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FINAL TECHNICAL REPORT

The Sixth SIAM Conference on Applied Linear Algebra was held October 29-November 1, 1997 at the Snowbird Ski and Summer Resort, Snowbird, Utah. The conference was conducted by SIAM, and sponsored by the SIAM Activity Group on Linear Algebra. It was organized and chaired by Alan George, University of Waterloo. The other members of the organizing committee were Ake Bjorck (Linkoping, Sweden), Richard Brualdi (Wisconsin, USA), Biswa Datta (Northern Illinois, USA), James Demmel (Berkeley, USA), John Gilbert (Xerox PARC, USA), Nick Gould (Rutherford Lab., UK), Anne Greenbaum (Washington U., USA), Nick Higham (Manchester, UK), Ilse Ipsen (NC State, USA), and Paul Van Dooren (Lueven, Netherlands).

The conference was supported in part by the National Science Foundation and the Department of Energy. A total of 166 people attended the conference. The attendance was down somewhat from previous meetings in the series, apparently due to the timing; several attendees from academia mentioned the difficulty of being away from their teaching duties during the busy fall academic term. As in the past, the objective of the meeting was to bring people who are actively developing new algorithms and software in linear algebra together with those who are primarily users of those algorithms and software. The plenary speakers were chosen with that objective in mind; the speakers and their titles were:

Doubly Stochastic Matrices: Theory and Application
Richard A. Brualdi
Department of Mathematics
University of Wisconsin, Madison

The Solution of Linear Systems Arising in Interior Methods for Optimization
Philip E. Gill
Department of Mathematics
University of California, San Diego

Geometrical Approaches to the Algebraic Eigenvalue Problem
Alan Edelman
Department of Mathematics
Massachusetts Institute of Technology

Robust Parallel Algorithms for Sparse Symmetric Eigen Applications
John Lewis
Boeing Information and Support Services
The Boeing Company
Seattle, Washington

DISCLAIMER

Lifting the Curse on the Hamiltonian and Symplectic Eigenproblem
Volker Mehrmann
Fakultat fur Mathematik
TU Chemnitz-Zwickau, Germany

Schur-type Methods for Toeplitz Structured Problems
Haesun Park
Computer Science Department
University of Minnesota, Minneapolis

Second Generation Wavelets: Theory and Applications
Wim Sweldens
Bell Laboratories, Lucent Technologies.

In addition to the plenary talks, there were 19 minisymposia, 7 common interest sessions, and a poster session. These were generally very well attended. The minisymposia and common interest topics covered a broad spectrum, from core algebra topics, through numerical methods for a variety of important problems including large eigenvalue problems, signal processing, optimization, control, sparse matrix reordering, image processing, to the design and implementation issues associated with building software and software libraries.

The common interest sessions were structured by the organizing committee on the basis of submitted abstracts, and moderated by people selected by the committee. The moderators for each session provided a brief overview of the work by the session contributors, and then acted as a "chair" for the discussion that followed. The debates in general were lively and informative. These common interest sessions serve as an alternative venue to the minisymposium structure, but their success depends heavily on having a coherent set of session contributions, and a skillful and dedicated moderator.

Since 1988, the SIAG LA prize has been awarded at this meeting. The submissions for the award this time were particularly strong, and the award committee decided that two papers should be recognized:

1) Ming Gu (UCLA) & Stanley Eisenstat (Yale University) for their paper "A Divide-and-Conquer Algorithm for the Symmetric Tridiagonal Eigenproblem"

2) Gerard Sleijpen and Henk Van Der Vorst (Math Institute at the University of Utrecht) for their paper "A Jacobi-Davidson Iteration Method for Linear Eigenvalue Problems"

An honorable mention was given for "A Formula for Computation of the Real Stability Radius" by L. Qui (Hong Kong University of Science), B. Bernhardsson and A.

Rantzer (Lund, Sweden), E.J. Davison (Toronto), P. M. Young (MIT), and J. C. Doyle (Caltech).

In order to reinforce the importance of good posters, the SIAG, at its last meeting in 1994, established two awards for the best poster of the session. The winners of the competition this year were

"On the Perturbation Theory for the Unitary Eigenvalue Problem", B. Bohnhorst, Schmidt, Vogel und Partner, Gesellschaft fur Organisation, und Management Beratung GmbH, Germany; A. Bunse-Gerstner and Heike Fassbender, Universitat Bremen, Germany

"Overview of the Semi-Discrete Matrix Decomposition and Its Applications", Tamara G. Kolda, Oak Ridge National Labs and Dianne P. O'Leary, University of Maryland, College Park

In summary, while the meeting was somewhat smaller than past meetings, the quality of the presentations was very high, and the feedback received by the chair from attendees was generally very positive.

Submitted by:

Alan George
University of Waterloo
December, 1997

Society for Industrial and Applied Mathematics
3600 University City Science Center
Philadelphia, PA 19103-2688

CONF-9711130--Absts.

FINAL PROGRAM AND ABSTRACTS

Sixth SIAM Conference on

APPLIED LINEAR ALGEBRA

Sponsored by SIAM Activity Group on Linear Algebra

October 29 thru November 1, 1997

Snowbird Ski and Summer Resort
Snowbird, Utah

Linear algebra plays a central role in mathematics and applications. The analysis and solution of problems from an amazingly wide variety of disciplines depend on the theory and computational techniques of linear algebra. In turn, the diversity of disciplines depending on linear algebra also serves to focus and shape its development. Some problems have special properties (numerical, structural) that can be exploited. Some are simply so large that conventional approaches are impractical. New computer architectures motivate new algorithms, and fresh ways to look at old ones.

The pervasive nature of linear algebra in analyzing and solving problems means that people from a wide spectrum — universities, industrial and government laboratories, financial institutions, and many others — share an interest in current developments in linear algebra. This conference aims to bring them together for their mutual benefit.

The first common-interest ("birds-of-a-feather") discussion sessions proved to be popular at the 1994 conference. The feedback with respect to this innovation has been very positive, and the Organizing Committee has decided to continue it in 1997. Thus, the general format of this conference will involve plenary speakers, minisymposia, and common-interest sessions preceded by related poster displays.

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http://www.siam.org/meetings/la97/la97home.htm

Funding Agency

SIAM and the Organizing Committee would like to express their thanks and appreciation to the National Science Foundation and Department of Energy for their support in conducting this conference.

Get-Togethers

Welcoming Reception (Cash Bar)
Tuesday, October 28, 1997
6:00 PM - 8:00 PM
Golden Cliff Room

Coffee and Business Meeting
SIAM Activity Group on Linear Algebra
Saturday, November 1, 1997
5:00 PM-5:30 PM
Ballroom 3
The business meeting is open to all attendees.

Cocktails/Cash Bar
Saturday, November 1, 1997
7:00 PM-7:30 PM
Eagles Nest Room

Banquet Dinner
Guest speaker: Charles Van Loan, Cornell University

Professor Van Loan will speak about "Looking for Kronecker Products."
Saturday, November 1, 1997
7:30 PM - 9:30 PM
Golden Cliff Room
Cost: $37.50

The evening begins with a cash bar, an opportunity to review the conference and past few days activities with your colleagues. Dinner will consist of a choice of Cornish Game Hen stuffed with wild rice, or Broiled Top Sirloin with Chasseur Sauce. Vegetarian meals will be available for those with special dietary preferences. Wine will be served with dinner followed by dessert.

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A Message from the Conference Organizers ...

Dear Colleagues:

Welcome to Snowbird for the Sixth SIAM Conference on Applied Linear Algebra, sponsored by the SIAM Activity Group on Linear Algebra.

The use of linear algebra in the analysis and solution of problems is pervasive. Its use in such a wide variety of disciplines means that these meetings bring together people from a broad spectrum to discuss current developments in this extraordinarily important field.

The Organizing Committee is grateful to all who have contributed to the program: plenary speakers, minisymposia organizers and participants, and contributors to the poster and discussion sessions. The result is a rich and varied agenda, which we hope you will find stimulating and enjoyable.

Thank you all for coming to the conference.

Alan George
Chair, Organizing Committee

Organizing Committee

Alan George, Conference Chair
University of Waterloo, Canada
John R. Gilbert, SIAG/LA Program Chair
Xerox Palo Alto Research Center
Paul M. Van Dooren, SIAG/LA Chair
Université Catholique de Louvain, Belgium
Åke Björck
Linköping University, Sweden
Richard A. Brualdi
University of Wisconsin, Madison
Biswa N. Datta
Northern Illinois University
James W. Demmel
University of California, Berkeley
Nicholas M. Gould
Rutherford Appleton Laboratory, United Kingdom
Anne Greenbaum
Courant Institute of Mathematical Sciences, New York University
Nicholas J. Higham
University of Manchester, United Kingdom
Ilse Ipsen
North Carolina State University

Audiovisual Notice

Two standard overhead projectors and two screens will be provided in every meeting room. Speakers with special audiovisual equipment needs should inform SIAM of their specific requirements by Friday, October 3, 1997. If we do not hear from speakers by that date, it is understood that a standard overhead projector is all that is needed.

If a speaker sends a request for special audiovisual equipment and decides not to use the requested equipment after it has been installed, or does not show up to present his/her talk, the speaker is responsible for paying the rental fee.

Some examples of special audiovisual equipment and rental fees are

LCD Panel	$300
35mm Slide Projector	$38
Video Projector	$500
1/2" VHS VCR	$55
26" Data Monitor	$200
Shure Mixer	$50
Xenon 35mm Projector	$200

Important Notice to all Meeting Participants

Times allowed for each presentation, including questions and answers:
IP = Invited Plenary Presentations (60 minutes) MS = Minisymposium (30 minutes)

The conference organizers expect every speaker of a scheduled minisymposium presentation to register and attend the conference. If it becomes necessary for a speaker to cancel the presentation, the speaker is expected to find an alternate presenter immediately, preferably one of the speaker's co-authors. The speaker should inform the SIAM conference department of any change to his/her scheduled presentation.

Common-Interest Sessions = Is a two-hour focus session with 1/2 hour devoted to attended poster session followed by 1 1/2 hours of discussion led by the session moderator. The common-interest sessions will not involve formal presentations of results by the authors. Everyone is expected to provide a poster display as part of participating in the common-interest sessions. Poster boards will be available to put up your poster early, starting on Tuesday evening, October 28 in the room designated by the schedule. All posters will remain on display until 7:00 PM, Saturday, November 1.

For those who have asked for a poster presentation in a traditional manner, the poster session will take place 5:30 PM-7:00 PM, Saturday, November 1. Each poster presenter must be available during that entire session to present their work and interact with the attendees. If a presenter does not show up to give his/her presentation, he or she will be billed for the poster board rental that SIAM has incurred. To give attendees ample time to view your posters, poster presenters are asked to post and set up their poster displays starting on Tuesday evening, October 28 at the Ballroom Foyer. On Saturday afternoon, November 1 the poster boards will be moved to Ballroom 3 at the time designated by the schedule. Displayed materials should be removed from the poster boards at 7:00 PM immediately after the poster session is over. Any materials left on the board after that time will be removed and discarded. SIAM is not responsible for any poster displays that are left on the board at the end of the session.

For papers with multiple authors, the speaker is shown in italics if known at press time.

A "no-show" or canceled presentation can cause serious inconvenience to the attendees and conference organizers.

Tuesday, October 28

EVENING

6:00 PM-8:00 PM Registration

Room: Ballroom Foyer

6:00 PM-8:00 PM Welcoming Reception (Cash Bar)

Room: Golden Cliff

Wednesday, October 29

MORNING

7:30 AM-4:00 PM Registration

Room: Ballroom Foyer

8:20 AM Welcome Remarks and Announcements

Alan George, University of Waterloo, Canada

Room: Ballroom 3

IP1

Geometrical Approaches to the Algebraic Eigenvalue Problem

8:30 AM-9:30 AM

Chair: Ilse Ipsen, North Carolina State University

Room: Ballroom 3

Nearness of a matrix to a multiple eigenvalue is indicated by a small cosine between left and right eigenvectors, as for example is computed by MATLAB's condeig routine or the RCONDE variable in LAPACK. What can we supply the user who wishes to *exactly* obtain the nearest matrix with a multiple eigenvalue or more generally the nearest matrix (or pencil) with a particular canonical form? Such problems have been motivated from problems in systems and control, and have been studied by many experts in numerical linear algebra. We are working towards solving these problems so that the information could be available easily to users of library software.

In this talk, the speaker will indicate how new geometrical approaches are being successfully applied towards the solution of this problem. His proposed solution combines the power of a new understanding of the perturbation theory of so-called "staircase algorithms" with manifold techniques for optimization on the Grassmann and Stiefel manifolds. By way of background, the speaker will discuss how manifold approaches provide a unifying taxonomy for any eigenvalue algorithm, linear or nonlinear, involving orthogonality constraints.

The talk surveys a number of recent developments representing joint work with Arias, Demmel, Elmroth, Kagstrom, Ma, Ripper, and Smith and will consider some open problems.

Alan Edelman
Department of Mathematics
Massachusetts Institute of Technology

9:30 AM-10:00 AM Coffee

Room: Ballroom Foyer

MS1

Numerical Methods for Large Eigenvalue Problems

10:00 AM-12:00 PM

Room: Ballroom 1

The computation of a few eigenvalues and eigenvectors of a large matrix, and the corresponding computation for matrix pencils, arises in many applications in science and engineering. In recent years many new methods that do not require the factorization of a large matrix have been developed. This minisymposium presents an overview of state-of-the-art methods of this kind. Applications and parallel implementation issues will be discussed.

Organizers: Daniela Calvetti,
Stevens Institute of Technology;
Lothar Reichel,
Kent State University

10:00 An Iterative Block Method for Computing a Few Close Eigenvalues of Large Sparse Symmetric Matrix
James Baglama, Kent State University; Daniela Calvetti and Lothar Reichel, Organizers; and A. Ruttan, Kent State University

10:30 Computing Guided Waves for Optical Fibers
Richard Lehoucq, Argonne National Laboratory; and Lawrence Cowsar, Bell Laboratories, Lucent Technologies

11:00 An Implicitly Restarted QZ-Like Projection Method for Large Generalized Eigenproblems
Danny C. Sorensen, Rice University

11:30 An Iterative Algorithm for the Partial QZ Reduction of Very Large Generalized Eigenproblems
Henk A. van der Vorst, University of Utrecht, The Netherlands

MS2

Linear Algebra in Signal Processing

10:00 AM-12:00 PM

Room: Ballroom 2

Linear algebra is one of the most useful tools in signal processing. However, the stability of algorithms and the ill-conditioning of problems must be considered when solving signal processing problems on computers because of finite precision arithmetic. In this minisymposium, the speakers will consider applications of linear algebra to signal processing and investigate the stability and ill-conditioning issues that arise.

Organizer: James R. Bunch
University of California, San Diego

10:00 Stability, Finite Precision, and Adaptive Filtering in Signal Processing
Richard C. LeBorne, University of Tennessee, Chattanooga

10:30 Algorithms and Architectures for Fast Recursive Least Squares
Ian K. Proudler, Defense Evaluation and Research Agency, United Kingdom

11:00 Fast TLS Algorithm Based on the Low-Rank Revealing ULV Decomposition with Applications in MRS Data Quantification
Sabine Van Huffel and Leentje Vanhamme, Katholieke Universiteit Leuven, Belgium; and Ricardo Fierro, California State University, San Marcos

11:30 A Blind Deconvolution Method for Image Restoration
Michael K. Ng, Australian National University, Australia; Robert J. Plemmons, Wake Forest University; and *Sanzheng Qiao*, McMaster University, Canada

MS3

Combinatorial and Algebraic Matrix Theory

10:00 AM-12:00 PM

Room: Ballroom 3

Many current lines of research in matrix theory are concerned with the placement of entries in a matrix (zeros versus nonzeros, positively signed entries versus negatively signed entries, etc.). Combinatorial ideas such as graphs and digraphs have remarkable connections with several matrix theoretic concepts, e.g., nonsingularity, factorizations, eigenvalues, and determinantal maximization. Another theme involving the entries of a matrix is associating an algebraic structure with the minors of a matrix of a fixed size to give new information about

Wednesday, October 29

certain generalized inverses. Applications include qualitative properties of mathematical models and statistical design theory.

Organizer: Wayne W. Barrett
Brigham Young University

10:00 John Maybee's Contributions to Combinatorial Matrix Theory
J. Richard Lundgren, University of Colorado, Denver

10:30 D-Optimal Designs
William Watkins, California State University, Northridge

11:00 Some Remarks on Eigenvalues of Graphs
Robert Grone, San Diego State University

11:30 The Image of the Adjoint Mapping
Donald W. Robinson, Brigham Young University

AFTERNOON

12:00 PM-1:30 PM Lunch (Box Lunches in Ballroom Foyer or attendees are on their own)

IP2

The Solution of Linear Systems Arising in Interior Methods for Optimization

1:30 PM-2:30 PM

Chair: Nicholas J. Higham, University of Manchester, United Kingdom

Room: Ballroom 3

Almost all interior methods need to solve a sequence of large sparse unsymmetric linear systems in the primal and dual variables.

A common approach is to use block elimination to derive a symmetric reduced system that is positive semidefinite (at least at a solution).

The speaker will focus on alternative approaches that solve a symmetric indefinite system that is larger than the reduced system while being more sparse.

Philip E. Gill
Department of Mathematics
University of California, San Diego

2:30 PM-3:00 PM Coffee
Room: Ballroom Foyer

MS4

Recent Developments in Eigenvalue Perturbation Theory and Algorithms (Part I of II)

3:00 PM-5:00 PM

Room: Ballroom 1

Eigenvalues and eigenvectors are one of the central concerns in numerical linear algebra. There has been a lot of recent work in eigenvalue perturbation theory and accurate algorithms. A common thread linking much of this work is the realization that it is possible to obtain much more accurate results and tighter bounds that was thought possible. The speakers in this minisymposium will discuss perturbation theory for eigenvalues and eigenvectors—in particular techniques for obtaining stronger and more precise perturbation bounds and how these improved perturbation bounds can be exploited to derive more accurate and faster algorithms for computing eigenvalues and eigenvectors. They will consider tridiagonal, full, structured and unstructured, symmetric and non-symmetric matrices.

Organizer: Roy Mathias
College of William & Mary

3:00 Spectral Variation for Diagonalizable Matrices
Ren-Cang Li, University of Kentucky; Rajendra Bhatia, Indian Statistical Institute, India; and Fuad Kittaneh, University of Jordan, Jordan

3:30 On the Lidskii-Mirdky-Wielandt Theorem
Chi-Kwong Li, College of William & Mary; and Roy Mathias, Organizer

4:00 First Order Eigenvalue Perturbation Theory and the Newton Diagram
Julio Moro, Universidad Carlos III, Spain; James V. Burke, University of Washington; and Michael L. Overton, New York University

4:30 When Are Factors of Indefinite Matrices Relatively Robust?
Inderjit Dhillon and *Beresford Parlett*, University of California, Berkeley

MS5

Advances in Sparse Matrix Reorderings

3:00 PM-5:00 PM

Room: Ballroom 2

Sparse systems of linear equations arise in a large variety of scientific and engineering applications. Sparsity preservation is crucial in solving such linear systems using matrix factorizations as fill occurs during the computation. The speakers in this minisymposium will discuss recent work on developing robust and efficient ordering algorithms for sparse matrix factorizations. The effectiveness of direct methods for solving linear systems is affected by the initial ordering of the rows and/or columns of the coefficient matrix. For symmetric matrices, the most popular fill-reducing ordering algorithms are minimum degree and nested dissection. Minimum degree is a greedy heuristic. Although it is effective on most problems, there are instances for which minimum degree can perform poorly. Simple nested dissection heuristics are fast, but typically less effective for unstructured problems. For nonsymmetric matrices, little ordering work has been done.

Organizer: Esmond G. Ng
Oak Ridge National Laboratory

3:00 Practical Extensions of the Multisection Ordering for Sparse Matrices
Cleve Ashcraft, Boeing Information and Support Services; Stanley C. Eisenstat, Yale University; and Joseph W. H. Liu, York University, Canada

3:30 Multilevel Graph Partitioning and Nested Dissection
George Karypis, University of Minnesota, Minneapolis

4:00 Performance of Greedy Ordering Heuristics for Sparse Cholesky Factorization
Esmond G. Ng, Organizer; and *Padma Raghavan*, University of Tennessee, Knoxville

4:30 A Column Approximate Minimum Degree Ordering Algorithm
Timothy A. Davis, University of Florida; John R. Gilbert, Xerox Palo Alto Research Center; Esmond G. Ng, Organizer; and Barry W. Peyton, Oak Ridge National Laboratory

5:00 PM-5:30 PM Coffee
Room: Ballroom Foyer

EVENING

Common Interest Session 1

Data Fitting, Regularization and Related Problems

5:30 PM-7:30 PM

Moderator: Paul M. Van Dooren, Université Catholique de Louvain, Belgium

Room: Ballroom 2

Fast Iterative Image Restoration with a Space-Variant Blur
James G. Nagy, Southern Methodist University; and Dianne P. O'Leary, University of Maryland, College Park

Wednesday, October 29

Subspace-based Exponential Data Modeling using Prior Knowledge
Sabine Van Huffel, Katholieke Universiteit Leuven, Belgium; and Hua Chen, Eindhoven University of Technology, The Netherlands

A Dynamic Method for Weighted Linear Least Squares Problems
Xinyuan Wu, Nanjing University, People's Republic of China; Hongwei Wu, Southeast University, People's Republic of China; and Zixiang Ouyang, Nanjing University, People's Republic of China

Information Filtering Using the Riemannian SVD
Eric Jiang and Michael W. Berry, University of Tennessee, Knoxville

Efficient Modifications of the CG Method for Tikhonov-Phillips Regularization
Andreas Frommer, Bergische Universität Wuppertal, Germany; and Peter Maab, Universität Potsdam, Germany

Optimal Partitions and Clustering
Christopher Marron and Joseph McCloskey, National Security Agency, Fort George G. Meade, Maryland

Common Interest Session 2

Non-Hermitian Eigenvalue Problems

5:30 PM-7:30 PM

Moderator: Youcef Saad, University of Minnesota, Minneapolis

Room: Ballroom 1

Structured Backward Error and Condition of Generalized Eigenvalue Problems
Desmond J. Higham, University of Strathclyde, Scotland; *Nicholas J. Higham*, University of Manchester, United Kingdom

On the Perturbation Theory for the Unitary Eigenvalue Problem
B. Bohnhorst, Schmidt, Vogel und Partner, Gesellschaft für Organisation, und Management Beratung mbH, Germany; *A. Bunse-Gerstner* and Heike Fabbender, Universität Bremen, Germany

Nearly-Defective Eigenvalues in Finite Precision
Raffaella Pavani, Politecnico di Milano, Italy

A Formula for Computation of a Distance to Flutter
Alexander Malyshev, University of Bergen, Norway

A Supplement to the Ky Fan Trace Inequality for Singular Values
Hector F. Miranda, Universidad del Bio-Bio, Chile

Truncated Singular Value Decompositions for Non-Hermitian Matrices
Karl Meerbergen, LMS Numerical Technologies, Belgium

Implicitly Filtering the Rational Krylov Method
Gorik De Samblanx, Katholieke Universiteit Leuven, Belgium; Karl Meerbergen, LMS Numerical Technologies, Belgium; Adhemar Bultheel, Katholieke Universiteit Leuven, Belgium

Structure-preserving Jacobi Methods for Doubly-structured Matrices
Niloufer Mackey, Western Michigan University; D. Steven Mackey, State University of New York, Buffalo, Buffalo; and Heike Fabbender, Universität Bremen, Germany

On the Second Real Eigenvalue of Nonnegative and Z-Matrices
Shmuel Friedland, University of Illinois at Chicago and *Reinhard Nabben*, Universität Bielefeld, Germany

7:30 PM Dinner (attendees are on their own)

Thursday, October 30

MORNING

8:00 AM-4:00 PM Registration
Room: Ballroom Foyer

IP3

Doubly Stochastic Matrices: Theory and Application

8:30 AM-9:30 AM

Chair: Paul M. Van Dooren, Université Catholique de Louvain, Belgium

Room: Ballroom 3

The speaker will highlight the development of the theory and application of doubly stochastic matrices, in particular, the connection with majorization of vectors. He will concentrate on the fifty years since Birkhoff (in 1946) proved his famous theorem.

Richard A. Brualdi
Department of Mathematics
University of Wisconsin, Madison

9:30 AM-10:00 AM Coffee
Room: Ballroom Foyer

MS6

Positive Semidefinite Matrices and Hermitian Matrices

10:00 AM-12:00 PM

Room: Ballroom 1

Positive semidefinite and Hermitian (or symmetric) matrices have been intensively studied because of their attractive properties and their many applications, e.g., optimization, statistics, and discrete schemes for the solution of differential equations. This minisymposium will explore the developing area of semidefinite programming, extensions and refinements of themes in the subject of Hermitian matrices such as eigenvalues of principal submatrices and diagonalization by congruence, and a cone of inequalities associated with the positive semidefinite matrices.

