International Workshop on Matrix Computations

Lanzhou University

Lanzhou, P. R. China

April 15 - 19, 2022

The Third
International Workshop on Matrix Computations

Lanzhou University, Lanzhou, P.R. China
April 15–19, 2022

The International Workshop on Matrix Computations --- Gene Golub Memorial Day 2022, will be held at Lanzhou University, Lanzhou, P.R. China, during April 15--19, 2022. The workshop is organized virtually and all talks will be delivered online only.

This workshop is dedicated to commemorate Gene H. Golub (February 29, 1932--November 16, 2007), Fletcher Jones Professor of Computer Science at Stanford University, USA, who was one of the most preeminent numerical analysts of his generation. It is held on the occasion of the 90th anniversary of Gene H. Golub’s birthday.

The workshop aims at bringing together former friends and students of Gene Golub, researchers interested in matrix computations, as well as scientists, engineers and graduate students to exchange and stimulate ideas from different disciplines, and to discuss the practical challenges encountered in numerical linear algebra, scientific computing, and multi-disciplinary applications.

As an important event, the winners of the “Gene Golub Memorial Workshop Best Presentation Prize” will be selected among the oral speakers and the poster presentationers, and the prize will be awarded during the workshop. Each winner will receive a plaque, a certificate, and a gift. (This time, the Prize Committee consists of Zhong-Zhi Bai, Michele Benzi, Chen Greif, Walter Gander, Galina V. Muratova, Maya G. Neytcheva, and Lothar Reichel)

This workshop is the third one of this series of academic events. The first one was held at Hangzhou (Hangzhou Normal University, April 20-24, 2018), and the second one was held at Lanzhou (Lanzhou University, April 19-23, 2019).

Invited Plenary Speakers:

Feng-Shan Bai (Tsinghua Univ, China)
Zhong-Zhi Bai (Chinese Academy of Sciences, China)
Michele Benzi (Scuola Normale Superiore, Italy)
Claude Brezinski (Univ Lille, France)
Yang Cao (Nantong Univ, China)
Wai-Ki Ching (Univ Hong Kong, China)
Hua Dai (Nanjing Univ Aeron Astron, China)
Petros Drineas (Purdue Univ, USA)
Michael Elad (Technion-Israel Inst Tech, Israel)
Walter Gander (ETH Zurich, Switzerland)
Chen Greif (Univ British Columbia, Canada)
Ming Gu (Univ California Berkeley, USA)
Chun-Hua Guo (Univ Regina, Canada)
Martin H. Gutknecht (ETH Zurich, Switzerland)
Yu-Mei Huang (Lanzhou Univ, China)
Zheng-Da Huang (Zhejiang Univ, China)
Wen Li (South China Normal Univ, China)
Fu-Rong Lin (Shantou Univ, China)
Galina V. Muratova (Southern Federal Univ, Russia)
James G. Nagy (Emory Univ, USA)
Maya G. Neytcheva (Uppsala Univ, Sweden)
Lothar Reichel (Kent State Univ, USA)
Zhi-Ru Ren (Central Univ Finance Econom, China)
Wen-Ting Wu (Beijing Inst Tech, China)
Tie-Yong Zeng (Chinese Univ Hong Kong, China)

Invited Participants:

Fang Chen (Beijing Inform Sci Tech Univ, China)
Xiao-Ping Chen (Taizhou Univ, China)
Pei-Chang Guo (China Univ Geosci, China)
Xiao-Xia Guo (Ocean Univ China, China)
Zhuo-Heng He (Shanghai Univ, China)
Rui Li (Jiaxing Univ, China)
Xu Li (Lanzhou Univ Tech, China)

Hao Liu (Nanjing Univ Aeron Astron, China)
Kang-Ya Lu (Beijing Inform Sci Tech Univ, China)
Qiang Niu (Xi'an Jiaotong-Liverpool Univ, China)
Xiao-Fei Peng (South China Normal Univ, China)
Yu-Hong Ran (Northwest Univ, China)
Xue-Yuan Tan (Nanjing Normal Univ, China)
Jun-Gang Wang (Northwestern Polytech Univ, China)
Gang Wu (China Univ Mining Tech, China)
Yu-Jiang Wu (Lanzhou Univ, China)
Wei-Wei Xu (Nanjing Univ Inform Sci Tech, China)
Min-Li Zeng (Putian Univ, China)
Guo-Feng Zhang (Lanzhou Univ, China)
Jian-Jun Zhang (Shanghai Univ, China)
Ju-Li Zhang (Shanghai Univ Engrg Sci, China)
Li-Li Zhang (Henan Univ Finance Law, China)
Nai-Min Zhang (Wenzhou Univ, China)
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Scientific Committee:

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Maya G. Neytcheva (Uppsala Univ, Sweden)
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Organizing Committee:

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Abstract

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Biography

Understanding the BIG DATA as a Novel Paradigm

Feng-Shan Bai

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Abstract

The concept Paradigm is introduced by Thomas Kuhn in his well known book *The Structure of Scientific Revolution*. We will link this concept with scientific computing in this talk. I hope this would be helpful for our young researchers to reach higher innovation in their research works.

Biography

Feng-Shan Bai is a full professor of Tsinghua University. In 1989, he got his Ph.D. degree from the department of applied mathematics of Tsinghua University. From 1991 to 1994, he worked as a postdoctor of Bath University in the United Kingdom and Stanford University in the United States. His main research areas are large-scale scientific computing, data mining, computational statistics, and mathematics software. He was a member of the Organizing Committee of the 3rd, 4th and 10th China-US Frontier Science Symposium, and a member of the Organizing Committee of Mathematical Modeling for University Students. He is a member of the editorial board of the journal "Numerical Computing and Computer Applications", "Mathematical Modeling and Its Application", "Journal of Computational Mathematics in Higher Education Institutions", and "Applied Mathematics–A Journal of Chinese Universities". He is the deputy director of the Teaching Committee of Chinese Ministry of Education for University Students, the deputy director and secretary general of the Mathematical Modeling Committee for Middle School Students, and a member of the Committee of the International Mathematical Modeling Challenge for Middle School Students.

