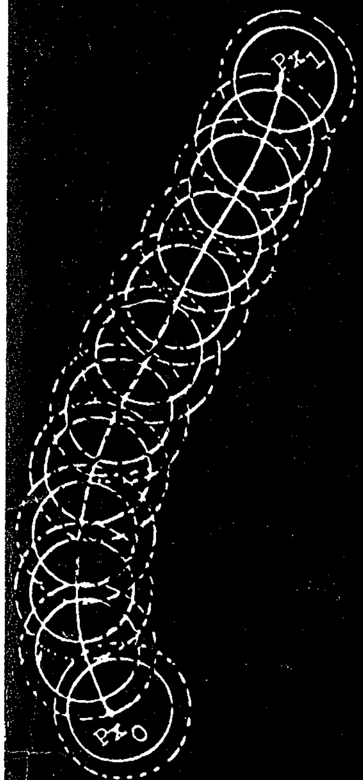
SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS

Final Program



Third SIAM Conference on Applied Linear Algebra

MAY 23–26, 1988

The Concourse Hotel, Madison, Wisconsin

Sponsored by the SIAM Activity Group on Linear Algebra

And Short Course on Linear Algebra in Statistics
MAY 22, 1988

CONFERENCE THEMES

- Large Scale Computing and Numerical Methods
- Inverse Eigenvalue Problems
- Qualitative and Combinatorial Analysis of Matrices
- Linear Systems and Control
- Parallel Matrix Computations
- Signal Processing
- Optimization
- Multivariate Statistics
- Core Linear Algebra
- Iterative Methods for Solving Linear Systems

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ORGANIZING COMMITTEE

Richard A. Brualdi, Co-Chair
University of Wisconsin, Madison

Hans Schneider, Co-Chair
University of Wisconsin, Madison

David H. Carlson
San Diego State University

John G. Lewis
Boeing Computer Services

Robert J. Plemmons
North Carolina State University

Charles Van Loan
Cornell University

FUNDING AGENCIES

SIAM is conducting this conference with the partial support of the Department of Energy and the National Science Foundation.

SHORT COURSE

Short Course on Linear Algebra in Statistics
Sunday, May 22, 1988
The Concourse Hotel
Ballroom A

SPEAKERS

Ingram Olkin, (Co-Organizer), Stanford University
George P. H. Styan, (Co-Organizer), McGill University
Douglas Bates, (Co-Organizer), University of Wisconsin, Madison

Linear algebra is a fundamental tool for the development of statistical methods. Conversely, statistical questions often give rise to new problems in linear algebra and matrix theory. This short course will illustrate this mutual interdependence and feedback by citing a number of examples from statistics that have led to interesting developments in matrix theory and linear algebra.

In the morning session Professor Olkin will illustrate how the characterization of distributions in multivariate analysis leads to functional equations with matrices as arguments and how linear algebra is being used in rather novel ways. In this context Chebyshev-type probability inequalities arise, for example. The design of experiments can be described in the form of extremal problems that present themselves as solutions of certain integral equations which, in turn are based on estimates for the eigenvalues of the integral operators.

In the second part of his session Professor Ingram will show how maximum likelihood estimates pose challenges to linear algebraists in the form of yet unsolved problems. The speakers will conclude the morning session with some observations on simulation methods for multivariate distributions.

The afternoon session will be conducted by Professor Styan who will discuss least squares problems and regression analysis and how they lead to fascinating questions on commutativity and generalized inverses. He will show how the theory of Markov chains has produced a host of problems involving non-negative and/or stochastic matrices.

Professor Bates will conclude the afternoon session with a description of various commercial and public software packages for numerical linear algebra and computational statistics that run on mainframes and minicomputers. He will describe the computational and iterative aspects of these programs and discuss the symbolic manipulation features that some of these packages have in order to create a comfortable user interface.

PROGRAM

9:00 AM	**Multivariate Analysis** Ingram Olkin, Stanford University
10:30 AM	Coffee
11:00 AM	**Maximum Likelihood Estimates and Simulation** Ingram Olkin, Stanford University
12:00 PM	Lunch
1:30 PM	**Least Squares and Regression** George P. H. Styan, McGill University
2:30 PM	Coffee
3:00 PM	**Least Squares and Experimental Design** George P. H. Styan, McGill University
4:00 PM	Coffee
4:30 PM	**Statistical Software Packages** Douglas Bates, University of Wisconsin, Madison
5:30 PM	Discussion
6:00 PM	Short Course Adjourns

Registration Fees*

	SIAG/LA SIAM Member	Non Member	Student
Advance	$95	$115	$50
On-Site	$115	$135	$65

** Registration Fee for the Short Course includes preprints, coffee and lunch*

PROGRAM DESIGN: TOM JACKSON

MEETING HIGHLIGHTS

INVITED PRESENTATIONS

Monday, May 23, 8:30 AM
Invited Presentation 1
Qualitative Analysis of Linear Systems

To what extent can the important properties of an algebraic or dynamical system be deduced from the sign-pattern of its coefficients? The question was posed in 1947 by the Nobel economist, Paul Samuelson, and has since then been studied by economists, ecologists, chemists, computer scientists and mathematicians. This lecture will focus on what is known about linear systems, with emphasis on questions of solvability and stability. A fairly complete picture has been obtained with the aid of graph-theoretic methods, but several unsolved problems remain. Perhaps the most interesting is the famous "even cycle" problem, which arises from the study of qualitative solvability.

Victor Klee
University of Washington, Seattle

Monday, May 23, 9:30 AM
Invited Presentation 2
Applications of Linear Algebra to Problems of Direction-Finding and High-Resolution Spectral Analysis

High-resolution spectral analysis techniques, such as Burg's maximum-entropy and Capon's maximum-likelihood methods, have been applied in many areas. Recently, a variety of matrix and linear algebra concepts has been used to obtain new families of useful high-resolution methods, especially the so-called MUSIC algorithm of Schmidt-Bienvenu-Kopp and the ESPRIT algorithm of Roy-Paulraj-Kailath. This survey will introduce some of the applications, explain the algebraic concepts underlying the proposed solution methods, and indicate some open problems.

Thomas Kailath
Stanford University

Tuesday, May 24, 11:00 AM
Invited Presentation 3
Numerical Linear Algebra On A Shared-Memory Multiprocessor

The design of efficient algorithms depends heavily on the architecture of the computer under consideration. For example, on a vector machine such as one CPU of a Cray X-MP an algorithm is designed primarily so as to enhance the average vector length, while on distributed-memory multiprocessors, such as the commercially-available hypercubes, the parallel algorithm is designed so as to achieve an efficient tradeoff between parallelism and interprocessor communications. On a shared-memory parallel machine with a hierarchial memory, however, a parallel algorithm is designed mainly so as to enhance data locality as well as concurrency. An example of such an architecture is the Alliant FX/8. This presentation reviews the design and performance of parallel algorithms for dense and sparse matrix computations on the Alliant FX/8. The architecture of this multi-vector machine is described together with the basic linear algebra modules (or BLAS3) that manage efficiently the vector registers of its eight processors, and its hierarchial memory. It is also shown how such basic modules are used in block algorithms for dense matrix computations to ensure high performance. Examples are given for dense matrix factorizations, solving narrow-banded systems, and solving the dense eigenvalue and singular-value problems. Furthermore, parallel direct and iterative solvers for sparse linear systems on the above architecture will be presented, together with reordering schemes and preconditioning strategies that are suitable for hierarchical memories.

Ahmed Sameh
University of Illinois, Urbana

Tuesday, May 24, 2:45 PM
Invited Presentation 4
Direct Methods for Solving Sparse Systems on Parallel Computers

Solving sparse systems on parallel computers presents both problems and opportunities. Many effective sparse matrix algorithms access the data in ways that cannot be predicted before the algorithm is executed. Thus, it is difficult to determine how to map the problem onto the processors. In addition, many effective techniques for solving sparse systems make heavy use of context, which is inevitably lost when parts of the problem data are in different processors. On the positive side, orderings for sparse matrices that are ideal for serial machines in the sense of reducing arithmetic and fill-in also turn out to be desirable when using multiprocessors.

The presentation will provide a review of some of the ideas and techniques that are being developed in connection with solving large sparse systems of equations and least squares problems on parallel computers, and report on experience gained using two quite different parallel computers at the Oak Ridge National Laboratory.

J. Alan George
University of Tennessee, Knoxville and Oak Ridge National Laboratory

Wednesday, May 25, 3:00 PM
Invited Presentation 5
Group-Symmetry Covariance Models

Group-symmetry covariance models describe symmetries present in the error structure of multivariate observations on, for example, biological objects. Such models are formally described as a family of covariance matrices that remain invariant under a finite group of orthogonal transformations. From the theory of group representations, the Danish statisticians S. Andersson, H. Brns, and S. T. Jensen, have shown that all classical statistical hypothesis-testing problems for the covariance structure of a multivariate normal population reduce to problems of testing one group-symmetry model against another.

The theory of such covariance models will be reviewed and several examples presented to illustrate their main features—maximum likelihood estimates and least squares estimators coincide, and hypothesis testing problems admit ANOVA-like decompositions. In order to recognize when a given set of symmetries arises from group invariance, an intrinsic characterization of a group symmetry covariance model will be described. As a bonus, such models provide analogues of Hadamard's determinantal inequality.

Michael Perlman
University of Washington, Seattle

Thursday, May 26, 9:45 AM
Invited Presentation 6
On a Class of Robust Numerical Methods in Linear System Theory

The algebraic theory of linear time-invariant systems and its use in control systems design have been studied in detail over the last few decades. The successful use of such modern techniques in an industrial environment, for example, largely depend on the availability of good numerical methods in this area. Unfortunately, many of the currently available algorithms are either too time consuming, or numerically unreliable. The speaker will give a survey of a class of numerical methods in linear system theory which nicely combined the properties of computational efficiency and numerical robustness. These methods are based on matrix decompositions borrowed from numerical linear algebra.

Paul Van Dooren
Philips Research Laboratory, Belgium

MEETING HIGHLIGHTS

INVITED PRESENTATIONS

Thursday, May 26, 11:15 AM
Invited Presentation 7
The Formulation and Analysis of Inverse Eigenvalue Problems for Symmetric Matrices

In his presentation, the speaker will survey various approaches to solving inverse eigenvalue problems (I.E.P.) arising from scattering theory, nuclear spectroscopy, geophysics, electrical circuit theory, optimal control theory, factor analysis, educational testing, graph theory and other branches of pure and applied mathematics. Most inverse eigenvalue problems can be expressed as polynomial equations, thus giving rise to many solutions which are complex. The author will give a sufficient condition for the solvability of the polynomial equation. Next, a variational approach will lead to a numerical algorithm for the solution of the I.E.P. For simple spectra, several quadratically convergent methods—including Newton's method—will be discussed. The case of multiple eigenvalues can be restated so that modified numerical methods will retain the quadratic convergence property. Numerical experiments will illustrate the results.

Shmuel Friedland
University of Illinois, Chicago

MINISYMPOSIA

Minisymposia 1, 2, 6, 8, and 15
Iterative Methods for the Solution of Linear Algebraic Systems 1, 2, 3, 4, and 5
A. Hajidimos, Purdue University

Minisymposium 3
Signal Processing
George Cybenko, Tufts University

Minisymposium 4
Combinatorial Matrix Analysis
Charles R. Johnson, College of William and Mary

Minisymposium 5
Numerical Methods for Structured Eigenvalue Problems
Ralph Byers, University of Kansas, Lawrence

Minisymposium 7
Canonical Forms of Matrices 1
Roger A. Horn, Johns Hopkins University

Minisymposium 9
Canonical Forms in Matrices 2
Roger A. Horn, Johns Hopkins University

Minisymposium 10
Numerical Linear Algebra for Parallel Architectures
Robert J. Plemmons, North Carolina State University

Minisymposium 11
Geometric and Lie-Theoretic Methods in Numerical Linear Algebra
Gregory S. Ammar, Northern Illinois University and Mark A. Shayman, University of Maryland, College Park

Minisymposium 12
Lanczos Algorithms
Beresford N. Parlett, University of California, Berkeley

Minisymposium 13
Matrix Computations in Statistics
George Ostrouchov, Oak Ridge National Laboratory

Minisymposium 14
Large Eigenvalue Problems
Beresford N. Parlett, University of California, Berkeley

SPECIAL EVENTS

Welcoming Reception
Sunday, May 22, 8:00 PM–10:00 PM
Diplomat Rooms
Cash Bar

Beer Party
Monday, May 23, 6:00 PM–8:00 PM
Diplomat Rooms $12.00

The beer party will consist of beer, sodas, Wisconsin Bratwurst, hamburgers, potato salad, cole slaw and Wisconsin cheese and crackers.

Annual Meeting of the SIAM Activity Group on Linear Algebra
Wednesday, May 25, 11:00 AM
Ballroom A–B

Presentation of the First SIAM Linear Algebra Prize
Wednesday, May 25, 11:30 AM
Ballroom A–B

Banquet
Wednesday, May 25, 6:00 PM
Memorial Union, University of Wisconsin.
Guest Speaker: Hans Schneider, University of Wisconsin, Madison "When Does Linear Algebra Become Applied?"
Cash Bar: 6:00 PM–7:00 PM
Buffet Dinner: 7:00 PM
$15.00

The dinner will be held at the Memorial Union of the University of Wisconsin. The evening will begin with a cash bar from 6 PM to 7 PM. The buffet dinner will consist of: baked chicken, roast beef, baked ham, oven browned potatoes, rice pilaf, broccoli normandy, green beans almondine, dessert, bread and rolls, and wine.

UPCOMING CONFERENCES

June 13–16, 1988
Fourth SIAM Conference on Discrete Mathematics
Cathedral Hill Hotel
San Francisco, CA

July 11–15, 1988
SIAM Annual Meeting
Hyatt Regency Hotel
Minneapolis, MN

March 20–22, 1989
SIAM Conference on Domain Decomposition Methods
Intercontinental Hotel
Houston, TX

FINAL PROGRAM

Saturday, May 21/PM

5:00 PM/Ballroom Foyer
Registration opens for Short Course

9:00 PM/Ballroom Foyer
Registration closes

Sunday, May 22/AM

8:00 AM/Ballroom Foyer
Registration opens for Short Course

9:00 AM/Ballroom A
Multivariate Analysis
Ingram Olkin, Stanford University

10:30 AM/Ballroom Foyer
Coffee

11:00 AM/Ballroom A
Maximum Likelihood Estimates and Simulation
Ingram Olkin, Stanford University

Sunday, May 22/PM

12:00 PM/Ballroom B
Lunch

1:30 PM/Ballroom A
Least Squares and Regression
George P. H. Styan, McGill University

2:30 PM/Ballroom Foyer
Coffee

3:00 PM/Ballroom A
Least Squares and Experimental Design
George P. H. Styan, McGill University

4:00 PM/Ballroom Foyer
Coffee

4:30 PM/Ballroom A
Statistical Software Packages
Douglas Bates, University of Wisconsin, Madison

5:30 PM/Ballroom A
Discussion

6:00 PM/Ballroom A
Short Course Adjourns

6:00 PM/Ballroom Foyer
Registration Opens for Conference

8:00 PM/Diplomat Rooms
Welcoming Reception

9:00 PM/Ballroom Foyer
Registration Closes

Monday, May 23/AM

7:00 AM/Ballroom Foyer
Registration Opens

8:15 AM/Ballroom A–B
Opening Remarks

8:30 AM/Ballroom A–B
Invited Presentations 1 and 2
Chairs: Richard Brualdi, University of Wisconsin, Madison and Gene Golub, Stanford University (currently on sabbatical at the University of Maryland, College Park)

8:30 AM/Ballroom A–B
Qualitative Analysis of Linear Systems
Victor Klee, University of Washington, Seattle

9:30 AM/Ballroom A–B
Applications of Linear Algebra to Problems of Direction-Finding and High-Resolution Spectral Analysis
Thomas Kailath, Stanford University

10:30 AM/Diplomat Rooms
Coffee

11:00 AM
CONCURRENT SESSIONS

Monday, May 23/11:00 AM–12:00 Noon
Minisymposium 1/Ballroom A–B

ITERATIVE METHODS FOR THE SOLUTION OF LINEAR ALGEBRAIC SYSTEMS 1

The aim of this minisymposium is to bring together researchers working in the area of iterative methods for the solution of linear algebraic systems. Particular attention will be focused on: new iterative methods and algorithms for indefinite, overdetermined, singular or nonsymmetric linear systems; recent results on preconditioning techniques; and iterative solution of PDEs. The computational topics involve parallel implementation of iterative methods and analysis of numerical experiments.

Chair: A. Hajidimos
Purdue University

11:00/M-1/A1
Inner/Outer Iterations and Domain Decomposition
Gene Golub,*
Stanford University (on sabbatical at the University of Maryland, College Park)
* Represents work done jointly with Michael Overton
Courant Institute of the Mathematical Sciences, New York University

11:30/M-2/A1
Iterative Solution for Linear Systems with Gapped Spectra
John de Pillis
University of California, Riverside

Monday, May 23/11:00 AM–12:00 Noon
Contributed Presentations 1/Empire Room

CORE LINEAR ALGEBRA 1

Chair: Robert Thompson, University of California, Santa Barbara

11:00/12/A15
Algebraic and Geometric Properties of the Numerical Range
Marvin Marcus, University of California, Santa Barbara

11:15/96/A15
The G-Radius and the G-Invariant Norms
Chi-Kwong Li, University of Wisconsin, Madison
Nam-Kiu Tsing, Auburn University

11:30/26/A15
An Analog of the Cauchy-Schwarz Inequality for Hadamard Products and Unitarily Invariant Norms
R.A. Horn, R. Mathias, The Johns Hopkins University, Baltimore

11:45/30/A16
On Maximizing the Minimum Eigenvalue of a Linear Combination of Symmetric Matrices
J.C. Allwright, Imperial College of Science and Technology, London

Monday, May 23/11:00 AM–12:00 Noon
Contributed Presentations 2/State B-C

APPLICATIONS 1

Chair: John Lewis, Boeing Computer Services

11:00/1/A16
A Generalized Inverse Method for Asymptotic Linear Programming
Bernard F. Lamond, University of Arizona, Tucson

11:15/88/A16
P-Functions in Applied Mathematics
Michael M. Kostreva, Clemson University

11:30/140/A16
Postoptimality Analysis via Projective Algorithms
Abdellah Salhi and George R. Lindfield, Aston University, Birmingham, U.K.

