenvalues of the IAPSS-preconditioned matrix are real and located in the interval $(0, 2)$. Numerical examples also show the efficiency of the proposed preconditioner.

A Projection Method Based on Discrete Normalized Dynamical System for Computing the C-Eigenpairs of a Piezoelectric Tensor

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Abstract

The largest C-eigenvalue of piezoelectric tensors determines the highest piezoelectric coupling constant, which reflects the coupling between the elastic and dielectric properties of crystal. Here a projection method based on discrete normalized dynamical system (PDND) is established for computing the largest C-eigenvalue. Theoretical analysis of the convergence for PDND algorithm is given. In numerical experiment, the longitudinal piezoelectric modulus and the unit uniaxial direction that the extreme piezoelectric effect along took place of different piezoelectric materials are given to display the physical meaning of the C-eigenvalues and eigenvectors. Furthermore, the largest C-eigenvalue and all the corresponding eigenvectors can be obtained, which is advantage of the proposed method.

A Block Lanczos Method for Large-Scale Quadratic Minimization Problems with Orthogonality Constraints

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Abstract

Quadratic minimization problems with orthogonality constraints (QMPO) play an important role in many applications of science and engineering. However, some existing methods may suffer from low accuracy or large overhead for large-scale QMPO. Krylov subspace methods are popular for large-scale optimization problems. In this work, we propose a block Lanczos method for solving the large-scale QMPO. In the proposed method, the original problem is projected into a small-sized one, and the Riemannian Trust-Region method is employed to solve the reduced QMPO. Convergence results on the optimal solution, the optimal objective function value, the multiplier and the KKT error are established. Moreover, we give the convergence speed of optimal solution, and show that if the block Lanczos process terminates, then an exact KKT solution is derived. Numerical experiments illustrate the numerical behavior of the proposed algorithm, and demonstrate that it is more powerful than many state-of-the-art algorithms for large-scale quadratic minimization problems with orthogonality constraints.

Randomized Kaczmarz Method for Solving Large-Scale Sylvester Matrix Equations

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Abstract

The randomized Kaczmarz method is a simple and powerful method for solving large-scale linear systems. Despite the popularity of randomized Kaczmarz method, there are few studies applying it to solving large-scale Sylvester matrix equations. In this talk, we propose a randomized Kaczmarz iteration method for solving large-scale Sylvester matrix equation $AX - XB = C$ and a probability criterion based on two indices is introduced in the new algorithm. We prove that our method has exponential convergence rate. Numerical experiments demonstrate the effectiveness of our new method and theoretical results.

On Computing HITS ExpertRank via Lumping the Hub Matrix

Yue-Hua Feng

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Abstract

The dangling nodes are the nodes with no out-links in the web graph. It saves many computational costs if the dangling nodes are lumped into one node. In this paper, motivated by so many dangling nodes in web graphs, we mainly develop theoretical results for the modified hyperlink-induced topic search (MHITS) model by the lumping method, and the results are also suitable for the HITS model. There are three main findings in the theoretical analysis. First, MHITS can be lumped, although the matrix involved is not stochastic. Second, the hub vector of the nondangling nodes can be computed separately from dangling nodes, and the hub vector of the dangling nodes is parallel to a vector of all ones in MHITS. Third, the authority vector of the nondangling nodes is difficult to compute separately from dangling nodes. The numerical results not only show the feasibility and effectiveness of theoretical analyses, but also demonstrate that the lumped MHITS method can produce a better initial authority vector after the iteration of computing the hub vector.