The Power Method and Beyond

Zhong-Zhi Bai

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Abstract

For computing the dominant eigenvalue and the corresponding eigenvector of a real and symmetric matrix, inspired by the classic and powerful power method, we construct a general paradigm of nonstationary Richardson methods and gradient descent methods, called also as the parameterized power methods, and establish their convergence theory. This paradigm also includes the power method as a special case. Both theoretical analysis and numerical experiments show that the parameterized power methods can result in iteration methods that may be much more effective than the power method, provided the involved iteration parameters are chosen appropriately.

Biography

Zhong-Zhi Bai is a full professor of Academy of Mathematics and Systems Science of Chinese Academy of Sciences. His main research subjects are numerical linear and nonlinear algebra as well as parallel computations with applications.

He was a standing member and secretary-general of China Society of Computational Mathematics and a member of China Society of Industrial and Applied Mathematics. He has been involved in the organizations of many international conferences on numerical algebra and scientific computing by serving as the members of the organizing, the program and the scientific committees, and the co-chairs of the conferences. Now, he is the editors of more than 15 top journals in the area of numerical analysis and scientific computing such as Journal of Computational and Applied Mathematics, Numerical Algorithms, and Numerical Linear Algebra with Applications. He has mainly studied high-performance numerical methods, synchronous and asynchronous parallel iterative methods, and their convergence and complexity theories for large sparse linear and nonlinear systems of equations, and variational and complementarity problems. As an author of more than 200 journal papers, he has delivered many academic lectures in institutes and universities in England, Holland, Hong Kong, Japan, Russian, Sweden, Switzerland and USA. Also, he has been awarded many prizes such as The Young Scientist Prize (2nd grade) of Chinese Academy of Sciences, and Feng Kang Prize on Scientific Computing. Starting from 2016, five times in a row he has been named as the Web of Science Highly Cited Researchers (Clarivate Analytics).

The Hermitian and skew-Hermitian splitting (HSS) iteration method and its convergence theory, established jointly with Gene H. Golub and Michael K. Ng in 2003, have been recognized as a milestone in matrix computations, and also as the most important scientific achievement in the last 20 years in the area of iterative methods for solving large sparse linear systems.

Block Preconditioners for the Coupled Stokes-Darcy Problem

Michele Benzi

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Abstract

In this talk I will describe some preconditioning techniques for a class of block three-by-three linear systems of equations arising from finite element discretizations of the coupled Stokes-Darcy flow problem. In particular, I will consider preconditioning techniques including block preconditioners, constraint preconditioners, and augmented Lagrangian-based ones. Spectral and field-of-value analyses are presented for the exact versions of these preconditioners. The results of numerical experiments are reported to illustrate the performance of inexact variants of the various preconditioners used with flexible GMRES in the solution of a challenging 3D test problem.

This is joint work with Fatemeh Beik of Vali-e-Asr University of Rafsanjan, Iran.

Solving Linear Systems of the Form $(A + \gamma UU^T)x = b$

Michele Benzi

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Abstract

I will discuss the iterative solution of large linear systems of equations in which the coefficient matrix is the sum of two terms, a sparse matrix A and a possibly dense, rank deficient matrix of the form γUU^T, where $\gamma > 0$ is a parameter which in some applications may be taken to be 1. The matrix A itself can be singular, but I assume that the symmetric part of A is positive semidefinite and that $A + \gamma UU^T$ is nonsingular. Linear systems of this form arise frequently in fields like optimization, fluid mechanics, computational statistics, finance, and others. I will describe an effective iterative strategy for the solution of such linear systems. The performance of the proposed approach is demonstrated by means of numerical experiments on linear systems from different application areas.

This is joint work with Chiara Faccio (Scuola Normale Superiore).

Biography

Michele Benzi is a full professor of Numerical Analysis at the Scuola Normale Superiore in Pisa. He was previously the Samuel Candler Dobbs Professor of Mathematics and Computer Science at Emory University, which he joined in 2000 after holding positions at the University of Bologna, CERFACS, and Los Alamos National Laboratory. His degrees are from the University of Bologna (1987) and North Carolina State University (1993). His research interests are in numerical linear algebra, with a focus on the solution of large sparse linear systems, especially preconditioning techniques for saddle point problems, and matrix functions. In recent years he has contributed algorithms for the numerical solution of the incompressible Navier-Stokes equations and for the analysis of complex networks.

Stein and Rosenberg

Claude Brezinski

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Abstract

The Stein-Rosenberg theorem on the convergence of the Jacobi and Gauss-Seidel methods for solving systems of linear equations is well known. It shows that both methods are simultaneously convergent or divergent and compares their speeds of convergence.

In this talk, we first remind it, discuss its proofs and its history. Then, we give a brief account of the lives and the works of Stein and Rosenberg.

The Work of Peter Wynn

Claude Brezinski

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Abstract

In this talk, we tell how we learned the death of Peter Wynn in 2017. Then, we began to write an analysis of his published works. But, for introducing them, we had to give an overview of the topics he covered. We also realized that the works of his predecessors should be described, and those of the followers also. Thus, our paper's project rapidly evolved into a book, which also contains the testimonies of several researchers in the domain.

Some time after, we received a message from Sandy Norman, from the University of Texas at San Antonio, USA, informing us that, from time to time, Peter Wynn was visiting some friends of him there and left mathematical documents at their home. He asked us if we were interested in them and he proposed to gather and scan them and send them to us. Of course we accepted and we analyzed these unpublished handwritten documents in an open access paper.

Finally, Andrea Rosolen, a student of the University of Padua, constructed a web site dedicated to P. Wynn where all the documents found in San Antonio could be downloaded.

We remind that the work of Wynn foreshadows the development of the Minimal Polynomial Extrapolation, the Modified Minimal Polynomial Extrapolation, the Reduced Rank Extrapolation, and the Topological Epsilon Algorithm and its simplified form.

Biography

Claude Brezinski is an Emeritus professor at the University of Lille, France, where he had been the head of the Laboratory of Numerical Analysis and Optimization for 30 years. He is the author of 22 books and over 240 papers. He is the founder and editor-in-chief of the journal *Numerical Algorithms*.

Cell-by-Cell Approximate Schur Complement Technique in Preconditioning of Meshfree Discretized Piezoelectric Equations

Yang Cao

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Abstract

The radial point interpolation meshfree discretization is a very efficient numerical framework for the analysis of piezoelectricity, in which the fundamental electrostatic equations governing piezoelectric media are solved without mesh generation. Due to the mechanical-electrical coupling property and the piezoelectric constant, the discrete linear system is sparse, of generalized saddle point form and often very ill conditioned.