Organizer: Wayne W. Barrett
Brigham Young University

10:00 The Gauss-Newton Direction for Interior-Point Methods in Linear and Semidefinite Programming
Henry Wolkowicz, University of Waterloo, Canada

10:30 Eigenvalue Multiplicities in Principal Submatrices
Brenda K. Kroschel, Macalester College

Thursday, October 30

11:00 Congruence of Polynomial Matrices
Stephen Pierce, San Diego State University

11:30 The Cone of Class Function Inequalities for Positive Semidefinite Matrices
Wayne W. Barrett, Organizer; Raphael Loewy, Technion-Israel Institute of Technology; Israel; and H. Tracy Hall, Brigham Young University

MS7

Linear Algebra and Control

10:00 AM-12:30 PM

Room: Ballroom 2

(This session will run until 12:30 PM.)

This minisymposium focuses on the interaction between linear algebra (both theory and numerics) and the application area of systems and control. This interdisciplinary area of research has grown steadily in the last few decades. The speakers in this minisymposium present some of its latest developments.

Organizer: Paul Van Dooren
Université Catholique de Louvain, Belgium

10:00 A Jacobi-Like Method for Solving the Hamiltonian Eigenproblem (On Parallel Computers)
Heike Faßbender and Angelika Bunse-Gerstner, Universität Bremen, Germany

10:30 Reduced Order Simulation of Nonlinear Systems
Marlis Hochbruck and Christian Lubich, Universität Tübingen, Germany

11:00 Perturbation Theory for the Pole Placement Problem
Volker Mehrmann and Hongguo Xu, Fachbereich Mathematik, Germany

11:30 Inertia Theorems, Bezoutians, and Stability Bounds of Operator Polynomials
Leiba Rodman, College of William & Mary; and Leonid Lerer, Technion-Israel Institute of Technology, Israel

12:00 On Stability Radii of Generalized Eigenvalue Problems
Paul Van Dooren, Organizer; and *V. Vermaut*, Université Catholique de Louvain, Belgium

MS8

Fast and Superfast Toeplitz Solvers

10:00 AM-12:00 PM

Room: Ballroom 3

Toeplitz systems arise in a variety of applications in mathematics and engineering, including signal processing, adaptive filtering, circuit simulations, geodesy, partial differential equations, Padé approximations, minimal realizations, and many others. From the practical standpoint it is important to exploit the structure of these systems to design special efficient algorithms which compute the solution rapidly and without loss of numerical accuracy. There are two classical fast algorithms, the Levinson and the Schur algorithms which exploit the structure to solve a Toeplitz system in only $O(n^2)$ arithmetic operations (general algorithms are slower, requiring $O(n^3)$). The purpose of this minisymposium is to report a recent progress in the design of superfast accurate methods which require even less, $O(n \log^2 n)$ operations. The presentations will cover both direct and iterative superfast methods, multigrid and splitting approaches; they will pay attention to both efficiency (speed, memory, amenability to parallel implementations) and numerical accuracy.

Organizer: Georg Heinig,
Kuwait University, Kuwait;

and Vadim Olshevsky,
Stanford University

10:00 Superfast Algorithms for Positive Definite Toeplitz Systems
Gregory S. Ammar, Northern Illinois University

10:30 Practical Multigrid Methods for Toeplitz Matrices
Thomas K. Huckle, Institut für Informatik, TU München, Germany

11:00 Displacement Structure Approach to Discrete Transform Based Preconditioners of G. Strang and T. Chan Types
Vadim Olshevsky, Organizer

11:30 The Splitting Approach for Real Based Superfast Toeplitz Solvers
Georg Heinig, Organizer

AFTERNOON

12:00 PM-1:30 PM Lunch (Box Lunches in Ballroom Foyer or attendees are on their own)

IP4

Schur-type Methods for Toeplitz Structured Problems

1:30 PM-2:30 PM

Chair: Åke Björck, Linköping University, Sweden

Room: Ballroom 3

Fast algorithms based on generalizations of the classical Schur algorithm, for solving least squares problems with Toeplitz structure, are discussed. Such methods are potentially very fast, but they may suffer from stability problems, when the matrix is ill-conditioned. The speaker will give an overview of generalized Schur methods, and discuss their stability properties. Postprocessing methods that can be used in order to obtain a more accurate solution will be presented. Some numerical tests will also be reported, where different variants of the generalized Schur algorithm and other fast methods for Toeplitz least squares and Toeplitz linear systems will be compared for their accuracy and speed. (Joint work with Lars Elden, Linköping University, Sweden).

Haesun Park
Computer Science Department
University of Minnesota, Minneapolis

2:30 PM-3:00 PM Coffee

Room: Ballroom Foyer

MS9

Matrix Functions

3:00 PM-5:00 PM

Room: Ballroom 2

Functions of matrices arise in many areas of scientific computation. The exponential is intimately associated with the solution of differential equations and the logarithm arises in corresponding inverse problems. The square root of a matrix is a useful theoretical tool and needs to be computed in some applications. The speakers in this minisymposium will describe recent progress on the theory of matrix functions and on their numerical computation. They will give an overview of recent progress in the theory and computation of matrix functions. They will not assume prior knowledge of research in this area.

Organizer: Nicholas J. Higham
University of Manchester, United Kingdom

3:00 Stable Iterations for the Matrix Square Root
Nicholas J. Higham, Organizer

3:30 A Chain Rule for Matrix Functions
Roy Mathias, College of William & Mary

4:00 Schur-Fréchet Algorithms for Matrix Functions
Charles S. Kenney, University of California, Santa Barbara; and Alan J. Laub, University of California, Davis

4:30 Logarithms of Matrices and Applications
Luca Dieci, Georgia Institute of Technology; and Benedetta Morini, Alessandra Papini, and Aldo Pasquali, University of Florence, Italy

Thursday, October 30

MS10

Sparse Approximate Inverse Preconditioners (Part I of II)

3:00 PM-5:00 PM

Room: Ballroom 1

Recently, renewed interest in sparse approximate inverse preconditioners (SAIP) has emerged. The motivation for the renewed interest is largely from parallel processing. Many new techniques and results have been proposed in recent years for identifying an effective sparsity pattern of the approximation. The new insight to this "old" idea has offered new promise. Some difficult problems can be effectively solved using these new techniques. In this minisymposium, some of the leading experts in this field discuss new results and challenging problems. To construct a good, but sparse approximation depends on the sparsity pattern and initial approaches failed to provide a robust technique to determine an effective sparsity pattern. To reduce the cost of preconditioning, the sparse approximation has to be as sparse as possible. Unfortunately, this goal has to be balanced with the quality of the preconditioner since the inverse in general is a dense matrix. The search for an optimal sparsity pattern would be a much more expensive proposition than the solution itself. Effective heuristics are required and many open problems still remain to be resolved.

Organizer: Wei-Pai Tang
University of Waterloo, Canada

3:00 New Techniques and Applications for Approximate Inverse Preconditioning
Edmond Chow and Yousef Saad, University of Minnesota, Minneapolis

3:30 Ordering Techniques for Sparse Approximate Inverse Preconditioning
Robert E. Bridson, University of Waterloo, Canada; and Wei-Pai Tang, Organizer

4:00 A Comparative Study of Sparse Approximate Inverse Preconditioners
Michele Benzi, Los Alamos National Laboratory; and Miroslav Tuma, Czech Academy of Sciences, Czech Republic

5:00 PM-5:30 PM Coffee

Room: Ballroom Foyer

EVENING

Common Interest Session 3

Direct Methods for Systems of Equations

5:30 PM-7:30 PM

Moderator: Joseph W. H. Liu, York University, Canada

Room: Ballroom 2

Modifying a Sparse Cholesky Factorization
Timothy A. Davis and William W. Hager, University of Florida

Kalman Filters and the Global Positioning System (GPS)
Gilbert Strang, Massachusetts Institute of Technology; and Steven L. Lee, Oak Ridge National Laboratory

How Sparse Can a Matrix with Orthogonal Rows Be?
Gi-Sang Cheon, Dae Jin University, Korea; and *Bryan L. Shader*, University of Wyoming

The Object-Oriented Design of a Family of Direct Solvers
Florin Dobrian and Gary Kumfert, Old Dominion University; and Alex Pothen, Old Dominion University and ICASE, NASA Langley Research Center

The Minimum Degree Family of Algorithms for Indefinite Problems: A Rigorous C++ Implementation
Gary Kumfert and Florin Dobrian, Old Dominion University; and Alex Pothen, Old Dominion University and ICASE, NASA Langley Research Center

Efficient Computation of Incomplete Factorization Preconditioners
David A. Hysom, Old Dominion University; and Alex Pothen, Old Dominion University and ICASE, NASA Langley Research Center

Common Interest Session 4

Applications and Computation of the Singular Value Decomposition

5:30 PM-7:30 PM

Moderator: Volker Mehrmann, Technische Universität Chemnitz-Zwickau, Germany

Room: Ballroom 1

On Approximate Construction of Projections onto Invariant Subspaces of Matrices
Gennadii V. Demidenko, Siberian Branch of Ruissian Academy of Sciences, Russia

Complete System of Structural Invariants of Linear Multivariable Systems
M. Isabel Garcia-Planas, Universitat Politecnica de Catalunya, Spain

Successive Matrix Squaring Algorithm for Computing the Weighted Moore-Penrose Inverse $A^{\dagger}_{M,N}$
Yimin Wei, Fudan University, People's Republic of China

A Comparison of Parallel Linear Algebra Libraries for the Implementation of the Product SVD
Zlatko Drmac and *Elizabeth R. Jessup*, University of Colorado, Boulder

A Recursive Method to Invert Laplace Transformed Matrix
Marco Tullio de Vilhena and *Cynthia Feijo Segatto*, Universidade Federal do Rio Grande do Sul, Brazil

A Stable Block Diagonalization Method: Application to the Spectral Portrait of Matrices and Matrix Pencils
P. F. Lavalle and M. Sadkane, IRISA-INRIA, Campus Universitaire de Beaulieu, France

7:30 PM Dinner (attendees are on their own)

Friday, October 31

MORNING

8:00 AM-4:00 PM Registration
Room: Ballroom Foyer

IP5

Robust Parallel Algorithms for Sparse Symmetric Eigen Applications

8:30 AM-9:30 AM

Chair: John R. Gilbert, Xerox Palo Alto Research Center

Room: Ballroom 3

As the power of our computers grows, so generally does our appetite for more accurate solutions to ever harder problems. In the arena of sparse symmetric eigenproblems, the size of problems solved routinely in commercial settings has grown over the last decade from finding perhaps ten eigenpairs of order ten thousand matrices to finding thousands of eigenpairs of generalized symmetric eigenproblems of several millionth order.

This talk will focus on three important characteristics of these problems and their potential solutions:
(1) the potential deleterious effects of size on guarantees, robustness and computational feasibility; (2) the characteristics of algorithms that have been proposed or are being used for these eigenproblems; and (3) the need to adapt our mathematics to today's and tomorrow's computer architectures and programming paradigms, without which we will not have sufficient cycles to solve these problems.

These problems are being solved to build products that you and I will buy or use. The solutions to these problems improve the products or ensure their safety; we have a stake in the solutions. Can we, in fact, get them right in a reasonable amount of time? Can we package our mathematics so that commercial vendors will use our work?

John G. Lewis
Boeing Information and Support Services
The Boeing Company

9:30 AM-10:00 AM Coffee
Room: Ballroom Foyer

MS11

Accurate Computation of Eigenproblems

10:00 AM-12:00 PM

Room: Ballroom 1

We want to compute eigenvalues and invariant subspaces of Hermitian (and more generally: normal) matrices accurately. The ultimate goal is highly accurate and efficient numerical software. In the context of floating point computations we attain high accuracy by bounding relative rather than absolute eigenvalue errors, and by expressing invariant subspace bounds in terms of relative rather than absolute eigenvalue separations. Because of the close connection to Hermitian eigenvalue problems, we also discuss the computation of singular values and singular vector subspaces.

Organizer: Ilse C. F. Ipsen
North Carolina State University

10:00 On the Eigenvalues of Indefinite Matrices
Kresimir Veselic, Fernuniversität Hagen, Germany; Z. Drmac, University of Colorado, Boulder; and Striko E. Kovac, University of Zagreb, Croatia

10:30 Relative Perturbation Bounds for Eigenvalues and Eigenvectors of Indefinite Hermitian Matrices
Ninoslav Truhar, University Josip Juraj Strossmayer, Croatia; and Ivan Slapnicar, University of Split, Croatia

11:00 Relative Error Bounds for Eigenvalues of Normal Matrices
Ilse C.F. Ipsen, Organizer

11:30 More Accurate Bidiagonal Reduction for Computing the Singular Value Decomposition
Jesse L. Barlow, The Pennsylvania State University

MS12

Linear Algebra for Ill-Posed Problems and Image Processing

10:00 AM-12:00 PM

Room: Ballroom 2

Many problems in science and engineering are concerned with the determination of the internal structure of a system from exterior measurements. These problems typically are ill-posed. Their discretization can give rise to large severely ill-conditioned linear or nonlinear systems of equations. The computation of a meaningful approximate solution in the presence of errors in the data requires regularization. Recently, the development of special iterative methods for determining a regularized approximate solution of large-scale discrete ill-posed problems has received considerable attention, in particular for image processing applications. The purpose of this minisymposium is to present an overview of state-of-the-art methods for the numerical solution of ill-posed problems with particular emphasis on the linear algebra involved.

Organizer: Daniela Calvetti,
Stevens Institute of Technology;

and Lothar Reichel,
Kent State University

10:00 Efficient Algorithms for Least-squares Type Problems
Gene H. Golub, Stanford University

10:30 A Regularizing Lanczos Iteration for Underdetermined Linear Systems
Daniela Calvetti and Lothar Reichel, Organizers; and F. Sgallari and G. Spaletta, Università di Bologna, Italy

11:00 Numerical Linear Algebra and Constrained Deconvolution
Curtis R. Vogel, Montana State University; and James G. Nagy, Southern Methodist University

11:30 A Modular Solver for Constrained Regularization Problems in Image Restoration
Tony F. Chan and Peter Blomgren, University of California, Los Angeles

MS13

Indefinite Inner Products (Part I of II)

10:00 AM-12:00 PM

Room: Ballroom 3

This minisymposium will highlight recent advances in the area of indefinite inner product in finite dimensional real and complex spaces, with emphasis on numerous recent applications. The applications include gyroscopic systems, transport equations, Schur-type algorithms, de Branges spaces on Riemann surfaces, factorization problems, state space description of linear time invariant systems with symmetries, and H-infinity (worst case) control.

Organizer: Leiba Rodman
College of William & Mary

10:00 Backward Shift-Invariant Finite Dimensional Reproducing Kernel Spaces: From the Disk to Compact Riemann Surfaces
Daniel Alpay, Ben Gurion University of the Negev, Israel

Friday, October 31

10:30 Stability of Nonnegative Invariant Subspaces of H-Accretive Matrices and Applications to Stationary Transport Equations
Cornelis V. M. Van der Mee, Università di Cagliari, Italy; Andre C. M. Ran, Vrije Universiteit Amsterdam, The Netherlands; and Leiba Rodman, Organizer

11:00 Extensions and Factorizations on Indefinite Metric Spaces
Tiberiu Constantinescu, University of Texas, Dallas; and Aurelian Gheondea, Institute of Mathematics, Romania

11:30 Rate of Stability of Symmetric Factorizations
Andre C. M. Ran, Vrije Universiteit Amsterdam, The Netherlands; and *Leiba Rodman*, Organizer

AFTERNOON

12:00 PM-1:30 PM Lunch (Box Lunches in Ballroom Foyer or attendees are on their own)

IP6

Second Generation Wavelets: Theory and Applications

1:30 PM-2:30 PM

Chair: John G. Lewis, Boeing Information and Support Services, The Boeing Company

Room: Ballroom 3

In the last decade wavelets have been applied successfully to sound (1D), image (2D), and video (3D) processing. Typical applications include compression, noise reduction, progressive transmission, etc. Each time the data is defined on an Euclidean space R^n and sampled on a regular grid.

Many applications, however, need wavelets defined on general geometries (curves, surfaces, manifolds), wavelets adjusted to irregular sampling, or adaptive wavelet transforms. Therefore we introduce Second Generation Wavelets: wavelets which are not necessarily translates and dilates of one function, but still enjoy all powerful properties such as time-frequency localization, multiresolution, and fast algorithms.

While the Fourier transform has been the principal tool in constructing classical wavelets, e.g., Daubechies, it can no longer be used to build Second Generation Wavelets. We present the lifting scheme, an entirely spatial construction technique for Second Generation Wavelets.

The speaker will give examples how lifting can be used to build wavelets for irregular samples, spherical wavelets, and multiresolution geometry. He will also show that all classical wavelets can be obtained through lifting, that lifting speeds up the fast wavelet transform by a factor of two, and that lifting allows for integer-to-integer wavelet transforms which are important in lossy compression. (P.S.: No preliminary knowledge of wavelets will be assumed.)

Wim Sweldens
Bell Laboratories, Lucent Technologies

2:30 PM-3:00 PM Coffee
Room: Ballroom Foyer

MS14

Recent Developments in Eigenvalue Perturbation Theory and Algorithms (Part II of II)

3:00 PM-5:00 PM

Room: Ballroom 1

(For description, see Part I, MS4).

Organizer: Roy Mathias
College of William & Mary

3:00 Computing the Singular Value Decomposition with High Relative Accuracy
Ming Gu, University of California, Los Angeles; James Demmel, University of California, Berkeley; Stanley Eisenstat, Yale University; Zlatco Drmac, University of Colorado, Boulder; Kresimir Veselic, Fernuniversität Hagen; and Ivan Slapnicar, University of Split, Croatia

3:30 What Does it Mean for Hermitian Eigenvalue Problem to be Well-Behaved?
Jesse L. Barlow, Pennsylvania State University; and Ivan Slapnicar, University of Split, Croatia

4:00 On Accurate Algorithms for Canonical Correlations, Weighted Least Squares and Related Generalized Eigenvalue and Singular Value Decompositions
Zlatko Drmac, University of Colorado, Boulder

4:30 The Fundamental Role of Weyl's and Ostrowskii's Inequalities
Roy Mathias, Organizer

MS15

The Multilevel Method

3:00 PM-5:00 PM

Room: Ballroom 2

The multilevel method has emerged as one of the most effective methods for solving numerical and combinatorial problems. It has been used in multigrids, domain decomposition, geometric search structures, as well as optimization algorithms for problems such as partitioning and sparse-matrix ordering. The multilevel method is a class of algorithmic techniques for solving computational and optimization problems. The trademark of these techniques is that in the solution of a problem P, we define a hierarchical set of problems $P_0 = P, P_1, ..., P_L$, where P_i is in some sense a coarser approximation of P_{i-1}. The basic strategy is to find the solution for P_L first and then, level by level, construct the solution of P_{i-1} from that of P_i. The research directions of multilevel methods are to find effective methods for coarsening, recognize the class of problems that can be solved efficiently by multilevel methods.

The speakers will discuss algorithms and numerical issues for unstructured meshes, geometric techniques for provably good coarsening and applications in combinatorial optimization

Organizer: Shang-Hua Teng
University of Illinois, Urbana-Champaign and University of Minnesota, Minneapolis

3:00 Multilevel Domain Decomposition for Unstructured Meshes
Susie Go and *Tony F. Chan*, University of California, Los Angeles

3:30 Optimal Good Aspect - Ratio Coarsening for Unstructured Meshes
Gary L. Miller, and *Dafna Talmor*, Carnegie Mellon University; and Shang-Hua Teng, Organizer

4:00 Multilevel Algorithms for Combinatorial Problems
Bruce Hendrickson, Sandia National Laboratories, Albuquerque; and Erik G. Boman, Stanford University

4:30 Coarsening, Sampling, and Smoothing: Elements of the Multilevel Method
Shang-Hua Teng, Organizer

5:00 PM-5:30 PM Coffee
Room: Ballroom Foyer

EVENING

Common Interest Session 5

Iterative Methods and Preconditioning

5:30 PM-7:30 PM

Moderator: Tony F. Chan, University of California, Los Angeles

Room: Ballroom 3

Conditions for Convergence and Comparison for Matrix Splittings
Zbigniew I. Woznicki, Institute of Atomic Energy, Poland

Friday, October 31

Variational/Algebraic Finite-Difference Analysis of the Incremental Unknowns Preconditioner
Salvador Garcia, Universidad de Talca, Talca, Chile

Parallel Domain Decomposition Preconditioning for Casting Process Simulation on 3D Unstructured Meshes
John A. Turner, Los Alamos National Laboratory; Robert C. Ferrell, Cambridge Power Computing Associates, Ltd., Brookline, Massachusetts; and D. B. Kothe, Los Alamos National Laboratory

Orderings for Incomplete LU Factorization Preconditioners
Michele Benzi, Los Alamos National Laboratory; *Daniel B. Szyld*, Temple University; and Arno van Duin, Leiden University, The Netherlands

SEAM: Spectral Embedding for Algebraic Multilevel
Shang-Hua Teng and Andreas Stathopoulos, University of Minnesota, Minneapolis

Common Interest Session 6

Core Algebra Topics

5:30 PM-7:30 PM

Moderator: Richard Brualdi, University of Wisconsin, Madison

Room: Ballroom 2

The Algebraic Fourier Transformation
Stephen R. Gerig, Envirospace Software Research, Venice, Florida

Controlling a Controllable System with the Least Number of Inputs
Vishwesh Kulkarni and S.D. Agashe, University of Southern California

Using Alternating Projections (POCS) on Nonconvex Sets
Caroline N. Haddad, State University of New York, Geneseo

Linear Algebra for Large Nonlinear Algebra Over the Reals
J. Maurice Rojas, Massachusetts Institute of Technology

Common Interest Session 7

Hermitian Eigenvalue Problems

5:30 PM-7:30 PM

Moderator: John G. Lewis, Boeing Information and Support Services, The Boeing Company

Room: Ballroom 1

Extended Krylov Subspaces Reduction for Solutions of Elliptic and Parabolic PDE's
Vladimir Druskin, Schlumberger-Doll Research; and Leonid Knizhnerman, Central Geophysical Expedition, Russia

Parallelizing the Divide and Conquer Algorithm for the Symmetric Tridiagonal Eigenvalue Problem
Francoise Tisseur and Jack Dongarra, University of Tennessee, Knoxville

Iterative Determination of Vibrational Energy Levels of Four-Atom Molecules
Richard Lehoucq and Stephen Gray, Argonne National Laboratory

The Group Homotopy Method For Symmetric Matrices
Karabi Datta and Yoopyo Hong, Northern Illinois University; and Ran Lee, Honam University, Korea

Large Sparse Symmetric Eigenvalue Problems with Homogeneous Linear Constraints: The Lanczos Process with Inner-Outer Iterations
Hongyuan Zha, Pennsylvania State University

Accelerating the Lanczos Algorithm via Polynomial Spectral Transformations
Danny C. Sorensen and *C. Yang*, Rice University

Computing the Smallest Eigenvalue of a Symmetric Positive Definite Toeplitz Matrix
Nicola Mastronardi, Università della Basilicata, Italy

A Subspace Preconditioning Algorithm for Eigenvector/Eigenvalue Computation
Andrew Knyazev, University of Colorado, Denver

Eigenvalue Solvers for Electromagnetic Fields in Cavities
Stefan Adam, Paul-Scherrer-Institute, Switzerland; *Peter Arbenz* and Goman Geus, Swiss Federal Institute of Technology, Switzerland

Saturday, November 1

MORNING

8:00 AM-2:00 PM Registration

Room: Ballroom Foyer

IP7

Lifting the Curse on the Hamiltonian and Symplectic Eigenproblem

8:30 AM-9:30 AM

Chair: James W. Demmel, University of California, Berkeley

Room: Ballroom 3

A new method is presented for the computation of the generalized eigenvalues and the stable invariant subspaces of real Hamiltonian or symplectic pencils and matrices. Simultaneously this method can be used to obtain the stabilizing solutions of the continuous-time and discrete-time algebraic Riccati equation. These problems are of great importance in the solution of optimal control and H-infinity control problems.

The new method that we propose is numerically backwards stable, has complexity $O(n^3)$ and uses the Hamiltonian or symplectic structure to a maximum extend and in this sense solves the open problem known as Van Loan's curse.

The main ingredients for the new approach are the relationship between the invariant subspaces of a Hamiltonian matrix H and the extended matrix $\left[\begin{smallmatrix} 0 & H \\ H & 0 \end{smallmatrix}\right]$ and the symplectic URV-decomposition. (This is joint work with P. Benner and H. Xu.)