A Semi-Randomized Sketch-and-Project Method with Simple Random Sampling for Large-Scale Linear Systems

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Abstract

The sketch-and-project is a randomized iterative method proposed for solving large-scale linear systems. The key of this method is how to select the sketch in each step. Recently, an adaptive sketch-and project method based on max-distance rule was proposed in [R. Gower, D. Molitor, J. Moorman, D. Needell, *SIAM J. Matrix Anal. Appl.*, 42(2021), pp. 954-989]. However, to compute the sketch residual, it is required to scan the whole coefficient matrix and the sketches in each step. This is unfavorable for big-data problems. To deal with these difficulties, we first propose a semi-randomized sketch-and-project method. An advantage of this approach is that we can reconstruct new sketches based on the given sketches, and access more useful information from the data. Moreover, compared with the adaptive sketch-and project method, the cost of choosing the sketches in our method is much smaller. However, we still have to access the whole data in the proposed semi-randomized method. Inspired by the Chebyshev's law of large numbers, we then propose a semi-randomized sketch-and-project method with simple random sampling. Compared with the adaptive sketch-and project method, only a small portion of the data and sketches are utilized for the computation of residual and probability criterion. Convergence results are established to show the rationality and feasibility of the proposed methods. Numerical experiments are performed to demonstrate the superiority of the new methods over many state-of-the-art ones for large-scale linear systems.

A Restarted Large-Scale Spectral Clustering with Self-Guiding and Block Diagonal Representation

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Abstract

Spectral clustering is one of the most popular unsupervised machine learning methods. Constructing similarity matrix is crucial to this type of method. In most existing works, the similarity matrix is computed once for all or is updated alternatively. However, the former is difficult to reflect comprehensive relationships among data points, and the latter is time-consuming and is even infeasible for large-scale problems. In this work, we propose a restarted clustering framework with self-guiding and block diagonal representation. An advantage of the framework is that some useful clustering information obtained from previous cycles could be preserved as much as possible. To the best of our knowledge, this is the first work that applies this strategy to spectral clustering. The key difference is that we reclassify the samples in each cycle of our method, while they are classified only once in existing methods. To further release the overhead, we introduce a block diagonal representation with Nyström approximation for constructing the similarity matrix. Theoretical results are established to show the rationality of inexact computations in spectral clustering. Comprehensive experiments are performed on some benchmark databases, which show the superiority of our proposed algorithms over many state-of-the-art algorithms for large-scale problems. Specifically, our framework has a potential boost for clustering algorithms and works well even using an initial guess chosen randomly.

Logarithmic Determinant Calculation Based on Variance Reduction Technique

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Abstract

Calculating logarithms of determinants of large positive definite matrices is a fundamental problem in several research fields, such as Gaussian process kernel learning, Markov random fields, and Bayesian inference. The typical method to solve this problem is Cholesky decomposition, but it is not always affordable for large scale computation as it costs $O(n^3)$ flops in dense cases, which is computationally prohibitive when n is quite large. Stochastic Lanczos Quadrature (SLQ) method is one promising approach to scale the computing. In this talk, we will present our recent results on speeding up SLQ with variance reduction technique.

Practical RPCG Methods for Complex Symmetric Linear Systems

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Abstract

We investigate the restrictively preconditioned conjugate gradient (RPCG) method for complex symmetric linear systems. First, we transform the complex symmetric linear system into an equivalent block two-by-two linear system. Then, by making full use of the real and imaginary parts of the coefficient matrix, we construct a restrictive preconditioner with a parameter and propose a practical RPCG method for solving the complex symmetric linear systems. Finally, we analyze the spectral properties of the preconditioned matrix and give a formula for estimating the parameter. In numerical experiments, we use two examples to demonstrate the robustness and effectiveness of the practical RPCG method for solving the complex symmetric linear systems.

TV Regularized Method for Multivariate Time Series Segmentation

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Abstract

Multivariate time series segmentation is an important problem in data mining and it has arisen in more and more practical applications in recent years. The task of time series segmentation is to partition a time series into segments by detecting the abrupt changes or anomalies in the time series. Multivariate time series segmentation can provide meaningful information for further data analysis, prediction and policy decision etc. A time series can be considered as a piece-wise continuous function, it is natural to take its total variation (TV) norm as a prior information of this time series. In this talk, by minimizing the negative log-likelihood function of a time series, we propose a total variation based model for multivariate time series segmentation. An iterative process is applied to solve the proposed model and a search combined the dynamic programming method is designed to determine the breakpoints. The experimental results show that the proposed method is efficient for multivariate time series segmentation and it is competitive to the existing methods for multivariate time series segmentation.