In this work, we propose a technique for constructing a family of cell-by-cell approximate Schur complement matrices, to be used in preconditioning to accelerate the convergence of Krylov subspace iteration methods for such problems. The approximate Schur complement matrices are simply constructed in the process of the meshfree discretization and have a sparse structure. It is proved that the so-constructed approximate Schur complement matrices are spectrally equivalent to the exact Schur complement matrix. In addition, nondimensionalization of the piezoelectric equations is considered to make the computations more stable. The robustness and the efficiency of the proposed preconditioners is illustrated numerically on two test problems. Numerical results show that the number of iterations to achieve a given tolerance is independent of the number of degrees of freedom as well as of the various problem parameters.

Biography

Dr. Yang Cao is a doctor, professor and doctoral supervisor of School of Transportation and Civil Engineering, Nantong University. He is also the winner of the "Applied Numerical Algebra Prize" of Chinese Society of Computational Mathematics, the mathematical reviewer of American Mathematical Society and the member of Jiangsu Youth Federation. He has been selected as "Young Science and Technology Talents in Transportation" by the Ministry of Transport, outstanding Young backbone teachers and young and middle-aged academic leaders of "Qinglan Project" of Jiangsu Province, and third-level talents of the fifth "333 Project" of Jiangsu Province. His research interest covers numerical algebra, computational mechanics and intelligence transportation. He has presided 2 national Natural Science Foundation projects, authorized 5 national invention patents and published over 50 papers in high level journals, including Numerical Linear Algebra with Applications, IMA Journal of Numerical Analysis, BIT Numerical Mathematics, Numerical Algorithms, Journal of Computational Mathematics, Journal of Optimization Theory and Applications, Engineering Analysis with Boundary Elements, Acta Mechanica Sinica and Acta Mechanica Solida Sinica and so on.

Sparse Probabilistic Boolean Networks

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Abstract

Boolean Networks (BNs) and their extensions Probabilistic Boolean Networks (PBNs) are useful models for studying genetic regulatory interactions and many other real-world problems. For the purpose of network inference and system synthesis, one has to construct such a network. It is a challenging problem, because there may be many networks or no network having the required properties. The construction of PBNs from observed data sets is an interesting problem of huge size. In this talk, we shall propose some construction methods. Numerical examples will be given to demonstrate the effectiveness of the proposed method.

Biography

Wai-Ki Ching is a Professor in the Department of Mathematics, the University of Hong Kong. He obtained his B.Sc. (Hons) and M.Phil. degrees from the University of Hong Kong and his Ph.D. degree from the Chinese University of Hong Kong. He is a visiting fellow of Hughes Hall, Cambridge University. He received 2013 Higher Education Outstanding Scientific Research Output Awards (Second Prize) from the Ministry of Education in China and 2019 Higher Education Outstanding Scientific Research Output Awards (Second Prize), Hunan Province, China. His research interests are stochastic modelling and matrix computations for Markov chains, bioinformatics, and management science.

A Class of Matrix Minimization Problems

(Joint Work with Mei-Ling Xiang)

Hua Dai

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Abstract

In this talk, we propose a class of matrix minimization problems arising in the nearest correlation matrix and structural dynamics model updating, which aims to update an existing but inaccurate matrix with incomplete measured data. The problems can be mathematically reduced to the problem of finding the best approximation to a given matrix under the constraints that the desired matrix is symmetric and positive semidefinite, satisfies the characteristic equation, has expected structure, and keeps the remaining eigenvalues in required range. Conditions ensuring the feasible region of the matrix minimization problem being nonempty are analyzed. An alternating projection algorithm is developed for solving the problem. Furthermore, by partial Lagrangian multipliers, the matrix minimization problem is reformulated as a matrix linear variational inequality, and the projection and contraction method is presented to solve the problem. Numerical examples show that the proposed methods are effective.

Biography

Hua Dai received the B.S. degree and M.S. degree in computational mathematics from Nanjing University of Aeronautics and Astronautics in 1982 and 1986, respectively, and Ph.D. degree in computational mathematics from Nanjing University in 1988. In Dec. 1988, he joined the Department of Mathematics, Nanjing University of Aeronautics and Astronautics, Nanjing, China. Prof. Dai is engaged in the research of numerical algebra, scientific computing, inverse problem in vibration and so on. He has published about 200 peer-reviewed journal papers. His research interest includes numerical methods for solving large-scale linear systems, algebraic eigenvalue problems and discrete ill-posed problems, sensitivity analysis for eigenvalue problems, inverse eigenvalue problems and structural dynamics model updating.

Randomized Linear Algebra for Interior Point Methods
— Part A and Part B

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Abstract

The introduction of randomization in the design and analysis of algorithms for matrix computations (such as matrix multiplication, least-squares regression, the Singular Value Decomposition (SVD), etc.) over the past two decades provided a new paradigm and a complementary perspective to traditional numerical linear algebra approaches. These novel approaches were motivated by technological developments in many areas of scientific research that permit the automatic generation of large data sets, which are often modeled as matrices. In this talk, we will outline how such approaches can be used in the context of problems such as solving regression problems and Interior Point Methods for linear programming.

Biography

Petros Drineas is a Professor and Associate Head at the Computer Science Department of Purdue University. He earned a Ph.D. in Computer Science from Yale University in 2003 and a BS in Computer Engineering and Informatics from the University of Patras, Greece, in 1997. From 2003 until 2016, Prof. Drineas was an Assistant (until 2009) and then an Associate Professor at Rensselaer Polytechnic Institute. His research interests lie in the design and analysis of randomized algorithms for linear algebraic problems, as well as their applications to the analysis of modern, massive datasets, with a particular emphasis on the analysis of genetics data. Prof. Drineas is the recipient of an Outstanding Early Research Award from Rensselaer Polytechnic Institute as well as an NSF CAREER award. He was a Visiting Professor at the US Sandia National Laboratories during the fall of 2005, a Visiting Fellow at the Institute for Pure and Applied Mathematics at the University of California, Los Angeles in the fall of 2007, a long-term visitor at the Simons Institute for the Theory of Computing at the University of California Berkeley in the fall of 2013, and has also worked for industrial labs (e.g., Yahoo Labs and Microsoft Research). From October 2010 to December 2011, he served the US National Science Foundation as a Program Director in the Information and Intelligent Systems (IIS) Division and the Computing and Communication Foundations (CCF) Division. Prof. Drineas has published over 140 papers (cited over 11,500 times) in theoretical computer science, applied mathematics, and genetics venues, including the Proceedings of the National Academy of Sciences, PLOS Genetics, Genome Research, the Journal of Medical Genetics, PLoS One, the Annals of Human Genetics, etc.