Volker Mehrmann
Fakultat für Mathematik
Technische Universität Chemnitz-Zwickau, Germany

9:30 AM-10:00 AM Coffee

Room: Ballroom Foyer

MS16

Unsymmetric Eigenvalue Alternatives

10:00 AM-12:30 PM

Room: Ballroom 1

Alternatives to reduction to Hessenberg form followed by QR iteration for computing eigenvalues of dense matrices will be described. A few methods take advantage of methods which do not destroy band structure after reduction to tridiagonal, striped tridiagonal or banded Hessenberg form.

Saturday, November 1

Modified Lanczos reduction with improved efficiency for solution of sparse systems will also be presented.

Organizer: Eugene L. Wachspress
Retired, Windsor, CA

10:00 Gaussian Reduction to Similar Hessenberg or Banded Hessenberg Form
Gary W. Howell, Florida Institute of Technology

10:30 Calculating Eigenvalues of Large Matrices using the BR Algorithm
David S. Watkins, Washington State University; Gary W. Howell, Florida Institute of Technology; and G. A. Geist, Oak Ridge National Laboratory

11:00 Striped Tridiagonal Eigenvalue Algorithms
Eugene L. Wachspress, Organizer

11:30 Parallel QR Reduction of Large Systems
Greg Henry, Intel

12:00 Reduction of Systems to Fishbone Form
Jianxun He, KLA Instruments Corporation, San Jose; and Beresford Parlett, University of California, Berkeley

MS17
Lanczos-Type Methods

10:00 AM-12:00 PM

Room: Ballroom 2

Among the iterative methods for solving large linear systems or eigenvalue problems with a sparse nonsymmetric matrix, those that are based on the Lanczos process feature low computational cost and low memory requirements.In the last ten years much progress has been made regarding new, faster converging algorithms, avoiding breakdowns by look-ahead, understanding other stability problems, and taking appropriate measure to avoid or reduce them. New related results for the symmetric case are also of high relevance. In this minisymposium, the speakers will present some of the most recent findings. The presentations should be of interest to a wide audience of people applying or investigating iterative methods.

Organizer: Martin H. Gutknecht
ETH-Zentrum, Switzerland

10:00 On the Role of the Left Starting Vector in the Nonsymmetric Lanczos Algorithm
Anne Greenbaum, Courant Institute of Mathematical Sciences, New York University

10:30 Look-Ahead Lanczos Revisited
Martin H. Gutknecht, Organizer; and *Marlis Hochbruck*, Universität Tübingen, Germany

11:00 The Main Effects of Rounding Errors in Krylov Solvers for Symmetric Linear Systems
Gerard Sleijpen and *Henk van der Vorst*, University of Utrecht, The Netherlands; and Jan Modersitzki, Medical University of Lübeck, Germany

11:30 Residual Smoothing: Does it Help at All?
Martin H. Gutknecht, Organizer

AFTERNOON

12:00 PM-1:30 PM Lunch (Box Lunches in Ballroom Foyer or attendees are on their own)

Award and Presentation
The SIAM Activity Group on Linear Algebra Prize

1:30 PM-2:30 PM

Winner to be announced

Chair: Biswa N. Datta, Northern Illinois University

Room: Ballroom 3

2:30 PM-3:00 PM Coffee

Room: Ballroom Foyer

MS18
Innovations in Teaching Applied and Numerical Linear Algebra

3:00 PM-5:00 PM

Room: Superior A

In recent years there has been a great deal of effort to improve linear algebra education. Much of this activity has been stimulated by the recommendations of the Linear Algebra Curriculum Study Group and the activities of the ATLAST Project which has conducted sixteen faculty workshops. The result of these efforts has been a number of significant innovations in the teaching of linear algebra courses. This minisymposium will focus on recent trends in teaching linear algebra, the use of software in teaching linear algebra, and the teaching of numerical linear algebra. The Linear Algebra Curriculum Study Group and the ATLAST have organized many sessions on innovations in teaching linear algebra at national conferences. The ATLAST Project workshops have helped over 400 faculty to learn to use software in their linear algebra courses. The project has also developed a large database of software and course materials for teaching linear algebra. The minisymposium will focus on recent trends in teaching linear algebra, the use of software in teaching linear algebra, and the teaching of numerical linear algebra.

Organizers: Steven J. Leon,
University of Massachusetts, Dartmouth;

and David C. Lay,
University of Maryland, College Park

3:00 Recent Trends in Teaching Linear Algebra
David C. Lay, Organizer

3:30 Using Software to Teach Linear Algebra
Steven J. Leon, Organizer

4:00 Teaching of Algorithms in Classrooms
Biswa Nath Datta, Northern Illinois University

4:30 Teaching Numerical Linear Algebra to Undergraduates
James R. Bunch, University of California, San Diego

MS19
Sparse Approximate Inverse Preconditioners (Part II of II)

3:00 PM-5:00 PM

Room:Superior B

(For description, see Part I, MS10).

Organizer: Wei-Pai Tang
University of Waterloo, Canada

3:00 Sparse Approximate Inverses and Multigrid Methods
Thomas Huckle, Technical University of Munich, Germany

3:30 Wavelet Sparse Approximate Inverse Preconditioners
Tony F. Chan, University of California, Los Angeles; Wei-Pai Tang, Organizer; and *Wing-Lok Wan*, University of California, Los Angeles

4:00 Sparse Approximate Inverses and Factorized Sparse Approximate Inverses
L. Lolotilina, A. Nikishin, and *A. Yeremin*, Russian Academy of Sciences, Russia

4:30 Parallel Implementation of Factorised Sparse Approximate Preconditioner for Large Structural Analysis Problems
Martyn R. Field, Trinity College, Ireland

Saturday, November 1

MS20

Indefinite Inner Products (Part II of II)

3:00 PM-5:00 PM

(For description, see Part I, MS13.)

Room: Maybird

Organizer: Leiba Rodman
College of William & Mary

3:00 Gyroscopic Systems and Indefinite Inner Products
Peter Lancaster, University of Calgary, Canada

3:30 Title to be determined
S. Chandrasekara, University of California, Santa Barbara

4:00 Title to be determined
J. William Helton, University of California, San Diego

Coffee and Business Meeting

SIAM Activity Group on Linear Algebra

5:00 PM-5:30 PM

Room: Ballroom 3

The business meeting is open to all attendees.

EVENING

Poster Session

5:30 PM-7:00 PM

Room: Ballroom 3 (Ballrooms 1/2/3 will open as one ballroom.)

Important Notice to Poster Presenters (those who opted not to participate in the common-interest "birds-of-the-feather" sessions):

To give all attendees ample opportunity to view your posters, you are asked to put up your poster displays starting on Tuesday evening, October 28 at the Ballroom Foyer. On Saturday afternoon, November 1 your poster boards will be moved to Ballroom 3 for presentation and interaction with attendees at the time designated—5:30 PM to 7:00 PM, together with the posters of the participants at the common-interest "birds-of-the-feather" sessions. Ballrooms 1/2/3 will open as one ballroom

Matrix Algebra: Testing and Pairwise Testing for Homogeneity of Odds Ratios using Pseudo-Bayesian Estimators
Paul Johnson, University of California, San Francisco

Invertibility of Superalgebras' Elements
Sam L. Blyumin and Kat Krivovyaz, Lipetsk State Technical University, Russia

Multivariate Time Series State Space Modeling with High Performance SVD Computation of an Hankel Matrix
Celso Pascoli Bottura, Gilmar Barreto, and Mauricio Jose Bordon, State University of Campinas - UNICAMP, Brazil; and Jose Tarcisio Costa Filho, Federal University of Maranhao, Brazil

About Effectiveness of Closeness Measures for Positively-Defined Operators Method and Experiments
Steve K. Galitsky and Andrey S. Galitsky, Vernon Hills, Illinois

On Special Matrices with Prescribed Singular Values
Alicja Smoktunowicz, Warsaw University of Technology, Poland; and Marek Aleksiejczyk, Pedagogical University of Olsztyn, Poland

On the Kogan-Bermans' Question for the Set of Factorization Indices of a Graph
Li Jiong-Sheng and Zhang Xiao-dong, University of Science and Technology of China, The People's Republic of China

Applied Multidimensional Matrix for Simulation and Research of Spatial Extensive Mechanical Systems
S. V. Tarasov and L. V. Michshanin, Dniepropetrovsk State University, Ukraine

Sensitivity of Eigenvalues of a Defective Matrix
Grace E. Cho, North Carolina State University

Pivoting Strategies for Sparse Factorizations
Cleve Ashcraft and Roger Grimes, Boeing Information and Support Services, The Boeing Company

Promoting Understanding in Undergraduate Linear Algebra
Lila F. Roberts, Georgia Southern University

Controllable Completions
Jane M. Day, San Jose State University; *Luz M. DeAlba*, Drake University; and Charles R. Johnson, College of William & Mary

Overview of the Semi-Discrete Matrix Decomposition and Its Applications
Tamara G. Kolda and Dianne P. O'Leary, University of Maryland, College Park

Asynchronous Weighted Additive Schwarz Methods
Andreas Frommer, Bergische Universität Wuppertal, Germany; Hartmut Schwandt, Technische Universität Berlin, Germany; and *Daniel B. Szyld*, Temple University

MINRES for the Regularization of Ill-posed Problems
Misha E. Kilmer and G. W. Stewart, University of Maryland, College Park

7:00 PM Conference adjourns

Important Notice: *At 7:00 PM, Saturday, November 1, all poster presenters must remove their poster displays from the boards. Any materials left on the boards at the end of the poster session will be discarded. SIAM is not responsible for any materials that are left on the boards at the end of the session.*

Cocktails/Cash Bar

7:00 PM-7:30 PM

Room: Eagles Nest

The cocktails will precede the banquet and speech by Charles Van Loan, Cornell University. The banquet is by purchased tickets only.

Banquet

Looking for Kronecker Products

7:30 PM-9:30 PM

Guest Speaker: Charles Van Loan, Cornell University

Chair: Alan George, University of Waterloo, Canada

Room: Golden Cliff

In this presentation, the speaker will do everything possible to convince the audience that the Kronecker product (KP) is the matrix operation of the 1990's! He will explain why various trends in image processing, computer science, and optimization point to the increasing occurrence of the KP. On the algorithmic side, the focus will be on some highly structured nonlinear least square problems that arise when seeking "best" KP approximations.

General Information

Non-SIAM Members

Non-SIAM members are encouraged to join SIAM to obtain the member rate for conference registration fees and enjoy the additional benefits of SIAM membership. As a member, you will receive free subscriptions to *SIAM Review* and *SIAM News*, and substantial discounts on SIAM books and journal subscriptions. Join SIAM now! Ask a SIAM staff at the SIAM registration desk, or contact SIAM Customer Service for an application form at

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MacNeal-Schwendler Corporation

Mathematical Sciences Research Institute

National Security Agency

NEC Research Institute

Oak Ridge National Laboratory Managed by the Lockheed Martin Energy

Research Corporation for the Department of Energy

United Technologies Corporation

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Chan, Tony F.: MS12: 11:30, Fri 8
  MS15: 3:00, Fri 9
Chandrasekara, S.: MS20: 3:30, Sat 12
Cho, Grace E.: Poster: 5:30, Sat 12
Chow, Edmond: MS10: 3:00, Thu 7
Constantinescu, Tiberiu: MS13: 11:00, Fri 9

D

Datta, Biswa Nath: MS18: 4:00, Sat 11
Datta, Karabi: CIS7: 5:30, Fri 10
Davis, Timothy A.: CIS3: 5:30, Thu 7
  MS5: 4:30, Wed 4
De Samblanx, Gorik: CIS2: 5:30, Wed 5
DeAlba, Luz M.: Poster: 5:30, Sat 12
Demidenko, Gennadii V.: CIS4: 5:30, Thu 7
Dieci, Luca: MS9: 4:30, Thu 6
Dobrian, Florin: CIS3: 5:30, Thu 7
Drmac, Zlatko: MS14: 4:00, Fri 9
Druskin, Vladimir: CIS7: 5:30, Fri 10

E

Edelman, Alan: IP1: 8:30, Wed 3

F

Faßbender, Heike: MS7: 10:00, Thu 6
Feijo Segatto, Cynthia: CIS4: 5:30, Thu 7
Field, Martyn R.: MS19: 4:30, Sat 11
Frommer, Andreas: CIS1: 5:30, Wed 5

G

Galitsky, Steve K.: Poster: 5:30, Sat 12
Garcia, Salvador: CIS5: 5:30, Fri 10
Garcia-Planas, M. Isabel: CIS4: 5:30, Thu 7
Gerig, Stephen R.: CIS6: 5:30, Fri 10
Gill, Philip E.: IP2: 1:30, Wed 4
Golub, Gene H.: MS12: 10:00, Fri 8
Greenbaum, Anne: MS17: 10:00, Sat 11
Grone, Robert: MS3: 11:00, Wed 4
Gu, Ming: MS14: 3:00, Fri 9
Gutknecht, Martin H.: MS17: 11:30, Sat 11

H

Haddad, Caroline N.: CIS6: 5:30, Fri 10
He, Jianxun: MS16: 12:00, Sat 11
Heinig, Georg: MS8: 11:30, Thu 6
Helton, J. William: MS20: 4:00, Sat 12
Hendrickson, Bruce: MS15: 4:00, Fri 9
Henry, Greg: MS16: 11:30, Sat 11
Higham, Nicholas J.: CIS2: 5:30, Wed 5
  MS9: 3:00, Thu 6
Hochbruck, Marlis: MS17: 10:30, Sat 11
  MS7: 10:30, Thu 6
Howell, Gary W.: MS16: 10:00, Sat 11
Huckle, Thomas: MS19: 3:00, Sat 11
Huckle, Thomas K.: MS8: 10:30, Thu 6
Hysom, David A.: CIS3: 5:30, Thu 7

I

Ipsen, Ilse C.F.: MS11: 11:00, Fri 8

J

Jessup, Elizabeth R.: CIS4: 5:30, Thu 7
Jiang, Eric: CIS1: 5:30, Wed 5
Jiong-Sheng, Li: Poster: 5:30, Sat 12
Johnson, Paul: Poster: 5:30, Sat 12

K

Karypis, George: MS5: 3:30, Wed 4
Kenney, Charles S.: MS9: 4:00, Thu 6
Kilmer, Misha E.: Poster: 5:30, Sat 12
Knyazev, Andrew: CIS7: 5:30, Fri 10
Kolda, Tamara G.: Poster: 5:30, Sat 12
Kroschel, Brenda K.: MS6: 10:30, Thu 5
Kulkarni, Vishwesh: CIS6: 5:30, Fri 10
Kumfert, Gary: CIS3: 5:30, Thu 7

L

Lancaster, Peter: MS20: 3:00, Sat 12
Lavalle, P. F.: CIS4: 5:30, Thu 7
Lay, David C.: MS18: 3:00, Sat 11
LeBorne, Richard C.: MS2: 10:00, Wed 3
Lehoucq, Richard: CIS7: 5:30, Fri 10
  MS1: 10:30, Wed 3
Leon, Steven J.: MS18: 3:30, Sat 11
Lewis, John G.: IP5: 8:30, Fri 8
Li, Chi-Kwong: MS4: 3:30, Wed 4
Li, Ren-Cang: MS4: 3:00, Wed 4
Lundgren, J. Richard: MS3: 10:00, Wed 4

M

Mackey, Niloufer: CIS2: 5:30, Wed 5
Malyshev, Alexander: CIS2: 5:30, Wed 5
Marron, Christopher: CIS1: 5:30, Wed 5
Mastronardi, Nicola: CIS7: 5:30, Fri 10
Mathias, Roy: MS14: 4:30, Fri 9
  MS9: 3:30, Thu 6
Meerbergen, Karl: CIS2: 5:30, Wed 5
Mehrmann, Volker: IP7: 8:30, Sat 10
  MS7: 11:00, Thu 6
Miranda, Hector F.: CIS2: 5:30, Wed 5
Moro, Julio: MS4: 4:00, Wed 4

N

Nabben, Reinhard: CIS2: 5:30, Wed 5
Nagy, James G.: CIS1: 5:30, Wed 4

O

Olshevsky, Vadim: MS8: 11:00, Thu 6

P

Park, Haesun: IP4: 1:30, Thu 6
Parlett, Beresford: MS4: 4:30, Wed 4
Pavani, Raffaella: CIS2: 5:30, Wed 5
Pierce, Stephen: MS6: 11:00, Thu 6
Proudler, Ian K.: MS2: 10:30, Wed 3

Q

Qiao, Sanzheng: MS2: 11:30, Wed 3

R

Raghavan, Padma: MS5: 4:00, Wed 4
Roberts, Lila F.: Poster: 5:30, Sat 12
Robinson, Donald W.: MS3: 11:30, Wed 4
Rodman, Leiba: MS13: 11:30, Fri 9
  MS7: 11:30, Thu 6
Rojas, J. Maurice: CIS6: 5:30, Fri 10

S

Shader, Bryan L.: CIS3: 5:30, Thu 7
Smoktunowicz, Alicja: Poster: 5:30, Sat 12
Sorensen, Danny C.: MS1: 11:00, Wed 3
Strang, Gilbert: CIS3: 5:30, Thu 7
Sweldens, Wim: IP6: 1:30, Fri 9
Szyld, Daniel B.: CIS5: 5:30, Fri 10
  Poster: 5:30, Sat 12

T

Talmor, Dafna: MS15: 3:30, Fri 9
Tarasov, S. V.: Poster: 5:30, Sat 12
Teng, Shang-Hua: CIS5: 5:30, Fri 10
  MS15: 4:30, Fri 9
Tisseur, Francoise: CIS7: 5:30, Fri 10
Truhar, Ninoslav: MS11: 10:30, Fri 8
Turner, John A.: CIS5: 5:30, Fri 10

V

Van der Mee, Cornelis V. M.: MS13: 10:30, Fri ... 9
van der Vorst, Henk: MS17: 11:00, Sat 11
van der Vorst, Henk A.: MS1: 11:30, Wed 3
Van Huffel, Sabine: CIS1: 5:30, Wed 5
  MS2: 11:00, Wed 3
Van Loan, Charles: Banquet: 7:30, Sat 12
Vermaut, V.: MS7: 12:00, Thu 6
Veselic, Kresimir: MS11: 10:00, Fri 8
Vogel, Curtis R.: MS12: 11:00, Fri 8

W

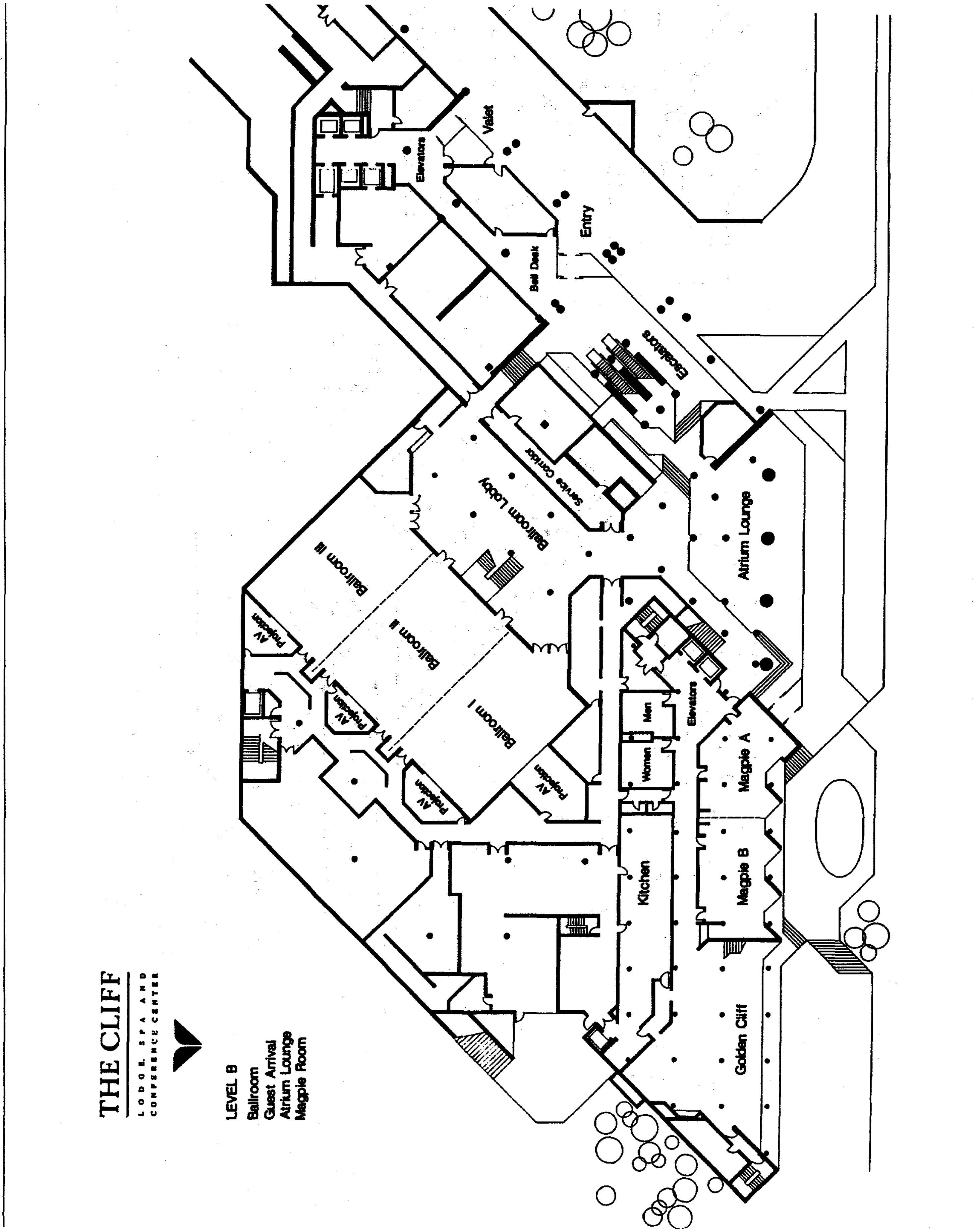
Wachspress, Eugene L.: MS16: 11:00, Sat 11
Wan, Wing-Lok: MS19: 3:30, Sat 11
Watkins, David S.: MS16: 10:30, Sat 11
Watkins, William: MS3: 10:30, Wed 4
Wei, Yimin: CIS4: 5:30, Thu 7
Wolkowicz, Henry: MS6: 10:00, Thu 5
Woznicki, Zbigniew I.: CIS5: 5:30, Fri 9
Wu, Xinyuan: CIS1: 5:30, Wed 5

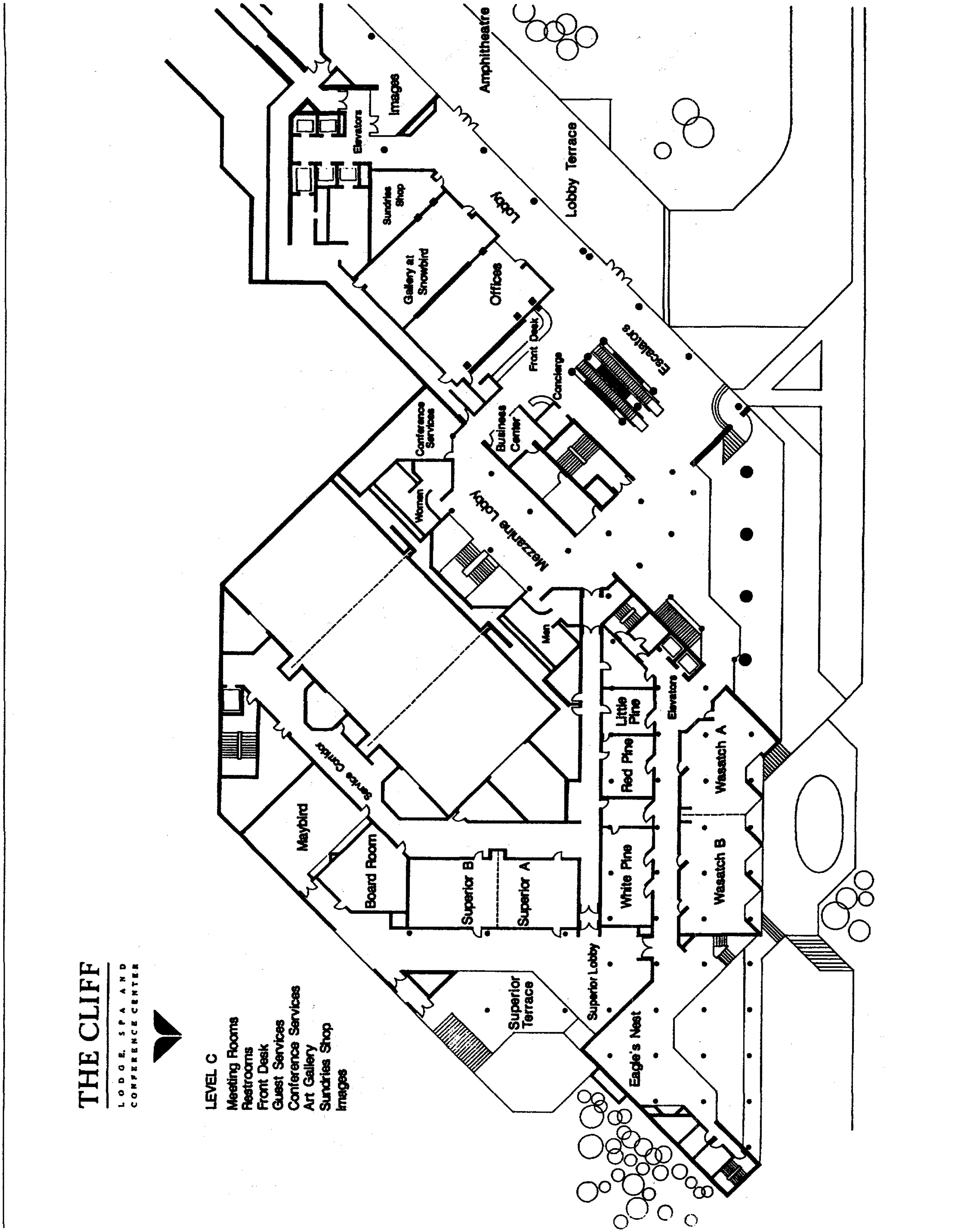
Y

Yang, C.: CIS7: 5:30, Fri 10
Yeremin, A.: MS19: 4:00, Sat 11

Z

Zha, Hongyuan: CIS7: 5:30, Fri 10


Valet
Elevators
Entry
Bell Desk
Escalators
Service Corridor
Ballroom Lobby
Atrium Lounge
Ballroom III
Ballroom II
Ballroom I
AV Projection
AV Projection
AV Projection
AV Projection
Elevators
Men
Women
Magpie A
Magpie B
Kitchen
Golden Cliff
THE CLIFF
LODGE, SPA AND CONFERENCE CENTER
LEVEL B
Ballroom
Guest Arrival
Atrium Lounge
Magpie Room