Structure Preserving Quaternion Biconjugate Gradient Method

Tao Li

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Abstract

In this talk, we will present a novel structure-preserving method for solving non-Hermitian quaternion linear systems arising from color image deblurred problems. From the quaternion Lanczos biorthogonalization procedure that preserves the quaternion tridiagonal form at each iteration, we derive the quaternion biconjugate gradient (QBiCG) method for solving the linear systems, and then establish the convergence analysis of the proposed algorithm. Finally, we provide some numerical examples to illustrate the feasibility and validity of our method in comparison with some existing methods.

Analysis of Stochastic Lanczos Quadrature for logdet(A) Approximation

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Abstract

We discuss the probabilistic error bound of the stochastic Lanczos quadrature (SLQ) method in the application of estimating log determinants for symmetric positive definite (SPD) matrices that have eigenvalues smaller than 1. A novel technique of studying the error allocation is utilized to further minimize the total number of matrix vector multiplications required by SLQ. We further proposed two theorems for the cases in which additional matrix information, such as the stable rank, is given. The experimental results demonstrate that our theory is feasible and worthy of reference.

Fast Rotated SOR Method for Block Two-by-Two Linear Systems with Application to PDE-Constrained Optimal Control Problems

Zhao-Zheng Liang

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Abstract

In this talk, we consider iterative solution of certain large scale block two-by-two linear systems arising from numerical solution process of some PDE-constrained optimal control problems. Based upon skillful rotating technique, a new fast and robust stationary iteration method is constructed from the idea of classical block successive over relaxation (BSOR) iteration. Equipped with a practical problem independent parameter choice strategy, the proposed method can result in a sharp parameter independent convergence rate close to 0.17. Moreover, a robust preconditioner is developed from an equivalent form of the new iteration method, which is suitable for inexact variable right preconditioning within Krylov subspace acceleration. Numerical examples from both distributed steady control problem and unsteady control problem which leads to complex Kronecker structured linear system are tested to show that the new solution methods are competitive to some existing ones.

Fractional Centered Difference Schemes and Banded Preconditioners for Nonlinear Riesz Space Variable-Order Fractional Diffusion Equations

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Abstract

High-order finite difference methods are proposed to solve the initial-boundary value problem for one- and two-dimensional Riesz space variable-order fractional diffusion equations. We first introduce fractional centered difference (FCD) and weighted and shifted fractional centered difference (WSFCD) schemes for Riesz space variable-order fractional derivatives. Then the Crank-Nicolson (CN) scheme and the linearly implicit conservative (LIC) difference scheme are applied to discretize the time derivative in linear problems and nonlinear problems, respectively. Thus, we get CN-FCD and CN-WSFCD schemes, and LIC-FCD and LIC-WSFCD schemes, respectively. Theoretical results about the stability and convergence for the above-mentioned schemes are presented and proved. Banded preconditioners are introduced to speed up GMRES methods for solving the discretization linear systems. The spectral property of the preconditioned matrix is analyzed. Numerical results show that the proposed schemes and preconditioners are very efficient.

An Economic Implementation of the Optimal Rotated Block-Diagonal Preconditioning Method

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Abstract

The numerical discretization of the optimal control problems constrained with certain kind of time-dependent fractional diffusion equations leads to a class of highly structured block two-by-two linear systems. We present a different and economic implementation of the *approximated rotated block diagonal* (ARBD) preconditioner, denoted briefly as the ARBDe preconditioner, for solving this class of linear systems effectively by making use of the correspondingly preconditioned Krylov subspace iteration methods such as the ARBDe-preconditioned *flexible GMRES* (FGMRES) method, or the ARBDe-FGMRES method. Compared with the ARBD-GMRES method constructed and analyzed by Bai and Lu in 2021 (*Appl. Numer. Math.* 163:126–146), the ARBDe-FGMRES method requires a lower computational complexity and can achieve much higher computational efficiency in practical applications. With numerical experiments, we have examined and confirmed the robustness, accuracy, and effectiveness of the ARBDe-FGMRES method in solving this class of discrete optimal control problems.