Prof. Drineas has presented keynote talks and tutorials in major conferences (e.g., SIAM ALA, KDD, VLDB, SDM, etc.) and over 100 invited colloquia and seminar presentations in the US and Europe. He received two fellowships from the European Molecular Biology Organization for his work in genetics and his research has been featured in various popular press articles, including SIAM News, LiveScience, ScienceDaily, Scitizen, the National Geographic, Yahoo! News, etc. Prof. Drineas has co-organized the widely attended Workshops on Algorithms for Modern Massive Datasets held bi-annually from 2006 to 2016 and is an editor of the SIAM Journal on Matrix Analysis and Applications (SIMAX), the SIAM Journal on Scientific Computing (SISC), the Applied and Computational Harmonic Analysis (ACHA) journal, and PLoS One.

Image Denoising - Not What You Think!
— Part A

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Abstract

Image denoising - removal of white additive Gaussian noise from an image - is one of the oldest and most studied problems in image processing. An extensive work over several decades has led to thousands of papers on this subject, and to many well-performing algorithms for this task. As expected, the era of deep learning has brought yet another revolution to this subfield, and took the lead in today's ability for noise suppression in images. All this progress has led some researchers to believe that "Denoising Is Dead", in the sense that all that can be achieved is already done. Part A of this talk we will introduce the above evolution of this field, and highlight the tension that exists between classical approaches and modern AI alternatives.

Image Denoising - Not What You Think!

— Part B

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Abstract

Part B of this talk will focus on recently discovered abilities and vulnerabilities of image denoisers. In a nut-shell, we expose the possibility of using image denoisers for serving other problems, such as regularizing general inverse problems and serving as the engine for image synthesis. We also unveil the (strange?) idea that denoising (and other inverse problems) might not have a unique solution, as common algorithms would have you believe. Instead, we will describe constructive ways to produce randomized and diverse high perceptual quality results for inverse problems.

Biography

Michael Elad holds a B.Sc. (1986), M.Sc. (1988) and D.Sc. (1997) in Electrical Engineering from the Technion in Israel. Since 2003 he holds a faculty position in the Computer-Science department at the Technion. Prof. Elad works in the field of signal and image processing, specializing in particular on inverse problems, sparse representations and deep learning. He has authored hundreds of publications in leading venues, many of which have led to exceptional impact. Prof. Elad has served as an Associate Editor for IEEE-TIP, IEEE-TIT, ACHA, SIAM-Imaging-Sciences - SIIMS and IEEE-SPL. During the years 2016-2021 Prof. Elad served as the Editor-in-Chief for SIIMS.

Michael received numerous teaching and research awards and grants, including an ERC advanced grant in 2013, the 2008 and 2015 Henri Taub Prizes for academic excellence, and the 2010 Hershel-Rich prize for innovation, the 2018 IEEE SPS Technical Achievement Award for contributions to sparsity-based signal processing; the 2018 IEEE SPS Sustained Impact Paper Award for his K-SVD paper, and the 2018 SPS best paper award for his paper on the Analysis K-SVD. Michael is an IEEE Fellow since 2012, and a SIAM Fellow since 2018.

The First Algorithm to Compute the SVD

Walter Gander

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Abstract

The singular values of a matrix A can be computed as the square roots of the eigenvalues of the matrix $A^T A$. However, the calculation of $A^T A$ in finite arithmetic seriously violates the smaller singular values. Therefore the pioneers Gene Golub, William Kahan and Christian Reinsch constructed new algorithms which compute the singular values directly from A without forming $A^T A$. We describe the first algorithm proposed by Golub/Kahan 1965. Then we discuss the two algorithms by Golub/Businger 1967 and by Reinsch 1967 which were developed independently at the same time. The current algorithm used in all software packages is the one of Reinsch. We explain why the algorithm of Reinsch appeared in "Handbook of Automatic Computation" under joint authorship with G.H. Golub.

Infinity and Finite Arithmetic

Walter Gander

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Abstract

The notion of infinity is important in mathematics and computer science. However, a computer is a finite machine. It can represent only a finite set of numbers and an algorithm has to terminate and cannot run forever. Nevertheless we are able to deal with infinity on the computer. We discuss and implement some convergence acceleration methods and extrapolation algorithms which enable us to compute limits. This paper is dedicated to Juraj Hromkovic on the occasion of his 60th birthday.

Biography

Academic degrees and positions: Ph.D. in mathematics ETH Zurich, 1973, supervisor Peter Henrici. Privatdozent in Numerical Analysis at ETH 1979-1986, Professor in Computer Science at ETH 1987-2009, founder of the Institute of Computational Science at ETH.

1989-1991: Head of the evaluation committee for the Swiss national supercomputer. Purchased the first supercomputer for the Swiss National Supercomputing Center in Manno.

1997-2001: Chairman of the Department of Computer Science at ETH and also Head of Education of Computer Science.

Research interests: Scientific computing, Numerical Linear Algebra and Parallel Computing.

A Scalable Approximate Inverse Block Preconditioner for Incompressible MHD Problems

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Abstract

We introduce an approximate inverse preconditioner for a mixed finite element discretization of an incompressible magnetohydrodynamics model problem. The derivation exploits the nullity of the discrete curl-curl operator in the Maxwell subproblem. We show that the inverse of the coefficient matrix contains zero blocks and use discretization considerations to obtain a practical preconditioner based on further sparsification. We demonstrate the viability of our approach with a set of numerical experiments.

Eigenvalue Analysis and Numerical Solvers for Double Saddle-point Systems

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Abstract

We derive bounds on the eigenvalues of double saddle-point matrices. The bounds are expressed in terms of extremal eigenvalues and singular values of the associated block matrices. Inertia and algebraic multiplicity of eigenvalues are considered as well. We apply these bounds and consider numerical solvers for a 3-by-3 block formulation of the Darcy-Stokes problem, discretized using the marker-and-cell scheme. The proposed solvers include a block preconditioning approach and a block-structured multigrid relaxation scheme. Discretization of the interface conditions is discussed, and numerical results illustrate the convergence behavior of the proposed schemes.