THE CLIFF
LODGE, SPA AND CONFERENCE CENTER
LEVEL C
Meeting Rooms
Restrooms
Front Desk
Guest Services
Conference Services
Art Gallery
Sundries Shop
Images
Amphitheatre
Images
Elevators
Lobby Terrace
Lobby
Sundries Shop
Gallery at Snowbird
Offices
Front Desk
Concierge
Escalators
Conference Services
Business Center
Women
Mezzanine Lobby
Men
Elevators
Little Pine
Red Pine
Wasatch A
Service Corridor
Maybird
Board Room
Superior B
Superior A
White Pine
Wasatch B
Superior Lobby
Superior Terrace
Eagle's Nest

Abstracts

Sixth SIAM Conference on

APPLIED LINEAR ALGEBRA

October 29 thru November 1, 1997

Snowbird Ski and Summer Resort
Snowbird, Utah

CIS1

Information Filtering Using the Riemannian SVD

An interesting nonlinear generalization of the singular value decomposition (SVD) has been proposed by De Moor for applications in system and control. Given a rectangular (real) matrix A this decomposition, referred to as the Riemannian SVD (R-SVD) of A is defined by

$$Av = D_v u\sigma, \ u^T D_v u = 1,$$
$$A^T u = D_u v\sigma, \ v^T D_u v = 1,$$

where D_u and D_v are nonnegative or positive definite matrix functions of the left and right singular vectors u and v, respectively, of the matrix A corresponding to the singular value σ. Such a decomposition can be used to formulate an enhanced information retrieval technique known as Latent Semantic Indexing (LSI) which normally encodes term-document associations using the SVD. Updating LSI models based on user feedback can be accomplished using constraints modeled by the R-SVD of a low-rank approximation to the original (sparse) term-by-document matrix.

Eric Jiang and Michael W. Berry
Department of Computer Science
University of Tennessee
Knoxville, TN 37996-1301
jiang@cs.utk.edu, berry@cs.utk.edu

CIS1

Optimal Partitions and Clustering

We present new clustering algorithms based on techniques from graph partitioning and linear models. Given a data set, we recursively partition the data into clusters, stopping when some user–specified criteria is met. Though similar in overall function to other divisive clustering algorithms, the partitioning functions we employ to determine the clustering at each iteration are new to this arena, though well–known among graph theorists and experts in sparse matrix computations. The two objective functions we consider are easily optimized using spectral methods, but a simple post–processing scheme, called *adaptive thresholding*, can improve the results of the spectral optimization considerably. To construct a clustering algorithm, we simply choose a partitioning method and iterate. This algorithm, implemented in C, has performed well and is competitive with standard hierarchical and divisive clustering schemes.

Christopher Marron
Mathematical Research Division
National Security Agency
Fort George G. Meade, MD 20755
cmarron@afterlife.ncsc.mil

Joseph McCloskey
Mathematical Research Division
National Security Agency
Fort George G. Meade, MD 20755
jpmcclo@afterlife.ncsc.mil

CIS1

Fast Iterative Image Restoration with a Space-Variant Blur

A linear algebraic approach to image restoration with a spatially variant blur is described. Linear interpolation of point source images is used to approximate the blurring matrix as a weighted sum of block Toeplitz matrices. Compared to methods using locally or globally invariant blurs, this approach is shown to significantly improve the quality of the restored image. Efficient implementation of matrix-vector products and conjugate gradient preconditioning are suggested. Numerical experiments with realistic problems are presented.

James G. Nagy
Department of Mathematics
Southern Methodist University
Dallas, Texas 75275
Email: jnagy@mail.smu.edu
www.smu.edu/ jnagy/conferences/1997/SIAM_LA/abs.html

Dianne P. O'Leary
Department of Computer Science and
Institute for Advanced Computer Studies
University of Maryland, College Park, MD 20742
E-mail: oleary@cs.umd.edu

CIS1

Efficient Modifications of the CG Method for Tikhonov-Phillips Regularization

We consider Tikhonov–Phillips regularization with the Morosov discrepancy principle to determine the optimal regularization parameter α in

$$(A^*A + \alpha I)x = 3DA^*y^\delta \qquad (1)$$

We propose two efficient modifications of the cg method for (1). The first one is based on a new theoretical result and stops the cg-iteration at an early stage when α is too large. The second method exploits the shifted structure in (1). Numerical experiments indicate acceleration factors of at least 3.

Andreas Frommer
Bergische Universität–
Gesamthochschule Wuppertal
Department of Mathematics
Gaußstr. 20
D-42097 Wuppertal
frommer@math.uni-wuppertal.de

Peter Maaß
Universität Potsdam
Department of Mathematics
Am Neuen Palais 10
D-14469 Potsdam
maass@rz.uni-potsdam.de

CIS1

Subspace-based Exponential Data Modeling using Prior Knowledge

Subspace-based parameter estimators, like HTLS in nuclear magnetic resonance spectroscopy, are efficient and accurate in estimating parameters of a sum of exponentially damped sinusoids. But they suffer from a serious drawback that little prior knowledge can be incorporated. It is shown how to incorporate different types of prior knowledge into HTLS, such as known frequencies, damping factors and/or phases of some exponentials. The resulting improvements in resolution and accuracy are illustrated.

Sabine Van Huffel
Department of Electrical Engineering (ESAT)
Katholieke Universiteit Leuven
Kardinaal Mercierlaan 94
3001 Leuven-Heverlee, Belgium

sabine.vanhuffel@esat.kuleuven.ac.be
ftp://ftp.esat.kuleuven.ac.be/pub/SISTA/vanhuffel/reports/SP97.ps.Z

Hua Chen
Department of Electrical Engineering
Eindhoven University of Technology
P.O.Box 513
5600 MB Eindhoven, The Netherlands
h.chen@ele.tue.nl

CIS1

A Dynamic Method for Weighted Linear Lease Squares Problems

A new method for solving the weighted linear least squares problems with full rank is proposed. Based on the theory of Liapunov's stability, the method associates a dynamic systems with a weighted linear least squares problems, whose solution we are interested in and integrates the former numerically by a A-stable explicit numerical method.

Xinyuan Wu
Department of Mathematics
Nanjing University
Nanjing 210093, People's Republic of China

Hongwei Wu
Department of Mathematics and Mechanics
Southeast University
Nanjing 210096, People's Republic of China

Zixiang Ouyang
Department of Mathematics
Nanjing University
Nanjing 210093, People's Republic of China

CIS2

On the Perturbation Theory for the Unitary Eigenvalue Problem

Some aspects of the perturbation problem of the eigenvalues of unitary matrices are considered. The mathematical structure of the unitary matrices is closely analogous to the structure of symmetric/Hermitian matrices. Using this relationship a Courant-Fischer-type theorem for the eigenvalues of unitary matrices is presented and a Kahan-like inclusion theorem is given.

B. Bohnhorst
Schmidt, Vogel und Partner
Gesellschaft für Organisation
und Management Beratung mbH
Baumerstr. 19
33602 Bielefeld, Germany

A. Bunse-Gerstner and Heike Faßbender
Universität Bremen
Fachbereich 3 - Mathematik und Informatik
D-28334 Bremen, Germany
angelika@mathematik.uni-bremen.de

CIS2

Implicitly Filtering the Rational Krylov Method

The implicitly restarted Arnoldi method implicitly applies a polynomial filter to the Arnoldi vectors by use of orthogonal transformations. We propose here an implicit filtering by rational functions for the rational Krylov method. This filtering is performed in an efficient way. Two applications are considered. The first one is the filtering of unwanted eigenvalues using exact shifts. This approach is related to the use of exact shifts in the implicitly restarted Arnoldi method. Second, eigenvalue problems can have an infinite eigenvalue without physical relevance. This infinite eigenvalue can corrupt the eigensolution. An implicit filtering is proposed for avoiding such corruptions.

Gorik De Samblanx
Katholieke Univeriteit Leuven
Department of Computer Science
Celestijnenlaan 200A, B-3001 Heverlee, Belgium
Gorik.DeSamblanx@cs.kuleuven.ac.be

Karl Meerbergen
LMS Numerical Technologies
Interleuvenlaan 70
3001 Heverlee, Belgium,
km@lmsnit.be

Adhemar Bultheel
Katholieke Universiteit Leuven
Department of Computer Science
Celestijnenlaan 200A, B-3001 Heverlee, Belgium
Adhemar.Bultheel@cs.kuleuven.ac.be

CIS2

Structured Backward Error and Condition of Generalized Eigenvalue Problems

Backward errors and condition numbers are defined and evaluated for eigenvalues and eigenvectors of generalized eigenvalue problems. Both normwise and componentwise measures are used. Unstructured problems are considered first, and then the basic definitions are extended so that linear structure in the coefficient matrices (for example, Hermitian, Toeplitz or band structure) is preserved by the perturbations.

Desmond J. Higham
Department of Mathematics
University of Strathclyde, Glasgow, G1 1XH, Scotland

Nicholas J. Higham
Department of Mathematics
University of Manchester, Manchester, M13 9PL, England
E-mail: na.nhigham@na-net.ornl.gov

CIS2

Structure-preserving Jacobi Methods for Doubly-structured Matrices

We consider four classes of real matrices with "double-structure": Hamiltonian or skew-Hamiltonian together with symmetric or skew-symmetric. Each class has a simple normal form with respect to symplectic-orthogonal similarity; we develop them all simultaneously in a single unified framework. Using the tensor square of the quaternions, 4×4 structured subproblems for each of these classes can be directly solved in closed form. The resulting structure-preserving Jacobi algorithms have asymptotic quadratic convergence.

Heike Fassbender
Universität Bremen
Fachbereich 3 – Mathematik & Informatik
Postfach 330 440, 28334 Bremen, Germany.

heike@mathematik.uni-bremen.de

D. Steven Mackey
Department of Mathematics
SUNY at Buffalo, Buffalo, NY 14215.

Niloufer Mackey
Department of Mathematics & Statistics
Western Michigan University
Kalamazoo, MI 49008-5152.
nil.mackey@wmich.edu

CIS2

A Formula for Computation of a Distance to Flutter

Given a real matrix $A \in \mathbf{R}^{n\times n}$, $n \geq 2$, which has only real distinct eigenvalues. We effectively construct a real matrix $\Delta \in \mathbf{R}^{n\times n}$ of minimal 2-norm so that the matrix $A + \Delta$ have a multiple eigenvalue. We compute the norm $\|\Delta\|_2$, which is a distance from A to the set of all real matrices with complex eigenvalues.

Alexander Malyshev
Department of Informatics
University of Bergen
5020 Bergen, Norway
E-mail: Alexander.Malyshev@ii.uib.no

CIS2

Truncated Singular Value Decompositions for Non-Hermitian Matrices

A nonsymmetric $n \times n$ matrix can be approximated by a matrix of rank $m \leq n$ by the singular value decomposition (SVD). This gives m left and m right singular vectors, so $2m$ in total. For the treatment of random acoustic pressure fields in vibro-acoustic simulation, the SVD is used to reduce the number of 'load cases' from n to $2m$, provided $2m < n$. The number of load cases determines the total cost, so an efficient reduction is very important. By reformulating the SVD, one can derive a decomposition of the same rank and of the same accuracy that gives rise to p load cases, where $m \leq p \leq 2m$.

Karl Meerbergen
LMS Numerical Technologies
Interleuvenlaan 70
3001 Heverlee, Belgium
E-mail: km@lmsnit.be

CIS2

A Supplement to the Ky Fan Trace Inequality for Singular Values

The von Neumann trace inequality for singular values was generalized by Ky Fan. It says that

$$\max_{U_l, 1\leq l\leq m} |tr(A_1U_1 \cdots A_mU_m)| = \sum_{i=1}^{n}\prod_{j=1}^{m}\alpha_i^{(j)}$$

where the $\alpha_i^{(j)}$ are the singular values of the $n \times n$ complex matrices A_j. This expression is reexamined by determining all the possible values for the diagonal elements contributing to the trace. The possible values for the eigenvalues contributing to the trace is also found.

Hector F. Miranda
Department of Mathematics
Universidad del Bio-Bio
Casilla 5-C, Concepcion, Chile
hmiranda@zeus.dci.ubiobio.cl

CIS2

On the Second Real Eigenvalue of Nonnegative and Z-Matrices

We give bounds for the second real eigenvalue of nonnegative matrices and Z–matrices. Furthermore, we establish upper bounds for the maximal spectral radii of principal submatrices of nonnegative matrices. Using this bounds we prove that our inequality for the second real eigenvalue of the adjacency matrix of a connected regular graph improves a well known bound for the second eigenvalue using Cheeger's inequality.

Shmuel Friedland
University of Illinois at Chicago
Department of Mathematics
851 S. Morgan St., Chicago, Illinois 60607-7045, USA

Reinhard Nabben
Fakultät für Mathematik
Universität Bielefeld
Postfach 10 01 31
33 501 Bielefeld, Germany
email: nabben@mathematik.uni-bielefeld.de

CIS2

Nearly-Defective Eigenvalues in Finite Precision

We are concerned with ill-conditioned well-separated eigenvalues, which are getting more and more ill-conditioned for increasing n (where n is the order of the matrix). As a working test, we consider a Bessel matrix. The aim of this work is to monitor these ill-conditioned eigenvalues by means of a sharp estimate of the distance to the closest defective matrix. This estimate has already attracted the attention of many researchers in numerical linear algebra. However here we propose two other approaches: a geometric method and a statistical method. The results coincide.

Raffaella Pavani
Dipartimento di Matematica
Politecnico di Milano
Piazza L. da Vinci 32
20133 Milano, Italy
rafpav@mate.polimi.it

CIS3

Modifying a Sparse Cholesky Factorization

We present a method for modifying the sparse Cholesky factorization of $\mathbf{AA^T}$ after adding or deleting a column from $\mathbf{A}$. We use a new concept, the multiplicity of an entry in $\mathbf{L}$, which is the number of times an entry is modified during symbolic factorization. The method extends to the general case where an arbitrary sparse symmetric positive definite matrix is modified. The time taken is proportional to the number of entries modified in $\mathbf{L}$.

Timothy A. Davis
Department of Computer and Information Science and Engineering
University of Florida, Gainesville, FL 32611

davis@cise.ufl.edu
http://www.cise.ufl.edu/ davis/SIAMLinAlg97.ps

William W. Hager
Department of Mathematics
University of Florida, Gainesville, FL 32611
hager@math.ufl.edu

CIS3

The Object-Oriented Design of a Family of Direct Solvers

Scientific computing software is traditionally written in Fortran and C, languages well known for the efficiency of the programs they generate. However, procedural design does not scale as well as object-oriented design with regard to ease of understanding, maintenance, and software reuse. We have implemented an object-oriented sparse Cholesky solver using C++; we are currently implementing an indefinite solver and extending these for parallel computing and out-of-core methods. We conclude that with a careful design there no loss of efficiency due to the object-oriented approach.
URL: http://www.cs.odu.edu/ pothen/conferences.shtml

Florin Dobrian and Gary Kumfert
Department of Computer Science
Old Dominion University
Norfolk, VA 23529
dobrian@cs.odu.edu; kumfert@cs.odu.edu

Alex Pothen
Department of Computer Science
Old Dominion University
Norfolk, VA 23529
pothen@cs.odu.edu
and
ICASE, MS 403
6 N. Dryden St.
NASA Langley Research Center
Hampton, VA 23681-0001
pothen@icase.edu

CIS3

Efficient Computation of Incomplete Factorization Preconditioners

We describe new graph-theoretic characterizations of level-based fill for incomplete factorization preconditioners. Two different definitions of level have been used in the literature, and these lead to substantially different characterizations. We design efficient, naturally parallel, algorithms for computing preconditioners from these structural theorems. We report results from these algorithms and from an algorithm that bases the definition of fill on the elimination tree of the original matrix.
URL: http://www.cs.odu.edu/ pothen/conferences.shtml

David A Hysom
Computer Science Department
Old Dominion University
Hampton Blvd, Norfolk, VA 23529
hysom@cs.odu.edu

Alex Pothen
Department of Computer Science
Old Dominion University
Norfolk, VA 23529
pothen@cs.odu.edu
and
ICASE, MS 403
6 N. Dryden St.
NASA Langley Research Center
Hampton, VA 23681-0001
pothen@icase.edu

CIS3

The Minimum Degree Family of Algorithms for Indefinite Problems: A Rigorous C++ Implementation

We present C++ implementations of several minimum degree algorithms — MMD, AMD, and AMF — with modifications for handling indefinite matrices. These matrices pose an additional challenge to a family of already complicated algorithms because matrix values and stability issues must be taken into account. To keep our implementation competitive with C and Fortran codes, we made extensive use of the Standard Template Library and investigate tradeoffs involved when using some non-traditional object-oriented paradigms.
URL: http://www.cs.odu.edu/ pothen/conferences.shtml

Gary Kumfert and Florin Dobrian
Department of Computer Science
Old Dominion University, Norfolk, VA 23529
kumfert@cs.odu.edu; dobrian@cs.odu.edu

Alex Pothen
Department of Computer Science
Old Dominion University
Norfolk, VA 23529
pothen@cs.odu.edu
and
ICASE, MS 403
6 N. Dryden St.
NASA Langley Research Center
Hampton, VA 23681-0001
pothen@icase.edu

CIS3

How Sparse Can a Matrix with Orthogonal Rows Be?

The least number of nonzero entries among the m by n row-orthogonal matrices that are not direct summable is determined. The analogous number for matrices which do not contain a zero submatrix whose dimensions sum to n is determined. In addition, the zero patterns of the matrices for which equality holds are characterized.

Gi-Sang Cheon
Department of Mathematics
Dae Jin University
Pocheon 487-800, Korea
E-mail: gscheon@rotgut.uwyo.edu

Bryan L. Shader
Department of Mathematics
University of Wyoming
Laramie, Wyoming 82071
E-mail: bshader@uwyo.edu

CIS3

Kalman Filters and the Global Positioning System (GPS)

GPS data is processed by Kalman filters to reduce the position error from meters to millimeters. This linear algebra problem becomes dynamic when the receiver (which is constantly measuring its distance from several satellites) is moved. We describe three aspects:

1. The governing equations of the Kalman filter come from the LDL^T factorization of a block tridiagonal matrix $T = A^T \Sigma^{-1} A$. The key tool is the Sherman-Morrison update formula.
2. For the simplest "steady model", the tridiagonal T has -1, 3, -1 on each row (except $T_{11} = T_{nn} = 2$). Its LDL^T factors contain *Fibonacci numbers*. This discrete random walk is a remarkable example.
3. We discuss the basic problem of estimating velocity from position measurements (and their covariance matrices). In GPS this may be the velocity of tectonic plates. Extreme accuracy is required.

Gilbert Strang
Massachusetts Institute of Technology
Cambridge, MA 02139
gs@math.mit.edu

Steven L. Lee
Oak Ridge National Laboratory
Oak Ridge, TN 37830
slee@alcyone.epm.ornl.gov

CIS4

Complete System of Structural Invariants of Linear Multivariable Systems

Considering the set of all linear multivariable systems over $K = \mathbf{C}$ or $\mathbf{R}$ represented by the set of matrices in the form $\begin{pmatrix} A & B \\ C & D \end{pmatrix} \in M_{n+p\times m+n}(K)$ with $A \in M_n(K)$, partitioned into equivalence classes under the action of the Lie group, consisting of basis changes in the state space, input space, output space and the operations of state feedback and output injection. Transformations arising in various control and estimation problems. In this paper we provide a new complete system of structural invariants such that the discrete invariants can be obtained as ranks of matrices Moreover, we present the relation with the classical invariants obtained by Kronecker. Then, in this paper we provide a new derivation of the canonical reduced form over $\mathbf{C}$, firstly obtained by Morse, and we also derive from it a canonical reduced form over $\mathbf{R}$.

M. Isabel Garcia-Planas
Dept. Matematica Aplicada I
Universitat Politecnica de Catalunya
Marques de Sentmenat 63, 4, 3
08029 Barcelona, Spain
E-mail: igarcia@ma1.upc.es

CIS4

A Comparison of Parallel Linear Algebra Libraries for the Implementation of the Product SVD

Recent work has lead to the development of highly accurate algorithms for the SVD of the product of two or three matrices that reduce those matrices to a single matrix and then accurately compute its SVD. The reduction phase can be implemented in whole via calls to level 3 BLAS and LAPACK routines. This modular construction makes them appropriate vehicles for a study of how the parallel implementation of a sophisticated numerical algorithm can be built from library routines. We report on our experiences with parallel implementation of one such algorithm by means of at least two parallel libraries. We evaluate the general approaches underlying those libraries in terms of both accuracy and ease of use.

Zlatko Drmač
Department of Computer Science
University of Colorado, Boulder, CO 80309-0430
E-mail: zlatko@cs.colorado.edu

Elizabeth R. Jessup
Department of Computer Science
University of Colorado, Boulder, CO 80309-0430
E-mail: jessup@cs.colorado.edu

CIS4

A Stable Block Diagonalization Method: Application to the Spectral Portrait of Matrices and Matrix Pencils

We first describe an algorithm that reduces a matrix A to a block diagonal form using only well conditioned transformations. The spectral properties of A are then carried out from the resulting block diagonal matrix. We show in particular that the spectral portrait of A can be obtained cheaply from that of the block diagonal matrix. We also generalize this work to regular matrix pencils. Several numerical examples illustrate this presentation.

Lavalle P.-F. and Sadkane M.
IRISA-INRIA
Campus Universitaire de Beaulieu
35042 Rennes Cedex, France
pflaval@irisa.fr, Sadkane@irisa.fr

CIS4

Successive Matrix Squaring Algorithm for Computing the Weighted Moore-Penrose Inverse $A^\dagger_{M,N}$

We derive a successive matrix squaring (SMS) algorithm to approximate the weighted Moore-Penrose inverse $A^\dagger_{M,N}$ of an arbitrary matrix $A \in C^{m\times n}$. The iterative scheme for $A^\dagger_{M,N}$ can be expressed by

$$X_1 = Q, \quad with \quad X_{k+1} = PX_k + Q.$$

where $P = I - \beta N^{-1}A^*MA$, $Q = \beta N^{-1}A^*M$, β is a relaxation parameter. This can be computed in parallel by considering $T = \begin{bmatrix} P & Q \\ 0 & I \end{bmatrix}$ so that $T^k = \begin{bmatrix} P^k & \sum_{i=0}^{k-1} P^iQ \\ 0 & I \end{bmatrix}$. The top right block of T^k is X_k, the $k-$th approximant to $A^\dagger_{M,N}$. T^k can be computed by repeated squaring,namely, $T_0 = T$ with $T_{i+1} = T_i^2$. If suitable assumptions about the number of avaiable processors are made, T_k can be computed in $O(k\log(m+n))$ time.