Multi-Dimensional Data Processing with Bayesian Inference via Structural Block Decomposition

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Abstract

How to handle large multi-dimensional datasets such as hyperspectral images and video information efficiently and effectively plays a critical role in big-data processing. The characteristics of low-rank tensor decomposition in recent years demonstrate the essentials in describing the tensor rank, which often leads to promising approaches. However, most current tensor decomposition models consider the rank-1 component simply to be the vector outer product, which may not fully capture the correlated spatial information effectively for large-scale and high-order multi-dimensional datasets. In this paper, we develop a new novel tensor decomposition model by extending it to the matrix outer product, or called Bhattacharya-Mesner product, to form an effective dataset decomposition. The fundamental idea is to decompose tensors structurally in a compact manner as much as possible, while retaining data spatial characteristics in a tractable way. By incorporating the framework of Bayesian inference, a new tensor decomposition model on the subtle matrix unfolding outer product is established for both tensor completion and robust principal component analysis problems, including hyperspectral image completion and denoising, traffic data imputation, and video background subtraction. Numerical experiments on real-world datasets demonstrate the highly desirable effectiveness of the proposed approach.

The New Solution Bounds of the Discrete Algebraic Riccati Equation and Their Applications in Redundant Control Inputs Systems

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Abstract

Redundant control inputs play an important part in engineering, and are often used in H_2 control problems, dynamic control allocation, quadratic performance optimal control, and many uncertain systems. In this paper, by the equivalent form of the discrete algebraic Riccati equation (DARE), we propose new upper and lower bounds of the solution for the equivalent DARE. Compared to some existing work on this topic, the new bounds are more tighter. Next, when increasing the columns of the input matrix, we give the applications of these new upper and lower solution bounds to obtain a sufficient condition for strictly decreasing feedback controller gain. Finally, corresponding numerical examples illustrate the effectiveness of our results.

On Relaxed Greedy Randomized Augmented Kaczmarz Methods for Solving Large Sparse Inconsistent Linear Systems

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Abstract

For solving large-scale sparse inconsistent linear systems by iteration methods, we introduce a relaxation parameter in the probability criterion of the greedy randomized augmented Kaczmarz (GRAK) method, obtaining a class of relaxed greedy randomized augmented Kaczmarz (RGRAK) methods. The RGRAK method can be also derived directly by applying the relaxed greedy randomized augmented Kaczmarz method to an equivalent consistent augmented linear system. We prove the convergence of this method and estimate an upper bound for its convergence rate. Theoretical analysis and numerical experiments show that the RGRAK method can outperform the GRAK method if the relaxation parameter is chosen appropriately.

Modulus-Based Matrix Splitting Iteration Methods for Horizontal Quasi-Complementarity Problem

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Abstract

Modulus-based matrix splitting (MMS) iteration method is a useful tool to solve the classical linear complementarity problem and has been successfully extended to solve various complementarity problems, including the horizontal linear complementarity problem, the weakly nonlinear complementarity problem, the implicit complementarity problem, the quasi-complementarity problem and so on. In this talk, the MMS iteration method is further studied to solve the horizontal quasi- complementarity problem (HQCP), which is characterized by the presence of two system matrices and two nonlinear mappings. By equivalently transforming the HQCP into a fixed point equation and using the matrix splitting technique, a series of MMS relaxation iteration methods are presented. Convergence analyses are carefully studied when the system matrices are either positive definite or H_+-matrices. Particularly, in the case of H_+-matrices, some sufficient conditions on the values of the iteration parameters to guarantee the convergence of the proposed iteration methods are provided. Finally, two numerical examples are illustrated to show the effectiveness of the proposed iteration methods.