Biography

Chen Greif is a Professor in the Department of Computer Science at the University of British Columbia in Vancouver, Canada. He recently completed a five-year term as the Department Head. He specializes in preconditioning techniques for iterative methods for solving large and sparse linear systems arising from partial differential equations, with special interest in saddle-point problems. Chen is a co-author of the SIAM bestselling book, A First Course in Numerical Methods, and has co-authored and edited two other books. He served as SIAM Secretary, was Chair of the Gene Golub SIAM Summer School Committee, and has held other leadership roles in SIAM in the past few years. He was a postdoctoral fellow under the mentorship of Gene Golub at Stanford University from 1998 to 2000.

Recent Progress on Iterative Methods for the Matrix pth Root

— Part A and Part B

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Abstract

For a square matrix A with no eigenvalues on the closed real axis, its principal pth root, $A^{1/p}$, is uniquely defined. When all eigenvalues of A are in a suitable region in the complex plane, $A^{1/p}$ can be approximated by using an iterative method, starting from the identity matrix. Such a region is called a convergence region for the iterative method. We are mostly interested in Newton's method, Halley's method and Chebyshev's method. Newton's method and Chebyshev's method are two special cases of Schröder's method. It has been known for some time that the disk $|z - 1| < 1$ is a convergence region for each of these methods. When all eigenvalues of A are in this open disk, we obtain for each aforementioned iterative method a neat error estimate for the matrix sequence generated, a monotonic convergence result when A is a nonsingular M-matrix, and a structure preserving result when A is a nonsingular M-matrix or a real nonsingular H-matrix with positive diagonal entries. We also explain how a convergence region larger than the disk $|z - 1| < 1$ can be obtained for Schröder's method, and present large explicit convergence regions for Newton's method and Chebyshev's method.

Biography

Chun-Hua Guo is a Professor of Mathematics at University of Regina in Canada. His research interest includes matrix equations, matrix functions, and tensor eigenvalue problems.

New Insight on How Rutishauser Discovered the QD Algorithm

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Abstract

Heinz Rutishauser's quotient-difference algorithm (qd algorithm) introduced in an article in ZAMP (received on August 5, 1953, published in 1954), which was shortly followed by further publications, is the origin of a whole class of algorithms for computing the eigenvalues of a matrix.

Roughly one year later, Rutishauser realized that computing the LU factorization (or, in German, LR-Faktorisierung) of a tridiagonal matrix (if possible) and computing the product of the two bidiagonal factors in reverse order is equivalent to one step of the qd-algorithm. Moreover, this approach can also be applied to a full square matrix, but, of course, in general it may break down because an LU factorization may not exist. Iterating such steps yields Rutishauser's LR algorithm of 1955.

The process becomes much more stable, if QR factorizations are used instead of LU factorizations, an idea brought up by John G.F. Francis in 1961 in a article submitted in October 1959 that introduced the ubiquitous QR algorithm.

But how did Rutishauser discover the qd algorithm initially? In their article "From qd to LR and QR, or, How were the qd and LR algorithms discovered?" Martin H. Gutknecht and Beresford N. Parlett addressed this question by checking Rutishauser's early publications on the topic. Unfortunately, these publications do not contain an answer. In particular, where the qd algorithm is introduced, there is no full proof or derivation.

Recently, Heinz Rutishauser's older daughter Hanna, who has been screening her father's notes and correspondence in the archive of the library of ETH Zurich, found a document that reveals the answer. In this talk we review first basic facts on the qd algorithm and turn then to this document.

How Accurate is Gauss Quadrature with Indefinite or Complex Weight Function?

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Abstract

It is well known that there is a rich circle of closely related algorithms and theories that include Padé approximation, orthogonal or formal orthogonal polynomials (FOPs), fast Hankel solvers, the Stieltjes and Lanczos algorithms, Gauss quadrature, the qd and Chebyshev algorithms, as well as model reduction in systems and control. Classically these topics were mostly restricted to symmetric positive situations, but e.g., Padé approximation theory does not suffer from this restriction. For the nonsymmetric Lanczos algorithm (introduced by Lanczos already) and the FOPs there is a straightforward theory that is valid until the iteration breaks down, and there is look-ahead Lanczos for proceeding further. However, for Gauss quadrature it is not so easy to allow real indefinite or even complex weight functions. The same is true if we want to approximate any linear functional instead of an integral. Therefore, Chihara in his "An Introduction to Orthogonal Polynomials" of 1978 restricted himself to so-called quasi-definite functionals. This corresponds to applying the nonsymmetric Lanczos algorithm at most until it breaks down, i.e., without proceeding by applying look-ahead. In further work by Pozza, Pranić, and Strakoš (IMA J. Numer. Anal., 2017; ETNA, 2018) and others this restriction was kept, though in my referee report to the second paper I proposed to drop it. Reportedly, this was done in the thesis of Draux (1983) already. In a highly interesting survey article, Pozza and Pranić (Numer Alg, 2021) now cover the general case. In particular they can answer the question posed in the title. We will outline a simpler proof of the answer.

Biography

Martin Gutknecht was born in Berne, Switzerland, in 1944. He received his diploma in Mathematics in 1969, his Dr.sc.math. in 1973, and his venia legendi (habilitation) in 1980, all from ETH Zurich. His advisor was Peter Henrici. He has spent a year at each the University of British Columbia in Vancouver (1976), Stanford University (1979/80), and the IBM Thomas J. Watson Research Center in Yorktown Heights, NY (1985/86). In 1988 he became the head of the newly founded Interdisciplinary Project Center for Supercomputing (IPS) at ETH Zurich. At the end of 1995 the IPS was merged with the Swiss Center for Scientific Computing (CSCS/SCSC) in Manno, Ticino, and Martin Gutknecht became till the end of 1998 the Scientific Director of CSCS/SCSC and the head of its scientific section. Since 1999 he has been a professor in the Mathematics Department of ETH Zurich. End of October 2009 he had to retire from ETH Zurich, but kept some office space and the title of professor.

Martin Gutknecht is a numerical analyst. In the 1970s his research concentrated on complex approximation theory and fast methods for numerical conformal mapping. Later, his interests have moved to Krylov space methods for sparse unsymmetric systems and to fast methods for matrix moment problems, rational interpolation (including Padé approximation), and Toeplitz systems. In particular, he has developed and promoted the look-ahead Lanczos algorithm and related methods.