Yimin Wei
Institute of Mathematics
Fudan University, Shanghai 200433

People's Republic of China
E-mail:mathlab@ms.fudan.edu.cn

CIS5

Variational/Algebraic Finite-Difference Analysis of the Incremental Unknowns Preconditioner

Incremental unknowns are efficient in the numerical solution of elliptic linear differential equations, however, a theoretical justification developed in the strict variational/algebraic finite-difference context was not available; hereafter, we establish that the condition number of the incremental unknowns matrix associated to the Laplace operator is $O(1/h_0^2)O((\log h)^2)$ where h_0 is the mesh size of the coarsest grid and where h is the mesh size of the finest grid. Furthermore, if block diagonal scaling is used then the condition number of the preconditioned incremental unknowns matrix associated to the Laplace operator comes out to be $O((\log h)^2)$; last, we observe that block diagonal scaling by the Laplace operator (scaled by h_0^2) on the coarsest grid and by $4I$ on the fine grids appear as an acceptable alternative.

Salvador Garcia
Universidad de Talca, Talca, Chile
E-mail: sgarcia@pehuenche.utalca.cl

CIS5

Orderings for Incomplete LU Factorization Preconditioners

It is often overlooked that preorderings can have a significant effect on the solution of nonsymmetric linear systems, e.g. those arising from the discretization of certain convection-diffusion equations. Numerical experiments are presented whereby this effect of reorderings on the convergence of preconditioned Krylov subspace methods is shown. Different variants of incomplete factorizations are used. The reverse Cuthill-Mckee and minimum degree orderings are shown to be very beneficial for strongly nonsymmetric problems. The benefit can be seen in the reduction of number of iterations and also in measuring the deviation of the preconditioned operator from the identity.

Michele Benzi
Scientific Computing Group (CIC-19)
Los Alamos National Laboratory
Los Alamos, NM 87545
benzi@lanl.gov

Daniel B. Szyld
Department of Mathematics
Temple University
Philadelphia, PA 19122-2585
szyld@math.temple.edu

Arno van Duin
Department of Computer Science
Leiden University
P.O. Box 9512, 2300 RA Leiden
The Netherlands
arno@cs.leidenuniv.nl

CIS5

SEAM: Spectral Embedding for Algebraic Multilevel

An important computational problem in numerical simulation is the solution of a sparse linear system $Ax = b$. Let $G_0 = G(A)$ be the graph defined by the non-zero pattern of A. Algebraic multilevel methods solve this linear system by first building a hierarchical structure $G_1,...,G_k$. Then based on the algebraic information in $Ax = b$, they construct the transformation operators R_i from G_{i-1} to G_i and P_i from G_i to G_{i-1} for i in the range $1 \leq i \leq k$. These operators can be used to define a hierarchy of linear systems $A^{(i)}x^{(i)} = b^{(i)}$. The multilevel method uses this hierarchy to iteratively correct an approximate solution of the linear system in different levels. The key problems in algebraic multilevel methods is to construct proper hierarchy and robust transformation operators. We present a spectral embedding based method for building the hierarchy and for defining transformation operators. Our research in this work is strongly motivated by following set of recent advances in parallel numerical computing.

Shang-Hua Teng and Andreas Stathopoulos
Department of Computer Science
University of Minnesota
Minneapolis, MN 55455
E-mail: steng@cs.umn.edu, andreas@cs.umn.edu

CIS5

Parallel Domain Decomposition Preconditioning for Casting Process Simulation on 3D Unstructured Meshes

We describe the implementation of block incomplete domain decomposition preconditioning within the framework of **Telluride**, a 3D unstructured-mesh casting simulation tool under development at Los Alamos National Laboratory. We use a mesh partitioning tool to obtain non-overlapping subdomains, then perform a global solve of the linear systems arising from finite volume discretization of the liquid and solid energy, momentum, and mass conservation equations. The Krylov subspace methods used for the global solves are block-preconditioned by inexact solves on the subregions, and results are presented for a variety of subdomain solver and preconditioning options. The linear algebra package **JTpack90** implements the Krylov subspace algorithms investigated, and **PGSlib** provides the required parallel computing functionality.

John A. Turner
Los Alamos National Laboratory, Group TSA-10
Box 1663, MS K575, Los Alamos, NM 87545
turner@lanl.gov

Robert C. Ferrell
Cambridge Power Computing Associates, Ltd.
2 Still St., Brookline, MA 02146
Ferrell@cpca.com

D. B. Kothe
Los Alamos National Laboratory, Group T-3
Box 1663, MS B216, Los Alamos, NM 87545
Dbk@lanl.gov

CIS5

Conditions for Convergence and Comparison for Matrix Splittings

The main purpose of this paper is to discuss convergence conditions used as hypotheses in comparison theorems. Different types of matrix splittings, representing a large class of applications, are defined with consistent names and progressively weaking conditions. The scheme of condition implications is derived from the properties of regular splittings of a monotone matrix $A = M_1 - N_1 = M_2 - N_2$. The equivalence and separability of some conditions as well as an autonomous character of the conditions $M_1^{-1} \geq M_2^{-1} \geq 0$ and $A^{-1}N_2 \geq A^{-1}N_1 \geq 0$ are pointed out.

Zbigniew I. Woźnicki
Institute of Atomic Energy
05-400 Otwock–Świerk, Poland
r05zw@cx1,cyf.gov.pl

CIS6

The Algebraic Fourier Transformation

First, an extension of the concept of the Fourier transformation, called the algebraic Fourier transformation (AFT), is defined. Some of the basic theory of the AFT is then described. Finally, it is shown that this theory of the AFT includes the fast Fourier transformation (FFT).

Stephen R. Gerig
Envirospace Software Research
507 Alhambra Road
Venice, FL 34285

CIS6

Using Alternating Projections (POCS) on Nonconvex Sets

Projection Onto Convex Sets (POCS) is an iterative technique which finds an intersection of closed, convex sets. We discuss how POCS may be extended to nonconvex sets. Two POCS-based algorithms are presented that converge to the solution of the two-dimensional linear complementarity problem. Further, the algorithms are shown to converge to the solution of the two-dimensional generalized linear complementarity problem. Numerical results are provided and indicate that the algorithm works in higher dimensions. Relaxation is employed to accelerate convergence.

Caroline N. Haddad
Department of Mathematics
State University of New York at Geneseo
Geneseo, NY 14454
Fax: (716) 245-5128
E-mail: haddad@uno.cc.geneseo.edu

CIS6

Controlling a Controllable System with the Least Number of Inputs

The problem of controlling a linear controllable system using the least number of inputs is solved. The problem is formulated as a more general subspace mapping problem and an interesting algorithm is obtained to map the finitely many subspaces in a one to one manner onto a vector space whose dimension equals that of the largest subspace. Computational complexity of the algorithm is studied and the method is illustrated by a simple example.

Vishwesh Kulkarni and S.D. Agashe
EEB303 Department of Electrical Engineering
University of Southern California
Los Angeles, CA 9089-2563
E-mail: vishwesh@scf.usc.edu

CIS6

Linear Algebra for Large Nonlinear Algebra Over the Reals

We point out some of the gaps between computational algebraic geometry and numerical linear algebra, and then state some results bridging these gaps. More precisely, we describe some recent efficient methods for reducing polynomial system solving to large linear algebra. One application of these techniques is a new fast algorithm for counting the number of real roots of a polynomial system. Structured matrices, arising from the use of sparse resultants, figure prominently.

J. Maurice Rojas
Mathematics Department, 2-339
Massachusetts Institute of Technology
77 Massachusetts Ave., Cambridge, MA 02139
rojas@math.mit.edu

CIS7

Eigenvalue Solvers for Electromagnetic Fields in Cavities

The computation of electro-magnetic waves in a cavities with perfectly conducting surface leads to the eigenvalue problem

$$\begin{aligned} &\mathbf{curl}\,\mathbf{curl}\,\mathbf{E}(\mathbf{x}) = \lambda\,\mathbf{E}(\mathbf{x}), \quad \operatorname{div}\mathbf{E}(\mathbf{x}) = 0, \quad \mathbf{x} \in \Omega \subset \mathbf{R}^3, \\ &\mathbf{n} \times \mathbf{E} = 0, \quad \mathbf{x} \in \partial\Omega, \end{aligned} \tag{2}$$

in a domain Ω with connected boundary $\partial\Omega$. We consider two variational approaches for solving (2) one of which leads to large sparse eigenvalue problems of the form

$$\begin{bmatrix} A & C \\ C^T & O \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ \mathbf{y} \end{bmatrix} = \lambda \begin{bmatrix} M & O \\ O & O \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ \mathbf{y} \end{bmatrix} \tag{3}$$

with a huge number of contraints. In this work we compare finite element approaches as well as numerical methods (subspace iteration, Lanczos, restarted Lanczos, Jacobi-Davidson) to compute a few of the lowest eigenvalues and corresponding eigenvectors of (3).

Stefan Adam
Paul-Scherrer-Institute (PSI)
CH-5232 Villigen, Switzerland
Stefan.Adam@psi.ch

Peter Arbenz, Roman Geus
Swiss Federal Institute of Technology (ETH)
Institute of Scientific Computing
CH-8092 Zurich, Switzerland
[arbenz,geus]@inf.ethz.ch

CIS7

The Group Homotopy Method For Symmetric Matrices

In this paper we develop a general Homotopy method called the Group Homotopy method to solve the symmetric eigenproblem. The Group Homotopy method overcomes notable drawbacks of the existing Homotopy method, namely, (i) the possibility of breakdown or having a slow rate of convergence in the presence of clustering of the eigenvalues and (ii) the absence of any definite criterion to choose a step size that guarantees the convergence of the method. On the other hand, the Group Homotopy method maintains attractive features of the ordinary Homotopy method such as the natural parallelism and the structure preserving properties.

Karabi Datta, Yoopyo Hong
Department of Mathematical Sciences
Northern Illinois University
DeKalb, IL 60115

Ran Lee
Department of Mathematics
Honam University
Kwang Ju, Korea

CIS7

Extended Krylov Subspaces Reduction for Solutions of Elliptic and Parabolic PDE's

The problem of computing the action of a function of a real symmetric matrix is considered. We introduce a short Gram-Schmidt orthogonalization on the extended Krylov subspace originated by actions of a symmetric matrix and its inverse. Effective error bounds for the matrix square root, resolvent and exponential are obtained. Examples of the solution of a 2.5-D and 3-D PDE problems attest to the computational efficiency of the method for large-scale problems.

Vladimir Druskin
Schlumberger-Doll Research
Old Quarry Road, Ridgefield, CT 06877-4108, U.S.A.,
E-mail druskin@ridgefield.sdr.slb.com

Leonid Knizhnerman
Central Geophysical Expedition
Narodnogo Opolcheniya St., House 40, Bldg. 3
Moscow 123298, Russia
E-mail knizhner@cgemath.msk.su

CIS7

A Subspace Preconditioning Algorithm for Eigenvector/Eigenvalue Computation

We consider the problem of computing a modest number of the smallest eigenvalues along with orthogonal bases for the corresponding eigenspaces of a symmetric positive definite operator A defined on a finite dimensional real Hilbert space V. In our applications, the dimension of V is large and the cost of inverting A is prohibitive. In this paper, we shall develop an effective parallelizable technique for computing these eigenvalues and eigenvectors utilizing subspace iteration and preconditioning for A. Estimates will be provided which show that the preconditioned method converges linearly when used with a uniform preconditioner under the assumption that the approximating subspace is close enough to the span of desired eigenvectors.

Andrew Knyazev
aknyazev@math.cudenver.edu
http://www-math.cudenver.edu/ aknyazev
Department of Mathematics
University of Colorado at Denver
P.O. Box 173364, Campus Box 170
Denver, CO 80217-3364

CIS7

Iterative Determination of Vibrational Energy Levels of Four-Atom Molecules

We have developed a parallel computer code that utilizes the implicitly restarted Arnoldi method to determine the vibrational eigenstates of four-atom molecules. There are two key aspects to our parallel program. First, we use the MPI based parallel implementation of ARPACK. The second aspect is the use of state-of-the-art methods from the chemical physics literature for compactly and efficiently representing the matrix Hamiltonian and evaluating the associated matrix-vector products. Specifically, we implement a discrete variable representations (DVR). We present the results of a series of experiments for finding 50 of the lowest vibrational levels of the four atom molecule Hydrogen-Oxygen-Carbon-Oxygen where the size of matrix was of order 1.1 million through 2.3 million.

Richard Lehoucq
Mathematics and Computer Science Division
Argonne National Laboratory
9700 S. Cass Avenue, Argonne, IL 60439-4844
E-mail: lehoucq@mcs.anl.gov
http://www.mcs.anl.gov/home/lehoucq/index.html

Stephen Gray
Theoretical Chemistry Division
Argonne National Laboratory
9700 S. Cass Avenue, Argonne, IL 60439

CIS7

Computing the Smallest Eigenvalue of a Symmetric Positive Definite Toeplitz Matrix

We present two algorithms for computing the smallest eigenvalue of a symmetric definite positive matrix. The problem to compute this eigenvalueis of considerable interest in signal processing and estimation. The methods presented here combine a modified version of the Levinson–Durbin algorithm with the Newton and Halley methods applied to the characteristic polynomial associated to the Toeplitz matrix. The methods converge to the minimum eigenvalue choosing the origin as starting point.

Nicola Mastronardi
Dipartimento di Matematica
Università della Basilicata
Via N. Sauro, 85
I-85100 Potenza, Italy
mastronardi@unibas.it

CIS7

Parallelizing the Divide and Conquer Algorithm for the Symmetric Tridiagonal Eigenvalue Problem

We describe a new parallel implementation for distributed memory machines of a divide and conquer algorithm for the symmetric tridiagonal eigenvalue problem. Early parallel implementations had mixed success. We choose to implement the rank-one update of Cuppen and use the "Loewner Theorem" approach of Gu and Eisenstat to maintain orthogonality rather than the rank-two update and extended precision for maintaining orthogonality used by Gates and Arbenz. The 2D block cyclic distribution of our matrices is a key to load balance the work and the deflations. Our algorithm is well suited to computing all the eigenvalues and eigenvectors of large matrices with clusters of eigenvalues.

Françoise Tisseur and Jack Dongarra
Department of Computer Science
University of Tennessee, Knoxville, TN 37996-1301
E-mail: ftisseur@cs.utk.edu, dongarra@cs.utk.edu
http://www.cs.utk.edu/ ftisseur/reports/sh_ala97.tex

CIS7

Accelerating the Lanczos Algorithm via Polynomial Spectral Transformations

We investigate the possibility of using several classical approximation techniques to construct effective polynomial spectral transformations. These transformations are useful in accelerating the Lanczos method for computing interior and/or clustered eigenvalues of symmetric matrices without matrix factorizations.

D. C. Sorensen and C. Yang
Department of Computational & Applied Mathematics
Rice University, Houston, TX 77005
sorensen@caam.rice.edu; chao@caam.rice.edu
URL: http://www.caam.rice.edu/ chao/psfile/abs.ps

CIS7

Large Sparse Symmetric Eigenvalue Problems with Homogeneous Linear Constraints: The Lanczos Process with Inner-Outer Iterations

We study the inner-outer iteration approach for large eigenproblems using the symmetric eigenproblem with homogeneous linear constraints as a concrete example. We provide a careful error analysis of the inner-outer iteration Lanczos process with special emphasis on the orthogonality of the computed Lanczos vectors. In order to reduce the total number of inner iteration steps, we introduce two methods: variable-accuracy inner-outer Lanczos process and successive inner-outer Lanczos process. We provide some analysis to explain the behaviors of these two methods. We also present various numerical examples to demonstrate the efficiency and accuracy of these methods.

Hongyuan Zha
Department of Computer Science and Engineering
The Pennsylvania State University
University Park, PA 16802
zha@cse.psu.edu
URL: http://www.cse.psu.edu/~zha/

MS01

An Iterative Block Method for Computing a Few Close Eigenvalues of a Large Sparse Symmetric Matrix

We present an Implicitly Restarted Block Lanczos method designed for the computation of a few extreme multiple or close eigenvalues and associated eigenvectors of a large sparse symmetric matrix. Our method generalizes the Implicitly Restarted Lanczos method introduced by Sorensen [1992]. The method requires that certain acceleration parameters, referred to as shifts, be chosen. The storage requirement and convergence rate depends on the choice of shifts. We present a new strategy for choosing shifts. Numerical examples illustrate that our method gives rapid convergence, reliably detects extreme multiple or close eigenvalues, and requires little computer storage.

James Baglama
Kent State University
Kent, OH 44242

D. Calvetti
Stevens Institute of Technology
Hooekn, NJ 07030

L. Reichel
Kent State University
Kent, OH 44242

A. Ruttan
Kent State University
Kent, OH 44242

MS01

Computing Guided Waves for Optical Fibers

We present a new approach for computing guided waves in optical fibers. We review the standard approaches and discuss our formulation which results in a non-symmetric generalized eigenvalue problem. The resulting non-symmetric generalized eigenvalue problem is solved with two different methods. The first method combines a spectral transformation with an implicitly restarted block Arnoldi method. The resulting sets of linear equations are solved with a direct method. The second method transforms the generalized eigenvalue problem to a standard one and also uses an implicitly restarted block Arnoldi method. We present computational results comparing the two methods and show that a block approach leads to a more efficient method.

Richard Lehoucq
Mathematics and Computer Science Division
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439-4844
lehoucq@mcs.anl.gov
http://www.mcs.anl.gov/home/lehoucq/index.html

Lawrence Cowsar
Lucent Technologies
Bell Laboratories
Murray Hill, NJ 07974-0636
cowsar@bell-labs.com
http://cm.bell-labs.com/who/cowsar/

MS01

An Implicitly Restarted QZ-Like Projection Method for Large Generalized Eigenproblems

This talk will present a new method for the large scale generalized eigenvalue problem

$$Ax = Bx\lambda$$

that does not require accurate solution of shift-invert equations. The method is developed within a subspace projection framework as a truncation and modification of the *QZ*-algorithm for dense problems. This is combined with an implicit restarting technique that naturally extends the implicitly restarted Arnoldi method to the generalized problem.

D.C. Sorensen
Rice University
Department of Computational & Applied Math.
6100 Main St.
Houston, TX 77005-1892
sorensen@rice.edu

MS01

An Iterative Algorithm for the Partial QZ Reduction of Very Large Generalized Eigenproblems

In our presentation we will describe a new iterative tech-

nique for the computation of a number of selected solutions for the eigenproblem

$$(A - \lambda B)q = 0,$$

with A, B general large sparse $(n \times n)$ matrices. The technique is based on the Jacobi-Davidson method with QZ-reduction to Schur form. With this technique we are able to compute a number of eigenvalues and eigenvectors, with subspaces of restricted dimension, and without inversion of any of the matrices involved. The standard methods of Arnoldi and Lanczos are not well-suited for this.

Henk A. van der Vorst
Department of Mathematics
University of Utrecht
P.O. Box 80.010
NL-3508 TA Utrecht
The Netherlands

MS02

Stability, Finite Precision, and Adaptive Filtering in Signal Processing

We present the numerical analysis of a simplified one dimensional version of Peskin's immersed boundary method, which has been used to solve the 2 and 3 dimensional Navier-Stokes equations in the presence of immersed boundaries. We consider the heat equation in a finite domain with a moving source term. We denote the solution as $u(x, t)$ and the location of the source term $X(t)$. The source term is a moving delta function whose strength is a function of u at the location of the delta function. The pde is coupled to an ode whose solution gives the location of the source term. The ode is $X'(t) = u(X(t), t)$, which can be interpreted as saying the source term moves at the local velocity.

Richard LeBorne
University of Tennessee-Chattanooga

MS02

Algorithms and Architectures for Fast Recursive Least Squares

Recursive least squares (RLS) minimisation is an important tool in adaptive signal processing. In the case time-series adaptive filtering, algorithms can be derived that have computational complexity linearly proportional to the problem size. These are the so-called fast RLS algorithms. In this talk, we will present an overview of these algorithms showing how they relate to each other by use of the QR decomposition approach to RLS. We will also discuss the, largely unresolved, numerical stability issues associated with these algorithms.

Ian K. Proudler
Defence Evaluation and Research Agency
St Andrews Road, Malvern
Worcestershire WR14 3PS
UK
proudler@signal.dra.hmg.gb

MS02

A Blind Deconvolution Method for Image Restoration

Image restoration involves the removal or minimization of degradation (blur, clutter, noise, etc.) in an image using a priori knowledge about the degradation phenomena. Blind restoration is the process of estimating both the true image and the blur from the degraded image characteristics, using only partial information about degradation sources and the imaging system. In this paper, we provide a method to incorporate truncated eigenvalue and total variation regularization into a nonlinear recursive inverse filter blind deconvolution scheme.

Michael K. Ng
ACSys, Computer Science Laboratory
Research School of Information Sciences and Engineering
The Australian National University
Canberra, Australia ACT0200
mng@cslab.anu.edu.au

Robert J. Plemmons
Department of Mathematics and Computer Science
Wake Forest University
Winston-Salem, NC, USA 27109
plemmons@wfu.edu

Sanzheng Qiao
Department of Computer Science and Systems
McMaster University
Hamilton, Ontario, Canada L8S 4K1
qiao@maccs.dcss.mcmaster.ca

MS02

Fast TLS Algorithm Based on the Low-Rank Revealing ULV Decomposition with Applications in MRS Data Quantification

A fast algorithm based on the low-rank revealing ULV decomposition with implicit deflation is presented for solving sets of equations $Ax \approx b$ with the total least squares (TLS) method. The rank-revealing form $[A\ b] = U\ L\ V^T$ is computed, in which the matrix $[A\ b]$ is unaltered and none of the factors U, L, V are formed explicitly. The efficiency of this algorithm is demonstrated within the context of an exponential data modeling problem encountered in magnetic resonance spectroscopy (MRS) data quantification.

Sabine Van Huffel and Leentje Vanhamme
Department of Electrical Engineering (ESAT)
Katholieke Universiteit Leuven
Kardinaal Mercierlaan 94
3001 Leuven-Heverlee, Belgium
sabine.vanhuffel@esat.kuleuven.ac.be

Ricardo Fierro
Department of Mathematics
California State University San Marcos
San Marcos, CA 92096
fierro@thunder.csusm.edu

MS03

John Maybee's Contributions to Combinatorial Matrix Theory

In memory of John Maybee this talk will discuss his many contributions to combinatorial matrix theory over the last 30 years. Topics covered will include sign-nonsingular matrices, nearly sign-nonsingular matrices, tournament matrices, and the relationship between matrix factorizations and clique and biclique covering problems on graphs and digraphs. Proof techniques for these topics vary between matrix theoretic, graph theoretic, and frequently a combination of both. There are a wide variety of applications of his work, some of which will be discussed.

J. Richard Lundgren
University of Colorado at Denver

MS03

D-Optimal Designs

The statistical root of our problem is to estimate the weights of j objects. Any subset of the objects can be placed on a scale and we are allowed $d(>= j)$ weighings. How many and which objects should be placed on the scale for each of the d weighings? With certain assumptions about measurement errors, the problem becomes that of maximizing det (AA^t) over the $j-by-d(0,1)$-matrices.

William Watkins
Mathematics Department
California State University, Northridge
Northridge, CA 91330-8313
Telephone: (818) 677 2721
FAX: (818) 677 3634

MS03

The Image of the Adjoint Mapping

Let $\mathcal{R}$ be a commutative ring with 1, and let A be an $m \times n$ matrix over $\mathcal{R}$ with determinantal rank $r \geq 1$. If 1 is in the ideal of $\mathcal{R}$ generated by the $r \times r$ minors of A, then every inner inverse of A is in the image of a linear mapping $\mathcal{R}^{\binom{n}{r}\times\binom{m}{r}} \rightarrow \mathcal{R}^{n\times m}$ that is specified in terms of the classical adjoints of the $r \times r$ submatrices of A.

Donald W. Robinson
Department of Mathematics
312 TMCB
Brigham Young University
Provo, UT 84602
(801) 378-5868
Fax: (801) 378-3703
email: robinson@math.byu.edu

MS04

On the Lidskii-Mirsky-Wielandt Theorem

We use a simple matrix replacement technique to give an elementary new proof of the Lidskii-Mirsky-Wielandt Theorem and to obtain a multiplicative analog of the Lidskii-Mirsky-Wielandt Theorem. We apply the latter to obtain various bounds on the matching distance between the eigenvalues and singular values of matrices. This extends and improves work of R.-C. Li.

Chi-Kwong Li
College of William and Mary, Williamsburg, Virginia

Roy Mathias
College of William and Mary, Williamsburg, Virginia

MS04

Spectral Variation for Diagonalizable Matrices

Inequalities that compare unitarily invariant norms of $A-B$ and those of $A\Gamma-\Gamma B$ and $\Gamma^{-1}A-B\Gamma^{-1}$ are obtained, where both A and B are either Hermitian or unitary or normal operators and Γ is a positive definite operator in a complex separable Hilbert space. These inequalities when applied to the spectral variation of diagonalisable matrices yield bounds that improve substantially previously published ones.