11:45/11/A16
A Bivariate Optimizing Algorithm Simulates Alternative Economic Policies
Mirek Karasek, PCA-IAP, Jeddah, Saudi Arabia

Monday, May 23/11:00 AM–12:00 Noon
Contributed Presentations 3/State A

MATRIX ALGORITHMS 1

Chair: Jeffrey Stuart, University of Southern Mississippi

11:00/54/A17
Fast Symmetric Discrete Fourier Transform Algorithms Involving Only Real Arithmetic
Jaime Seguel, Saint John's University, Staten Island

11:15/7/A17
Faster than Linear Time Matrix Multiplication Using Multiple Processor Arrays
Dan Kalman, The Aerospace Corporation, Los Angeles

11:30/33/A17
An Algorithm for the Exact Characterization of the Zeros of a Polytope of Polynomials
R. Tempo, CENS-CNR, Politecnico Torino, Italy
B.R. Barmish and A. Takach, University of Wisconsin, Madison

11:45/60/A17
Fujiwara's Hermitian Forms and Algorithms for the Inertia and Unit Circle Problems
Karabi Datta, Northern Illinois University, DeKalb
T.M. Viswanathan, University of North Carolina, Charlotte and Universidade Estadual de Campinas, Brazil

Note: The numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

FINAL PROGRAM

Monday, May 23/PM

12:00 PM
Lunch

1:30 PM
CONCURRENT SESSIONS

Monday, May 23/1:30 –3:30 PM
Minisymposium 2/Ballroom A–B

ITERATIVE METHODS FOR THE SOLUTION OF LINEAR ALGEBRAIC SYSTEMS 2

Chair: A. Hajidimos
Purdue University

1:30/M-3/A1
Some New Results on Optimal Preconditioning
Ted Ferretta
University of California, Davis
and
Garry Rodrigue
Lawrence Livermore National Laboratory

2:00/M-4/A2
The 3D Linear Hierarchial Basis Preconditioners
Maria E. G. Ong and Loyce M. Adams
University of Washington, Seattle

2:30/M-5/A2
An Almost Optimal Preconditioner in Domain Decomposition
W. Proskurowski
University of Southern California, Los Angeles

3:00/M-6/A2
NSPCG-Nonsymmetric Preconditioned Conjugate Gradient Package
Thomas C. Oppe, Wayne D. Joubert, and David R. Kincaid
University of Texas, Austin

Monday, May 23/1:30–3:30 PM
Minisymposium 3/Empire Room

SIGNAL PROCESSING

Signal processing is an area of growing interest to applied mathematicians and linear algebraists. This minisymposium will present the ideas and techniques currently used in the areas of harmonic retrieval and direction finding which have been particularly active this past decade. A large number of novel numerical problems arise in these problems quite naturally. The presentations in the minisymposium will introduce the problems and describe current avenues of research.

Chair: George Cybenko
Tufts University

1:30/M-7/A2
Harmonic Retrieval and Source Location—A Survey
(To be presented by the Chair)

2:00/M-8/A2
Mathematical Tools for Signal Processing: Multilinear (Exterior) Algebra and Multivectors
Ralph Schmidt
Saxpy Computer Corporation

2:30/M-9/A3
Geometric Methods and Invariance Techniques in Signal Processing
Richard Roy
Stanford University

3:00/M-10/A3
A Unitary Method for the ESPRIT Direction-of-Arrival Estimation Algorithm
Charles Van Loan
Cornell University

Monday, May 23/1:30–3:30 PM
Contributed Presentations 4/State B-C

MATRIX METHODS IN ODEs AND PDEs

Chair: Seymour Parter, University of Wisconsin, Madison

1:30/22/A18
Algebraic Properties of Derivative Arrays and Linear Time Varying Descriptor Systems
Stephen L. Campbell, North Carolina State University, Raleigh

1:45/67/A18
Toeplitz Matrices Arising from the Sinc-Galerkin Method
Kenneth L. Bowers, John R. Lund and Ralph C. Smith, Montana State University, Bozeman

2:00/14/A18
Simplified Dynamical System for the Gauss-Galerkin Method
Ali Hajjafar, The University of Akron

2:15/6/A18
Discrete-Time Cone Reachability
Michael Neumann, University of Connecticut, Storrs; Ronald J. Stern, Concordia University, Montreal

2:30/23/A19
Domain Decomposition for Linear Elliptic Boundary Value Problems on Locally Refined Meshes
Christoph Borgers, University of Michigan, Ann Arbor

2:45/119/A19
The Ordering of Tridiagonal Matrices in the Cyclic Reduction Method for Poisson's Equation
Lothar Reichel, Bergen Scientific Centre, Norway

3:00/118/A19
On Finding the Singular Values and Singular Vectors of a Bidiagonal Matrix by Means of Isosingular Flows
Kenneth R. Driessel, Idaho State University, Pocatello

3:15/L-2/A47
Refining Invariant Subspaces of Integral and Partial Differential Operators with Newton's Method
Dennis Phillips, Davis Hibbard Mayer Norton and Phillips, Inc., Middleton, WI

Monday, May 23/1:30–3:30 PM
Contributed Presentations 5/State A

SINGULAR VALUES AND EIGENVALUES

Chair: Bryan Cain, Iowa State University

1:30/35/A19
Parallel Solution of Nonsymmetric Eigenvector Problems
Daniel Boley and Joung kook Kim, University of Minnesota, Minneapolis

1:45/34/A20
A Parrallel QR Algorithm for the Non-Symmetric Eigenvalue Algorithm
Daniel Boley and Robert Maier, University of Minnesota, Minneapolis

2:00/44/A20
A Parallel, Hybrid Algorithm for the Generalized Eigenproblem
Shing C. Ma, Merrell L. Patrick, Daniel B. Szyld, Duke University

2:15/93/A20
A Hybrid Method for Computing the Singular Value Decomposition on a Multiprocessor
Michael Berry and Ahmed Sameh, University of Illinois, Urbana

2:30/24/A21
A Direct Algorithm for Computing the Generalized Singular Value Decomposition
Zhaojun Bai, Courant Institute of Mathematical Sciences, New York University

2:45/120/A21
On Singular Values of Hankel Operators of Finite Rank
William B. Gragg, Naval Postgraduate School, Monterey, CA
Lothar Reichel, Bergen Scientific Centre, Norway

3:00/142/A21
On Optimal Parallel Givens Schemes
Kermit Sigmon, University of Florida, Gainesville

3:15/L-16/A50
Iterative Solution of the Sylvester Equation
Eugene L. Wachspress, University of Tennessee, Knoxville

3:30 PM/Diplomat Rooms
Coffee

... individual time for each presentation represent the numerical order and page number of the abstracts.

4:00 PM
CONCURRENT SESSIONS

Monday, May 23/4:00–6:00 PM
Minisymposium 4/Ballroom A–B

COMBINATORIAL MATRIX ANALYSIS

Combinatorial matrix analysis is a broad and growing area of research that acknowledges the importance of combinatorial techniques and thinking in the conceptualization and solution of matrix analytic problems. With classical roots in determinant theory, the connection between matrices and analytic function theory and the analysis of non-negative and M-matrices, this has become an important area of modem research with the applications in such diverse areas as numerical analysis, the systems theory of electrical engineering and economics, and seismic reconstruction. The purpose of the minisymposium is to give a broad (but necessarily incomplete) sample of some of the specific topics that constitute this field: algebraic matrix theory; qualitative matrix theory; numerical analysis; and matrix completion problems. These should be sufficient to highlight the interplay between attractive mathematical structure and utility that has brought pure and applied attention to combinatorial matrix analysis.

Chair: Charles R. Johnson
College of William and Mary

4:00/M-12/A3
Some Combinatorial Issues in Algebraic Matrix Analysis
Richard A. Brualdi
University of Wisconsin, Madison

4:30/M-13/A3
Combinatorial Factorings of Matrices
John S. Maybee
University of Colorado, Boulder

5:00/M-14/A4
Inheritance of Matrix Entries
D. Dale Olesky and Pauline van den Driessche
University of Victoria, British Columbia

5:30/M-15/A4
Matrix Completion Problems
(To be presented by the Chair)

Monday, May 23/4:00–6:00 PM
Minisymposium 5/Empire Room

NUMERICAL METHODS FOR STRUCTURED EIGENVALUE PROBLEMS

The minisymposium focuses on recently developed computational methods for eigenvalue and inverse eigenvalue problems. Of particular interest are problems with special structure including condition estimation, eigenvalues of matrices with special symmetries, and robust pole placement. Speakers will present techniques for exploiting special structure to obtain robust, efficient, numerically stable algorithms. Special structure algorithms in addition to providing improved performance in conventional settings may also adapt to advanced architecture computers.

Chair: Ralph Byers
University of Kansas, Lawrence

4:00/M-16/A4
Robust Eigenvalue Assignment by Output Feedback
Nancy Nichols, North Carolina State University; and Sharon Slade, University of Reading, United Kingdom

4:30/M-17/A4
Jacobi Type Methods for Matrices with Very Special Structure
Angelika Bunse-Gerstner,
Universitat Bielefeld, W. Germany;
Ralph Byers,
University of Kansas, Lawrence;
and Volker Mehrmann,
Universitat Bielefeld, W. Germany

5:00/M-18/A5
QR Algorithms for Matrices with Very Special Structure
Angelika Bunse-Gertsner,
Universitat Bielefeld, W. Germany;
Ralph Byers,
University of Kansas, Lawrence;
and Volker Mehrmann,
Universitat Bielefeld, W. Germany

5:30/M-19/A5
Condition Estimates for Matrix Functions
Charles Kenney and Alan J. Laub
University of California, Santa Barbara

Monday, May 23/4:00–6:00 PM
Contributed Presentations 6/State B-C

ITERATIVE TECHNIQUES 1

Chair: David Watkins, Washington State University

4:00/90/A21
Block Elimination with One Iterative Refinement Solves Bordered Linear Systems
W. Govaerts, Seminarie Voor Hogere Analyse, Belgium
J.D. Pryce, University of Bristol, England

4:15/114/A22
On Convergence Rates for Parallel Multisplitting Methods
Ludwig Elsner, Universitat Bielefeld, Germany

4:30/124/A22
Two Parametric "SOR" Method
Saadat Moussavi, University of Wisconsin, Oshkosh

4:45/79/A22
An Algebraic Convergence Theory for Multigrid Methods for Nonsymmetric Problems
Zhi-hao Cao, Fudan University, Shanghai, China

5:00/L-13/A50
A New Preconditioner for Linear and Nonlinear Deconvolution Problems
Julia A. Olkin, SRI International; and William W. Symes, Rice University

5:15/85/A23
A New Downdating Algorithm With Application to the Q-R Factorization of Toeplitz Matrix
Ching-Tsuan Pan, Northern Illinois University, DeKalb

5:30/106/A23
Modifications of the Normal Equations Method That Make it Numerically Stable
Leslie V. Foster, San Jose State University

5:45/62/A23
Deflated Krylov Subspace Methods for Nearly Singular Linear Systems
Juan C. Meza, Sandia National Laboratories, Livermore, CA; and W.W. Symes, Rice University, Houston

Monday, May 23/4:00–6:00 PM
Contributed Presentations 7/State A

MATRIX COMPUTATIONS 1

Chair: Elizabeth Yip, Boeing Aerospace Co.

4:00/19/A23
A Block LDL^T Factorization Algorithm for Skyline Systems of Equation
Jim Armstrong, Convex Computer Corporation, Richardson, TX

4:15/78/A24
Reduced Polynomial Based Algorithms for Hermitian Toeplitz Matrices
Bal Krishna, Bahrain University and Hari Krishna, Syracuse University

4:30/3/A24
A CS Decomposition Approach to Estimator-Correlator Array Processing
Leon H. Sibul, Applied Research Laboratory, State College, PA;
John A. Tague, Ohio University, Athens

4:45/63/A24
A Necessary and Sufficient Condition for the Convergence of GMRES (k)
E.L. Yip, Boeing Aerospace Company, Seattle

5:00/143/A24
Applications of Quadratic Parametric Programming to be Quadratic Assignment Problem
Franz Rendl, Technische Universit, Graz, Austria and Henry Wolkowicz, University of Waterloo, Ontario, Canada

5:15/L-1/A47
The Matrix Foundations for Combining Vector Estimators and Evaluating Shrinkage Estimator Models
Patrick L. Odell and Dovalee Dorsett, Baylor University

5:30/L-5/A48
Fast Adaptive RLS Algorithms: A Generalized Inverse Unification
Sanzheng Qiao, Ithaca College

5:45/L-7/A48
Iterative Solution of Burgers Equation
John. Lund, Montana State University

6:00 PM/Diplomat Rooms
Beer Party

Note: The numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

FINAL PROGRAM

Tuesday, May 24/AM

8:30 AM
CONCURRENT SESSIONS

Tuesday, May 24/8:30–10:30 AM
Minisymposium 6/Ballroom A–B

ITERATIVE METHODS FOR THE SOLUTION OF LINEAR ALGEBRAIC SYSTEMS 3

Chair: A. Hajidimos
Purdue University

8:30/M-20/A5
A Note on the SSOR and USSOR Iterative Methods Applied to P-Cyclic Matrices
Xiezhang Li and Richard Varga
Kent State University

9:00/M-21/A6
Block Iterative Solutions of Large Overdetermined Systems
Yiannis G. Saridakis
Clarkson University

9:30/M-22/A6
Robust Iterative Methods for General Sparse Linear Systems
Youcef Saad
University of Illinois, Urbana

10:00/M-23/A6
A Dynamic Parameter Algorithm for Richardson's Method for General Non-Symmetric Matrices
Paul E. Saylor
University of Illinois, Urbana

Tuesday, May 24/8:30–10:30 AM
Minisymposium 7/Empire Room

CANONICAL FORMS OF MATRICES 1

A classical problem in matrix theory is to determine whether two given matrices lie in the same equivalence class with respect to a given equivalence relation, e.g., similarity, unitary equivalence, congruence, etc. A classical approach to a solution is to seek a "simple" set of representative matrices of prescribed form, one from each equivalence class, and try to reduce each given matrix to one of them. Such a set of representatives is a *canonical form.*

New approaches to calculating or interpreting old or new canonical forms, the development of new canonical forms motivated by modern applications, and the solution of new problems with old or new canonical forms will be the themes of this minisymposium.

Chair: Roger A. Horn
Johns Hopkins University

8:30/M-24/A6
Pairs of Matrices
Robert C. Thompson
University of California, Santa Barbara

9:00/M-25/A7
Simultaneous Block Diagonalization of Pairs of Hermitian Matrices
Helene Shapiro
Swarthmore College

9:30/M-26/A7
Canonical Forms and Invariant Subspaces
Leiba Rodman
College of William and Mary; and Arizona State University

10:00/M-27/A7
Applications of a Concanonical Form
(To be presented by the Chair)

Tuesday, May 24/8:30–10:30 AM
Contributed Presentations 8/State B-C

STATISTICS 1

Chair: George P.H. Styan, McGill University

8:30/36/A25
On an Ordering of Symmetric Matrices with Applications to Statistical Problems
Kenneth Nordstrom, Helsinki, Finland

8:45/55/A25
On Multivariate Normality and a Schur Product Ordering for Correlation Matrices
Robert A. Koyak, The Johns Hopkins University, Baltimore

9:00/49/A25
Generating Multivariate Covariance Sequences and Statistical Filter Design
Stefan Mittnik, SUNY, Stony Brook

9:15/37/A25
Eigenvalues and Condition Numbers of Random Matrices
Alan Edelman, Massachusetts Institute of Technology

9:30/20/A26
Some Matrix-Equation Solutions with Statistical Applications
K. G. Jinadasa, Illinois State University, Normal

9:45/144/A26
Conditional Intensity Functions
Nancy Flournoy, National Science Foundation

10:00/L-12/A49
Generalized Correlations in the Singular Case
Ashis SenGupta, Indian Statistical Institute, Calcutta, India

Tuesday, May 24/8:30–10:30 AM
Contributed Presentations 9/State A

SIGNALS AND SYSTEMS 1

Chair: David H. Wood, Naval Underwater Systems Center

8:30/73/A26
Composite Controller Design for Two-time-scale Systems with Low Sensitivity to Small Time Delay
H. Oloomi, R. Challoo and M. E. Sawan, Wichita State University

8:45/77/A27
Application of Matrix Gradients to Optimal Decentralized Control
Bahram Shahian, California State University, Long Beach

9:00/117/A27
Sensitivity Analysis for the Single Input Pole Assignment Problem
William F. Moss and Christopher L. Cox, Clemson University

9:15/112/A27
Realization Problem of a Class of Nonlinear Systems
Li Tiejun and Steve McCormick, University of Colorado, Denver

9:30/121/A27
Synthesis Algorithms for Multi-port Multi-dimensional Digital Filters
Sankar Basu, Stevens Institute of Technology, Hoboken

9:45/109/A27
Iterative Algorithms for Real Time Signal Processing
Stephen T. Welstead, Colsa, Inc. and University of Alabama, Huntsville

10:00/31/A27
The Rate of Growth of Linear Systems in Some Control Applications
M.J. Gonzalez-Gomez, Universidad del Pais Vasco, Baracaldo, Spain
M. de la Sen, Universidad del Pais Vasco, Leioa, Spain

10:15/28/A27
Constrained Controllability of Linear Systems
Zoubir Benzaid, Illinois Wesleyan University, Bloomington; and Donald A. Lutz, San Diego State University