Martin Gutknecht has been an editorial board member of seven professional journals, including Numerische Mathematik, SIMAX, and SINUM.

Rank Minimization with Applications to Image Restoration

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Abstract

Rank minimization problem has a wide range of applications in different areas. However, since this problem is NP-hard and non-convex, the frequently used method is to replace the matrix rank minimization with nuclear norm minimization. Nuclear norm is the convex envelope of the matrix rank and is more computationally tractable. Matrix completion is a special case of the rank minimization problem. In this talk, we consider directly using matrix rank as the regularization term instead of nuclear norm in the cost function for matrix completion problem. The solution is analyzed and obtained by a hard-thresholding operation on the singular values of the observed matrix. Then by exploiting patch-based nonlocal self-similarity scheme, we apply the proposed rank minimization algorithm to remove white Gaussian additive noise in images. We also develop a model for image restoration using the sum of block matching matrix weighted nuclear norm to be the regularization term in the cost function. An alternating iterative algorithm is designed to solve the proposed model and the convergence analysis of the algorithm is also presented. Numerical experiments show that the proposed method can recover the images much better than the existing regularization methods in terms of both recovered quantities and visual qualities.

Biography

Yu-Mei Huang is a professor in School of Mathematics and Statistics, Lanzhou University. She received her Ph.D. Degree from Hong Kong Baptist University, in 2008. Her research interests include image restoration and numerical linear algebra and has published many papers on some journals in image processing and numerical mathematics such as SIAM Journal on Imaging Sciences, IEEE transactions on Image Processing and SIAM Journal on Scientific Computing.

On Two Block Methods for Solving Linear Least-Squares Problems

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Abstract

A fast block coordinate descent method and a randomized double block Kaczmarz method for solving linear least-squares problems are proposed. The first is based on a greedy criterion of the column selection used at each iteration, and the second is a kind of the extended block Kaczmarz methods. The convergence and error estimates are obtained. Numerical experiments show the effectiveness of these two approaches, does not matter whether the coefficient matrix is of full column rank or not.

Biography

Dr. Zheng-Da Huang, a full professor of Zhejiang University, obtained Ph.D. in 1992 at Hangzhou University. He has been engaged in the research on the convergence of Newton's and Newton-like methods for solving nonlinear equations, the conjugate gradient method in numerical optimization theory, the application of these methods in solving specific partial differential equations, and solvers for the saddle point problem based on coefficient matrix splitting. In recent years, his research focuses mainly on the application of the preconditioner technology and the Kaczmarz-type method for solving systems of linear equations. He likes teaching very much and is the executive deputy director of the teaching center of the basic mathematical courses of the university.

Numerical Analysis on Multi-Linear PageRank

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Abstract

Multi-linear PageRank is a generalization of PageRank, which can be applied to Data clustering, Hypergraph partitioning et al. In this talk we focus on theoretical analysis and numerical algorithms for solving multi-linear PageRank in recent years. Numerical examples are given to illustrate the efficiency of the proposed algorithms.

Biography

Dr. Wen Li is a full professor and a dean of School of Mathematical Sciences, South China Normal University, council member of Chinese Mathematical Society, Vice-chairman of Guangdong Mathematical Society. His research interest is in numerical algebra and its application. He is a PI of five general projects of National Natural Science Foundation of China, and has published some academic papers in famous academic journals such as Numer Math, SIAM J Optim, SIAM J Matrix Anal Appl, SIAM J Imaging Sci, J Sci Comput and Pattern Recognition. In 2012 and 2021, the achievements "A Study on Several Problems in Numerical Algebra" and "Theory, Computation and Application of Structural Tensors" won the second prize of Natural Science Award of Guangdong Province, respectively.

DNT and NTD Preconditioners for One-sided Space Fractional Diffusion Equations

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Abstract

In this talk, we consider preconditioners for Toeplitz-like linear systems arising from one-sided space fractional diffusion equations (OSFDE) with variable coefficients. We first consider diagonal-times-nonsymmetric-Toeplitz (DNT) preconditioner to Toeplitz-like linear systems arising form OSFDEs, where high order difference operators are applied to discretize the fractional derivative. Then we propose nonsymmetric-Toeplitz-times-diagonal (NTD) preconditioner. We prove that the condition number of the preconditioned matrices is bounded by a constant under mild assumptions and verify that several discretization schemes from the literature satisfy the required assumptions. Numerical results are reported to show the efficiency of the proposed preconditioners.

Biography

Fu-Rong Lin is a professor at Department of Mathematics, Shantou University, China. His research interests include constructions and analyses of preconditioners, methods and theories of Toeplitz matrices, numerical methods for fractional diffusion equations, image processing, and inverse problems. He has more than 50 research articles published in top journals such as Journal of Scientific Computing, Applied Numerical Mathematics, SIAM Journal on Numerical Analysis, SIAM Journal on Scientific Computing, BIT Numerical Mathematics, Inverse Problems, etc. He was also awarded four research grants from the National Natural Science Foundation of China.

Algebraic Multigrid Method with Skew-Hermitian Smoothers

(Joint Work with Tatiana S. Martynova)

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Abstract

The multigrid method with a special type of smoothers is used for solving large sparse systems of linear algebraic equations with a strongly non-Hermitian matrix. Hermitian/skew-Hermitian splitting (HSS) and skew-Hermitian triangular splitting (STS) methods are considered as smoothers in the MGM for solving the SLAE. When implementing the algebraic multigrid method, the parallel modified independent set algorithm has been used. the two-dimensional unsteady Navier-Stokes problem for viscous incompressible fluid, written in primitive variables "velocity-pressure", is considered as a model one. Numerical results for an algebraic multigrid (AMG) method are presented. Numerical experiments have shown high efficiency of the algebraic multigrid method with the skew-Hermitian smoothers for this problem.

The research was funded by a grant of the Russian Science Foundation N 22-21-00318 at Southern Federal University.