Ren-Cang Li
Department of Mathematics
University of Kentucky
Lexington, KY 40506

Rajendra Bhatia
Indian Statistical Institute
New Delhi 110 016, India

Fuad Kittaneh
University of Jordan
Amman, Jordan

MS04

First Order Eigenvalue Perturbation Theory and the Newton Diagram

Given a complex matrix A with arbitrary Jordan structure, consider a small perturbation $A + \varepsilon B$ of A. We make use of the Puiseux-Newton diagram, an elementary geometrical construction formally derived by Newton, to obtain explicit formulas for the leading coefficients of the fractional power expansions of the perturbed eigenvalues. The fact that these formulas involve only the perturbation matrix B and the eigenvectors of A suggests a new Hölder condition number for multiple eigenvalues, depending only on the associated left and right eigenvectors, not on the Jordan vectors.

Julio Moro
Universidad Carlos III
Madrid, Spain

James V. Burke
University of Washington
Seattle, WA

Michael L. Overton
New York University
New York, NY

MS04

When Are Factors of Indefinite Matrices Relatively Robust?

Recently, we have found new techniques that allow us to compute eigenvectors of a symmetric tridiagonal matrix T that are orthogonal to working precision without resorting to Gram-Schmidt. A central requirement in these techniques is the existence of relatively robust bidiagonal factors of T and its translates. Most bidiagonal factorizations of $T-\mu I$ do not suffer from large element growths and are observed to be relatively robust. Even when large element growths occur, locally small eigenvalues $T-\mu I$ are often determined to high relative accuracy with respect to small componenwise changes in entries of the bidiagonal factor. We present examples, theory and preliminary results.

Inderjit Dhillon and Beresford Parlett
Computer Science Division,
University of California, Berkeley

MS05

Practical Extensions of the Multisection Ordering for Sparse Matrices

The multisection ordering has been shown to be a robust and effective reordering scheme for use with sparse direct methods. The approach is based on the notion of a multisector, a subset of vertices whose removal decomposes the graph (associated with the given sparse matrix) into a number of disconnected subgraphs called domains. The matrix reordering is obtained by numbering the vertices in each domain using a fill-reducing ordering and then numbering the multisector vertices using a (possibly different) fill-reducing ordering. In previous work the minimum degree algorithm and its variants were used to order both the domains and the multisector. Here we consider the use of nested dissection orderings for the domains. This allows us to explore efficiently a spectrum of orderings based on a hierarchy of multisectors and to select the best. Furthermore, in previous work multisectors were chosen so that the domains were roughly equal in size. Here we allow the sizes to vary greatly. We present some simple strategies to find such multisectors and domains. Together with using nested dissection to order the domains, they form a practical ordering combination. Experimental results show that these new extensions produce consistently better orderings for a wide spectrum of sparse problems.

Cleve Ashcraft
Boeing Computer Services
P. O. Box 24346, Mail Stop 7L-22
Seattle, Washington USA 98124

Stanley C. Eisenstat
Department of Computer Science
Yale University
P. O. Box 208285
New Haven, CT 06520-8285

Joseph W.H. Liu
Department of Computer Science
York University
North York, Ontario, Canada M3J 1P3

MS05

A Column Approximate Minimum Degree Ordering Algorithm

The sparse partial pivoting method for factorizing unsymmetric matrices relies on a column pre-ordering to control fill-in, and on a row ordering (performed during the numerical factorization) to maintain numerical accuracy. A purely symbolic pre-analysis phase finds Q so that the numerical factorization of $P(AQ) = LU$ will suffer low fill-in, no matter what the choice of P is. Consider the Cholesky factor L_C of A^TA. It is known that the nonzero patterns of the lower triangular factor L and the upper triangular factor U are subsets of the nonzero patterns of L_C and L_C^T, respectively, no matter what P is (assuming that A is not permutable to a block triangular form). Thus we can find Q such that the Cholesky factor of Q^TA^TAQ has low fill-in, and thus bound the fill-in in L and U for arbitrary row pivoting. This is also the bound on Q and R if we were to perform a QR factorization of A. However this approach requires computing the explicit nonzero pattern of A^TA. In this talk we will present our work on a column approximate minimum degree algorithm for computing Q that represents the pattern of A^TA implicitly. Results with several heuristics for pivot selection will be presented.

Timothy A. Davis
Computer and Information Science and Engineering Department
University of Florida
P.O. Box 116120
Gainesville, FL 32611-6120

John R. Gilbert
Computer Science Laboratory
Xerox Palo Alto Research Center
3333 Coyote Hill Road
Palo Alto, CA 94304-1314

Esmond G. Ng
Barry W. Peyton
Computer Science and Mathematics Division
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6367

MS05

Multilevel Graph Partitioning and Nested Dissection

Graph partitioning has been extensively used in computing fill reducing orderings of sparse matrices via nested dissection. Recently, multilevel graph partitioning algorithms has been shown to be quite effective in producing very good bisections. In this talk we will present a parallel formulation of multilevel nested dissection ordering. This algorithm significantly reduces the time required for ordering, while producing orderings whose quality is comparable to those of the serial algorithm. Our formulation uses a fast parallel k-way graph partitioning algorithm to initially distribute the sparse matrix among the processors. This distribution allow us to quickly compute the vertex separators that are needed by the nested dissection algorithm. Even though vertex separators can be computed from the edge separators returned by the graph partitioning algorithms, smaller vertex separators can be computed if we focus on the hypergraph that corresponds to the dual of the graph. In this hypergraph, a hyperedge separator leads directly to a vertex separator; thus, minimizing the hyperedge-cut directly minimizes the size of the separator. However, until recently high quality hypergraph partitioning algorithms were significantly slower than their graph counterparts, making such approaches very computationally expensive. Recently, we develop a multilevel hypergraph partitioning algorithm that produces extremely high quality bisections much faster than any previously known algorithms. In this talk we will present experiments with using hypergraph partitioning to compute fill reducing orderings.

George Karypis
Computer Science Department
University of Minnesota
EE/CS Bldg.
200 Union St SE
Minneapolis, MN 55455

MS05

Performance of Greedy Ordering Heuristics for Sparse Cholesky Factorization

Greedy algorithms for ordering sparse matrices for Cholesky factorization can be based on different metrics.

Minimum degree, a popular and effective greedy ordering scheme, minimizes the number of nonzero entries in the rank-1 update at each step of the factorization. Alternatively, minimum deficiency minimizes the number of nonzero entries introduced into the matrix at each step of the factorization. We study the performance of the minimum deficiency algorithm and develop two new heuristics that are variants of minimum degree and minimum deficiency. Our experiments reveal that on the average, minimum deficiency orderings have 20% less factorization cost than minimum degree. The two variants have on the average 15-17% less factorization cost than minimum degree. Minimum deficiency orderings are prohibitively expensive to compute. On the other hand, one of the variants is no more expensive to compute than minimum degree while the other requires on the average only 30% more time than minimum degree.

Esmond G. Ng
Computer Science and Mathematics Division
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, TN 37831-6367

Padma Raghavan
107 Ayres Hall
Department of Computer Science
The University of Tennessee
Knoxville, TN 37996-1301

MS06

The Cone of Class Function Inequalities for Positive Semidefinite Matrices

Let c be a map from the symmetric group into $\mathbb{R}$ satisfying $c(\sigma) = c(\tau)$ whenever τ is conjugate to σ. To c associate a function d_c, which maps the real positive semidefinite matrices to $\mathbb{R}$, by replacing sgnσ by $c(\sigma)$ in the standard definition of the determinant. For $n = 3, 4$ we characterize the cone of those c such that $d_c(A) \geq 0$ for all n-by-n positive semidefinite matrices A.

Wayne W. Barrett, H. Tracy Hall
Department of Mathematics
Brigham Young University
Provo, Utah 84602

Raphael Loewy
Department of Mathematics
Technion-Israel Institute of Technology
Haifa 32000
ISRAEL

MS06

Eigenvalue Multiplicities in Principal Submatrices

Imagine an n-level hierarchy with $2^n - 1$ cells corresponding to the $2^n - 1$ nonempty subsets of $N = \{1, 2, \ldots, n\}$. Label the levels $0, 1, \ldots, n-1$ and on level i place all cells corresponding to subsets of cardinality $n - i$ (in lexicographic order); moreover, place an edge between α on level i and β on level $i - 1$ if and only if $\alpha \subset \beta$. Given an n-by-n matrix A associate with the cell α, the geometric multiplicity of λ as an eigenvalue of the principal submatrix of A lying in the rows and columns indexed by α. Here we present known restrictions on such hierarchies as a partial solution to the question of which hierarchies may occur. The hierarchies are far from arbitrary and there are many restrictions, some simple and some subtle, on their structure. Particular attention is paid to the case in which A is Hermitian. Note that in this case, classical interlacing already imposes much structure on the hierarchies.

Charles R. Johnson
College of William and Mary,
Williamsburg, VA 23187-8795
crjohnso@math.wm.edu)
The work of this author was supported, in part, by National Science Foundati on grant DMS-92-00899 and Office of Naval Research contract N00014-90-J-1739
Brenda K. Kroschel
Macalester College,
1600 Grand Avenue,
St. Paul, MN 55105-1899
kroschel@macalester.edu) The work of this author formed a portion of her Ph.D. dissertation at the College of William and Mary, Williamsburg, VA 23187-8795.
Matjaz Olmadic
Department of Mathematics,
University of Ljubljana,
Jadranska 19, 61000 Ljubljana, Slovenia
The work of this author is supported in part by the Ministry of Science and Technology of Slovenia

MS06

Congruence of Polynomial Matrices

Let $A(t)$ be a square matrix with entries which are polynomials with complex coefficients in a real variable t. The complex conjugate of a polynomial $f(t)$ is obtained by taking the complex conjugate of each of the coefficients. Suppose that $A(t)$ is hermitian. Then there exists a matrix $P(t)$ with non-zero constant determinant such that

$$P(t)^* A(t) P(t) = 0 \oplus B(t),$$

where $B(t)$ is diagonally dominant. In this case, diagonally dominant means that the degree of $b_{ii}(t) > \deg b_{ij}(t)$ for any $j \neq i$. We use this result to obtain some information on diagonalization of hermitian polynomial matrices by congruence.

Stephen Pierce
Department of Mathematics
and San Diego State University
San Diego, CA 92182

MS06

The Gauss-Newton Direction for Interior-Point Methods in Linear and Semidefinite Programming

We present a new paradigm for deriving interior point methods for linear and semidefinite programming. This is based on applying the Gauss-Newton method to solving the nonlinear optimality conditions. Though this paradigm does not provide a new search direction for linear programming, it does provide a new viewpoint and a new efficient direction for SDP that requires no symmetrization.

Henry Wolkowicz
University of Waterloo, Waterloo, Ont. Canada

MS07

A Jacobi-Like Method for Solving the Hamiltonian Eigenproblem On Parallel Computers

An algebraic Riccati equation of the form $-XGX + XA + A^H X + Q = 0$, where $X, G, Q, A \in C^{n \times n}$, $Q = Q^H$, and

$G = G^H$, arises for instance in linear-quadratic optimal control problems. One approach to solving such an equation is via computing an n-dimensional invariant subspace of the Hamiltonian matrix

$$H = \begin{bmatrix} A & G \\ Q & -A^H \end{bmatrix}.$$

We show how a Jacobi-like method of Eberlein for computing the Schur form of a general matrix can be modified to compute the Hamiltonian Schur form of H. By using only local information, efficient parallel implementations are possible.

Heike Faßbender and Angelika Bunse-Gerstner
Universität Bremen
Fachbereich 3 - Mathematik und Informatik
Zentrum für Technomathematik
Postfach 330 440
28334 Bremen
Germany
heike@mathematik.uni-bremen.de
angelika@mathematik.uni-bremen.de

MS07

Reduced Order Simulation of Nonlinear Systems

We study the simulation of large stiff nonlinear problems by methods that use reduced order models obtained from Krylov approximations to the exponential or a related function of the Jacobian. We first show that Krylov methods for approximating the exponential typically converge faster than those for the solution of the linear systems arising in standard stiff integrators. The exponential methods offer favorable properties in the integration of differential equations whose Jacobian has large imaginary eigenvalues.

Marlis Hochbruck and Christian Lubich
Mathematisches Institut
Universität Tübingen
Auf der Morgenstelle 10
D–72076 Tübingen
Germany
marlis@na.uni-tuebingen.de

MS07

Perturbation Theory for the Pole Placement Problem

For the solution of the multi-input pole placement problem we derive explicit formulas for the subspace from which the feedback gain matrix can be chosen and for particular choices we give explicit formulas for the feedback gain as well as the eigenvector matrix of the closed-loop system. We discuss which Jordan structures can be assigned and also when diagonalizability can be achieved. Based on these formulas we study the conditioning of the pole-placement problem in terms of perturbations in the data and show how the conditioning depends on the condition number of the closed loop eigenvector matrix, the norm of the feedback matrix and the distance to uncontrollability.

Volker Mehrmann and Hongguo XU
Fachbereich Mathematik
TU Chemnitz-Zwickau
Reichenhainer Str.41
D-O-9022 Chemnitz
Germany
mehrmann@mathematik.tu-chemnitz.de
xu@mathematik.tu-chemnitz.de

MS07

Inertia Theorems, Bezoutians, and Stability Bounds of Operator Polynomials

A well-known, and widely used in control theory, inertia theorem asserts that the matrices A and X=X* have same inertia with respect to the imaginary axis provided W=AX+XA* is positive semidefinite and the pair (A,W) is controllable. A generalization of this result is obtained, with a weaker controllability-type hypothesis and for infinite dimensional operators. We explore some implications of this generalization in a study of spectrum separation and inertia of operator polynomials, using the technique of Bezoutian operators. This in turns implies results concerning stability bounds of differential and difference equations with constant operator coefficients.

Leiba Rodman* and Leonid Lerer†
*Department of Mathematics
College of William and Mary
Williamsburg VA 23187-8795
USA
LXRODM@WMVM1.BITNET
†Department of Mathematics
Technion-Israel Institute of Technology
Haifa 32000
ISRAEL

MS07

On Stability Radii of Generalized Eigenvalue Problems

In this paper, we extend a known characterization of the stability radius of a standard eigenvalue problem to the generalized eigenvalue problem as well as that of cyclic pencils occuring in periodic systems. Thereby we prove that the optimal K-periodic perturbation can always be chosen as time-invariant for time-invariant systems with periodic perturbations. We also extend some of these results to norms different than the 2-norm.

P. Van Dooren and V. Vermaut
Université catholique de Louvain
Dept. Mathematical Eng.
4-6 Av. Georges Lemaître
B 1348 Louvain-La-Neuve
Belgium
vdooren@anma.ucl.ac.be
vermaut@anma.ucl.ac.be

MS08

Superfast Algorithms for Positive Definite Toeplitz Systems

We will give an overview of algorithms of complexity $O(n \log^2 n)$ for solving positive definite Toeplitz systems of equations. Aspects of our FORTRAN software will be described. We will also present some experimental comparisons of our superfast Toeplitz solver with some iterative techniques based on the preconditioned conjugate gradient method.

Gregory S. Ammar
Department of Mathematical Sciences
Northern Illinois University
DeKalb, IL 60115
ammar@math.niu.edu

MS08

The Splitting Approach for Real Based Superfast Toeplitz Solvers

In their classical versions the Schur and related algorithms for solving Toeplitz systems of equations require $O(n^2)$ operations. Using divide-and-conquer strategies and FFT the procedure can be speeded up to $O(n \log^2 n)$ complexity. All algorithms in the literature use complex DFT even if the matrix is real. It is desirable to have superfast solvers based on real trigonometric transformations. We show that such algorithms can be constructed using a splitting approach for symmetric Toeplitz or, more general, centrosymmetric Teoplitz-plus-Hankel matrices.

Georg Heinig
Dept. of Mathematics and Computer Science
Kuwait University, P.O.Box 5969
Safat 13060, Kuwait
georgmath-1.sci.kuniv.edu.kw

MS08

Practical Multigrid Methods for Toeplitz Matrices

In recent papers R. Chan and S. Serra et al. have introduced multigrid methods for symmetric positive definite Toeplitz matrices. Based on the underlying function they define projections such that the projected matrix again has the Toeplitz structure, and a multigrid method with Jacobi smoothing gives fast convergence. Here we assume that we have no knowledge of the underlying function. We show that again it is possible to derive projections such that multigrid methods with Jacobi smoothing lead to fast convergence.

Thomas K. Huckle
Institut für Informatik
TU München
Arcisstr. 21
D-80290 München, Germany
huckle@informatik.tu-muenchen.de

MS08

Displacement Structure Approach to Discrete Transform Based Preconditioners of G. Strang and T. Chan Types

We use a displacement structure approach to design explicit formulas for the G.Strang-type and T.Chan-type non-circulant preconditioners diagonalized by any of the 8 versions of the discrete cosine/sine transforms. Under the Wiener class assumption the clustering property is established for all of these preconditioners, guaranteeing a rapid convergence of the preconditioned conjugate gradient method (PCGM). All the computation related to the new preconditioners can be done in real arithmetic, and to fully exploit this property one has to suggest a new real-arithmetic fast method to multiply a Toeplitz matrix by a vector. It turns out that the formulas for the G.Strang-type preconditioners lead to a wide variety of new real-arithmetic algorithms for fast multiplication of Toeplitz-plus-Hankel matrices by a vector. Transformation to Cauchy-like matrices allows further reductions in the computational complexity of the PCGM for Toeplitz linear equations. Joint work with T.Kailath.

Vadim Olshevsky
Information Systems Laboratory
Stanford University
Stanford, CA 94305-4055
olshevsk@rascals.stanford.edu

MS09

Logarithms of Matrices and Applications

We give an overview of recent work on computation of logarithms of matrices. Particular attention is paid to the case of computation of logarithms of nearby matrices. Application to structured matrix interpolation is presented.

Luca Dieci
Georgia Institute of Technology, Atlanta, GA

Benedetta Morini, Alessandra Papini, Aldo Pasquali
University of Florence, Florence, Italy

MS09

Stable Iterations for the Matrix Square Root

Any matrix with no nonpositive real eigenvalues has a unique square root for which every eigenvalue lies in the open right half-plane. A link between the matrix sign function and this square root is exploited to derive both old and new iterations for the square root from iterations for the sign function. One new iteration is a quadratically convergent Schulz iteration based entirely on matrix multiplication; it converges only locally, but can be used to compute the square root of any nonsingular M-matrix. A new Padé iteration well suited to parallel implementation is also derived and its properties explained. Numerical experiments are included and some advice is offered on the choice of iterative method for computing the matrix square root.

Nicholas J. Higham
University of Manchester, Manchester, UK

MS09

Schur-Fréchet Algorithms for Matrix Functions

Continuously differentiable matrix functions can be evaluated by employing their Fréchet derivative together with a Schur transformation. An example of the Schur-Fréchet approach can be found in the method of Björck and Hammarling for computing the square root of a matrix. Reliable evaluation of the Fréchet derivative is essential to the success of any Schur-Fréchet algorithm. For the logarithm this can be done by using repeated square roots and a hyperbolic tangent form of the logarithmic Fréchet derivative. Padé approximations of the hyperbolic tangent lead to a Schur-Fréchet algorithm for the logarithm that avoids problems associated with the standard "inverse scaling and squaring" method. Inverting the order of evaluation in the logarithmic Fréchet derivative gives a method of evaluating the derivative of the exponential. The resulting Schur-Fréchet algorithm for the matrix exponential gives superior results compared to standard methods on a set of test problems from the literature.

Charles S. Kenney
University of California, Santa Barbara, CA

Alan J. Laub
University of California, Davis, CA

MS09

A Chain Rule for Matrix Functions

Let f be an analytic function. It is well known that

$$f\begin{pmatrix} \lambda & w \\ 0 & \lambda \end{pmatrix} = \begin{pmatrix} f(\lambda) & wf'(\lambda) \\ 0 & f(\lambda) \end{pmatrix}.$$

We generalize this by showing that

$$f\begin{pmatrix} A & W \\ 0 & A \end{pmatrix} = \begin{pmatrix} f(A) & \frac{d}{dt}f(A+tW)\big|_{t=0} \\ 0 & f(A) \end{pmatrix}$$

when A and W are square matrices. One can generalize this idea to obtain formulae for higher derivatives. This gives a very simple approach to differentiating matrix functions and yields slightly stronger results.

Roy Mathias
College of William and Mary, Williamsburg, VA

MS10

A Comparative Study of Sparse Approximate Inverse Preconditioners

There exist currently several alternative proposals for constructing sparse approximate inverse preconditioners, some of which have been compared with standard incomplete factorization techniques. However, there seems to be a lack of direct comparisons between different approximate inverse techniques on a broad range of problems. In this talk, we will survey many of the existing methods and we will present the results of a systematic computational study aimed at assessing the effectiveness of the various methods for different types of problems, with particular attention to their robustness, rates of convergence, and implementation issues.

Michele Benzi
CERFACS
Toulouse, France

Miroslav Tůma
Czech Academy of Sciences
Prague, Czech Republic

MS10

Ordering Techniques for Sparse Approximate Inverse Preconditioning

We investigate how reordering the rows and columns of a matrix can affect the performance of AIBC preconditioning (due to M. Benzi and M. Tůma). In particular we look at anisotropic problems. Our analysis indicates that the orientation of the strong connection of a matrix impacts the distribution of the values in its factorization, hence should be considered in the ordering for an effective preconditioner. Ordering algorithms and numerical results are presented.

Robert E. Bridson
University of Waterloo
Waterloo, Ontario, Canada

Wei-Pai Tang
University of Waterloo
Waterloo, Ontario, Canada

MS10

New techniques and applications for approximate inverse preconditioning

The major difficulties with sparse approximate inverses are:

1. how to select a sparsity pattern for the approximate inverse, statically or dynamically,
2. possible singularity of the approximate inverse or instability during its construction, and
3. their possibly large storage requirements, which is related to the excessive time required to construct these preconditioners in serial.

We will offer our latest ideas on low-cost, factorized approximate inverses with dynamic selection of the sparsity pattern, and show how to apply approximate inverses robustly to incomplete block factorizations.

Edmond Chow and Yousef Saad
Department of Computer Science, and
Minnesota Supercomputer Institute
University of Minnesota
Minneapolis, MN 55455

MS11

More Accurate Bidiagonal Reduction for Computing the Singular Value Decomposition

Bidiagonal reduction is the preliminary stage for the fastest stable algorithms for computing the singular value decompostion. However, the best error bounds on bidiagonal reduction methods are of the form

$$A + \delta A = UBV^T,$$

$$\|\delta A\|_2 \leq \varepsilon_M f(n) \|A\|_2$$

where B is bidiagonal, U and V are orthogonal, ε_M is machine precision, and $f(n)$ is a modestly growing function of the dimensions of A. A Givens-based bidiagonal reduction procedure is proposed that satisfies

$$A + \delta A = U(B + \delta B)V^T,$$

where δA is bounded *columnwise* and δB is bounded *componentwise*. Thus the routine obtains more accurate singular values for matrices that have poor column scaling or those arising from rank revealing decompositions. For an $m \times n$ matrix, this algorithm requires *const.* $* mn^2$ flops where the constant is only a little higher than that for the standard algorithm.

Jesse L. Barlow
Computer Science and Engineering Department
The Pennsylvania State University
University Park, PA 16802
E-mail: barlow@cse.psu.edu
URL: http://trantor.cse.psu.edu/~barlow
Telephone: 814-863-1705
FAX: 814-865-3176

MS11

Relative Error Bounds for Eigenvalues of Normal Matrices

We derive bounds for the relative error in the eigenvalues of a normal matrix. The bounds are invariant under congruence transformations. In particular they are invariant under diagonal scaling. Moreover the bounds make no distinction between definite and indefinite matrices. We conclude that the eigenvalues of normal matrices are no more sensitive than the eigenvalues of positive-definite matrices.

These results extend the bounds for Hermitian matrices by Slapnicar and Veselic to normal matrices. This is joint work with Stan Eisenstat.

Ilse Ipsen
Department of Mathematics
North Carolina State University
Raleigh, NC 27695-8205, USA
ipsen@math.ncsu.edu
http://www4.ncsu.edu/~ipsen/info.html

MS11

Relative Perturbation Bounds for Eigenvalues and Eigenvectors of Indefinite Hermitian Matrices

We are considering the Hermitian eigenvalue problem $Hx = \lambda x$ where $H = D^*AD$ is an indefinite non-singular graded matrix. We present two bounds for relative changes of the eigenvalues of H under perturbations of the form $H + \delta H = D^*(A + \delta A)D$. We also present two bounds for perturbations of invariant subspaces of H. Finally, we point to the close relationship between relative perturbation bounds for perturbations through factors where $H = GAG^*$ and $H + \delta H = (G + \delta G)A(G + \delta G)^*$, and multiplicative perturbations where $H + \delta H = D^*HD$.