10:30 AM/Diplomat Rooms
Coffee

11:00 AM/Ballroom A–B
Invited Presentation 3
Chair: Robert Plemmons, North Carolina State University, Raleigh

Numerical Linear Algebra on a Shared-Memory Multiprocessor
Ahmed Sameh, University of Illinois, Urbana

Note: The numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

FINAL PROGRAM

Tuesday, May 24/PM

12:00 PM
Lunch

1:30 PM
CONCURRENT SESSIONS

Tuesday, May 24/1:30–2:30 PM
Minisymposium 8/Ballroom A–B

ITERATIVE METHODS FOR THE SOLUTION OF LINEAR ALGEBRAIC SYSTEMS 4

Chair: A. Hajidimos
Purdue University

1:30/M-28/A7
Iterative Methods for Infinite Linear Equations
Pappur N. Shivakumar
University of Manitoba, Winnipeg, Canada

2:00/M-29/A8
On the Matrix Analogue of the Generalized Young-Varga's Relationship
Sofoklis Galanis*, A. Hajidimos + *, and Dimitrios Noutsos*
* University of Ionannina, Greece
+ Purdue University

Tuesday, May 24/1:30–2:30 PM
Minisymposium 9/Empire Room

CANONICAL FORMS OF MATRICES 2

Chair: Roger Horn
Johns Hopkins University

1:30/M-30/A8
Canonical Forms of Matrices Under Congruences
Yoopyo Hong
Northern Illinois University

2:00/M-31/A8
The Drazin Inverse of a Semi-Linear Transformation and Its Matrix Representation
Jean H. Bevis and Frank J. Hall
Georgia State University, Atlanta
and
Robert E. Hartwig
North Carolina State University, Raleigh

Tuesday, May 24/1:30–2:30 PM
Contributed Presentations 10/State B-C

PARALLEL MATRIX COMPUTATIONS 1

Chair: Wayne Barrett, Brigham Young University

1:30/99/A29
Exploiting Non-uniform Memory Hierarchies of Parallel Architectures for the Efficient Solution of Linear Systems
Mark T. Jones and Merrell Patrick, Duke University

1:45/130/A29
Implementing BLAS-n on a High Performance Multiprocessor
Marianne Mueller, Evans & Sutherland Computer Division, Mountain View, CA

2:00/110/A29
Basic Linear Algebra on the FPS T Series
M. Edward Borasky, Floating Point Systems, Inc., Portland, OR

2:15/83/A29
Solution of Fixed Cauchy Singular Integral Equations in Parallel Using Product Integration
Barbara S. Bertram, Michigan Technological University, Houghton

Tuesday, May 24/1:30–2:30 PM
Contributed Presentations 11/State A

GAUSSIAN ELIMINATION

Chair: Pauline van den Driessche, University of Victoria, BC, Canada

1:30/127/A30
Unraveling Some Mysteries of Gaussian Elimination Part I
Larry Neal and George Poole, East Tenessee State University, Johnson City

1:45/128/A30
Unraveling Some Mysteries of Gaussian Elimination Part II
George Poole and Larry Neal, East Tennessee State University, Johnson City

2:00/134/A30
Average-Case Stability of Gaussian Elimination
Robert S. Schreiber, Saxpy Computer Corporation, Sunnyvale, CA; and Lloyd N. Trefethen, Massachusetts Institute of Technology

2:15/139/A30
Solution of Linear Systems by Tearing
Peter W. Aitchison, University of Manitoba, Canada

2:45 PM/Ballroom A–B
Invited Presentation 4
Chair: Robert Ward, Oak Ridge National Laboratory

Direct Methods for Solving Sparse Systems on Parallel Computers
J. Alan George, University of Tennessee and Oak Ridge National Laboratory

3:45 PM/Diplomat Rooms
Coffee

4:15 PM
CONCURRENT SESSIONS

Tuesday, May 24/4:15–6:15 PM
Minisymposium 10/Ballroom A–B

NUMERICAL LINEAR ALGEBRA FOR PARALLEL ARCHITECTURES

The primary driving force for increased supercomputer performance is the fact that many applications in science and engineering currently consume excessive amounts of time and are infeasible to attempt on serial or even vector computers. Such important applications include problems in areas such as the simulation of elementary particle physics, multidimensional semiconductor devices, digital circuits, weather patterns, aerospace vehicles and propulsion, as well as research in molecular scattering, geodetic adjustments, and dynamic structural mechanics. Numerical linear algebra forms the dominating computational tool in all these applications. As a result, parallel processing algorithms for linear algebra has taken on ever increasing importance. The speakers in this minisymposium will address the issues just described and will discuss novel new algorithms for solving problems on high performance architectures. Emphasis will be placed on new innovative ideas.

Chair: Robert J. Plemmons
North Carolina State University

4:15/M-32/A8
Preconditioners on Parallel Computers
Loyce Adams
University of Washington, Seattle

4:45/M-33/A9
Parallel Triangular Solutions and Downdating on Distributed-Memory Multiprocessors
Michael T. Heath
Oak Ridge National Laboratory

5:15/M-34/A9
Parallel Preconditioned Conjugate Gradient Methods for General Sparse Systems
Youcef Saad
University of Illinois, Urbana

5:45/M-35/A9
Divide and Conquer Algorithms for Eigenvalue Problems
Danny C. Sorensen
Argonne National Laboratory

Tuesday, May 24/4:15–6:15 PM
Minisymposium 11/Empire Room

GEOMETRIC AND LIÉ-THEORETIC METHODS IN NUMERICAL LINEAR ALGEBRA

The fundamental relationships between Toda flows and the unshifted QR algorithm on real tridiagonal matrices and between matrix Riccati equations and the block triangularization of a matrix by block Gaussian similarity transformations have led to geometric studies of various aspects of numerical linear algebra. Lie theory can arise naturally in these studies, particularly with regard to the interplay between a discrete algorithm and its continuous analog. Geometric viewpoints provide general frameworks that relate to a variety of numerical algorithms, and also give rise to some new questions in geometry. The talks in this minisymposium will focus on geometric formulations for problems in numerical linear algebra as well as on some resulting interactions between geometry and numerical analysis.

Organizers
Gregory S. Ammar *(Chair)*
Northern Illinois University
and
Mark A. Shayman
University of Maryland, College Park

4:15/M-36/A9
Toward a General Theory of Algorithms of QR Type
David S. Watkins
Washington State University

4:45/M-37/A10
Isospectral Flows and Abstract Matrix Factorizations
Moody T. Chu and Larry K. Norris
North Carolina State University

Note: The numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

Tuesday, May 24/PM
Continued

5:15/M-38/A10
Connections Between Hessenberg Flags and Numerical Linear Algebra
(To be presented by the Chair)

5:45/M-39/A10
Geometry of the Lagrange-Hessenberg Variety and the QR Algorithm for Hamiltonian Matrices
Filippo de Mari
Washington University, St. Louis
and
Mark A. Shayman
University of Maryland, College Park

Tuesday, May 24/4:15–6:15 PM
Contributed Presentations 12/State B-C

CORE LINEAR ALGEBRA 2

Chair: Stephen Pierce, San Diego State University

4:15/2/A31
Tame Matrix Problems and Representations of Pairs of Partially Ordered Sets
Mark Kleiner, Syracuse University

4:30/32/A31
Uncoupling the Perron Eigenvector Problem
Carl D. Meyer, North Carolina State University, Raleigh

4:45/27/A31
The Jordan 1-Structure of a Matrix of Redheffer
Donald W. Robinson and Wayne W. Barrett, Brigham Young University

5:00/133/A31
The Inverse Eigenvalue Problem for Real Symmetric Toeplitz Matrices: Consistency Conditions for the Eigenvectors
B. David Saunders, University of Delaware; and David H. Wood, Naval Underwater Systems Center, New London, CT

5:15/81/A32
Scaling of Matrices Having Given Row and Column Sums
Uriel G. Rothblum, Israel Institute of Technology, Haifa; and Hans Schneider, University of Wisconsin, Madison

5:30/89/A32
Linear Complementarity Problems
M. Seetharama Gowda, University of Maryland, Baltimore County

5:45/115/A32
Convergent Splittings of Singular Matrices
Peter M. Gibson, Mustafa A.G. Abushagur, and H. John Caulfield, University of Alabama, Huntsville

6:00/105/A32
Matrices Whose Powers Are Completely Reducible Z-Matrices or M-Matrices
Jeffrey L. Stuart, University of Southern Mississippi, Hattiesburg

Tuesday, May 24/4:15–6:15 PM
Contributed Presentations 13/State A

APPLICATIONS 2

Chair: Pamela Coxson, The Aerospace Corporation

4:15/17/A33
A Rate-distortion Theoretic Approach to Pattern Recognition-Vector Recognition
Salvatore D. Morgera and Mohammad Reza Soleymani, McGill University, Montreal

4:30/5/A33
Adaptive Stochastic Algorithms: Open Issues
Mohamed El-Sharkawy, Bucknell University

4:45/29/A33
Mason's Unistor, Hill and King-Altman Diagrams and Network Thermodynamics. An Application to Dynamic Kinetic Systems Analysis
Donald C. Mikulecky, Medical College of Virginia Commonwealth University, Richmond

5:00/4/A33
The Mathematical Foundations of Unified Field Potential Theory
Mary Ann Slaby, Washington, D.C.

5:15/53/A34
Matrix Group Representations in Parallel Algorithms for Digital Filter Bank Structures
John J. Santa Pietro, Lockheed Electronics Co., Plainfield; and Thomas G. Marshall, Jr., Rutgers University, Piscataway

5:30/94/A34
Factorization Methods for Sequential Date Estimation with Arbitrary Given Gain Matrix
Daniel Chuo Chin, Johns Hopkins University, Laurel, MD

5:45/138/A34
Time Domain Radar Processing
Randolph H. Ott, The Aerospace Corporation, Albuquerque

6:00/141/A34
Data Compression of Multispectral Images
Pamela G. Coxson, The Aerospace Corporation, Los Angeles

Wednesday, May 25/AM

8:30 AM
CONCURRENT SESSIONS

Wednesday, May 25/8:30–10:30 AM
Minisymposium 12/Ballroom A-B

LANCZOS ALGORITHMS

There is more to Lanczos than reducing a symmetric matrix to tridiagonal form. It has been appreciated, little by little, that well chosen Krylov subspaces can capture the important action of a linear operator, whatever the application may be. The savings to be made by projecting onto these subspaces are attractive. The talks in this group will demonstrate what is involved in putting this idea to work.

Chair: Beresford N. Parlett
University of California, Berkeley

8:30/M-40/A10
A Generalized Eigenvalue Problem and the Lanczos Algorithm
Thomas Ericsson
Chalmers University of Technology and University of Goteborg, Sweden

9:00/M-41/A11
Implementing the Lanczos Algorithm on a Distributed Memory Message Passing Computer
David S. Scott
Intel Scientific Computers

9:30/M-42/A11
Vibration Analysis of Damped Systems Using Lanczos
B. Nour-Omid
Lockheed Palo Alto Research Laboratory

10:00/M-43/A11
Towards a Black Box Lanczos Program
(To be presented by the Chair)

Wednesday, May 25/8:30–10:30 AM
Minisymposium 13/Empire Room

MATRIX COMPUTATIONS IN STATISTICS

The applications of linear algebra, and in particular of matrix computations, in statistics are very diverse. Computationally intensive methods are becoming an increasingly more important and more utilized class of statistical procedures and the core of these procedures frequently involves some form of matrix computation. Recent advances in computa-

... the individual time for each presentation represent the numerical order and page number of the abstracts.

tional linear algebra often make computationally expensive statistical methods more accessible or help to clarify their properties or in some cases lead to the development of new methods. This minisymposium attempts to illustrate some recent developments in matrix computations that arise in or are applicable to statistical computation.

Chair: George Ostrouchov
Oak Ridge National Laboratory

8:30/M-44/A11
Sparse Matrix Computation in Analysis of Variance
(to be presented by the Chair)

9:00/M-45/A12
Error-Free Sparse Least Squares
Sallie Keller-McNulty
Kansas State University, Manhattan
and
George Ostrouchov
Oak Ridge National Laboratory

9:30/M-46/A12
Computation and Properties of the Total Least-Squares Approach with Applications in System Identification
Sabine Van Huffel, Marc Moonen and Joos Vandewalle
Katholieke Universiteit Leuven, Belgium

10:00/M-47/A12
Some Matrix Computations for Ill-Posed Problems with Large, Noisy Data Sets
Grace Wahba
University of Wisconsin, Madison
and Yale University

Wednesday, May 25/8:30–10:30 AM
Contributed Presentations 14/State B-C

COMBINATORIAL MATRIX ANALYSIS

Chair: Daniel Hershkowitz, Technion-Israel Institute of Technology

8:30/71/A35
Jordan Structure and Singular Graph of a Non-Negative Matrix
Rafael Bru, Universidad Politecnica, Valencia, Spain; and Rafael Canto, Universidad Politecnica en Alcoy, Spain

8:45/41/A35
Regular Matrices and Prime Matrices in the Hall Matrix Semigroups Hn.
Han-Hyuk Cho, University of Wisconsin, Madison

9:00/80/A35
Positive Semifinite Matrices with Given Sparsity Pattern
Stephen Pierce, San Diego State University

9:15/95/A35
Determinantal Identities and Inequalities Induced by Chordal Graphs
Wayne W. Barrett, Brigham Young University, Provo; and Charles R. Johnson, William and Mary, Williamsburg

9:30/111/A36
Multigraphs and Structure Matrices
T. S. Michael, University of Wisconsin, Madison

9:45/131/A36
On the Ranks of Matrix Completions
Nir Cohen, Michigan State University, East Lansing

10:00/L-8/A48
Maximum Permanents on Certain Polytopes of Doubly Stochastic Matrices
Suk Geun Hwang, Kyungpook University, Taegu, Korea

10:15/L-11/A49
Balancing Weighted Directed Graphs in l-Infinity Norm
Hans Schneider, University of Wisconsin, Madison; and Michael H. Schneider, The Johns Hopkins University

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Wednesday, May 25/8:30–10:30 AM
Contributed Presentations 15/State A

PARALLEL MATRIX COMPUTATIONS 2

Chair: Robert Hartwig, North Carolina State University

8:30/47/A36
Parallel Nested Iterations
Paul J. Lanzkron, Donald J. Rose, Daniel B. Szyld, Duke University

8:45/107/A36
Efficient Parallel Algorithm for Solving Positive Definite Systems
He Zhang, Temple University

9:00/91/A37
On the Parallelization of a Block Toeplitz Solver
Elise de Doncker and John Kapenga, Western Michigan University, Kalamazoo

9:15/66/A37
Displacement Structure and Improved Parallel Computations with Dense Structured Matrices
Victor Pan, SUNY, Albany and John Reif, Duke University

9:30/82/A37
A Parallel Algorithm for Computing the QR Factorization of a Rectangular Matrix
Charles R. Katholi and Bruce W. Suter, University of Alabama, Birmingham

9:45/125/A37
Numerical Factorization of Matrices Into Products of Local Matrices
Paul D. Gader, University of Wisconsin, Oshkosh

10:00/129/A37
Parallel VLSI Computing Array for Updating Principal Eigen-subspace
Yu-Hen Hu, University of Wisconsin, Madison

10:15/101/A22
Cholesky Factor Updating Techniques for Rank-two Matrix Modifications
Linda Kaufman, AT&T Bell Laboratories, Murray Hill, NJ; and Richard Bartels, University of Waterloo, Canada

10:30 AM/Diplomat Rooms
Coffee

11:00 AM/Ballroom A–B
Annual Meeting of the SIAM Activity Group on Linear Algebra

11:30 AM/Ballroom A–B
Presentation of the First SIAM Linear Algebra Prize

Wednesday, May 25/PM

12:15 PM
Lunch

1:30 PM
CONCURRENT SESSIONS

Wednesday, May 25/1:30–2:30 PM
Contributed Presentations 16/Ballroom A-B

SPARSE MATRIX COMPUTATIONS 1

Chair: Michael Heath, Oak Ridge National Laboratory

1:30/123/A38
Finding Separators for Sparse Matrix Partitioning
Joseph W.H. Liu, York University, North York, Ontario

1:45/135/A38
Parallelizing and Efficient Partial Pivoting Algorithm
John R. Gilbert, Cornell University, University of Bergen and Chr. Michelsen Institute, Norway

2:00/46/A38
A Linear-time Method for Block Ordering of Sparse Matrices
James O'Neil, Donald J. Rose, and Daniel B. Szyld, Duke University

2:15/45/A38
Orderings for Threshold Incomplete Factorizations
Christian J. Corley, and Daniel B. Szyld, Duke University

Wednesday, May 25/1:30–2:30 PM
Contributed Presentations 17/Empire Room

SIGNALS AND SYSTEMS 2

Chair: Ralph Byers, University of Kansas, Lawrence

1:30/69/A39
On the Problem of Robust Control of Linear Time Varying Systems
Bijoy K. Ghosh, Washington University, St. Louis

1:45/122/A39
Robust Controller Design for Linear Discrete-time Systems
Yiren Huang, Michigan Technological University, Houghton

2:00/72/A39
Robust Controller Design for a Class of Discrete-time Interconnected Systems
R. Challoo and M.E. Sawan, Wichita State University

2:15/84/A39
Robust Optimal Model Matching Control of Discrete-Time Singularly Perturbed Systems
B. Rosul and M.E. Sawan, Wichita State University

Wednesday, May 25/1:30–2:30 PM
Contributed Presentations 18/State B-C

APPROXIMATIONS

Chair: Leiba Rodman, College of William and Mary

Note: The numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

FINAL PROGRAM

Wednesday, May 25/PM
Continued

1:30/38/A40
A Generalized Rational Approximation Problem and Generalized Toeplitz and Hankel Matrices
Daniel W. Sharp, The MITRE Corporation, McLean, VA