Sharp Error Bounds of the Extended Vertical Linear Complementarity Problem

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Abstract

In this talk, we discuss the error bounds of the Extended Vertical Linear Complementarity Problem (EVLCP), which is an extension of the classic LCP. Besides the methods used in LCP, we also explore some new technique to derive sharper bounds. Some numerical examples are also given to show our theoretical results.

A Randomized Singular Value Decomposition for Third-Order Oriented Tensors

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Abstract

The oriented singular value decomposition (O-SVD) proposed by Zeng and Ng provides a hybrid approach to the t-product-based third-order tensor singular value decomposition with the transformation matrix being a factor matrix of the higher order singular value decomposition. Continuing along this vein, this paper explores realizing the O-SVD efficiently by drawing a connection to the tensor-train rank-1 decomposition and gives a truncated O-SVD. Motivated by the success of probabilistic algorithms, we develop a randomized version of the O-SVD and present its detailed error analysis. The new algorithm has advantages in efficiency while keeping good accuracy compared with the current tensor decompositions. Our claims are supported by numerical experiments on several oriented tensors from real applications.

A Class of Pseudoinverse-Free Greedy Block Nonlinear Kaczmarz Methods for Nonlinear Systems of Equations

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Abstract

In this report, we construct a class of nonlinear greedy average block Kaczmarz methods to solve nonlinear problems without computing the Moore-Penrose pseudoinverse. This kind of methods adopts the average technique of Gaussian Kaczmarz method and combines with the greedy strategy, which greatly reduces the amount of computation. The convergence analysis and numerical experiments show the effectiveness of the proposed methods.

A Divide-and-Conquer Method for Constructing a Pseudo-Jacobi Matrix from Mixed Given Data

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Abstract

For the given signature operator $H = I_r \oplus -I_{n-r}$, a pseudo-Jacobi matrix is a self-adjoint matrix relatively to a symmetric bilinear form $\langle \cdot, \cdot \rangle_H$, and it is the counterpart of a classical Jacobi matrix to the indefinite scalar product space setting. In this talk, an inverse eigenvalue problem for this class of matrices is considered. The main concern is to construct an $n \times n$ pseudo-Jacobi matrix from a prescribed n-tuple of distinct real numbers and a Jacobi matrix of order not less than $\lfloor n/2 \rfloor$, such that its spectrum is this tuple and the given Jacobi matrix is its trailing principal submatrix. A divide-and-conquer scheme is used to solve this problem, and a necessary and sufficient condition under which the problem is solvable is presented. A numerical algorithm is designed to solve this pseudo-Jacobi matrix inverse eigenvalue problem according to the obtained results. Some illustrative numerical examples are also given to test the reconstructive algorithm.

Multi-Parameter Dimensional Split Preconditioner for Three-by-Three Block System of Linear Equations

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Abstract

For a class of three-by-three block systems of linear equations arising from many practical problems, a multi-parameter dimensional split (MPDS) preconditioner is proposed to accelerate the convergence of the Krylov subspace methods. Since the preconditioning effect of the MPDS preconditioner depends on the values of its parameters, an effective method for computing the optimal parameters is also proposed. Moreover, the spectral property of the preconditioned matrix is carefully analyzed. Numerical examples arising from the discretizations of the Navier-Stokes equations and the partial differential equation (PDE) constraint optimization problems are employed to illustrate the robustness and the efficiency of the MPDS preconditioner.