Ninoslav Truhar
University Josip Juraj Strossmayer
Faculty of Civil Engineering
Drinska 16 a, 31000 Osijek, Croatia

Ivan Slapničar
University of Split
Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture
R. Boškovića b.b., 21000 Split, Croatia

MS11

On the Eigenvalues of Indefinite Matrices

Our task is to compute the eigensolution of a real symmetric matrix with high relative accuracy. This task is considerably more difficult, if the matrix is not positive definite. We will present some advances in this direction. This includes the idea of iterative improvement and block Jacobi methods.

Veselić K.
Lehrgebiet Mathematische Physik
Fernuniversitaet, Postf 940.
D-58084 Hagen, Germany
kresimir.veselic@fernuni-hagen.de

Drmač Z.
Department of Computer Science
University of Colorado, Boulder
Engineering Center ECOT 7-7
Boulder CO80309-0430
USA

Kovač Striko E.
Faculty of Transport and Traffic Engineering, University of Zagreb
Vukeliceva 4
HR-41000 Zagreb, Croatia

MS12

A Regularizing Lanczos Iteration for Underdetermined Linear Systems

We are concerned with the solution of underdetermined linear systems of equations with a very ill-conditioned matrix A, whose dimensions are so large to make solution by direct methods impractical or infeasible. Image reconstruction from projections often gives rise to such systems. In order to facilitate the computation of a meaningful approximate solution, we regularize the linear linear system, i.e., we replace it by a nearby system that is better conditioned. The amount of regularization is determined by a regularization parameter. Its optimal value is, in most applications, not known a priori. We present a new iterative method based on the Lanczos algorithm for determining a suitable value of the regularization parameter by the discrepancy principle and an approximate solution of the regularized system of equations.

Daniela Calvetti
Stevens Institute of Technology
Hoboken, NJ 07030

L. Reichel
Kent State University
Kent, OH

F. Sgallari
Universit'a di Bologna
Bologna, ITALY

G. Spaletta
Universit'a di Bologna
Bologna, ITALY

MS12

A Modular Solver for Constrained Regularization Problems in Image Restoration

Many problems in image restoration can be formulated as either an unconstrained optimization problem:

$$\min_u \alpha R(u) + ||u - z||^2$$

(the Tikhonov approach, with the regularization parameter α to be determined independently) or as a noise-constrained problem:

$$\min_u R(u), \quad \text{subject to} \quad ||u - z||^2 = \sigma^2,$$

where σ is the estimated noise level. In practice, it is much easier to devise methods for the unconstrained problem and not so obvious how to adapt such methods for the constrained problem. In this talk, we present a new method which can make use of ANY convergent method for the unconstrained problem to solve the constrained one. The method is based on an approximate Newton block-elimination algorithm applied to the constrained problem. We present numerical results which show that the constrained problem can be solved with cost not much more than that for solving one unconstrained problem.

Tony F. Chan
Department of Mathematics
University of California, Los Angeles
405 Hilgard Ave
Los Angeles, CA 90095-1555
chan@math.ucla.edu

Peter Blomgren
Department of Mathematics
University of California, Los Angeles

405 Hilgard Ave
Los Angeles, CA 90095-1555
blomgren@math.ucla.edu

MS12

Efficient Algorithms for Least-squares Type Problems

The standard least-squares problem is to minimize $\min_{x\in\mathcal{R}^n}\|Ax-b\|$, where A is an $m\times n$ matrix, with $m>n$, b is an m-dimensional vector, and $\|\cdot\|$ indicates the Euclidean norm of the vector. Frequently in practice, the data A and b are not known exactly. The TLS algorithm and regularization-based methods are popular schemes for handling such uncertainties. We propose several new formulations of least-squares type problems which explicitly include bounds on the uncertainties and which regularize the solution. We also provide efficient algorithms for their solution. The direct solution of the least squares problem may lead to a vector x that is severely contaminated with noise. Tikhonov regularization addresses this problem by solving instead the linear least squares problem

$$\min_{x\in\mathcal{R}^n}\|Ax-b\|^2+\alpha\|x\|^2.$$

The solution x_α satisfies the equation

$$(A'A+\alpha I)x_\alpha = A'b.$$

The choice of an appropriate regularization parameter α is crucial, and many methods have been proposed for this purpose. One method handles the case where the norm of the noise vector e is known:

Morozov's discrepancy principle The value of α is chosen such that the norm of the residual $\|b-Ax_\alpha\|$ equals the norm of the error term:

$$\phi_{\mathrm{M}}(\alpha) := \alpha^2 b'(AA'+\alpha I)^{-2}b = \|e\|^2.$$

Generalized cross-validation The value of α is computed as the global minimizer of

$$\phi_{\mathrm{GCV}}(\alpha) := \frac{\|b-A(A'A+\alpha I)^{-1}A'b\|}{\mathrm{trace}\left(\mathrm{I}-\mathrm{A}(\mathrm{A}'\mathrm{A}+\alpha\mathrm{I})^{-1}\mathrm{A}'\right)} = \frac{\|(AA'+\alpha I)^{-1}b\|}{\mathrm{trace}\left((\mathrm{AA}'+\alpha\mathrm{I})^{-1}\right)} = \min.$$

Another formulation is the following min-max problem

$$\min_{x\in\mathcal{R}^n}\max_{\|E\|\le\eta}\|(A+E)x-b\|,$$

which can be shown to be equivalent to

$$\min_{x\in\mathcal{R}^n}\|Ax-b\|+\eta\|x\|.$$

Its solution can be written in the form

$$(A'A+\alpha I)x = A'b,$$

where α is a non-negative real number obtained as the root of a certain secular equation. We have efficient and reliable numerical algorithms for finding α, which in fact can be interpreted as an automatic regularization parameter that minimises the worst-case residual. For large scale problems iterative methods become necessary. We will discuss how the Lanczos algorithm can be used to approximate the functions $\phi(\alpha)$. In most cases we can compute lower and upper bounds on $\phi(\alpha)$, and these bounds become tighter as the number of Lanczos iterations increases. In the case of GCV a stochastic trace estimator is used to approximate the denominator in $\phi_{\mathrm{GCV}}(\alpha)$. This talk represents joint work with S. Chandrasekaran, M. Gu, A. H. Sayed and U. von Matt.

Gene Golub,
Department of Computer Science,
Stanford University,
Stanford, CA 94305-2140,
golub@na-net.ornl.gov

MS12

Numerical Linear Algebra and Constrained Deconvolution

We will consider the ill-posed problem of image deblurring, i.e., recovering an image which has been convolved with a smooth kernel and contaminated by noise. Imposing constraints on the image in addition to regularization can substantially improve the reconstructions. In this talk we will discuss the numerical linear algebraic aspects of a projected Newton method for nonnegatively constrained deconvolution. Applications to atmospheric and astronomical imaging will be presented.

Curt Vogel
Department of Mathematical Sciences
Montana State University
Bozeman, MT 59717-0240
vogel@math.montana.edu

James G. Nagy
Department of Mathematics
Southern Methodist University
Dallas, TX 75275-0156
nagy@math.smu.edu

MS13

Backward Shift–Invariant Finite Dimensional Reproducing Kernel Spaces: From the Disk to Compact Riemann Surfaces

Let $\mathcal{M}$ be a finite dimensional space of functions, and let $\{f_1,\ldots,f_n\}$ be a basis of $\mathcal{M}$. The recipe $[f_\ell,f_k]_{\mathcal{M}}=p_{k\ell}$, where $\mathbb{P}=(p_{ij})$ is a non singular $n\times n$ matrix, makes $\mathcal{M}$ into an indefinite inner product space with reproducing kernel $K(z,\omega)=(f_1(z)\cdots f_n(z))\mathbb{P}^{-1}(f_1(\omega)\cdots f_n(\omega))^*$. It is of interest to relate the properties of $\mathcal{M}$, of its kernel and of $\mathbb{P}$. We review the case of de Branges spaces, and their generalizations to the *nonstationary case*.

Daniel Alpay
Department of Mathematics Ben–Gurion University of the Negev
POB 653 Beer–Sheva 84105
Israel
dany@cs.bgu.ac.il

MS13

Extensions and Factorizations on Indefinite Metric Spaces

We present an extension problem for families of factorizations in connection with the dilation theory for matrices on indefinite metric spaces. The main examples in this talk will refer to a Schur-type algorithm and some of its applications. For instance, it is remarked how the geometrical structure of (even singular) Hermitian matrices can be described using some sort of Schur parameters and this leads to a transmission-line factorization model.

Tiberiu Constantinescu
Programs in Mathematical Sciences
University of Texas at Dallas
Richardson, TX 75083
tiberiu@utdallas.edu

Aurelian Gheondea
Institute of Mathematics
Bucharest, Romania
gheondea@imar.ro

Leiba Rodman
Department of Mathematics
The College of William and Mary
Williamsburg, VA 23187-8795, USA
lxrodm@math.wm.edu

MS13

Rate of Stability of Symmetric Factorizations

Let $W(\lambda)$ be a proper rational $n \times n$ matrix function that takes positive semidefinite matrix values for real λ. It is well known that such $W(\lambda)$ admit *symmetric* factorizations, i.e., minimal factorization of the form $W(\lambda) = (L(\overline{\lambda}))^* L(\lambda)$, where $L(\lambda)$ is $n \times n$. We describe situations when symmetric factorizations are stable, i. e., a nearby function $\tilde{W}(\lambda)$ admits a symmetric factorization with the factor $\tilde{L}(\lambda)$ as small as we wish to $L(\lambda)$ provided $\tilde{W}(\lambda)$ is sufficiently close to $W(\lambda)$. The closeness of rational matrix functions is measured in terms of their minimal realizations.

André C.M. Ran
Faculteit Wiskunde en Informatica
Vrije Universiteit Amsterdam
De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands
ran@cs.vu.nl

Leiba Rodman
Department of Mathematics
The College of William and Mary
Williamsburg, VA 23187-8795, USA
lxrodm@math.wm.edu

MS13

Stability of Nonnegative Invariant Subspaces of H-Accretive Matrices and Applications to Stationary Transport Equations

We present results on the stability of nonnegative invariant subspaces of complex $n \times n$ that are accretive with respect to a nondegenerate indefinite scalar product. These results are then applied to a finite-dimensional version of the abstract stationary transport equation on the half-line relevant to the transfer of polarized light in planetary atmospheres. As a results, a complete theory for the stability of the solutions of these transport equations is obtained. Finally, similar stability results are derived for the abstract stationary transport equation in an infinite dimensional Hilbert space, using a reduction of the problem to an analogous finite dimensional stability problem.

Cornelis V.M. Van der Mee
Dipartimento di Matematica
Università di Cagliari
Via Ospedale 72, 09124 Cagliari, Italy
cornelis@krein.unica.it

André C.M. Ran
Faculteit Wiskunde en Informatica
Vrije Universiteit Amsterdam
De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands
ran@cs.vu.nl

Leiba Rodman
Department of Mathematics
The College of William and Mary
Williamsburg, VA 23187-8795, USA
lxrodm@math.wm.edu

MS14

What Does it Mean for Hermitian Eigenvalue Problem to be Well-Behaved?

In recent years, significant progress has been made in understanding how to solve eigenvalues problems more accurately. We give a perturbation theory that includes much of this progress. The main application of this work is the development of robust software for eigenvalue problems. The efforts described here have had great influence on the eigenvalue codes in the LAPACK project. There are two important thrusts to these efforts. The first is to find classes of matrices which are "well behaved." These are matrices for which structured relative changes in the entries of the matrices cause only relative changes in the eigenvalues. We also expect that the invariant subspaces associated with clusters of eigenvalues will be very stable. The second thrust is to find algorithms that compute the eigenvalues and eigenvectors to the expected accuracy. This talk will define a well-behaved matrix discuss its characterization.

Jesse L. Barlow
Computer Science and Engineering Department
The Pennsylvania State University
University Park, PA 16802
E-mail: barlowcse.psu.edu
URL: http://trantor.cse.psu.edu/~barlow
Telephone: 814-863-1705
FAX: 814-865-3176

Ivan Slapničar
Faculty of Electrical Engineering,
Mechanical Engineering, and Naval Architecture
University of Split
R. Boskovica bb.
21000 Split, URL: http://www.fesb.hr/~slap
E-mail: ivan.slapnicarfesb.hr

MS14

On Accurate Algorithms for Canonical Correlations, Weighted Least Squares and Related Generalized Eigenvalue and Singular Value Decompositions

We present new algorithms for accurate floating–point computation of the singular value decomposition (SVD) of the product of three matrices and the (H, K)–SVD of general matrices. The applications of these algorithms include weighted least squares, canonical correlation and generalized eigenvalue computations. For example, each eigenvalue λ of the positive definite $n \times n$ eigenvalue problem $S^\tau HSx = \lambda Kx$ is computed with relative error $|\delta\lambda|/\lambda$ bounded (up to a factor of n) by $\varepsilon\{\min_{\Delta=\text{diag}} \kappa_2(\Delta H \Delta) + \min_{\Delta=\text{diag}} \kappa_2(\Delta K \Delta) + C(S)\}$, where ε is round–off, $\kappa_2(\cdot)$ is the spectral condition number, and $C(S)$ is nearly invariant under two–sided diagonal scalings of S.

Zlatko Drmač
University of Colorado at Boulder
Department of Computer Science
Engineering Center ECOT 7–7
Boulder, CO 80309–0430

MS14

Computing the Singular Value Decomposition With High Relative Accuracy

Recently, methods have been developed to compute singular values to high relative accuracy, or tiny percentage error, for several special classes of matrices, whereas conventional methods only guarantee so in the singular values of largest magnitude. But the "link" among these matrix classes has been missing. In this talk, we resolve this issue by providing a common theory and a common numerical method for high relative accuracy computation for these and a number of new classes of matrices.

Ming Gu
University of California
J. Demmel
University of California, Berkeley
S. Eisenstat
Yale University
Z. Drmač
University of Colorado, Boulder,
K. Veselić
Fernuniversität Hagan,
I. Slapničar
University of Split

MS14

The Fundamental Role of Weyl's and Ostrowskii's Inequalities

There are numerous perturbation bounds for eigenvalues of symmetric matrices. I will show that almost of all of them can be easily derived from the two simplest, that is, Weyl's monotonicity principle:

$$B \geq 0 \Rightarrow \lambda_i(A+B) \geq \lambda_i(A),$$

and Ostrowskii's multiplicative version of it:

$$\sigma_n(C) \geq 1 \Rightarrow \frac{\lambda_i(C^T AC)}{\lambda_i(A)} \geq 1,$$

here A and B are symmetric and C is arbitrary. Thus if one needs to prove an eigenvalue perturbation bound for symmetric matrices one should first try to use Weyl's or Ostrowskii's bounds.

Roy Mathias
College of William and Mary, Williamsburg, VA

MS15

Multilevel Domain Decomposition for Unstructured Meshes

When multilevel iterative methods on unstructured meshes have a grid hierarchy with general coarse grids whose boundaries do not match the boundary of the fine grid, boundary conditions must be carefully treated. We present an algorithm for dealing with this and provide a convergence analysis for the multilevel methods in the additive subspace correction framework, adopting a matrix setting for the discussion. The key steps are to show local optimal L^2-approximation and H^1-stability.

Tony F. Chan
Department of Mathematics
UCLA
Los Angeles, CA 90095
chan@math.ucla.edu

Susie Go
Department of Mathematics
UCLA
Los Angeles, CA 90095
sgo@math.ucla.edu

MS15

Multilevel Algorithms for Combinatorial Problems

Although widely used in scientific computing, multilevel methods have only recently found applications in discrete mathematics. Not coincidentally, some of these early applications have been to discrete problems relevant to linear algebra. This talk will begin by reviewing multilevel methods for partitioning graphs, with applications to sparse direct methods and parallel iterative solvers. But the primary focus will be on a new multilevel algorithm for small envelope orderings of sparse matrices.

Bruce Hendrickson
Sandia National Laboratories
Albuquerque, NM 87185-1110
bah@cs.sandia.gov

Erik G. Boman
Scientific Computing & Computational Mathematics
Stanford University
Stanford, CA 94305
boman@sccm.stanford.edu

MS15

Optimal Good Aspect-Ratio Coarsening for Unstructured Meshes

A good aspect-ratio coarsening sequence of an unstructured mesh $\mathcal{M}_0$ is a sequence of meshes $\mathcal{M}_1, \ldots, \mathcal{M}_k$ such that:

- $\mathcal{M}_i$ is a good aspect-ratio mesh
- $\mathcal{M}_i$ is a smaller approximation of $\mathcal{M}_{i-1}$.

The effectiveness of a multi-level method that uses a coarsening sequence depends on the sequence quality. We present a new approach towards mesh coarsening that guarantees the sequence is of good aspect-ratio and is also of optimal size and width up to a constant factor. We developed a simple and efficient variant of our approach, and present experimental results that substantiate the theoretical claims.

Gary L. Miller
School of Computer Science
Carnegie-Mellon University
5000 Forbes Ave
Pittburgh, PA 15217
glmiller@cs.cmu.edu

Dafna Talmor
School of Computer Science
Carnegie-Mellon University
5000 Forbes Ave
Pittburgh, PA 15217
tdafna@cs.cmu.edu

Shang-Hua Teng
Department of Computer Science
University of Minnesota
200 Union Street SE
Minneapolis, MN 55455
steng@cs.umn.edu

MS15

Coarsening, Sampling, and Smoothing: Elements of the Multilevel Method

The multilevel method has emerged as one of the most effective methods for solving numerical and combinatorial problems. It has been used in multigrids, domain decomposition, geometric search structures, as well as optimization algorithms for problems such as partitioning and sparse-matrix ordering. This paper presents a systematic treatment of the fundamental elements of the multilevel method. We illustrate, using examples from several fields, the importance and effectiveness of coarsening, sampling, and smoothing (local optimization) in the application of the multilevel method.

Shang-Hua Teng
Deparment of Computer Science
UIUC
1304 W. Springfield
Urbana, IL 61801-2987
steng@cs.umn.edu

MS16

Reduction of Systems to Fishbone Form

No guaranteed backward stable method is known that reduces a matrix to tridiagonal form. We present a stable method to produce a Fishbone matrix (this is a new term). The idea behind the method is to change the Lanczos process when an instability is encountered, but to make the modifications as mild as possible. This modification of the Lanczos algorithm yields a matrix with its tridiagonal part and some extra rows or columns.

Jianxun He
KLA Instruments Corporation
160 Rio Robles San Jose, CA 95161
jhe@falcon.kla.com

Beresford Parlett
Department of Mathematics
University of California, Berkeley
CA 94720
parlett@math.berkeley.edu

MS16

Gaussian Reduction to Similar Hessenberg or Banded Hessenberg Form

Gaussian transformations can reduce a general matrix to either full or banded Hessenberg form. Algorithms under development take advantage of cache architectures and also of matrix sparsity. Allowing multipliers larger than one with two-sided eliminations gives a nearly tridiagonal matrix. Backward error estimates are presented. Iterative application gives a scalable bulge chasing algorithm which requires only $O(n)$ storage to determine the spectra of an $n \times n$ small-band unsymmetric matrix.

Gary W. Howell
Applied Mathematics
Florida Institute of Technology
150 W. University Blvd.
Melbourne, FL 32901
howell@zach.fit.edu

MS16

Striped Tridiagonal Eigenvalue Algorithms

Gaussian similarity reduction of an unsymmetric matrix to tridiagonal form is made robust by allowing row stripes. Stripe sparsity is governed by a prescribed bound on a norm of the transformation matrix. Algorithms for finding eigenvalues of stridiagonal (striped tridiagonal) matrices have been developed. Shifted inverse iteration followed by deflation is robust and efficient . Algorithms which take advantage of the significant subdiagonal elements generated during reduction to stridiagonal form are especially efficient.

Eugene L. Wachspress
Retired but not expired
9802 Montego Ct,
Windsor, CA 95492
104017.1325@compuserve.com

MS16

Calculating Eigenvalues of Large Matrices using the BR Algorithm

The BR algorithm is an effective method for calculating the eigenvalues of the non-symmetric, nearly tridiagonal matrices that are generated by the look-ahead Lanczos process. This talk will describe the BR algorithm briefly and discuss its performance on a variety of large problems. On the largest problems we have considered so far, the BR algorithm saves a factor of 60 in computing time and 100 in storage space, in comparison with the QR algorithm.

David S. Watkins
Department of Mathematics
Washington State University
Pullman, WA 99164-3113
watkins@wsu.edu

Gary W. Howell
Department of Applied Mathematics
Florida Institute of Technology
150 W. University Blvd.
Melbourne, FL 32901
howell@zach.fit.edu

G. A. Geist
Mathematical Sciences Section
Oak Ridge National Laboratory
Box 2008, Bldg. 6012
Oak Ridge, TN 37813-6367
gst@ornl.gov

MS17

On the Role of the Left Starting Vector in the Nonsymmetric Lanczos Algorithm

It is often observed that the BiCG/QMR algorithms require only moderately more iterations than (full) GMRES. Unfortunately, we have no idea why. It is shown that — whatever the explanation — it must take account of the left starting vector in the two-sided Lanczos algorithm. With a perversely chosen left starting vector, any 3-term recurrence can be generated during the first half of the algorithm. We show why the standard choices of, say, a random left starting vector or a left starting vector equal to the right starting vector usually perform better than a random recurrence. We show that a near optimal approximation can be obtained at any given step by appropriate choice of the left starting vector.

Anne Greenbaum
Courant Institute
251 Mercer St.
New York, NY 10012
greenbau@phantom2.nyu.edu

MS17

Residual Smoothing: Does it Help at All?

Some Lanczos-type solvers for non-Hermitian linear systems, such as BiCG and (Bi)CGS, are prone to erratic convergence: residual norms may increase and decrease by several orders of magnitude within a few iteration steps. By combining these methods with smoothing processes producing other iterates one can make the residual norm plots look much smoother. But does this really mean that the solution is found sooner? Or that the error can be made smaller?

Martin H. Gutknecht
Swiss Center for Scientific Computing (CSCS/SCSC)
ETH Zürich, ETH-Zentrum
CH-8092 Zürich, Switzerland
mhg@scsc.ethz.ch

MS17

Look-ahead Lanczos Revisited

In look-ahead Lanczos algorithms breakdowns of the Lanczos process are circumvented by replacing ill-defined or ill-conditioned Lanczos vectors by other, so-called inner vectors, which still expand the Krylov space, but do not satisfy all the biorthogonality conditions. There are various ways to define these inner vectors. We discuss the pros and cons of several choices and show that the introduction of certain auxiliary vectors reduces the memory overhead in the case of successive look-ahead steps.

Martin H. Gutknecht
Swiss Center for Scientific Computing (CSCS/SCSC)
ETH Zürich, ETH-Zentrum
CH-8092 Zürich, Switzerland
mhg@scsc.ethz.ch

Marlis Hochbruck
Mathematisches Institut
Universität Tübingen
Auf der Morgenstelle 10
D-72076 Tübingen, Germany
marlis@na.uni-tuebingen.de

MS17

The Main Effects of Rounding Errors in Krylov Solvers for Symmetric Linear Systems

Several well-known methods are based on the three-term Lanczos process for symmetric matrices: MINRES (GMRES), CG, CR, and SYMMLQ. We will discuss in what way and to what extent the various approaches are different in their sensitivity with respect to rounding errors.
Our findings are supported and illustrated by numerical examples.

Gerard Sleijpen and Henk van der Vorst
Mathematical Institute
Utrecht University
NL-3508 TA Utrecht, The Netherlands
sleijpen / vorst@math.ruu.nl

Jan Modersitzki
Institute of Mathematics
Medical University of Lübeck
D-23560 Lübeck, Germany
modersitzki@informatik.mu-luebeck.de

MS18

Teaching Numerical Linear Algebra to Undergraduates

Techniques of teaching numerical linear algebra to undergraduates will be discussed. How much theory? To what extent should rounding error analysis be discussed? ...

James R. Bunch
University of California, San Diego
La Jolla, CA

MS18

Teaching of Algorithms In Class Rooms

One of the most important aspects of Numerical Linear Algebra teaching is to figure out how algorithms be presented to the students in the classrooms. Describing an algorithm using a terse Pascal-like language is hardly helpful for a student to understand the basic ideas and underlying principles of the algorithm. Innovative ideas of teaching algorithms should be developed so that the students understand the mechanism of development of the algorithms, rather than only the algorithms themselves, their creative talents become stimulated, they develop an appreciation for beauty and usefulness of the algorithms, and after all, learning algorithms become fun for them.In this talk, I present some of my own personal ideas to these effects, based on experience in the class rooms.