1:45/76/A40
Polynomial Approximation of Functions of Matrices and Applications
Hillel Tal-Ezer, Brown University

2:00/65/A40
New Progress in Computing Polynomial Zeros and Its Impact on Matrix Eigenvalue Computation
Victor Pan, SUNY, Albany

2:15/61/A40
An Asymptotically Superior Algorithm for Computing the Characteristic Polynomial of a Tridiagonal Matrix
Hari Krishna, Syracuse University

Wednesday, May 25/1:30–2:30 PM
Contributed Presentations 18A/Director 6

CORE LINEAR ALGEBRA 5

Chair: George Poole, East Tennessee State University

1:30/L-9/A49
Nonlinear Factorization of Nonmonic Matrix Polynomials
M. Gasso and V. Hernandez, Universidad Politecnica de Valencia, Spain

1:45/L-4/A47
Classification of Triples of Matrices and Determinantal Curves
Victor Vinnikov, Ben-Gurion University of the Negev, Israel

2:00/L-3/A47
On the Invariant Factors of Block Triangular Matrices
Ion Zaballa, Escuela Universitaria de Magisterio de Alava, Spain; and College of William and Mary

2:15/L-6/A48
A Survey of Infinite Matrices and Applications
P. N. Shivakumar, University of Manitoba, Canada

2:30 PM/Diplomat Room
Coffee

3:00 PM/Ballroom A–B
Invited Presentation 5
Chair: John Lewis, Boeing Computer Services, Seattle

Group-Symmetry Covariance Models
Michael Perlman, University of Washington, Seattle

6:00 PM
Cocktails and Buffet Dinner
Speaker: Hans Schneider, University of Wisconsin, Madison
"When Does Linear Algebra Become Applied?"
(We will leave the hotel lobby at 5:30 PM to walk to the University)

Thursday, May 26/AM

8:30 AM
CONCURRENT SESSIONS

Thursday, May 26/8:30–9:30 AM
Contributed Presentations 19/Ballroom A-B

MATRIX ALGORITHMS 2

Chair: Frank Hall, Georgia State University

8:30/8/A41
Homotopy Algorithm for Symmetric Eigenvalue Problems
T.Y. Li, Michigan State University, East Lansing; Noah Rhee, University of Missouri, Kansas City

8:45/39/A41
Reconstructing ALL Jacobi Matrices from Spectral Data by the Homotopy Method
Moody T. Chu, North Carolina State University, Raleigh

9:00/10/A41
Leverrier's Algorithm: A New Proof and Extensions
Stephen Barnett, University of Bradford, England

9:15/102/A41
An Algorithm for Matrix Optimization Problems
William N. Anderson, Jr., Fairleigh Dickinson University, Thomas D. Morley, Georgia Institute of Technology, Atlanta, and George E. Trapp, West Virginia University, Morgantown

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Thursday, May 26/8:30–9:30 AM
Contributed Presentations 20/Empire Room

ITERATIVE TECHNIQUES 2

Chair: Michael Neumann, University of Connecticut, Storrs

8:30/113/A42
Application of Contractor Directions to Linear Algebra
Tom Altman, University of Kentucky, Lexington

8:45/103/A42
A General Theory for the Iterative Solution of $BX + XA + C = 0$
David F. Miller, Wright State University

9:00/64/A42
Iterative Improvement of the Singular Value Decomposition
Daniel P. Giesy, Planning Research Corporation, Hampton, VA

9:15/56/A42
Numerical Solution of the Eigenvalue Problem for Hermitian Toeplitz Matrices
William F. Trench, Trinity University, San Antonio

Thursday, May 26/8:30–9:30 AM
Contributed Presentations 21/State B-C

CORE LINEAR ALGEBRA 3

Chair: Chi-Kwong Li, University of Wisconsin, Madison

8:30/70/A43
Nonnegative Centrosymmetric Matrices
James R. Weaver, University of West Florida, Pensacola

8:45/68/A43
Points, Bases and Norms in Fuzzy Linear Spaces
Godfrey C. Muganda, Memphis State University

9:00/104/A43
Inflation Matrices That Commute with a Permutation Matrix
Jeffrey L. Stuart, University of Southern Mississippi, Hattiesburg

9:15/145/A43
Certain Isometries and Set Preservers on Matrix Spaces
Chi-Kwong Li, University of Wisconsin, Madison
Nam-Kiu Tsing, Auburn University

Thursday, May 26/8:30–9:30 AM
Contributed Presentations 22/State A

SPARSE MATRIX COMPUTATIONS 2

Chair: Michael Heath, Oak Ridge National Laboratory

8:30/18/A44
A Connectivity Coordinate System for Ordering
Ali Kaveh, Iran University of Science and Technology, Tehran

8:45/100/A44
Stretching of Linear Equations
Joseph Grcar, Sandia National Laboratories, Livermore

9:00/136/A44
Proposal for a Benchmark Package for Sparse Computations
Youcef Saad and Harry Wijshoff, University of Illinois, Urbana

9:15/L-10/A49
On One-Way Dissection with Singular Diagonal Blocks
Jesse L. Barlow and Udaya B. Vemulapati, Pennsylvania State University

9:45 AM/Ballroom A–B
Invited Presentation 6
Chair: Charles Van Loan, Cornell University

On a Class of Robust Numerical Methods in Linear System Theory
Paul Van Dooren, Philips Research Laboratory, Belgium

10:45 AM/Diplomat Rooms
Coffee

11:15 AM/Ballroom A–B
Invited Presentation 7
Chair: David Carlson, San Diego State University

The Formulation and Analysis of Inverse Eigenvalue Problems for Symmetric Matrices
Shmuel Friedland, University of Illinois, Chicago

... the numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

FINAL PROGRAM

Thursday, May 26/PM

12:15 PM
Lunch

1:45 PM
CONCURRENT SESSIONS

Thursday, May 26/1:45–3:45 PM
Minisymposium 14/Ballroom A-B

LARGE EIGENVALUE PROBLEMS

Success with standard eigenvalue problems such as Ax = x lambda, with A real and symmetric though large has prompted users to ask for algorithms to solve more realistic problems. In a number of applications A need not be symmetric, in engineering environments there may be three symmetric matrices (not just one) and a nonlinear problem A + lambda B + lambda squared C, or a generalized linear problem A + lambda B which is not definite and can have complex eigenvalues. These new cases are significantly harder and the speakers will indicate the difficulties encountered as well as the advances made in recent years.

Chair: Beresford N. Parlett
University of California, Berkeley

1:45/M-48/A12
Large Sparse Nonsymmetric Eigenvalue Problems: Applications and Algorithms
Youcef Saad
University of Illinois, Urbana-Champaign

2:15/M-49/A13
The Solution of Large Sparse Eigenvalue Problems in Structural Engineering Applications
Roger G. Grimes, John G. Lewis
Boeing Computer Services, Seattle
and
Horst D. Simon
NASA Ames Research Center

2:45/M-50/A13
An Algorithm for Nonsymmetric Generalized Eigenvalue Problems
Jane K. Cullum and Ralph Willoughby
IBM T. J. Watson Research Center and Wolfgang Kerner, Max-Planck Institut Für Plasmaphysik

3:15/M-51/A13
The Quadratic Eigenvalue Problem Of Damped Oscillations
K. Veselic
Fernuniversitat Hagen, W. Germany

Thursday, May 26/1:45–3:45 PM
Minisymposium 15/Empire Room

ITERATIVE METHODS FOR THE SOLUTION OF LINEAR ALGEBRAIC SYSTEMS 5

Chair: A. Hajidimos
Purdue University

1:45/M-52/A13
The Parallel Multisplitting Method for Linear Systems whose Coefficients Matrix is a Singular M-Matrix
Phillip Kavanaugh and Michael Neumann
University of Connecticut, Storrs

2:15/M-53/A14
The S-Step Conjugate Gradient Methods Implemented on Parallel Systems
A. T. Chronopoulos,
University of Minnesota, Minneapolis
and
C. W. Gear
University of Illinois, Urbana

2:45/M-54/A14
Asynchronous Multilevel Adaptive Methods for PDEs on Parallel Computers
Steve McCormick
University of Colorado, Denver

3:15/M-55/A14
Spline Collocation Iterative Methods for Elliptic PDEs
Emmanuel Vavalis
Purdue University

Thursday, May 26/1:45–3:45 PM
Contributed Presentations 23/State B-C

STATISTICS 2

Chair: Douglas Bates, University of Wisconsin, Madison

1:45/52/A44
Computer-aided Illustration of Regression Diagnostics
Tapio Nummi, Markku Nurhonen, Simo Puntanen, University of Tampere, Finland

2:00/51/A45
Robustness to Missing Data under the Growth Curve Model
Erkki P. Liski and Tapio Nummi, University of Tampere, Finland

2:15/50/A45
On the Canonical Correlations between the OLS Fitted Values and the Residuals in the General Linear Model
Simo Puntanen, University of Tampere, Finland

2:30/48/A45
Variance Inflation and Collinearity in Regression
Robert Schall, Institute for Biostatistics, Tygerberg, RSA, and Timothy T. Dunne, University of Cape Town, RSA

2:45/43/A45
A Usable Criterion of Multivariate Model Stationarity
Peter Vinella, Berkeley Investment Technologies

3:00/25/A45
Statistics on a Parallel Computer: All-Subsets Regression
Peter C. Wollan, Michigan Technological University, Houghton

Thursday, May 26/1:45–3:45 PM
Contributed Presentations 24/State A

CORE LINEAR ALGEBRA 4

Chair: Chi-Kwong Li, University of Wisconsin, Madison

1:45/57/A46
The Matrix Equation AX − XB = C and Its Special Cases
Jean H. Bevis, Frank J. Hall, Georgia State University, Atlanta
Robert E. Hartwig, North Carolina State University, Raleigh

2:00/9/A46
Extraction of mth Roots in Matrix Rings over Fields
Daniel E. Otero, Syracuse University

2:15/13/A46
Co-Solutions of Algebraic Matrix Equations of Polynomial Type and Applications
Lucas Jodar, University of Valencia, Spain

2:30/87/A46
Symmetric Bilinear Form and its Application in Matrix Theory
Dipa Choudhury, Loyola College, Baltimore

2:45/L-14/A50
On the Error Estimate for the Projection of a Point Onto a Linear Manifold
Musheng Wei, Michigan State University

3:00/L-15/A50
On the Spectral Radius of Functions of Nonnegative Matrices
Ludwig Elsner, Universitat Bielefeld, W. Germany
Daniel Hershkowitz, and Allan Pinkus, Technion-Israel Institute of Technology

3:15/L-17/A51
Multi-dimensional Levinson Recursions for Non-Causal Prediction
K. S. Arun, and L. C. Potter, University of Illinois, Urbana-Champaign

3:45 PM
Conference Adjourns

Special Notice to Contributed Presentation Authors and Chairmen of Contributed Presentation Sessions:

Fifteen minutes are allowed for each contributed presentation. Presenters are requested to spend a maximum of 12 minutes for their presentation, and 3 minutes for questions and answers.

Please note:

For presentations with more than one author, an underlineation is used to denote the author who will present the paper.

Note: The numbers that follow the individual time for each presentation represent the numerical order and page number of the abstracts.

MONDAY, MAY 23

11:00 AM - 12:00 Noon
Ballroom A-B

MINISYMPOSIUM 1
Iterative Methods 1

#M-1/11:00 AM
Inner/Outer Iterations and Domain Decomposition

In many situations, domain decomposition is equivalent to partitioning a matrix into submatrices and then solving a system of equations associated with each submatrix. Unfortunately, it is not always possible to solve each subsystem exactly. An inner-outer iteration procedure is necessary in obtaining the approximate solution on the subdomain. In this talk, we analyze the Chebyshev semi-iterative method and show the convergence properties of the algorithm.

Gene H. Golub
Department of Computer Science
Stanford University
Stanford, CA 94305
(on sabbatical at the University of Maryland, College Park)
and
Michael Overton
Courant Institute of Mathematical Sciences
New York University
New York, NY 10012

#M-2/11:30 AM
Iterative Solution of Linear Systems with Gapped Spectra

A stationary iterative method is developed for linear systems $Ax=f$ where the eigenvalues of A lie within two disjount colinear intervals in the complex plane.

Such linear systems include the case that A is hermitian (spectrum of A lies in two real intervals, one negative and the other positive.)

A corollary result is that the convergence rate of the SOR theory can be accelerated if consistently ordered matrix A has a positive spectrum with a "central gap." As the gap size increases, the convergence rate increases arbitrarily.

John E. de Pillis
University of California, Riverside
Departments of Mathematics and Computer Science
Riverside, CA 92521

MONDAY, MAY 23
1:30 - 3:30 PM
Ballroom A-B

MINISYMPOSIUM 2
Iterative Methods 2

#M-3/1:30 PM
Some New Results on Optimal Preconditioning

Garabedian's technique of regarding an accelerated matrix iteration as a time differencing approximation to a time-dependent partial differential equation leads to optimal preconditioners for solving the biharmonic equation. One can then obtain results that are extensions of Forsythe's results on optimal digonal preconditioners.

Ted Ferretta
University of California, Davis
L-794
Lawrence Livermore National Laboratory
Livermore, CA 94550

Garry Rodrigue
L-306
Lawrence Livermore National Laboratory
Livermore, CA 94550

#M-4/2:00 PM

The 3D Linear Hierarchical Basis Preconditioners

It is well known that the condition number of the coefficient matrix arising from discretizing a self-adjoint and positive definite elliptic problem in two dimensions using linear triangular elements and nodal basis functions is O(N), where N is the number of unknowns. Yserentant (1986) has shown that this can be improved to $O((\log\sqrt{N})^2)$ by using hierarchical basis functions. In this paper, we extend Yserentant's results to three dimensions and show that the condition number is $O(N^{1/3})$ as opposed to $O(N^{2/3})$ for nodal basis functions. We verify this result by comparing iteration counts to solve a linear system using the preconditioned conjugate gradient method. Parallel implementation issues are also discussed for 3D problems.

Maria Elizabeth G. Ong
Department of Applied Mathematics, FS-20
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Seattle, WA 98195

Loyce M. Adams
Department of Applied Mathematics, FS-20
University of Washington
Seattle, WA 98195

#M-5/2:30 PM

An almost optimal preconditioner in domain decomposition

Domain decomposition techniques for elliptic PDE problems give rise to a capacitance (or Schur complement) matrix. Large capacitance systems need to be solved by efficient iterative methods. We present an almost optimal preconditioner that leads to fast convergence, and illustrate it with numerical results.

W. Proskurowski
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#M-6/3:00 PM

NSPCG - Nonsymmetric Preconditioned Conjugate Gradient Package

A computer package NSPCG for solving large sparse linear systems by various iterative methods is presented. It contains a wide selection of preconditioners and accelerators for both symmetric and nonsymmetric coefficient matrices. In addition, several sparse matrix data formats are available for representing either sturctured or unstructured systems. NSPCG is a research-oriented computer package developed as part of the ITPACK Project of the Center for Numerical Analysis at The University of Texas at Austin.

Thomas C. Oppe, Wayne D. Joubert, David R. Kincaid
Center for Numerical Analysis
The University of Texas at Austin
Austin, Texas 78713-8510

MONDAY, MAY 23
1:30 - 3:30 PM
Empire Room

MINISYMPOSIUM 3
Signal Processing

#M-7/1:30 PM

Harmonic Retrieval and Source Location -- A Survey

Harmonic retrieval and source location are classical signal processing problems that have undergone intense development in recent years. The purpose of this talk is to give a mathematical treatment and background of these problems and survey recent developments in the area with particular focus on the linear algebraic interpretations and computations that arise. This talk is meant to be an introduction to the other three talks in the minisymposium.

George Cybenko
Department of Computer Science
Tufts University
Medford, MA 02155

#M-8/2:00 PM

Mathematical Tools for Signal Processing: Multilinear (Exterior) Algebra and Multivectors

Signal Processing makes more and better use of numerical linear algebra than ever before. "Signal Subspaces" have become a basis for multiple signal detection and parameter estimation algorithms which, in turn, are expressed in the language of linear algebra. The MUSIC and ESPRIT algorithms are examples. (Signal Subspaces are fundamental because they reflect the structure in data corresponding to multiple 'point sources'.) On the other hand, multilinear algebra---the algebra of multivectors within which the 'ordinary' vector space is a special case---is largely unknown to the signal processing community. However, Signal Subspaces are multivectors and Exterior Algebra is the algebra of subspaces. Thus, they could and should appear in system theory, control theory, Kalman filtering, spectral analysis, etc., in ways which are new and essential. We may indeed wish to estimate, control, filter, analyze other objects beyond ordinary vectors had we the tools. The question is, "Are multivector algorithms implementable in terms of linear algebra or are they outside its scope?" In this paper, multilinear or exterior algebra is discussed in the context of certain Signal Subspace algorithms and those solutions which require it are presented as an argument for the development of numerically sound procedures for multilinear algebra.

Ralph O. Schmidt
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#M-9/2:30 PM

Geometric Methods and Invariance Techniques in Signal Processing

In many signal processing applications, the objective is to estimate a set of unknown parameters upon which *deterministic* signals measured by an array of sensors depend. Direction-of-arrival estimation of narrowband sources and detection of sinusoids in noise are classic examples. These problems naturally possess multi-dimensional geometric characteristics that have only recently been recognized. The (multi-)linear algebraic techniques embodied in the *eigen* and *singular value decompositions* are some of the analytical tools employed in solving such problems; and the natural correspondence between such techniques and the geometry of the vector spaces being *decomposed* is responsible for the *high-resolution* properties of the solutions. In many of the recently developed algorithms (*e.g.*, Schmidt's MUSIC, Burg's MEM, and Capon's ML algorithms) however, the majority of the computational effort is expended in searching for intersections of *estimated signal subspaces* and the set of all possible array responses (*i.e.*, the *array manifold*). The objective of this presentation is to elucidate the geometric nature of the aforementioned class of signal processing problems, discuss techniques that have exploited the geometric nature in various ways, and describe a recently developed technique (**ESPRIT**) for dramatically reducing the computational requirements of the previous algorithms by exploiting *subspace invariances* induced by appropriate design of the sensor array.