Numerical Solution of Large Sparse Linear Systems and Algebraic Eigenvalue Problems

(Joint Work with Tatiana S. Martynova)

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Abstract

The solution of large sparse systems of linear algebraic equations (SLAEs) and the partial symmetric eigenvalue problems by iterative methods are considered. To solve nonsymmetric positive definite SLAEs, the algebraic multgrid method (AMG) with the PMIS coarsening algorithm is used with special smoothers based on the Hermitian/skew-Hermitian splitting and the skew-Hermitian triangular splitting of the coefficient matrix. To solve the large partial algebraic eigenvalue problem, the Lanczos method is applied. To find the eigenvalues of a tridiagonal matrix, QR-iteration with an implicit shift is used. Research has done in collaboration with P.A. Oganesyan and O.O. Shtein.

The research was funded by a grant of the Russian Science Foundation N 22-21-00318 at Southern Federal University.

Biography

Galina V. Muratova is a Professor of the Computer Science and Computational Experiment Department of Vorovich Institute of Mathematics, Mechanics and Computer Science, Southern Federal University. Her field of research is connected with mathematical modelling of different processes and numerical methods. Galina Muratova is one of the organizers and participants of Annual International Conference on Numerical Algebra and Scientific Computing, organized by Russian-Chinese numerical algebra group.

Golub-Kahan Bidiagonalization Algorithm: Low Rank Approximations, Inverse Problems, and Machine Learning

— Part A and Part B

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Abstract

Gene H. Golub, fondly known as Professor SVD, proposed the first practical algorithm for computing the singular value decomposition in 1965 with William (Velvel) Kahan. The paper, which was published in SIAM Journal on Numerical Analysis, presents two approaches, one based on Householder transformations, and the other is a "Lanczos-type" sequential scheme, which is now referred to as the Golub-Kahan bidiagonalization (GKB) algorithm. In this talk we discuss GKB's impact on many applications, including iterative solution of large-scale inverse problems, and more recently on applications in machine learning.

Biography

James G. Nagy is the Samuel Candler Dobbs Professor and Chair of the Department of Mathematics at Emory University, and a Fellow of the Society of Industrial and Applied Mathematics (SIAM). James G. Nagy received a Ph.D. in Applied Mathematics in 1991 from North Carolina State University. Before joining Emory University in 1999 he had postdoctoral research fellowships at the IMA at the University of Minnesota, with the NSF at the University of Maryland, and he was on the faculty at Southern Methodist University. The research interests of Professor Nagy include numerical linear algebra, structured matrix computations, numerical solution of inverse problems, and image processing.

On Stage-Parallel Preconditioning of Implicit Runge-Kutta Methods

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Abstract

The availability and accessibility of powerful computational resources enables us to perform computer simulations that require high resolution, both in space and time, enabling the successful studying of numerous problems of interest, modeling processes in physics, computational biology, financial and social processes, to name a few application areas. When combining the requirements for a (very) fine space resolution or very large space domains and long time intervals, we face the problem to balance the discretization error in space and time and keep the overall computational complexity of the simulations within acceptable bounds. In this context the higher order implicit time discretization methods become a viable way to go. At the same time, implicit integration methods automatically entail solutions with algebraic systems of large dimensions and, in general, possessing low degree of parallelism.

In this study we use a particular class of implicit time discretization schemes, namely, the implicit Runge-Kutta (IRK) methods, based on Radau quadratures. For general IRK methods all stages are coupled and cannot be decomposed in some easier to handle form. The solution of this system can be costly and somewhat involved, which has been the major reason why IRK methods are more rarely used. In practice, the system must be solved by some preconditioned iterative method. Preferably, it should be possible to implement the methods efficiently in a parallel computer environment.

Analysis of Spectral Properties of Preconditioned Matrices Using the Generalized Locally Toeplitz Theory

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Abstract

We show that we are able to construct and implement efficient preconditioners for the systems arising in IRK methods and illustrate their performance on a high performance computer platform.

We also discuss how we can analyze the spectral properties of preconditioned matrices, which are nonsymmetric and of tensor form. To this end we utilize analysis tools, such as the field of values of a matrix and the so-called Generalized Locally Toeplitz theory.

Biography

Maya Neytcheva graduated at the Faculty of Mathematics and Informatics, Sofia University, Bulgaria, with specialization in Mathematical Modelling. Her career started as a Research Associate at the Institute of Applied Systems Design 'SYSTEMISOT', Sofia, Bulgaria, where she worked as a developer and a group leader in various information systems projects. Later on she moved, again as a Research Associate, to the Institute of Mathematics of the Bulgarian Academy of Sciences, Sofia, working at the Computing Center and lately at the Laboratory of Telematics. In the period 1991-1995 she did her Ph.D. at the Faculty of Mathematics and Informatics, Catholic University of Nijmegen (now Radboud University), The Netherlands, under the supervision of Professor Owe Axelsson. There she worked on preconditioning techniques, multilevel methods and their applications on various High Performance Computing (HPC) architectures. She continued in the same group first as a postdoc and then as university lecturer until 2001, when she obtained the position of Associate Professor at Uppsala University, till present time. She became a professor in 2016.

Maya Neytcheva's research interests and experience lie in preconditioned iterative solution methods and HPC in the context of various problems, often originating from models, described by partial differential equations. She has been the main supervisor of five Ph.D. students, already completed their studies and has currently one Ph.D. student. Her scientific activities include organization of numerous international conferences and workshops. She has participated in many international, EU and national projects in the Netherlands and Sweden.

She has served the journal "Numerical Linear Algebra with Applications", John Wiley & Sons, Ltd. since its establishment in 1994 and since January 2002 is its Associate Editor.

Error Estimates for Golub-Kahan Bidiagonalization with Tikhonov Regularization for Ill-posed Operator Equations

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Abstract

Linear ill-posed operator equations arise in various areas of science and engineering. The presence of errors in the operator and the data often makes the computation of an accurate approximate solution difficult. We compute an approximate solution of an ill-posed operator equation by first determining an approximation of the operators of generally fairly small dimension by carrying out a few steps of a continuous version of the Golub-Kahan bidiagonalization (GKB) process to the noisy operator. Then Tikhonov regularization is applied to the low-dimensional problem so obtained and the regularization parameter is determined by solving a low-dimensional nonlinear equation. The effect of replacing the original operator by the low-dimensional operator obtained by the GKB process on the accuracy of the solution is analyzed, as is the effect of errors in the operator and data. Computed examples that illustrate the theory are presented. This talk presents joint work with A. Alqahtani, T. Mach, and R. Ramlau.