Biswa Nath Datta
Department of Mathematical Sciences
Northern Illinois University
DeKalb, IL 60115
E-mail: dattab@math.niu.edu

MS18

Recent Trends in Teaching Linear Algebra

This talk describes results of a nationwide survey of linear algebra teaching and discusses how the recommendations of the Linear Algebra Curriculum Study Group are being implemented at schools across the country. Connections with engineering, computer science, and numerical linear algebra are considered. Time for comments and suggestions from the audience is planned.

David C. Lay
Department of Mathematics
University of Maryland
College Park, MD 20742
lay@math.umd.edu

MS18

Using Software to Teach Linear Algebra

This talk focuses on how to use software in classroom presentations. An example is given of a classroom lecture involving geometric examples that lead students to discover an important linear algebra theorem. In the same lecture a simple application of the theorem is presented. MATLAB is used to both solve the application and to provide geometric motivation for the solution. The talk previews some of the teaching materials developed by the NSF sponsored ATLAST project.

Steven J. Leon
Department of Mathematics
University of Massachusetts Dartmouth
Dartmouth, MA 02747
sleon@umassd.edu

MS19

Parallel Implementation of Factorised Sparse Approximate Preconditioner for Large Structural Analysis Problems

In this paper we discuss the parallel implementation of a factorised sparse approximate inverse preconditioner. We distribute the large unstructured finite element meshes using a graph partitioning algorithm. We show that we can both calculate and apply the preconditioner efficiently. We test the preconditioner on some large (greater than 100,000 degrees of freedom) and highly ill conditioned problems that arise from real industrial structural analysis problems ranging from integrated circuits to train chassis parts.

Martyn R. Field
Hitachi Dublin Laboratory
O'Reilly Institute
Trinity College
Dublin 2, Ireland
martyn@hdl.ie

MS19

Sparse Approximate Inverses and Multigrid Methods

One possible formulation of the multigrid technique is based on a generating system. Here, the new linear equation is written as an extension $\tilde{A}$ of A. Then $\tilde{A}$ is singular, but the convergence of the conjugate gradient method depends on the nonzero spectrum only. The Gauss-Seidel preconditioning applied on $\tilde{A}$ leads to a bounded number of iteration steps but we have to solve triangular equations. Therefore, we replace the Gauss-Seidel smoother (or similar triangular preconditioners) by sparse approximate inverses. Then we get a fully parallel multigrid algorithm with nearly the same convergence.

Thomas Huckle
Department of Informatik
Technical University Munich
Arcisstr. 21
D-80290 Munich, Germany

MS19

Wavelet Sparse Approximate Inverse Preconditioners

We show how to use wavelet compression ideas to improve the performance of approximate inverse preconditioners. Our main idea is to first transform the inverse of the coefficient matrix into a wavelet basis, before applying standard approximate inverse techniques. In this process, smoothness in the entries of A^{-1} are converted into small wavelet coefficients, thus allowing a more efficient approximate inverse approximation. We shall justify theoretically and numerically that our approach is effective for matrices with smooth inverses.

Tony F. Chan
University of California, Los Angeles, CA
W. P. Tang
University of Waterloo, Waterloo, Ontario
Wing-Lok Wan
University of California, Los Angeles, CA

MS19

Sparse Approximate Inverses and Factorized Sparse Approximate Inverses

Sparse approximate inverses and factorized sparse approximate inverses provide a promising approach to construction of reliable parallel preconditioning strategies for solving large linear systems. It is well known that sparse approximate inverses underlie preconditioning strategies with large potential resources of parallelism but their serial arithmetic complexity doess prevent their exploitation on uniprocessor computers. It is little known about factorized sparse approximate inverses mainly due to their theoretical justification in the unsymmetric case. In the talk we provide a theoretical comparison of minimization techniques which underlie both approaches and present results of numerical experiments when solving linear systems which come from industrial applications.

L. Lolotilina, A. Nikishin, A. Yeremin,
Russian Academy of Sciences, Russia

PS

Pivoting Strategies for Sparse Factorizations

We are concerned with pivoting strategies for sparse matrix factorizations of the form $A = P(L+I)D(I+U)Q$ where P and Q are permutation matrices, L and U are strictly lower and upper triangular, respectively, D is diagonal or block diagonal, and the nonzero structures of L, U and D are disjoint. A has symmetric or nearly symmetric structure.
Stability requires that the magnitudes of entries in L and U be bounded and that D be well-conditioned. We study the influence of the bound on the factor entries and pivot block size on the factorization time and solution error. We also explore the role of pivoting in a drop tolerance factorization.

Cleve Ashcraft and Roger Grimes
Boeing Information and Support Services
P. O. Box 24346, Mail Stop 7L-22
Seattle, Washington 98124-0346
E-mail: cleve.ashcraft@boeing.com
roger.g.grimes@boeing.com

PS

Multivariate Time Series State Space Modeling with High Performance SVD Computation of an Hankel Matrix

State space realizations have been increasingly studied and applied to multivariate time series modeling. In this work we present a methodology for high performance computation of an algorithm developed by Masanao Aoki (*State Space Modeling of Time Series - Springer-Verlag, 1990*) for state space modeling of time series. From previous work we concluded that there is a computational bottleneck on the Hankel matrix calculation for this type of algorithm. In this paper we propose an higher performance solution based on the singular value decomposition of the Hankel matrix. The computational implementation of such algorithm is done via the utilization of parallel and distributed processing; with the objective of real time state space modeling of multivariate time series.

Celso Pascoli Bottura, Gilmar Barreto
and Maurício José Bordon
School of Electrical and Computer Engineering
State University of Campinas - UNICAMP
Caixa postal: 6101, Campinas, Sao Paulo, Brazil
E-mail: gbarreto@fee.unicamp.br

José Tarcisio Costa Filho
Departament Electrical Engineering
Federal University of Maranhão
São Luís, Brazil

PS

Invertibility of Superalgebras' Elements

Invertibility (usual, right, left, generalized) of different rings' and algebras' elements is one of the important problems of applied linear algebra. Some of these properties are investigated in superalgebras.

Let A be an superalgebra, or Z_2-graduated algebra, i.e. $A = A^0 \oplus A^1$ (direct sum of submodules) and $A^i \cdot A^j \subset A^{i+j}, i, j \in Z_2$; A^0 is subalgebra in A, e (identity of A)$\in A^0$.An element $a = a^0 + a^1 \in A, a^0 \in A^0, a^1 \in A^1$,under the assumption of existence of inverses $(a^0)^{-1} \in A^0, (a_i)^{-1} = (a^0 - a^1 \cdot (a^0)^{-1} \cdot a^1)^{-1} \in A^0$, is invertible and (in notation $a' = a^0 - a^1$) $a^{-1} = (a^0)^{-1} \cdot a' \cdot (a_i)^{-1} = (a_i)^{-1} \cdot a' \cdot (a^0)^{-1}$ (in the particular case of commutative $A, a^{-1} = (a' \cdot a)^{-1} \cdot a'$). Under the assumption of existence of right inverses $(a^0)^-_R \in A^0, a^0 \cdot (a^0)^-_R = e, (a_r)^-_R = (a^0 - a^1 \cdot (a^0)^-_R \cdot a^1)^-_R \in A^0$, a is right invertible and (in notations $p = e - (a^0)^-_R \cdot a^0 \in A^0$, $r = e - (a^0)^-_R \cdot a^1, p_r = e - (a_r)^-_R \cdot a_r \in A^0$) $a^-_R = r \cdot (a_r)^-_R + (e - r \cdot (a_r)^-_R \cdot a^1) \cdot p \cdot y + r \cdot p_r \cdot z$, any $y \in A, z \in A^0$. Investigation of left invertibility is analogous: in corresponding assumptions and notations $a^-_L = (a_l)^-_L \cdot l + y \cdot q \cdot (e - a^1 \cdot (a_l)^-_L \cdot l) + z \cdot q_l \cdot l$, any y, z, $q = e - a^0 \cdot (a^0)^-_L, l = e - a^1 \cdot (a^0)^-_L, a_l = a^0 - a^1 \cdot (a^0)^-_L \cdot a^1, q_l = e - a_l \cdot (a_l)^-_L$.

Investigation of generalized invertibility needs in special consideration.

Sam L. Blyumin and Kat Krivovyaz
Lipetsk State Technical University
30 Moskovskaya, 398055 Lipetsk, Russia
slb@stu.lipetsk.su

PS

Sensitivity of Eigenvalues of a Defective Matrix

We study how sensitive the defective eigenvalues of a complex matrix are with regard to perturbations. No restrictions are placed on the perturbations. Given a perturbed eigenvalue and an associated perturbed eigenvector, we express the difference between the perturbed and true eigenvalue in terms of the residual and a condition number. The condition number is the orthogonal projection of the perturbed eigenvector onto a (generalized) eigenspace. In particular, this implies that a defective eigenvalue can be well-conditioned.

Grace E. Cho
Department of Mathematics
North Carolina State University
Raleigh, NC 27695-8205
E-mail ehcho@eos.ncsu.edu

PS

Controllable Completions

Let A be an $n \times n$ matrix, and b an $n \times 1$ vector. It is well known that if the pair (A, b) is controllable then A is nonderogatory. We prove here, that if A is nonderogatory and b is a partial vector, then every completion $\hat{b}$ of b will yield a controllable pair $(A, \hat{b})$, except for those completions which lie in a finite union of proper A-invariant subspaces. We extend our results to the completion of a partial B so that the pair (A, B) is controllable.

Jane M. Day
Department of Mathematics & Computer Science
San Jose State University, San Jose, CA 95192-0103
day@sjsumcsu.sjsu.edu

Luz M. DeAlba
Deparment of Mathematics & Computer Science
Drake University, Des Moines, IA 50311
luz.dealba@drake.edu

Charles R. Johnson
Department of Mathematics
College of William & Mary, Williamsburg, VA 23187
crjohns@math.wm.edu

PS

About Effectiveness of Closeness Measures for Positively-Defined Operators Method and Experiments

We present a comparative analysis of several closeness measures for Positively-Defined Operators. We consider trace, det, other measures and the "shift measure". The latter has been developed on Karhunen-Loeve representation and included all operator's eigenvectors and eigenvalues. We studied very weak links between operator's parameters and poorly-defined operator's descriptions. The "shift measure" has shown more accuracy/stability than other measures and can be used for sparse matrices computation.

Steve K. Galitsky and Andrey S. Galitsky
985 Westmoreland Dr. #24
Vernon Hills, IL 60061
E-mail: andreyg@lnd.com

PS

Matrix Algebra: Testing and Pairwise Testing for Homogeneity of Odds Ratios using Pseudo-Bayesian Estimators

Pseudo-Bayes estimates for a log-linear model are obtained using matrix algebra. These estimates are used for testing, and pairwise testing, for homogeneity of odds ratios. To be considered is the distribution and abundance of Arctic char (Salvelinus alpinus) in the coastal areas of the central Beaufort sea of Alaska. The model fit is not the saturated model, hence the estimated pseudo-Bayesian cell counts are used in calculating odds ratios and corresponding variance estimates.

Paul Johnson, Ph.D.
University of California San Francisco, CA

PS

On the Kogan-Bermans'Question for the Set of Factorization Indices of a Graph

A simple graph G is completely positive if all doubly nonngative matrix realizations of G are completely positive. For a given(not necessarily completely positive) graph G, the set of factorization indices of all completely positive matrix realizations of G is denoted by I(G). Kogan and Berman in 1993 raised a question: If a and b belong to I(G), does I(G) contain all integers between a and b? Here we give an affirmative answer for completely positive graphs.

Li Jiong-Sheng and Zhang Xiao-dong
Department of Mathematics
University of Science and Technology of China
Hefei Anhui 230026
The People's Republic of China
E-mail address: lijs@sunlx06.nsc.ustc.edu.cn

PS

MINRES for the Regularization of Ill-posed Problems

We discuss the regularizing effect of the MINRES algorithm on discrete ill-posed problems involving symmetric positive definite matrices. We give a bound on the norm of the MINRES residual and show that the regularizing behavior of the algorithm can be better characterized by the convergence of the residual than by convergence of harmonic Ritz values. Numerical examples illustrate the tightness of the bound and the advantage of MINRES over the direct regularization method TSVD.

Misha E. Kilmer
Applied Mathematics Program
University of Maryland
College Park, MD 20742
mkilmer@cs.umd.edu

G. W. Stewart
Department of Computer Science
Institute for Advanced Computer Studies
University of Maryland
College Park, MD 20742
stewart@cs.umd.edu

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Overview of the Semi-Discrete Matrix Decomposition and Its Applications

The Semi-Discrete Decomposition (SDD) approximates a matrix by a sum of scaled outer products of vectors with entries restricted to the set $\{-1, 0, 1\}$. The SDD requires very little storage, in contrast to truncated singular value decompositions, and therein is its advantage. It has use in applications such as image compression, audio compression, and information retrieval. We will discuss how to create an SDD approximation, the properties of that approximation, and the demonstrate the applications.

Tamara G. Kolda
Applied Mathematics Program
University of Maryland
College Park, MD 20742-4015
kolda@math.umd.edu

Dianne P. O'Leary
Department of Computer Science
University of Maryland
College Park, MD 20742
oleary@cs.umd.edu

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Promoting Understanding in Undergraduate Linear Algebra

During recent years the national trend in linear algebra instruction has undergone major changes. Because many students who take linear algebra are not mathematics majors, the traditional theorem-proof look of linear algebra has been replaced by a matrix-oriented, application-based course. For some students, important topics are still elusive. The author will explore and discuss some demonstrations, exercises, projects, and testing strategies that promote understanding of basic concepts and their applications.

Lila F. Roberts
Department of Mathematics and Computer Science
Georgia Southern University
P. O. Box 8093
Statesboro, GA 30460
Email: lila@gsu.cs.gasou.edu

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On Special Matrices with Prescribed Singular Values

We present some algorithms for computing special matrices, eg. projections ($A^2 = A$), involutions ($A^2 = I$), nilpotents ($A^2 = 0$) and unit triangular matrices with prescribed singular values. The singular values of A are the positive square roots of the eigenvalues of A^*A. We develop algorithms for computing the singular value decomposition SVD and polar decomposition of projections, involutions and nilpotents with given Schur's form. We propose the efficient algorithm of the Horn method for finding an unit triangular matrix $A(n \times n)$. The numerical tests in MATLAB will be given to investigate the sensivity of eigenvalues of special matrices to perturbations in data.

Alicja Smoktunowicz
Warsaw University of Technology
Pl.Politechniki 1
00–661 Warsaw, Poland
E-mail: smok@im.pw.edu.pl

Marek Aleksiejczyk
Institute of Mathematics and Physics
Pedagogical University of Olsztyn
ul. Zolnierska 14a, 10-561 Olsztyn, Poland
E-mail: mareka@tufi.wsp.olsztyn.pl

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Asynchronous Weighted Additive Schwarz Methods

Asynchronous Schwarz methods for the parallel solution of nonsingular linear systems are investigated. Theorems are obtained demonstrating convergence. The results apply in the overlapping cas. Numerical experiments on systems of

PROGRAM-AT-A-GLANCE

	Tuesday	Wednesday	Thursday	Friday	Saturday
7:30 AM		Registration *Room: Ballroom Foyer*			
8:00 AM			Registration *Room: Ballroom Foyer*	Registration *Room: Ballroom Foyer*	Registration *Room: Ballroom Foyer*
8:20 AM		Welcome Remarks and Announcements *Alan George, University of Waterloo, Canada* *Room: Ballroom 3*			
8:30 AM		**IP1 Geometrical Approaches to the Algebraic Eigenvalue Problem** *Alan Edelman, Massachusetts Institute of Technology* *Chair: Ilse Ipsen, North Carolina State University* *Room: Ballroom 3*	**IP3 Doubly Stochastic Matrices: Theory and Application** *Richard A. Brualdi, University of Wisconsin, Madison* *Chair: Paul Van Dooren, Université Catholique de Louvain, Belgium* *Room: Ballroom 3*	**IP5 Robust Parallel Algorithms for Sparse Symmetric Eigen Applications** *John G. Lewis, Boeing Information and Support Services, The Boeing Company* *Chair: John R. Gilbert, Xerox Palo Alto Research Center* *Room: Ballroom 3*	**IP7 Lifting the Curse on the Hamiltonian and Symplectic Eigenproblem** *Volker Mehrmann, Technische Universität Chemnitz-Zwickau, Germany* *Chair: James W. Demmel, University of California, Berkeley* *Room: Ballroom 3*
9:30 AM		Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*
10:00 AM		Concurrent Sessions **MS1 Numerical Methods for Large Eigenvalue Problems** *Organizers: Daniela Calvetti, Stevens Institute of Technology; and Lothar Reichel, Kent State University* *Room: Ballroom 1* **MS2 Linear Algebra in Signal Processing** *Organizer: James R. Bunch, University of California, San Diego* *Room: Ballroom 2* **MS3 Combinatorial and Algebraic Matrix Theory** *Organizer: Wayne W. Barrett, Brigham Young University* *Room: Ballroom 3*	Concurrent Sessions **MS6 Positive Semidefinite Matrices and Hermitian Matrices** *Organizer: Wayne W. Barrett, Brigham Young University* *Room: Ballroom 1* **MS7 Linear Algebra and Control** *Organizer: P. Van Dooren, Université Catholique de Louvain, Belgium* *Room: Ballroom 2* **MS8 Fast and Superfast Toeplitz Solvers** *Organizers: Georg Heinig, Kuwait University, Kuwait; and Vadim Olshevsky, Stanford University* *Room: Ballroom 3*	Concurrent Sessions **MS11 Accurate Computation of Eigenproblems** *Organizer: Ilse C. F. Ipsen, North Carolina State University* *Room: Ballroom 1* **MS12 Linear Algebra for Ill-Posed Problems and Image Processing** *Organizers: Daniela Calvetti, Stevens Institute of Technology; and Lothar Reichel, Kent State University* *Room: Ballroom 2* **MS13 Indefinite Inner Products (Part I of II)** *Organizer: Leiba Rodman, College of William & Mary* *Room: Ballroom 3*	Concurrent Sessions **MS16 Unsymmetric Eigenvalue Alternatives** *Organizer: Eugene L. Wachspress, Retired, Windsor, CA* *Room: Ballroom 1* **MS17 Lanczos-Type Methods** *Organizer: Martin H. Gutknecht, ETH-Zentrum, Switzerland* *Room: Ballroom 2*
12:00		Lunch (Box Lunches in Ballroom Foyer or Attendees are on their own)	Lunch (Box Lunches in Ballroom Foyer or Attendees are on their own)	Lunch (Box Lunches in Ballroom Foyer or Attendees are on their own)	Lunch (Box Lunches in Ballroom Foyer or Attendees on their own)
1:30 PM		**IP2 The Solution of Linear Systems Arising in Interior Methods for Optimization** *Philip E. Gill, University of California, San Diego* *Chair: Nicholas J. Higham, University of Manchester, United Kingdom* *Room: Ballroom 3*	**IP4 Schur-Type Methods for Toeplitz Structured Problems** *Haesun Park, University of Minnesota, Minneapolis* *Chair: Åke Björck, Linköping University, Sweden* *Room: Ballroom 3*	**IP6 Second Generation Wavelets: Theory and Applications** *Wim Sweldens, Bell Laboratories, Lucent Technologies* *Chair: John G. Lewis, Boeing Information and Support Services, The Boeing Company* *Room: Ballroom 3*	**Award and Presentation: The SIAM Activity Group on Linear Algebra Prize** *Winner to be announced* *Chair: Biswa N. Datta, Northern Illinois University* *Room: Ballroom 3*
2:30 PM		Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*
3:00 PM		Concurrent Sessions **MS4 Recent Developments in Eigenvalue Perturbation Theory and Algorithms (Part I of II)**	Concurrent Sessions **MS9 Matrix Functions** *Organizer: Nicholas J. Higham, University of Manchester,*	Concurrent Sessions **MS14 Recent Developments in Eigenvalue Perturbation Theory and Algorithms (Part II of II)**	Concurrent Sessions **MS18 Innovations in Teaching Applied and Numerical Linear Algebra**

		Organizer: Roy Mathias, *College of William & Mary* *Room: Ballroom 1* **MS5 Advances in Sparse Matrix Reorderings** *Organizer: Esmond G. Ng,* *Oak Ridge National Laboratory* *Room: Ballroom 2*	*United Kingdom* *Room: Ballroom 2* **MS10 Sparse Approximate Inverse Preconditioners (Part I of II)** *Organizer: Wei-Pai Tang,* *University of Waterloo, Canada* *Room: Ballroom 1*	*Organizer: Roy Mathias,* *College of William & Mary* *Room: Ballroom 1* **MS15 The Multilevel Method** *Organizer: Shang-Hua Teng, University of Minnesota, Minneapolis* *Room: Ballroom 2*	*Organizers: Steven J. Leon,* *University of Massachusetts, Dartmouth; and David C. Lay,* *University of Maryland, College Park* *Room: Superior A* **MS19 Sparse Approximate Inverse Preconditioners (Part II of II)** *Organizer: Wei-Pai Tang,* *University of Waterloo, Canada* *Room: Superior B* **MS20 Indefinite Inner Products (Part II of II)** *Organizer: Leiba Rodman,* *College of William & Mary* *Room:Maybird*
5:00 PM		Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*	Coffee *Room: Ballroom Foyer*	Coffee and Business Meeting **SIAM Activity Group on Linear Algebra** *Room: Ballroom 3*
5:30 PM		**Common Interest Session 1** **Data Fitting, Regularization and Related Problems** *Moderator: Paul Van Dooren, Université Catholique de Louvain, Belgium* *Room: Ballroom 2* **Common Interest Session 2** **Non-Hermitian Eigenvalue Problems** *Moderator: Youcef Saad, University of Minnesota, Minneapolis* *Room: Ballroom 1*	**Common Interest Session 3** **Direct Methods for Systems of Equations** *Moderator: Joseph W. H. Liu, York University, Canada* *Room: Ballroom 2* **Common Interest Session 4** **Applications and Computation of the Singular Value Decomposition** *Moderator: Volker Mehrmann, Technische Universität Chemnitz, Germany* *Room: Ballroom 1*	**Common Interest Session 5** **Iterative Methods and Preconditioning** *Moderator: Tony F. Chan, University of California, Los Angeles* *Room: Ballroom 3* **Common Interest Session 6** **Core Algebra Topics** *Moderator: Richard A. Brualdi, University of Wisconsin, Madison* *Room: Ballroom 2* **Common Interest Session 7** **Hermitian Eigenvalue Problems** *Moderator: John G. Lewis, Boeing Information and Support Services, The Boeing Company* *Room: Ballroom 1*	**Poster Session** *Room: Ballrooms 1, 2, & 3* *There will be awards for the two best poster presentations. The winners will be announced and given the awards during the banquet.*
6:00 PM	Registration *Room: Ballroom Foyer* 6:00 PM-8:00 PM Welcoming Reception (Cash Bar) *Room: Golden Cliff*				
7:00 PM					Cocktails/Cash Bar *Room: Eagles Nest* Conference adjourns.
7:30 PM		Dinner (Attendees are on their own)	Dinner (Attendees are on their own)	Dinner (Attendees are on their own)	Banquet **Guest Speaker:** **Charles Van Loan, Cornell University** **"Looking for Kronecker Products"** *Chair: Alan George,* *University of Waterloo, Canada* 7:30 PM-9:30 PM *Room: Golden Cliff*

up to over ten million variableson up to 256 processors are presented. They illustrate the convergence properties of the method, as well as the fact that when the domains are not all of the same size, the asynchronous method can be up to 50% faster than the corresponding synchronous one.

Andreas Frommer
Fachbereich Mathematik
Bergische Universität GH Wuppertal
D-42097 Wuppertal, Germany
frommer@math.uni-wuppertal.de

Hartmut Schwandt
Fachbereich Mathematik
Technische Universität Berlin
D-10623 Berlin, Germany
schwandt@math.tu-berlin.de

Daniel B. Szyld
Department of Mathematics
Temple University
Philadelphia, PA 19122-2585
szyld@math.temple.edu

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Applied Multidimensional Matrix for Simulation and Research of Spatial Extensive Mechanical Systems

Mathematical simulation of spatial extensive mechanical systems (n-link manipulator of space robot) is a complex calculation task in terms the determination of matrix coefficients of equations of mathematical model of dynamics and kinematics. Applied mathematical tool of multidimensional or p-way matrix is a natural generalization of existing mathematical tool of usual two-dimensional matrix in case of simulation of system with large number of system state variables. Main kinematic correlations and Lagrangian dynamic manipulator model the state variables (generalized coordinates) were developed by the applied multidimensional matrix. Using that mathematical tool allowed us to consider a particular motions of the n-links mechanical systems when a several fixed state variables with previous accuracy without changing the model.

Tarasov S. V. and Michshanin L. V.
Faculty of radiophysics
Dniepropetrovsk State University
72, Gagarin avenue
Dniepropetrovsk, 320625 Ukraine