Richard H. Roy
Information Systems Laboratory
Stanford University
Stanford, Calif. 94305

#M-10/3:00 PM

A Unitary Method for the ESPRIT Direction-of-Arrival Estimation Algorithm

ESPRIT is an interesting new method for solving the Direction-of-Arrival estimation problem. It involves some rather tricky matrix manipulations. We show how these calculations can be carried out using only unitary transformations of the data. No inverses or cross-products are required making the new method extremely robust.

Charles Van Loan
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NOTE
There is no abstract that is numbered M-11.

MONDAY, MAY 23
4:00 - 6:00 PM
Ballroom A-B

MINISYMPOSIUM 4
Combinatorial Matrix Analysis

#M-12/4:00 PM

Some combinatorial issues in algebraic matrix analysis.

Algebraic coding theory is a source of many combinatorial problems in matrix theory and linear algebra. In coding theory the focus is on matrices and linear spaces over finite fields (not the traditional real and complex fields) with the binary field of primary interest. The norm of a vector is its Hamming weight (the number of nonzero coordinates). A linear code can be given by a parity check matrix H. The packing radius of the code (which determines its error correcting capabilities) is the minimum norm of a nonzero solution (codeword) of $Hx=0$; the covering radius is the smallest integer t such that $Hx=s$ has a solution with norm $\le t$ for all s. We shall discuss some issues concerning these two parameters.

Richard A. Brualdi
Department of Mathematics
University of Wisconsin
Madison, WI 53706

#M-13/4:30 PM

Combinatorial Factorings of Matrices

We present several results on the factorization of an n x n matrix into a product of two n x n matrices. Our results are based upon a purely combinatorial analysis; but they are applied in several ways. We show that such factorizations are, for example, helpful in identifying several classes of matrices as P-matrices. They can also be used to uncover classes of matrices diagonally similar to symmetric (anti-symmetric) matrices. Finally, these factorizations lead to some interesting representation of inverses.

John S. Maybee
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University of Colorado
Boulder, Colorado 80309-0426

#M-14/5:00 PM

Inheritance of Matrix Entries

The concept of fill-in in Gaussian elimination, which is well known in sparse matrix analysis, is extended to that of inheritance of an arbitrary matrix entry. Graph-theoretic necessary and sufficient conditions for inheritance are given, and are applied to the Schur complement and to the matrices L and U of the unit LU factorization.

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Pauline van den Driessche
Department of Mathematics
University of Victoria
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#M-15/5:30 PM

Matrix Completion Problems

A partial matrix is one in which some entries are specified elements of a given field and the others are unspecified. A completion of a partial matrix is a specification of the unspecified entries so as to produce an ordinary matrix over the given field. A matrix completion problem asks whether a given partial matrix has a completion with a certain property of interest, such as positive definite, rank $\leq k$, or spectral distribution. Our purpose is to give an elementary survey of this growing subarea of combinatorial matrix analysis, and to highlight a few of the key ideas (such as connections with chordal graphs) that have emerged thus far.

Charles R. Johnson
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Williamsburg, Virginia 23185

MONDAY, MAY 23

4:00 - 6:00 PM
Empire Room

MINISYMPOSIUM 5
Num. Mtds. for Eigenvalue Problems

#M-16/4:00 PM

Robust Eigenvalue Assignment by Output Feedback

We consider a linear time invariant system

$$\dot{x} = Ax + Bu$$
$$y = Cx.$$

The problem is to select a real mxp feedback matrix K such that the closed loop system matrix $M \equiv A + BKC$ has a prescribed set of eigenvalues $\{\lambda_i\}$. Necessary and sufficient conditions for the existence of solutions are given. Stable numerical techniques are described for constructing the feedback matrix K such that the closed loop system is 'robust', in the sense that the prescribed eigenvalues are insensitive to perturbations in the system. For arbitrary choices of the set $\{\lambda_i\}$, solutions may not exist; in this case, the eigenvalues are assigned to robust positions which approximate the desired results.

Nancy K. Nichols and Sharon Slade
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#M-17/4:30 PM

Jacobi Type Methods for Matrices with Very Special Structure

We discuss eigenproblem algorithms for matrices which have one or more of the following properties: symmetric (Hermitian), skew symmetric (skew Hermitian), symplectic (conjugate symplectic), J-symmetric (J-Hermitian), J-skew symmetric (J-skew Hermitian), orthogonal (unitary). Matrices with such properties arise in many different applications and robust, numerically stable software is needed, that also respects the underlying structure.
In this talk, we describe how the Jacobi algorithm can be adapted (or generalized) to have the required properties. We also discuss how well known parallelization techniques for the Jacobi algorithm may be used here to obtain parallel algorithms.

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ABSTRACTS: MINISYMPOSIA

#M-18/5:00 PM

QR Algorithms for Matrices with Very Special Structure

Eigenvalue problems which arise in applications often have special structures. Computing the optimal control of a continuous time or discrete time dynamical system for instance can result in determing an invariant subspace of a Hamiltonian or a symplectic matrix, respectively. Often the QR-algorithm can be adapted to exploit the special structure for such a problem, if the matrix has in addition another special feature, e.g. if it is Hamiltonian and Hermitian or symplectic and orthogonal. Here we study systematically the development of such methods for matrices which have two of the following properties: symmetric (Hermitian), skew symmetric (skew Hermitian), symplectic (conjugate symplectic), J-symmetric (Hamiltonian), J-skew symmetric (J-skew Hermitian) and orthogonal (unitary).

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Volker Mehrmann
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#M-19/5:30 PM

Condition Estimates for Matrix Functions

A theory is presented of analytic matrix function sensitivity based on Fréchet derivatives. Using this theory, a simple power method algorithm is derived which provides accurate condition estimates at a cost of only two function evaluations. When applied to a large set of problems for both the exponential and logarithm matrix functions, this method gave consistently reliable condition estimates, even on problems for which current sensitivity estimation procedures give inaccurate results. Using the Fréchet derivative approach, we also show that matrix functions evaluated at normal matrices exhibit minimal sensitivity, thus generalizing a result of Van Loan for the matrix exponential.

Charles Kenney
Alan J. Laub

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Computer Engineering
University of California
Santa Barbara, CA 93106

TUESDAY, MAY 24

8:30 - 10:30 AM
Ballroom A-B

MINISYMPOSIUM 6
Iterative Methods 3

#M-20/8:30 AM

A Note on the SSOR and USSOR Iterative Methods Applied to p-Cyclic Matrices

The purpose of this note is three-fold. First, we develop the **new** functional equations, viz.

$$[\lambda-(1-\omega)(1-\hat{\omega})]^p = \lambda^k[\lambda\omega+\hat{\omega}-\omega\hat{\omega}]^{|\zeta_L|-k}[\lambda\hat{\omega}+\omega-\omega\hat{\omega}]^{|\zeta_u|-k}(\omega+\hat{\omega}-\omega\hat{\omega})^{2k}\mu^p, \qquad (*)$$

which serves to generalize and unify all recent research results on the SSOR and USSOR iterative methods applied to a block p-cyclic matrix. Second, we give a graph-theoretic interprelation of the exponent k in (*), and finally, while (*) generalizes a recent result of Gong and Cai, we bring this result of Gong and Cai to a larger audience.

Xiezhang Li and Richard S. Varga
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#M-21/9:00 AM

Block Iterative Solutions of Large Overdetermined Systems

The problem of accelerating the rate of convergence of iterative schemes, as they apply to the solution of large overdetermined systems, is addressed. The fundamental problems of convergence and optimization are discussed for numerous 2 and 3-block iterative schemes including the Jacobi, Gauss-Seidel, Accelerated Gauss-Seidel, SOR and their Extrapolated counterparts. Efficient algorithmic procedures for the derivation of optimal extrapolation factors are introduced. Analytical and numerical results from the comparison of all the above schemes are included. The theoretical comparison of block iterative schemes against the Conjugate Gradient method is also discussed.

Yiannis G. Saridakis
Department of Mathematics and Computer Science
Clarkson University
Potsdam, New York 13676, U.S.A.

#M-22/9:30 AM

Robust iterative methods for general sparse linear systems.

Can iterative methods replace sparse direct methods as general purpose linear system solvers? With the current state of the art in iterative methods, the answer to this question is no. Most iterative methods work well only under some strong assumptions on the coefficient matrix. Conjugate gradient type methods which have recently emerged as strong rivals to direct solvers still suffer from the fact that there are no known good preconditionings for indefinite problems. We will consider several alternatives and discuss their merits and weaknesses. The first alternative is to turn to a method based on Conjugate Gradient for the normal equations. We will show how the normal equations can be preconditioned by block SSOR without even forming the coefficient matrix. This constitutes a robust solver but it may still be too slow. A second alternative is to employ a preconditioning that is based on incomplete LU with pivoting. There are difficulties associated with this approach and we will see how some of them can be resolved. Finally, we will consider preconditioners based on Incomplete QR techniques. Numerical tests on matrices from the Harewell/Boeing collection will be presented.

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USA

#M-23/10:00 AM

A dynamic parameter Algorithm for Richardson's method for general non-symmetric matrices

In this paper, Richardson's method is proposed for the iterative solution of complex linear algebraic systems, optimum parameters for which depend on the eigenvalues of the system matrix. An algorithm is presented for the parameters that first computes (a few) eigenvalue estimates as part of a projection step, then generates an approximate convex hull, from which parameters are computed by minimizing the residual polynomial on the convex hull. The Manteuffel algorithm is a well-known adaptive algorithm restricted however to matrices the eigenvalues of which appear in complex conjugate pairs, and is not therefore directly applicable to complex matrices.

Paul E. Saylor
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TUESDAY, MAY 24

8:30 - 10:30 AM
Empire Room

MINISYMPOSIUM 7
Canonical Forms of Matrices 1

#M-24/8:30 AM

Pairs of matrices

The results of Ju. Ermolaev on the simultaneous reduction of a Hermitian matrix and a complex symmetric matrix will be described. Similar results on the simultaneous reduction of a Hermitian matrix and a complex skew symmetric matrix will also be described. The various types of blocks in the canonical forms will be exhibited.

Robert C. Thompson
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Santa Barbara, CA 93106
USA

#M-25/9:00 AM

Simultaneous block diagonalization of pairs of Hermitian matrices.

Let H and K be n × n, complex Hermitian matrices and let $f(x,y,z) = \det(zI - xH - yK)$ be the characteristic polynomial of the pencil $xH + yK$. We consider the problem of simultaneously block diagonalizing the pair H and K with a similarity transformation. (This is equivalent to putting the single matrix $A = H + iK$ into a block triangular form via a unitary similarity.) In special cases, the factored form of the polynomial $f(x,y,z)$ gives information about the block structure of H and K.

As shown by Rellich, the eigenvalues of the pencil $H + \lambda K$ can be expressed as power series in λ in a neighborhood of 0. If a suitable similarity is applied to H and K, then the first two coefficients of these power series will appear on the main diagonals of the transformed pair. This raises questions about the relationship of higher order coefficients to the entries of H and K.

Helene Shapiro
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Swarthmore College
Swarthmore, PA 19081

#M-26/9:30 AM

Canonical Forms and Invariant Subspaces

Here is a survey of the recent advances in the understanding of invariant subspaces of matrices with various properties and applications. These advances are based on suitable canonical forms.

Leiba Rodman
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Williamsburg, Virginia 23185
Department of Mathematics
Arizona State University
Tempe, Arizona 85287

#M-27/10:00 AM

Applications of a Concanonical Form

The consimilarity relation "$A = SB\bar{S}^{-1}$ for some nonsingular S" partitions the space of square complex matrices of given size into equivalence classes. A concanonical form is a way of selecting a "canonical" representative from each equivalence class. We discuss concanonical forms that are close analogs of the Jordan Canonical Form with applications such as: test two matrices for consimilarity; consimilarity to a real or Hermitian matrix; consimilarity of a matrix to its own conjugate, adjoint, and transpose; analogs of the Shoda theorems on commutators.

Roger A. Horn
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TUESDAY, MAY 24

1:30 - 2:30 PM
Ballroom A-B

MINISYMPOSIUM 8
Iterative Methods 4

#M-28/1:30 PM

ITERATIVE METHODS FOR INFINITE LINEAR EQUATIONS

For the linear system $\underset{\sim}{x}=A\underset{\sim}{x}+\underset{\sim}{b}$, where (I-A) is an infinite diagonally dominant matrix and $\underset{\sim}{x}$ and $\underset{\sim}{b}$ are infinite vectors, sufficient conditions are imposed on (I-A) and b to ensure existence and uniqueness of bounded solutions for $(I-A)\underset{\sim}{x}=\underset{\sim}{b}$. An iteration scheme is now applied to the truncations of the given system and the convergence of this iteration scheme for the infinite system is established. An example is given to illustrate the theory.

Pappur N. Shivakumar
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CANADA.

#M-29/2:00 PM

On the Matrix Analogue of the Generalized Young-Varga's Relationship

Let A be a $(k-l,l)$-generalized consistently ordered matrix with T and L_ω its associated Jacobi and SOR matrices whose eigenvalues μ and λ satisfy the well-known relationship $(\lambda+\omega-1)^k = \omega^k\mu^k\lambda^{k-l}$. For a subclass of the above matrices A the matrix analogue of the previous relationship holds. Exploiting the matrix relationship one shows that the SOR method is equivalent to a certain monoparametric k-step iterative one used for the solution of the linear system x = Tx + c. This equivalence yields various results concerning the convergence properties of the aforementioned iterative methods.

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†Purdue University, Department of Computer Sciences, West Lafayette, IN 47907.

TUESDAY, MAY 24

1:30 - 2:30 PM
Empire Room

MINISYMPOSIUM 9
Canonical Forms in Matrices 2

#M-30/1:30 PM

Canonical Forms of Matrices under Congruences

We discuss canonical forms of matrices under (unitary) congruence transformations. We obtain necessary and sufficient conditions for two matrices to be equivalent under (unitarily) congruence. The conditions are then used to derive various canonical forms.

Yoopyo Hong
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Dekalb, IL 60115

#M-31/2:00 PM

The Drazin Inverse of a Semi-Linear Transformation and its Matrix Representation

The Drazin inverse T^d of a semi-linear transformation T on $\mathbb{C}^n$ is studied. A canonical form for the matrix A^δ of T^d is given, and algebraic as well as conspectral/spectral properties are investigated, including the notion of generalized eigenvector of the semi-linear transformations. The matrix linking these properties is $A\bar{A}$, which appears in earlier work. Some open questions are also presented.

Jean H. Bevis and Frank J. Hall
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and
Robert E. Hartwig
Department of Mathematics
North Carolina State University
Raleigh, NC 27695

TUESDAY, MAY 24

4:15 - 6:15 PM
Ballroom A-B

MINISYMPOSIUM 10
Num. Lin. Algebra for Parall. Arch.

#M-32/4:15 PM

Preconditioners on Parallel Computers

The coefficient matrix that results from a finite element discretization of an elliptic self-adjoint PDE using nodal basis functions is sparse and structured but has a large condition number. Hence, the conjugate gradient method can be applied efficiently but will converge too slowly without preconditioning. Recently Yserentant has shown the use of a hierarchical basis can improve the condition for two dimensional problems, and that on sequential machines, conjugate gradient can be efficiently applied to the matrix in factored form. We describe parallel implementations of this method on the Flexible-32 shared memory machine for two and three dimensional problems.

Loyce M. Adams
Department of Applied Mathematics, FS-20
University of Washington
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#M-33/4:45 PM

Parallel Triangular Solutions and Downdating on Distributed-Memory Multiprocessors

In this talk we review recent progress in the development of efficient parallel algorithms for solving triangular systems and for updating or downdating triangular factorizations of matrices on distributed-memory multiprocessors. These two types of problems have a similar structure, so that algorithms for solving them are closely related. In both cases the granularity of the computations is rather fine and communication costs tend to dominate on message-passing multiprocessors systems such as a hypercube. We discuss several types of parallel algorithms for solving triangular systems, including modified cyclic algorithms, and apply them to an updating/downdating problem arising in signal processing. Empirical results obtained on commercial hypercubes are presented.

Michael T. Heath
Mathematical Sciences Section
Oak Ridge National Laboratory
Oak Ridge, TN 37831

#M-34/5:15 PM

Parallel Preconditioned Conjugate Gradient Methods for General Sparse Systems

For very large general sparse linear systems such as those arising from three-dimensional models, preconditioned Krylov subspace methods represent a good alternative to using direct methods. When implementing these methods on parallel machines one faces the problem that the standard preconditioners are very sequential and lead to serious bottlenecks. In this talk we will consider several different ways of improving the parallelization of such techniques. The simplest approach is to use a polynomial preconditioning which consists of approximating A^{-1} by a polynomial in A. This preconditioning technique offers a high degree of parallelism and its performance can be enhanced by a simple diagonal or block-diagonal scaling. The second alternative is to reorder the nodes in order to increase the potential for parallel steps in the L and U solves. Finally, one can parallelize the triangular solves without reordering the nodes (frontal approach or blocking approach). Comparisons of these various approaches will be presented on general sparse nonsymmetric matrices from the Harewell/Boeing collection.

Youcef Saad
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#M-35/5:45 PM

Divide and Conquer Algorithms for Eigenvalue Problems

The divide and conquer paradigm has provided effective algorithms for the symmetric eigenvalue problem and the singular value decomposition. These algorithms are well suited to parallel vector architectures and are well matched respectively with block reductions to tridiagonal and bidiagonal form. Development and theoretical background of these algorithms will be reviewed. We also touch upon implementation and portability issues with particular attention paid to the role of these algorithms as library subroutines. We discuss techniques that may be used to implement the algorithms in code that may be transported to a significant number of existing parallel parallel computers.