Approximation of Stieltjes Matrix Functions via Rational Gauss-Type Quadrature Rules

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Abstract

This talk is concerned with the inexpensive approximation of expressions of the form $I(f) = v^T f(A)v$, when A is a large symmetric positive definite matrix, v is a vector, and $f(t)$ is a Stieltjes function. We are interested in the situation when A is too large to make the evaluation of $f(A)$ practical. Approximations of $I(f)$ are computed with the aid of rational Gauss quadrature rules. Error bounds or estimates of bounds are determined with rational Gauss-Radau or rational anti-Gauss rules. The talk presents joint work with J. Alahmadi and M. S. Pranić.

Biography

Lothar Reichel is a full professor at Kent State University. He received his Ph.D. degree in numerical analysis in 1982 from University of Stockholm. His research interests include Numerical Analysis/Scientific Computing. He serves as editor-in-chief, associate editor, or editor for about 21 academic journals. He has been an editor of two book series, and 25 books and special issues on journals. Till now, he has published more than 300 journal papers.

A Modified Modulus-Based Multigrid Method for Linear Complementary Problems

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Abstract

The linear complementarity problem arising from a free boundary problem can be equivalently reformulated as a fixed-point equation. We present a modified modulus-based multigrid method to solve this fixed-point equation. This modified method is a full approximation scheme using the modulus-based splitting iteration method as the smoother and avoids the transformation between the auxiliary and the original functions which was necessary in the existing modulus-based multigrid method. We predict its asymptotic convergence factor by applying local Fourier analysis to the corresponding two-grid case. Numerical results show that the W-cycle possesses an h-independent convergence rate and a linear elapsed CPU time, and the convergence rate of the V-cycle can be improved by increasing the smoothing steps. Compared with the existing modulus-based multigrid method, the modified method is more straightforward and is a standard full approximation scheme, which makes it more convenient and efficient in practical applications.

Biography

Zhi-Ru Ren is an associate professor of School of Statistics and Mathematics, Central University of Finance and Economics. She graduated from the Institute of Computational Mathematics and Scientific/Engineering Computing, Academy of Mathematics and Systems Science, Chinese Academy of Sciences, with a doctorate in Science in 2011. From June 2011 to June 2014, she worked as a postdoctoral in Academy of Mathematics and Systems Science, Chinese Academy of Sciences. Then, she joined the Central University of Finance and Economics. From September 2018 to September 2019, she visited and exchanged in the Department of Mathematics at the University of California, Berkeley. Dr. Ren has won the Applied Numerical Algebra Prize in 2016 and the second prize of Shanxi Natural Science Award (3/4) in 2020. Now, she is engaged in the research of stochastic algorithm and its application in Numerical Algebra. More over 20 papers have been published in Academic Journals. In addition, she presided over and participated in a number of National Natural Science Funds.

Two-Subspace Randomized Extended Kaczmarz Method for Linear Least-Squares Problems

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Abstract

The Kaczmarz method is a classic while effective row-action iteration solver for solving large systems of linear equations. Due to its simplicity, it has been widely used in the area of signal and image processing. Based on the Kaczmarz method, by choosing each row of the coefficient matrix randomly with probability proportional to its squared Euclidean norm, rather than sequentially in the given order, Strohmer and Vershynin constructed the randomized Kaczmarz method for solving consistent linear systems. Zouzias and Freris extended the randomized Kaczmarz method and proposed the randomized extended Kaczmarz method to iteratively compute the least Euclidean norm solution of the linear least-squares problem.

Based on a generalization of the two-subspace randomized Kaczmarz method without the assumptions of unit row norms and full column rank on the coefficient matrix, we propose a block version of the randomized extended Kaczmarz method for solving the large-scale linear least-squares problem, called the two-subspace randomized extended Kaczmarz method. This block method does not require any row or column paving. Theoretical analysis and numerical results show that this method is much more efficient than the randomized extended Kaczmarz method. When the coefficient matrix is of full column rank, it can also outperform the randomized coordinate descent method.

Biography

Wen-Ting Wu is an assistant professor in School of Mathematics and Statistics, Beijing Institute of Technology, P.R. China. She received the Ph.D. degree from Academy of Mathematics and Systems Science, Chinese Academy of Sciences in June, 2019. She was awarded the Applied Numerical Algebra Prize in 2019. She also serves as a member of the editorial board of "Numerical Linear Algebra with Applications". Her research interests are in numerical algebra and scientific computing, particularly in randomized iteration methods for solving systems of linear equations, and works were published on SIAM Journal on Scientific Computing, Numerical Linear Algebra with Applications, Numerical Algorithms, Linear Algebra and its Applications, etc.

Blind Image Deblurring: What is the Next Step?

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Abstract

Blind image deblurring is a challenging task in imaging science where we need to estimate the latent image and blur kernel simultaneously. To get a stable and reasonable deblurred image, proper prior knowledge of the latent image and the blur kernel is urgently required. In this talk, we address several of our recent attempts related to image deblurring. Indeed, different from the recent works on the statistical observations of the difference between the blurred image and the clean one, we first report the surface-aware strategy arising from the intrinsic geometrical consideration. This approach facilitates the blur kernel estimation due to the preserved sharp edges in the intermediate latent image. Extensive experiments demonstrate that our method outperforms the state-of-the-art methods on deblurring the text and natural images. Moreover, we discuss the Quaternion-based method for color image restoration. After that, we extend the quaternion approach for blind image deblurring.

Biography

Dr. Tie-Yong Zeng is a Professor at the Department of Mathematics, The Chinese University of Hong Kong (CUHK). Together with colleagues, he has founded the Center for Mathematical Artificial Intelligence (CMAI) since 2020 and served as the director of CMAI. He received the B.S. degree from Peking University, Beijing, China, the M.S. degree from Ecole Polytechnique, Palaiseau, France, and the Ph.D. degree from the University of Paris XIII, Paris, France, in 2000, 2004, and 2007, respectively. His research interests include image processing, optimization, artificial intelligence, scientific computing, computer vision, machine learning, and inverse problems. He has published more than 100 papers in the prestigious journals such as SIAM Journal on Imaging Sciences, SIAM Journal on Scientific Computing, Journal of Scientific Computing, IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), International Journal of Computer Vision (IJCV), IEEE Transactions on Neural Networks and Learning Systems (TNNLS), IEEE Transactions on Image Processing (TIP), IEEE Medical Imaging (TMI), and Pattern Recognition.