On Maximum Residual Nonlinear Kaczmarz-Type Algorithms for Large Nonlinear Systems of Equations

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Abstract

Recently, a class of nonlinear Kaczmarz (NK) algorithms has been proposed to solve large-scale nonlinear systems of equations. The NK algorithm is a generalization of the Newton-Raphson (NR) method and does not need to compute the entire Jacobian matrix. In this talk, we present a maximum residual nonlinear Kaczmarz (MRNK) algorithm for solving large-scale nonlinear systems of equations, which employs a maximum violation row selection and acts only on single rows of the entire Jacobian matrix at a time. Furthermore, we also establish the convergence theory of MRNK. In addition, inspired by the effectiveness of block Kaczmarz algorithms for solving linear systems, we further present a block MRNK (MRBNK) algorithm and a pseudoinverse-free block maximum residual nonlinear Kaczmarz (FBMRNK) method based on an approximate maximum residual criterion. Based on sketch-and-project technique and sketched Newton-Raphson method, we propose the deterministic sketched Newton-Raphson (DSNR) method which is equivalent to MRNBK, and then the convergence theories of DSNR and FBMRNK are established based on some assumptions and μ-strongly quasi-convex condition. Furthermore, the convergence theories of DSNR and FBMRNK are provided under star-convex assumption. Finally, some numerical examples are tested to show the effectiveness of our new algorithms.

Modulus-Based Multigrid Methods for Linear Complementarity Problems

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Abstract

By employing modulus-based matrix splitting iteration methods as smoothers, we establish modulus-based multigrid methods for solving large sparse linear complementarity problems. The local Fourier analysis is used to quantitatively predict the asymptotic convergence factor of this class of multigrid methods. Numerical results indicate that the modulus-based multigrid methods of the W-cycle can achieve optimality in terms of both convergence factor and computing time, and their asymptotic convergence factors can be predicted perfectly by the local Fourier analysis of the corresponding modulus-based two-grid methods.

Eigenvalue Embedding of Damped Vibroacoustic System with No-Spillover

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Abstract

The eigenvalue embedding problem of the damped vibroacoustic system with no-spillover (EEP-VA) is considered, which is to update the original system to a new damped vibroacoustic system such that some eigenvalues are replaced by newly given or measured ones, while the remaining eigenvalues and associated eigenvectors are kept unchanged. We provide a spectral decomposition of the damped vibroacoustic system and further give a set of parametric solutions to the EEP-VA. Moreover, our method can also be extended to the case of the undamped vibroacoustic system. Exploiting the freedoms of the parametric matrices in the solution, the modification on the coefficient matrices can be minimized. Numerical experiments illustrate the performance of the proposed algorithms.

A Modified Newton-Based Matrix Splitting Iteration Method for Generalized Absolute Value Equations

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Abstract

By considering the matrix splittings of both coefficient matrices in the differential and non-differential parts of the generalized absolute value equations and based on the Newton-type iteration scheme, a modified Newton-type matrix splitting (MNMS) iteration method is proposed for solving generalized absolute value equations. The proposed MNMS iteration method not only covers the well-known generalized Newton iteration method as well as the recent proposed modified Newton-type iteration method and the Newton-based matrix splitting iteration method, but also results in a series of relaxation versions which are very flexible in real applications. Convergence properties of the MNMS iteration method are studied in detail when the coefficient matrices are positive definite matrices and H_+-matrices. Finally, some numerical examples are presented to show the feasibility and effectiveness of the proposed MNMS iteration method.

Clique Partitions and Eigenvalues of Graphs

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Abstract

A clique partition of graph G is a set of cliques such that each edge of G belongs to exactly one clique. The clique partition number of G is the smallest cardinality of a clique partition of G. In this talk, we give eigenvalue bounds for the clique partition number of G. As applications, the De Bruijn-Erdos Theorem follows from our eigenvalue bounds.

Importance of Matrix Computing Education in the AI Era

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Abstract

Matrix computing is one of the corner stone for scientific computing and it has been an important branch for applied mathematics. There is no doubt that linear algebra plays an increasing important role as one fundamental course for science and engineering. However, many may have an illusion that matrix computing and numerical linear algebra is mature and our relevant course and syllabus remains unchanged for many years. Such an illusion contradicts the facts that several recent revolutionary techniques are based on rethinking and redesign of matrix computation. The talk aims to draw the attentions of such a need and invite the audience to discuss the importance of matrix computing, emerging research directions and what we should do for education in the new AI era.

List of Participants

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