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TUESDAY, MAY 24

4:15 - 6:15 PM
Empire Room

MINISYMPOSIUM 11
Geom. & Lie Theoretic Mtds.

#M-36/4:15 PM

Toward a General Theory of Algorithms of QR Type

The *QR* and *LR* algorithms are well known procedures for calculating eigenvalues of matrices. Less well known but also important is the *SR* algorithm, which can be used to solve the algebraic Ricatti equation, an eigenvalue problem in disguise. These three algorithms have numerous obvious similarities. I will use geometric and Lie theoretic ideas to sketch a general theory which includes all of them as special cases. The theory shows clearly the common elements of these algorithms and also, by its limitations, the differences.

David S. Watkins
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#M-37/4:45 PM

Isospectral Flows and Abstract Matrix Factorizations

A general framework for constructing isospectral flows in the space gl (n) of n by n matrices is proposed. Depending upon how gl (n) is split, this framework gives rise to different types of abstract matrix factorizations. When sampled at integer times, these flows naturally define special iterative processes, and each flow is associated to the sequence generated by the corresponding abstract factorizations. The proposed theory unifies as special cases the well known matrix decompositions techniques used in numerical linear algebra, and is likely to offer a broader approach to the general matrix factorization problem.

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and
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#M-38/5:15 PM

Connections Between Hessenberg Flags and Numerical Linear Algebra

Hessenberg and Hessenberg-type matrices play a fundamental role in many aspects of numerical linear algebra. Hessenberg matrices are particularly important in the implementation of the QR algorithm. The formulation of the QR algorithm as an iteration on the full flag manifold leads to the consideration of Hessenberg matrices in terms of certain subsets of the flag manifold, which we refer to as sets of Hessenberg flags. This formulation allows us to view properties of Hessenberg matrices in terms of the geometric structure of these sets. The generality of this approach extends naturally to aspects of Hessenberg and Hessenberg-type forms in a variety of numerical problems. In this talk we consider some connections between geometric aspects of Hessenberg flags and the roles of Hessenberg and Hessenberg-type matrices in numerical linear algebra.

Gregory S. Ammar
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Northern Illinois University
DeKalb, Illinois 60115

#M-39/5:45 PM

Geometry of the Lagrange-Hessenberg Variety and the QR-Algorithm for Hamiltonian Matrices

It has been recognized that the QR-algorithm applied to a Hamiltonian matrix H can be viewed as a discrete dynamical system on the so-called Lagrange flag manifold consisting of the complete flags S=(S(1),...,S(2n-1)) of subspaces in complex 2n-space which are isotropic relative to the symplectic form. The initial reduction of H to Hamiltonian-Hessenberg form corresponds to the restriction of this dynamical system to the Lagrange-Hessenberg variety consisting of those flags which are Hessenberg for H--i.e., for which H(S(i)) is contained in S(i+1) for all i. Consequently, the behavior of the QR-algorithm as applied to a Hamiltonian-Hessenberg matrix is closely related to the topology of the associated Lagrange-Hessenberg variety. We investigate this topology. If H has distinct eigenvalues, its Lagrange-Hessenberg variety is smooth and connected. The odd Betti numbers vanish, while the even Betti numbers can be regarded as symplectic analogues of the classical Eulerian numbers.

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Mark A. Shayman
Electrical Engineering Department and
Systems Research Center
University of Maryland
College Park, Maryland 20742

WEDNESDAY, MAY 25

8:30 - 10:30 AM
Ballroom A-B

MINISYMPOSIUM 12
Lanczos Algorithms

#M-40/8:30 AM

A Generalized Eigenvalue Problem and the Lanczos Algorithm

Some properties of the generalised eigenvalue problem $\mathbf{Kx} = \lambda\mathbf{Mx}$, where K and M are real and symmetric matrices, and K is nonsingular and M is positive semidefinite (and singular) are examined. We start by listing some basic properties of the problem such as the Jordan normal form of $\mathbf{K}^{-1}\mathbf{M}$. The next part deals with three standard algorithms (inverse iteration, the power method, and the Lanczos method) the focus being on the Lanczos method. It is shown that if the Lanczos starting vector is contaminated by a component, in a certain subspace, this component may grow rapidly and cause large errors in the eigenvectors. Some ways to refine the approximations are presented. The last part deals with problems of estimating the quality of an approximate eigenpair, given a residual $\mathbf{r} = \mathbf{K}\bar{\mathbf{x}} - \bar{\lambda}\mathbf{M}\bar{\mathbf{x}}$. We will discuss the choice of norm in the case when M is singular.

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ABSTRACTS: MINISYMPOSIA

#M-41/9:00 AM

Implementing the Lanczos Algorithm on a Distributed Memory Message Passing Computer

In the last fifteen years, the Lanczos algorithm has become the preferred method of computing some (or all) of the eigenvalues of large sparse symmetric matrices. When combined with LU factorization it becomes a powerful technique for generalized eigenvalue problems as well.
The Intel iPSC is an example of a DMMP (Distributed Memory Message Passing) parallel computer. Each node runs asynchronously and data is exchanged by passing messages. Implementing an algorithm on a DMMP machine requires partitioning the data and the work among the processors. This talk will describe how the Lanczos algorithm can be implemented efficiently on a DMMP machine. Implementation details and timings will be presented for an Intel Hypercube.

David S. Scott
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#M-42/9:30 AM

Vibration Analysis of Damped Systems Using Lanczos

In this paper we use the unsymmetric Lanczos algorithm for the dynamic analysis of structural systems with general matrix coefficients. The equations of dynamic equilibrium are first transformed to a system of first order differential equations. Then the unsymmetric Lanczos method is used to generate two sets of vectors. These vectors are used in a method of weighted residual to reduce the equations of motion to a small unsymmetric tridiagonal system.

The algorithm is further simplified for system of equations with symmetric matrices. By appropriate choice of the starting vectors we obtain an implementation of the Lanczos method that is remarkably close to that for the positive semi-definite system, but extended to the case with indefinite matrix coefficients. This simplification eliminates one of the sets of vectors generated by the unsymmetric Lanczos method and results in a symmetric tridiagonal, but indefinite system. We identify the difficulties that may arise when this implementation is applied to problems with symmetric indefinite matrices such as vibration of structures with velocity feedback control forces which lead to symmetric damping matrices. Favourable results were obtained when the symmetric form of the algorithm is used to obtain the response of a damped system.

B. Nour-Omid

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#M-43/10:00 AM

Towards a Black Box Lanczos Program

A common request is for a few eigenvectors of the general linear eigenvalue problem in which both matrices are symmetric and one of them is positive semidefinite. The order is large. Our goal is to use the Lanczos algorithm but remove the human user from decision making as far as possible. Several questions need to be addressed:
1) A block version or a simple one?;
2) Reorthogonalize the Lanczos vectors all the time, never, or sometimes?; 3) How to stay away from infinite eigenvalues?; 4) When to stop a Lanczos run?. The talk will describe our encounter with these questions.

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WEDNESDAY, MAY 25

8:30 - 10:30 AM
Empire Room

MINISYMPOSIUM 13
Matrix Computations in Statistics

#M-44/8:30 AM

Sparse Matrix Computations in Analysis of Variance

Analysis of Variance computations, when experimental data are not balanced with respect to factor combinations, require the explicit solution of a least squares problem. With four or more factors, the size of the least squares problem can be too large for full matrix direct methods. The least squares problem is sparse and therefore sparse matrix direct methods can be applied to solve it much more efficiently. Furthermore, special sparsity patterns and linear dependencies can be exploited for more efficiency.

George Ostrouchov, Mathematical Sciences Section, Engineering Physics and Mathematics Division, Oak Ridge National Laboratory, P.O.Box Y, Oak Ridge, TN 37831

#M-45/9:00 AM

Error-Free Sparse Least Squares

Numerical methods which allow error-free computation of sparse matrix decompositions and least squares solutions are developed. These methods require that the sparse linear system of equations have rational entries. To avoid error that is inherent in floating-point arithmetic, multiple modules residue arithmetic is applied to modified versions of LDU and Givens factorizations.

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George Ostrouchov
Mathematical Sciences Section
Engineering Physics and Mathematics Division
Oak Ridge National Laboratory
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#M-46/9:30 AM

Computation and Properties of the Total Least Squares Approach with Applications in System Identification

An analysis is made of the Total Least Squares (TLS) technique that has been devised for solving overdetermined sets of linear equations $AX \approx B$ in which both matrices A and B are noisy. After a short description of its basic principle, extensions of the TLS problem are discussed. The computational aspects are outlined and it is shown how to improve the computational speed directly and iteratively. Next, the validity of the TLS approach is studied. Hereto its sensitivity, algebraic and statistical properties are carefully analyzed. A comparison with other estimation methods (e.g. LS) highly elucidates the significance of TLS. Finally, the practical use of TLS in the identification of state space models for multivariable linear time-invariant systems is demonstrated.

S. Van Huffel, Analysis of the TLS problem and its use in param. estim., Ph. D. Thesis, Dept. of Electr. Eng., K.U. Leuven (1987).

SABINE VAN HUFFEL, MARC MOONEN and JOOS VANDEWALLE
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#M-47/10:00 AM

Some Matrix Computations for Ill-Posed Problems with Large, Noisy Data Sets.

We survey some recent work related to cross-validated regularization methods for ill-posed problems with extremely large data sets. We show how some seemingly unrelated model building and estimation problems reduce to the minimization of the generalized cross-validation function.

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THURSDAY, MAY 26

1:45 - 3:45 PM
Ballroom A-B

MINISYMPOSIUM 14
Large Eigenvalue Problems

#M-48/1:45 PM

Large sparse nonsymmetric eigenvalue problems: applications and algorithms.

Large sparse nonsymmetric eigenvalue problems are becoming increasingly common as scientific models become more complex and computing capabilities show impressive progress. In this talk we will give an overview of the applications areas where nonhermitian eigenvalue problems arise and present a few algorithms for solving them. Although nonhermitian eigenvalue problems may be extremely difficult to solve, the picture in realistic applications is not always dark. One of the important sources of nonhermitian eigenvalue problems is in the analysis of stability of dynamical systems, an important example being that of electrical networks. The numerical techniques used in stability analysis provide effective tools to analyse bifurcation phenomena. These typically involve solving the eigenvalue problem for a family of matrices that depend on a parameter. Turning to numerical methods we will briefly describe many of the well-known techniques such as Lanczos and Arnoldi's methods but will underline procedures based on shift-and-invert and deflation. These are typically far more reliable than the methods that only require matrix by vector multiplications.

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#M-49/2:15 PM

The Solution of Large Sparse Eigenvalue Problems in Structural Engineering Applications

Applications in structural engineering at Boeing generate a variety of large, sparse, and difficult eigenvalue problems. These problems arise as symmetric generalized problems in vibration and buckling analysis, or as quadratic problems in controlled systems or systems with damping. Typically these problems have up to 20,000 degrees of freedom.
In our talk we will describe how the combined progress of new hardware and of algorithm research allow us now to solve routinely problems that were considered intractable 10 years ago. Today the symmetric problems are solved using a block shifted and inverted Lanczos algorithm implemented by the authors in an industrial setting. We will survey some recent developments in software for sparse linear systems and show how faster sparse matrix solvers yield additional performance improvements for sparse eigenvalue solvers.

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John G. Lewis
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#M-50/2:45 PM

An Algorithm for Nonsymmetric Generalized Eigenvalue Problems

The Lanczos recursion with no reorthogonalization is considered in the setting of a generalized nonsymmetric eigenvalue problem, $Ax = \lambda x$ where A is nonsymmetric, B is real symmetric and positive definite, and the desired eigenvalues are small, interior to the spectrum, and dominated by large eigenvalues. A shift and invert strategy is required but shifting and inverting and the Lanczos recursion with no reorthogonalization are not totally compatible. Using examples from magnetohydrodynamics, we present a hybrid Lanczos/inverse iteration algorithm which 'solves' these difficult generalized problems.

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T.J. Watson Research Center
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Wolfgang Kerner
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#M-51/3:15 PM

The Quadratic Eigenproblem of Damped Oscillations

We study the behavior of the spectral properties of the symmetric quadratic matrix pencil describing damped oscillations of a mechanical structure if the damping matrix is varying. The results concern perturbation theory (global and analytic) as well as the inverse eigenvalue problems. They are expected to throw some light on the physical problem of optimal damping.

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THURSDAY, MAY 26

1:45 - 3:45 PM
Empire Room

MINISYMPOSIUIM 15
Iterative Methods 5

#M-52/1:45 PM

The Parallel Multisplitting Method for Linear Systems Whose Coefficients Matrix is a Singular M-matrix

Consider the linear system $Ax = b$, where A is a singular M-matrix and let $A = M_\ell - N_\ell$, $\ell = 1, \ldots, k$,

be k M-splittings of A. We shall discuss the questions of consistency and convergence of the parallel multisplittings iteration scheme

$$z_j = \sum_{\ell=1}^{k} E_\ell M_\ell^{-1} N_\ell z_{j-1} + \sum_{\ell=1}^{k} M_\ell^{-1} b$$

to a solution of $Ax = b$.

Phillip Kavanagh and Michael Neumann, Department of Mathematics, University of Connecticut, Storrs, Connecticut 06268

#M-53/2:15 PM

"The s-step conjugate gradient methods implemented on parallel systems"

S-step steepest descent methods have been studied. We derive on s-step conjugate gradient iteration based on directions formed by the Krylov subspace $(r_i, Ar_i, \ldots, A^{s-1} r_i)$. The approximate solution is advanced simultaneously in the s directions. This reorganization of the C.G. method provides more parallelism and has better data locality than the standard CG iteration. These results are supported by numerical tests on vector multiprocessor systems.

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C. W. Gear
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#M-54/2:45 PM

Asynchronous Multilevel Adaptive Methods for PDEs on Parallel Computers

Several mesh refinement methods exist for solving partial differential equations that make efficient use of local grids on scalar computers. On distributed memory multiprocessors, such methods benefit from their tendency to create multiple refinement regions, yet they suffer from the sequential way that the levels of refinement are treated. In this talk , we introduce the asynchronous fast adaptive composite grid method (AFAC) that can process refinement levels in parallel while maintaining full multilevel convergence speeds. We report on numerical experiments with AFAC on very large scale examples and develop a simple two-level AFAC theory.

Steve McCormick
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#M-55/3:15 PM

Spline Collocation Iterative Methods for Elliptic PDEs.

Applying a new cubic spline collocation descretization method to an Elliptic PDE leads us to a coefficient matrix A of the form

$$A = \begin{bmatrix} B & PB \\ PC & -C \end{bmatrix},$$

where B and C are square block diagonal matrices and P is a permutation matrix. We shall discuss the convergence, the computational performance and the parallel implementation of a block under-relaxation iteration scheme when applied to the solution of the linear problem $Ax = b$.

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ABSTRACTS: CONTRIBUTED PRESENTATIONS*

MONDAY, MAY 23

11:00 AM - 12:00 Noon
Empire Room

CONTRIBUTED PRESENTATIONS 1
Core Linear Algebra 1

#12/11:00 AM

Algebraic and Geometric Properties of the Numerical Range

Let A be an n-square complex matrix. The k^{th} numerical range of A, $W_k(A)$, is the set of complex numbers {tr(PAP)} as P runs over all k dimensional (i.e. rank k) orthogonal projections. This paper is concerned with the relation between algebraic properties of A and geometric properties of $W_k(A)$. Let $P_k(A)$ be the convex hull of all sums taken k at a time of the eigenvalues of A. The following results are typical: (i) if for a fixed k satisfying $n/2 - 1 \le k \le n - 1$ the equality $W_k(A) = P_k(A)$ holds, then A is normal; (ii) $W_k(A)$ is a polygon with the real axis as a line of symmetry for k = 1, ..., n if and only if A is unitarily similar to a real matrix; (iii) Let A be an n–square real nilpotent matrix. For n = 3, $W_1(A)$ is a disk centered at the origin iff $\mathrm{tr}((A^2)^T A) = 0$. If this condition holds then the radius of the disk is $\|A\|/2$ (Euclidean norm). For n = 4, $W_1(A)$ is a disk centered at the origin iff $\mathrm{tr}((A^p)^T A) = 0$, p = 2, 3. (iv) Let A be normal with eigenvalues $\lambda_1,\dots,\lambda_n$. Assume that $s = \lambda_1 + \cdots + \lambda_k$ is a vertex of $P_k(A)$ and no other sum of k eigenvalues of A is equal to s. If tr(PAP) = s then P reduces A. Similar results are available for the so-called decomposable numerical range associated with the compound operator on the k^{th} Grassmannian.

Marvin Marcus
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#96/11:15 AM

The G-Radius and the G-Invariant Norms

Let V be a finite dimensional inner product space (over $\mathbb{R}$ or $\mathbb{C}$) with inner product $\langle\cdot,\cdot\rangle$, and U the group of unitary operators on V. Suppose G is a compact subgroup of U. For any x, $y \in V$, we define the G(x)-radius of y as the quantity $\max\{|\langle y, L(x)\rangle| : L \in G\}$. Using the G-radius as a tool, we study those norms on V which are invariant under any operator in G. Particular cases in which V is a matrix space and the norm is a unitarily invariant norm or invariant under unitary similarity are considered.

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Nam-Kiu Tsing
Department of Algebra, Combinatorics and Analysis
Auburn University
Auburn, Alabama 36849

#26/11:30 AM

An Analog of the Cauchy-Schwarz Inequality for Hadamard Products and Unitarily Invariant Norms

The inequality

$$\|A^*B\|^2 \le \|A^*A\|\,\|B^*B\| \qquad (1)$$

arises in control theory. We show this holds for any unitarily invariant norm on the space of m×n matrices and determine the cases of equality. We will also discuss the set of norms for which (1) holds and related inequalities for Hadamard products.

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* All contributed abstracts are numbered in the order that they were received at the SIAM office.

#30/11:45 AM

On maximizing the minimum eigenvalue of a linear combination of symmetric matrices

The problem considered is that of maximizing, with respect to the weights, the minimum eigenvalue of a weighted sum of symmetric matrices when the Euclidean norm of the vector of weights is constrained to be unity. A procedure is given for determining the sign of the maximum of the minimum eigenvalue and for approximating the optimal weights arbitrarily accurately when that sign is positive or zero. A conical hull representation of the set of nxn symmetric positive semi-definite matrices and a new convex programming algorithm are employed.

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MONDAY, MAY 23

11:00 AM - 12:00 Noon
State B-C

CONTRIBUTED PRESENTATIONS 2
Applications 1

#1/11:00 AM

A Generalized Inverse Method for Asymptotic Linear Programming

Consider a linear program in which the entries of the coefficient matrix vary linearly with time. To study the behavior of optimal solutions as time goes to infinity, it is convenient to express the inverse of the basis matrix as a series expansion of powers of the time parameter. We show that an algorithm of Wilkinson (1982) for solving singular differential equations can be used to obtain such an expansion efficiently. The resolvent expansions of dynamic programming are a special case of this method.

Bernard F. Lamond
Systems and Industrial Engineering Department
The University of Arizona
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U.S.A.

#88/11:15 AM

P-Functions in Applied Mathematics

A very useful class of functions in applied mathematics is the class denoted P-functions by More and Rheinboldt. Sufficiency conditions which are polynomial in computational complexity will be described for the case of a differentiable P-function. Applications to proofs of uniqueness of solutions in various models will be reviewed.

Michael M. Kostreva
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Clemson University
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#140/11:30 AM

Postoptimality Analysis via Projective Algorithms

Since encouraging experimental results with the Karmarkar Algorithm have been reported in the literature (Chen [86], Adler et al. [86]), the question of how to update the optimal solution using projective algorithms when changes occur in the data of the problem is worth addressing. In the present paper the postoptimal analysis with respect to changes in the cost coefficients, the right hand side and the rim is carried out. A modified version of the Karmarkar algorithm providing the dual solutions to the LP problem is used. Also computational results on small dense problems are given.

Abdellah Salhi and George R. Lindfield
Department of Computer Science & Applied Mathematics, Aston University, Birmingham B4 7ET, U.K.

#11/11:45 AM

A Bivariate Optimizing Algorithm Simulates Alternative Economic Policies

There are two basic elements in the discussed methodology. An 'activity-resource' matrix substituting optimum-distribution table of O.R. framework, and the 'flip-flop' algorithm that optimizes in turn, both, LL and UR-corner variables in each cell of the matrix. Parameters are: closed intervals of positive real numbers for each cell's variables, and rows and columns constraints. Comparison of the base solution with alternative solutions for different starting parameters analyzes prospects of investigated economic policies. Finally, experience with actual application of the methodology to the real-life economic environment will be discussed.

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ABSTRACTS: CONTRIBUTED PRESENTATIONS

MONDAY, MAY 23

11:00 AM - 12:00 Noon
State A

CONTRIBUTED PRESENTATIONS 3
Matrix Algorithms 3

#54/11:00 AM

Fast Symmetric Discrete Fourier Transform Algorithms Involving Only Real Arithmetic

Using the ring structure of the indexing set of a fundamental data sequence we derive fast algorithms computing the discrete Fourier transform of real odd and real even, one and two-dimensional sequences. These algorithms involve only real arithmetic and are based on existing fast algorithms computing the Sine and the Cosine transforms of type IV.

Jaime Seguel
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Staten Island, NY 10301

#7/11:15 AM

Faster than Linear Time Matrix Multiplication Using Multiple Processor Arrays

It is well known that a product of n dimensional matrices can be performed in order n time using systolic arrays with order n^2 processors. This presentation discusses a construct using multiple processor arrays that performs the matrix product in order n^s time where $s < 1$. For example, with $n^{9/4}$ processors, execution time of order $n^{3/4}$ is observed. The construct resembles a systolic array each node of which is actually a processor array.

More specifically, each node is an $m \times p$ processor array with broadcast bus connections and can compute the product of $m \times n$ and $n \times p$ matrices in n steps (asymptotically). With partitioning, the product of $mm' \times nn'$ and $nn' \times p$ matrices can be computed in $m + n + n' - 2$ steps.

Dan Kalman
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#33/11:30 AM

An Algorithm for the Exact Characterization of the Zeros of a Polytope of Polynomials

Given a polytope of real n-th order polynomials

$$\mathcal{P} = conv\{p_1(s), p_2(s), \ldots, p_\ell(s)\},$$

this paper provides a computationally feasible algorithm to generate the *spectrum*

$$\sigma(\mathcal{P}) \doteq \{\lambda \in \mathbf{C} : p(\lambda) = 0 \; for \; some \; p(\cdot) \in \mathcal{P}\}.$$

This algorithm, based on a recent result of Barmish (1987), is also seen to be useful in the area of robust control.

Barmish, B. R. (1987). *A Generalization of Kharitonov's Four Polynomial Concept to Robust Stability Problems with Linearly Dependent Coefficient Perturbations*, Technical Report ECE-87-18, ECE Department, University of Wisconsin–Madison.

R. Tempo
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B. R. Barmish and A. Takach
Department of Electrical and Computer Engineering
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#60/11:45 AM

Fujiwara's Hermitian Forms and Algorithms for the Inertia and Unit Circle Problems

In the study of the inertia of a non-Hermitian matrix, a classical Hermitian matrix due to Fujiwara plays a central role. There exists an effective numerical computation of the inertia due to Carlson and Datta. By looking at Fujiwara's matrix as a Hermitian form, we show that the two matrices in question are Hermitian congruent. Inspired by a similar outlook, we present an algorithm for the unit circle problem, based on the second Hermitian matrix of Fujiwara. These algorithms use effective numerical computation of suitable symmetrizers of Hessenberg matrices.

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MONDAY, MAY 23

1:30 - 3:30 PM
State B-C

CONTRIBUTED PRESENTATIONS 4
Matrix Methods in ODEs and PDEs

#22/1:30 PM

Algebraic Properties of Derivative Arrays and Linear Time Varying Descriptor Systems

Arrays of derivatives of the coefficients of linear descriptor systems $E(t)x'(t)+F(t)x(t)=f(t)$ have been used in the numerical, analytic, and geometric analysis of these systems. This talk will discuss our efforts to unify these three approachs. Results from the numerical and analytic theory lead to extensions of the geometric theory and new algorithms for computing geometric objects of interest. Extensions to the nonlinear case will be discussed.

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#67/1:45 PM

Toeplitz Matrices Arising from the Sinc-Galerkin Method

When the Sinc-Galerkin method is applied to fourth-order, linear ordinary differential equations, a collection of matrices arise which are denoted $I^{(j)}$, $j = 1,2,3,4$. For j even, $I^{(j)}$ is symmetric, centrosymmetric, Toeplitz and negative definite. For j odd, $I^{(j)}$ is skew-symmetric, skew-centrosymmetric and Toeplitz. The properties of $I^{(j)}$ will be discussed and bounds given for the eigenvalues which indicate the conditioning of each. The resulting discrete system for the fourth-order problem will be given and the above properties used to determine an appropriate weight function for the method which provides good numerical conditioning for this approach. Numerical results will be presented for problems with highly singular solutions.

Kenneth L. Bowers
John R. Lund
Ralph C. Smith
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#14/2:00 PM

SIMPLIFIED DYNAMICAL SYSTEM FOR THE GAUSS-GALERKIN METHOD

An approximation of the law of the solution of a Stochastic differential equation, using the Fokker Planck equation, has been discussed in the literature by several methods. The Gauss-Galerkin method provides approximations to the well-known Gauss-Christoffel measure of the exact distribution. However, it results in a very ill-conditioned dynamical system. Using numerical methods and linear Algebra, we introduce a simplified dynamical system which leads to a numerically stable procedure for a larger number of modes. As an outcome of the analysis, we also show that the approximation is a probability measure.

Ali Hajjafar
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#6/2:15 PM

Discrete-Time Cone Reachability

The reachability cone X_A for the linear o.d.e. $\dot{x} = Ax$ is the set of initial points $x(0)$ such that $x(t) \geqslant 0$ for some $t \geqslant 0$. Analagously, we can define a discrete-time reachability cone $X_{A,h}$ for the Cauchy-Euler approximation to the o.d.e., with time increment $h > 0$. Intuition suggests that for small h, the cones $X_{A,h}$ in some sense approximate X_A. Under the assumption that A is essentially nonnegative, we prove that in fact more is true: There exists $\gamma > 0$ (depending on the spectrum of A) such that $X_A = X_{A,h}$ for $0 < h \leq \gamma$. This results in a procedure for testing individual points x for membership in X .

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#23/2:30 PM

Domain Decomposition for Linear Elliptic Boundary Value Problems on Locally Refined Meshes

This study is concerned with the Neumann - Dirchlet domain decomposition algorithm. There are several ways of applying this algorithm to elliptic problems on locally refined meshes. One of them is to use multigrid - like local mesh refinement techniques as approximate solvers on the subregions. This approach has apparently not yet been tested. We study it for a model problem. Numerical results and a theoretical convergence analysis indicate that an average error reduction factor of about 0.15 per iteration can be obtained, independently of the mesh size. Each iteration requires an amount of arithmetic work comparable to 5-10 Gauss - Seidel relaxation steps for the entire problem.

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#119/2:45 PM

The Ordering of Tridiagonal Matrices in the Cyclic Reduction Method for Poisson's Equation

Discretization of the Poisson equation on a rectangle by finite differences using the standard five-point stencil yields a linear system of algebraic equations, which can be solved rapidly by the cyclic reduction method. In this method a sequence of tridiagonal linear systems is solved. The matrices of these systems commute, and we investigate numerical aspects of their ordering. We present new ordering schemes that avoid loss of accuracy due to overflow or underflow. These ordering schemes improve the numerical performance of the routine HWSCRT of FISHPAK.

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#118/3:00 PM

On Finding the Singular Values and Singular Vectors of a Bidiagonal Matrix by Means of Isosingular Flows

In this report I shall consider the following "singular value" problem: Given an n-by-n real, bidiagonal matrix A, find its singular values and singular vectors. I shall use the theory of ordinary differential equations to solve this problem. In particular, let O(n)-Bidiagonal.A denote the set of pairs (U,V) of n-by-n orthogonal matrices such that U^TAV is a bidiagonal matrix. I shall show that O(n)-Bidiagonal.A is a regular surface in $R^{n\times n} \times R^{n\times n}$. I shall also describe several vector fields on this surface that are related to the singular value problem for A. These vector fields determine "isosingular flows" on this surface.

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MONDAY, MAY 23
1:30 - 3:30 PM
State A

CONTRIBUTED PRESENTATIONS 5
Singular Values and Eigenvalues

#35/1:30 PM

Parallel Solution of Nonsymmetric Eigenvector Problems

We investigate a parallel implementation of an algorithm for the real eigenvector problem for a given real Schur form on an MIMD hypercube multiprocessor computer. Our method is based on back substitution and back transformation. We show how this algorithm works and achieves O(n) speed-up over the serial algorithm using O(n) processors with local information. This is evaluated experimentally on an NCUBE/7 hypercube computer with 64 processors.

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#34/1:45 PM

A Parallel QR Algorithm for the Non-Symmetric Eigenvalue Algorithm

We describe a parallel algorithm for approximating eigenvalues of a dense nonsymmetric matrix. The algorithm is a parallel implementation of the explicitly-shifted QR, employing n processors to deliver all eigenvalues in $O(n^2)$ time. The algorithm uses Givens rotations to generate a series of unitary similarity transformations. The rotations are passed between neighboring processors, and applied, in pipeline fashion, to columns of the matrix. The algorithm involves only local communication, and confronts the problems of applying row rotations, convergence, splitting, and updating the shift in a pipelined scheme. The algorithm is implemented on a hypercube, using a ring of processors to stimulate a systolic array. Speedup and efficiency are estimated by comparing with EISPACK performance.

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#44/2:00 PM

A Parallel, Hybrid Algorithm for the Generalized Eigenproblem

We present a parallel algorithm for computing all eigenvalues, and their corresponding eigenvectors, in a specified interval for the generalized eigenproblem, $Ax=\lambda Bx$, where A and B are real, symmetric and B is positive definite. Eigenvalues are isolated, in parallel, using the Sturm sequence property of leading principal minors of $A-\mu B$. Concurrently, eigenvalues and eigenvectors are computed accurately using a superlinear method which combines inverse and Rayleigh quotient iterations. Results obtained from implementation of this algorithm on a shared memory MIMD architecture are presented. Factors which affect the efficiency of the algorithm are discussed.

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#92/2:15 PM

Trace Minimization Algorithm Generalized Eigenvalue Prob'

CANCELLED

A trace minimization a' ... a few of the smallest (or l' ... d associated eigenvectors of the generalized eigenvalue problem $Ax = \lambda Bx$ is presented. Here we assume that the matrices A and B are symmetric of order n, with B being positive definite, and that both A and B are so large and sparse that a factorization of either matrix is impractical. In each iteration of this algorithm, first investigated by A. Sameh and J. Wisniewski, we are simultaneously approximating the p desired eigenpairs $p<<n$ by minimizing the trace of a $p \times p$ matrix subject to quadratic constraints. This talk presents an improved computational scheme which incorporates a variety of acceleration strategies, as well as demonstrates the suitability of the algorithm on a multiprocessor with two levels of parallelism, such as the Alliant FX/8. Comparisons with both the Lanczos algorithm and subspace iterations will also be presented for this architectures.

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#93/2:15 PM

A Hybrid Method for Computing the Singular Value Decomposition on a Multiprocessor

We present a hybrid scheme for determining the singular value decomposition of rectangular matrices in which the number of rows is substantially larger or smaller than the number of columns. Initially, we perform an **QR** factorization on the tall matrix (either **A** or $\mathbf{A}^T$) using a multiprocessor block Householder algorithm. We then apply a one-sided Jacobi multiprocessor method on the resulting upper triangular **R** to effectively yield $\mathbf{RV} = \mathbf{U}\Sigma$, from which the desired singular value decomposition is obtained. Using color graphics to monitor the convergence of the one-sided Jacobi method on **R**, we have been able to isolate smaller matrices $\tilde{\mathbf{R}}_i$ (positioned along the diagonal of **R**) which yield clustered or multiple singular values of **A**. Based on this observation, we developed a hybrid algorithm that switches from the one-sided Jacobi method to a Kogbetliantz scheme which can be applied concurrently to the $\tilde{\mathbf{R}}_i$'s. This hybrid scheme capitalizes upon not only the efficient parallelism of the one-sided Jacobi method but also on the fast convergence rate of the Kogbetliantz algorithm. The scheme is well suited for rank deficient matrices as well as for those rectangular matrices having clustered or multiple singular values, and may be well suited for applications such as real-time signal processing. We present performance results on the Alliant FX/8 and Cray X-MP computer systems with particular emphasis on speedups obtained for our schemes over classical SVD algorithms. Color graphics will be used to demonstrate the nature of convergence for the global one-sided Jacobi and local Kogbetliantz sweeps.

Michael Berry
and
Ahmed Sameh

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#24/2:30 PM

A Direct Algorithm for Computing the Generalized Singular Value Decomposition

The generalized singular value decomposition (GSVD) is the simultaneous reduction of any two matrices having the same number of columns to diagonal matrices by premultiplying by two different orthogonal matrices and postmultiply by the same nonsingular matrix. It is a useful mathematical tool in matrix computations. Following the work of C.C. Paige on the sequential Jacobi-like GSVD algorithm (SIAM J. Sci. Stat. Comput. 7, 1986, pp. 1126-1146), we provide a clearer description of the algorithm and a more straightforward proof of its correctness. A new version of the algorithm is given.

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#120/2:45 PM

On Singular Values of Hankel Operators of Finite Rank

Let H be a Hankel operator defined by its symbol $r = p/q$, where q is monic polynomial of degree n, p is a polynomial of degree less than n, and p and q have no common zeros. Then H has rank n. We derive a generalized Takagi singular value problem defined by two n by n matrices, such that its n generalized Takagi singular values are the positive singular values of H. If r is real then the generalized Takagi singular value problem reduces to a generalized symmetric eigenvalue problem. The computations can be carried out so that the Lanczos method applied to the latter problem requires only $O(n \log n)$ arithmetic operations for each iteration. If p and q are given in power form, then the elements of all n by n matrices required can be determined in $O(n^2)$ operations.

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#142/3:00 PM

On Optimal Parallel Givens Schemes

Cosnard, Muller, and Robert have shown that the greedy parallel algorithm of Modi and Clarke for performing the QR factorization of a dense matrix using Givens rotations is optimal in the sense that the number of time steps required is minimal. Their proof is long and tedious. We show, more generally, that any greedy parallel Givens scheme, if it exists, is optimal for matrices having a (possibly empty) distinguished set of initial zeros. Our proof is conceptually different and significantly simpler than that mentioned above. Necessary and sufficient conditions are also given on the distribution of initial zeros of the matrix for a greedy parallel Givens scheme to exist.

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MONDAY, MAY 23

4:00 - 6:00 PM
State B-C

CONTRIBUTED PRESENTATIONS 6
Iterative Techniques 1

#90/4:00 PM

Block Elimination with one Iterative Refinement Solves Bordered Linear Systems.

We consider a well-conditioned linear system Mz=h where $M=\begin{bmatrix} A & b \\ c & d \end{bmatrix}$, the width of the border is 1 or a small number and a 'black box' solver is available for A or a matrix near A. We show that Block Elimination with Iterative Refinement is very successfull if A tends to be singular, provided the 'black box' has a property that is possessed with high probability by solvers based on LU and QR decompositions. The method is supported by extensive numerical evidence as well as a careful error analysis in which a Singular Value Inequality Theorem is remarkable. The problem arises naturally in numerical continuation theory and related fields.

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#114/4:15 PM

On Convergence Rates for Parallel Multisplitting Methods

In a recent paper in Lin. Algebra Appl. 88-89, M. Neumann and R.J. Plemmons have given upper bounds for the convergence rates of parallel multisplitting iterative methods for M-matrices. By proving their results in a different and more simple way we are also able to derive lower bounds and consider some more general situations.

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#124/4:30 PM

Two Parametric "SOR" Method

The well known "SOR" method is obtained from a one-part splitting of the system matrix A, using one weight or parameter ω. Sisler introduced a new method by using one parameter for the lower triangular matrix. We generalize Sisler's theorem and show an optimal parameter. When the eigenvalues of "SOR" method are in a certain well-defined region our two-parametric method converges faster than standard "SOR" method. Also, DeVogelaere considered yet another two parametric method called "Modified SOR" method. We prove for certain case where "SOR" method diverges that "MSOR" $B_{(1,2)}$ (our iteration matrix) converges.

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#79/4:45 PM

An Algebraic Convergence Theory for Multigrid Methods for Nonsymmetric Problems

An algebraic convergence theory is developed for multigrid methods for nonsymmetric,indefinite problems in a variational setting. Fast convergence with any bounded positive number of smoothing steps for V- and W-cycles is proved. In addition, a wide class of smoothers, including arbitrarily preconditioned iterations, Gauss-Seidel, quasi-Gauss-Seidel, SOR, quasi-SOR and Chebyshev-like iterations is analyzed and sharp estimates of contration numbers for multigrid methods with these smoothers are obtained.

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#101 (Moved to Contributed Session 15, Wed. AM; Room State A; presentation time 10:15)

Cholesky factor Updating Techniques for rank-two matrix Modifications

Gill, Golub, Murray and Saunders have described 5 methods by which the Cholesky factors of a positive-definite matrix may be updated when the matrix is subjected to a symmetric rank-one modification. In many minimization algorithms symmetric rank two modification are found.

We show how each of the rank-one methods gives rise to a single-application rank-two method. For some of the methods this involves a new Householder transformation technique designed to eliminate elements of two vectors at once using a rank 1 correction of the identity matrix.

On parallel and vector machines it is more economical to perform rank-two updates than two rank-one updates.

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#85/5:15 PM

A New Downdating Algorithm With Application To The Q-R Factorization Of Toeplitz Matrix

Let R be an upper triangular matrix of size n-by-n and z be a vector of n-by-1, the oomputation of the Cholesky factorization of $\bar{R}^T\bar{R} = R^TR - ZZ^T$ is called downdating problem, provided that $R^TR - ZZ^T$ is positive definite. There are two existing algorithms to handle the problem which requires $5/2\ n^2$ and $2n^2$ multiplications respectively. A new algorithm based on the one written in LINPACK is proposed. The new algorithm merges the triangular solving and orthogonal downdating as one process and thus reduce the multiplications required form $5/2\ n^2$ to $3/2\ n^2$. We also will apply it to modify the algorithm of Q-R factorization of Toeplitz matrix proposed by Bojanczyk,Brent and Hoog (1986).

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#106/5:30 PM

Modifications of the Normal Equations Method That Make it Numerically Stable

For solving the linear least squares problem, min||Ax-b|| where A is an m x n matrix, the method of normal equations can require as little as half the work but will frequently produce less accurate solutions than methods based on orthoganol decomposition. Also it may fail completely. We use iterative refinement with fixed precision arithmetic to overcome both of these problems. The calculated x is as accurate as permitted by the condition number of the least squares problem. For m>>n and if A has just a few small singular values the new algorithm can require as little as half the work of alternative stable algorithms.

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#62/5:45 PM

Deflated Krylov Subspace Methods for Nearly Singular Linear Systems

In this paper, we present a new method for solving large nonsymmetric linear systems which are nearly singular. The new method computes a deflated solution of a nearly singular linear system by using a Krylov method in conjunction with the singular value decomposition.

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MONDAY, MAY 23

4:00 - 6:00 PM
State A

CONTRIBUTED PRESENTATIONS 7
Matrix Computations 1

#19/4:00 PM

A Block LDL^T Factorization Algorithm for Skyline Systems of Equations

This paper describes a block algorithm for computing the LDL^T factorization of a symmetric, positive definite matrix stored in skyline or envelope storage. The traditional compact elimination algorithm is inner product bound and cannot be directly expressed in matrix-vector format because of the envelope structure of the matrix. The block algorithm presented here illustrates how to overcome this difficulty at the expense of some initial overhead and extra working storage. Not only does the block algorithm vectorize more efficiently, it also introduces several opportunities to exploit parallelism. Thus, the algorithm will run quite efficiently on both single and multi-headed vector machines. In addition to a description of the algorithm and presentation of performance increases, a brief discussion of alternative solution techniques will be provided.

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#78/4:15 PM

Reduced Polynomial Based Algorithms for Hermitian Toeplitz Matrices

In this work, we analyze the mathematical structure associated with the fast order recursive algorithms for computing the reflection coefficients and the predictor polynomial associated with a Hermitian, positive-definite Toeplitz matrix. Such a problem arises in many diverse applications including statistical signal processing, linear prediction, and spectral estimation. A new form of three-term recurrence relation is derived and computationally efficient alternatives to the classical Levinson, Schur, and lattice algorithms are derived. The computational complexity of the new algorithms is the same as those of the split algorithms described in recent literature. The new algorithms also provide further insight into mathematical properties of the structurally rich Toeplitz matrices.

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#3/4:30 PM

A CS Decomposition Approach to Estimator-Correlator Array Processing

This paper proposes a new, numerically robust method for implementing the estimator-correlator processor used to detect stochastic signals in additive Gaussian noise. The test statistic is computed by correlating the conditional mean estimate of the signal with a filtered version of the array output. In particular, implementing the estimator half of the structure requires solving a matrix pencil for its generalized eigenvalues and eigenvectors. The matricies are in the form $\underline{A}^T\underline{A}$, suggesting that the CS decomposition is a numerically robust method for implementing the estimator branch. A derivation and numerical results will be presented.

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#63/4:45 PM

A Necessary and Sufficient Condition for the Convergence of GMRES(k)

We present a necessary and sufficient condition for assuring the convergence of the Saad and Schultz truncated generalized minimum residual algorithm GMRES(k). The proof for the sufficient part of our result is a generalization of Elman's work on the convergence of generalized minimum residual algorithms for solving unsymmetric linear systems. The new theory leads to a class of schemes for modifying GMRES(k) which ensures that the modified algorithm converges. We apply one of these schemes to published examples which illustrate the stagnation phenomena of GMRES(k) and find that the modified algorithm converges as predicted by the theory.

This work leads to the following open question: What is the optimal scheme to modify GMRES(k)?

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#143/5:00 PM

Applications of Quadratic Parametric Programming to the Quadratic Assignment Problem

We study the quadratic assignment problem, QAP: find an n by n permutation matrix X which minimizes the trace $\min_{X\in\Pi} tr(C+AXB^t)X^t$. A lower bound for the quadratic part can be found using eigenvalue decompositions; while a lower bound for the linear part is found by solving the corresponding linear assignment problem as a linear program. We apply a steepest ascent algorithm to increase the sum of the two bounds. This requires some differential calculus for eigenvalue perturbations and subdifferential calculus for a quadratically perturbed linear program.

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ABSTRACTS: CONTRIBUTED PRESENTATIONS

TUESDAY, MAY 24

8:30 - 10:30 AM
State B-C

CONTRIBUTED PRESENTATIONS 8
Statistics 1

#36/8:30 AM

On an Ordering of Symmetric Matrices with Applications to Statistical Problems

Numerous problems in statistics reduce to comparing symmetric or nonnegative definite (n.n.d.) matrices with respect to the n.n.d. (Loewner) ordering, or the corresponding positive definite (p.d.) ordering. This paper introduces a stronger ordering of symmetric matrices, which is motivated by problems in linear model theory. For symmetric matrices A and B, we define $A \geqq B\ (r)$ iff $A - B$ is n.n.d. and of rank r. The basic properties of this ordering are given, and certain known results on the monotonicity and convexity of various matrix functions are seen to hold w.r.t. this stronger ordering. This new ordering is also seen to provide further insight into various statistical problems, including comparisons of linear experiments.

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#55/8:45 AM

On Multivariate Normality and a Schur Product Ordering for Correlation Matrices

If $(X_1,\ldots,X_n)'$ is a Gaussian random vector with correlation matrix U, transformations of the type $(\phi_1(X_1),\ldots,\phi_n(X_n))'$ have correlation matrices of the form $U \circ D$, where D is a correlation matrix. From this fact, the optimality of certain "classical" multivariate statistical procedures for Gaussian data follows. This, in turn, leads to interesting results -- and conjectures -- of a matrix theoretic nature.

Robert A. Koyak
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#49/9:00 AM

Generating Multivariate Covariance Sequences and Statistical Filter Design

Analytical expressions for deriving autocovariance sequences of multivariate ARMA models are presented. They relate the theoretical autocovariances directly to the ARMA parameters and, in addition to simplifying the design of multivariate digital filters, provide theoretical insight. The usefulness of the results in maximum likelihood estimation procedures based on Kalman filtering is demonstrated.

Stefan Mittnik
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#37/ 9:15 AM

Eigenvalues and Condition Numbers of Random Matrices

Given a random matrix, what should we expect the condition number to be? What can we say about the eigenvalue distribution? We show that for real or complex $n \times n$ matrices with elements from a standard normal distribution, the expected value of the log of the 2-norm condition number is asymptotic to $\log n$ as $n \to \infty$. We further discuss large rectangular real and complex matrices, and specify the exact distributions of the condition numbers for $2 \times n$ matrices.

Intimately related to this problem is the distribution of the eigenvalues of Wishart matrices. We study in depth the largest and smallest eigenvalues and the characteristic polynomial.

Alan Edelman
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#20/9:30 AM

Some Matrix-Equation Solutions with Statistical Applications

We present solutions to three matrix equations and give statistical applications. One is applied to obtain the covariance matrix of the Wishart matrix in nonsingular form. The other two are applied to obtain the maximum likelihood estimators for a multivariate normal data matrix with a missing data pattern, using matrix derivative methods.

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#15/9:45 AM

Unbiased Estimates of Multiva... Functions of the Populati... pling without Replacem... ...ion

CANCELLED

Unbiased estim... moment func... when sampli... and power sum... multivariate ... obtained as exa... - general ... are obtained ...ations. Partitions ... Unbiased estimates of ... and moment functions are ... of application.

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#144/9:45 AM

Conditional Intensity Functions

Multivariate extensions of univariate probability models are not unique and so it is a challenge to find multivariate models that preserve critical properties of the univariate analogs. One important property of those univariate Markov chains that can be described by the Chapman-Komolgorov equations is that these equations then completely determine the intensity functions. For example, this is true for birth and death processes.

After defining bivariate Markov chains and extending the notion of the Chapman-Komolgorov equations to accommodate the dual processes, Komologov's differential equations are extended to arrive naturally at bivariate functions.

Similarly, transition probabilities for one process conditional on another are defined; these are incorporated into equations analogous to the Chapman-Komolgorov equations and a definition of conditional intensity functions is derived which maintains the property of being one-to-one with the conditional transition probabilities. The differences between this conditional function and another being called the "conditional intensity function" are discussed.

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TUESDAY, MAY 24

8:30 - 10:30 AM
State A

CONTRIBUTED PRESENTATIONS 9
Signals and Systems 1

#73/8:30 AM

COMPOSITE CONTROLLER DESIGN FOR TWO-TIME-SCALE SYSTEMS WITH LOW SENSITIVITY TO SMALL TIME DELAY

The problem of designing composite controllers for systems with slow and fast modes is considered. The controller has the property of reducing the trajectory sensitivity to small time delay. Design of a control with partial state feedback to approximate the performance cost of a given full state feedback control for the case of linear regulator problem with singularly perturbed plants has been previously considered. Here the above result is extended to the case for which small time-delay is expected to occur in the feedback path. The controller obtained here is function of delayed slow and fast states and has the property of minimizing a quadratic cost functional, including sensitivity functions, while reducing the trajectory sensitivity to small time delay.

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#77/8:45 AM

Application of Matrix Gradients to Optimal Decentralized Control

Matrix Gradients are used to obtain necessary conditions for optimal decentralized control of large scale systems. Large scale systems are modeled as interconnection of lower order subsystems and the objective criterion is the standard quadratic cost function. Linear control laws are found by optimizing the cost function over the class of block diagonal matrices. This is suboptimal with respect to the centralized solution but is the optimal decentralized control gain matrix. Necessary conditions are obtained by application of Matrix gradients. Cost comparisons are also made relative to the centralized optimal control solution.

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#117/9:00 AM

Sensitivity Analysis for the Single Input Pole Assignment Problem

Given data $(A,b, s_1,\ldots,s_n)$ with the pair (A,b) completely controllable, let the vector k denote the gain corresponding to specified eigenvalues $s_1,\ldots, s_n$. Let $k + \Delta k$ denote the gain corresponding to perturbed data. We show that Δk is determined by the data perturbations and the left and right eigenvectors of $A - bk^T$ if the eigenvalues $s_1,\ldots,s_n$ are distinct. Our implementation of the PCK algorithm has been modified to return an estimate of $||\Delta k||$, where $\hat{k} = k + \Delta k$, and an estimate of the distance from the eigenvalues of $A - b\hat{k}^T$ to the specified eigenvalues. We suggest a computational test for deciding if given data will yield a practical closed loop system.

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Christopher L. Cox
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#112/9:15 AM

Realization Problem of a Class of Nonlinear Systems

Here we study realization problem of nonlinear systems of form

$$x(t+1)=Ax(t)+\sum_{i,k} u_i^k(t)D_{ik}x(t)+\sum_{i,k} u_i^k(t)B_{ik}$$
$$y(t)=Cx(t)$$

where $x(t)$ is in R^n, A,D_{ik} are nxn, and B_{ik} and C are nx1 and pxn matrices, respectively. Let W_j, $j=1,2,\ldots,$ be the input-output(I/O) matrix sequence of this system. A matrix H is defined for W_j(its effect is similar to Hankel matrix in linear systems), and then a series of commutative diagrams can be obtained from H. A necessary and sufficient condition of realizability of an I/O matrix sequence and an algorithm to construct its realization are given by means of these diagrams.

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#121/9:30 AM

Synthesis algorithms for multi-port multi-dimensional digital filters

Motivated by potential applications in multi-port/multidimensional structurally passive digital filters synthesis, the problem of factorizing a prescribed J-lossless matrix into the product of matrices of identical type is undertaken. The synthesis algorithm to be discussed can be considered as multiport/multidimensional generalizations of techniques discussed earlier in the literature. The continuous domain counterpart of the results to be presented can also be viewed as new algorithms for synthesis of passive multi-port networks treated in classical network theory.

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#109/9:45 AM

Iterative Algorithms for Real Time Signal Processing

This paper examines a new way of implementing iterative algorithms in a real time signal processing environment. This particular implementation is significant since optical computing techniques offer the possibility of its realization in an actual processor. The methodology consists of incorporating the flow of incoming signal data directly into the iteration loop. Thus, the problem to be solved is reformulated on every iteration. In the application considered, namely adaptive noise cancellation, one obtains a sequence of distinct linear systems all of which have the same solution. The iterative algorithm converges to this common solution. This method is applied to the steepest descent and conjugate gradient algorithms. Convergence results are given, as well as results from a numerical simulation of an adaptive noise cancelling processor employing this technique.

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#31/10:00 AM

The Rate of Growth of Linear Systems in Some Control Applications

This paper deals with the rate of growth of the solutions of linear systems which appear in certain practical control applications in the presence of unmodelled dynamics. The presence of unmodelled dynamics cause the controlled linear system to be of higher order than the nominal controlled object which is in fact used to design the controller. The main feature being used for this study is that the current linear plant can be partitioned into subsystems, one of them being the nominal model of the linear system. Consecuently, The deviation of the truncated solution of the erroneously controlled plant from the solution of its model is studied in terms of a law of growth of the solutions, it depends on the unmodelled dynamics mathematical characterization and on the norms of the block-matrices.

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#28/10:15 AM

Constrained Controllability of Linear Systems

Problems concerning global null-controllability of discrete-time, linear systems are considered, when the control sequences are constrained in norm. Using analogous arguments to those of R. Conti for the continuous case, it can be shown that such problems can be reduced to the divergence of certain infinite series, whose terms involve products of matrix functions. While it is generally not advisable or practical to calculate the terms exactly, one can still obtain some reasonable sufficient conditions for various types of constrained controllability by estimating them, also using some recent results on asymptotic behavior of matrix products. This is where the matrix analysis and inequalities come in.

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TUESDAY, MAY 24

1:30 - 2:30 PM
State B-C

CONTRIBUTED PRESENTATIONS 10
Parallel Matrix Computations 1

#99/1:30 PM

Exploiting Non-uniform Memory Hierarchies of Parallel Architectures for the Efficient Solution of Linear Systems

In order to achieve high-performance, new parallel architectures such as the Cedar multiprocessor, the BBN Butterfly, and the Flex/32 have a non-uniform memory hierarchy. To efficiently utilize these machines, numerical algorithms must exploit this hierarchy. We have implemented representative direct and iterative methods for the solution Ax=b on architectures of this type. Techniques used to efficiently implement these algorithms will be described.

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and
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#130/1:45 PM

Implementing BLAS-n on a High Performance Multiprocessor

Matrix-vector and matrix-matrix primitives are needed to support a wide range of numerical methods on high performance multiprocessors. Efficient, parallel implementations of BLAS 1, 2 and 3 can be used to achieve significant performance improvements in applications that call upon basic linear algebra subprograms. Our implementation takes advantage of pipelining and the large shared memory of the Evans & Sutherland multiprocessor. Two interesting implementation trade-offs are considered. We examine the tradeoff between static and dynamic data decomposition. Also, we locate that point where communication/synchronization overhead intrudes upon the speed-up of multiprocessing. We use insight gained from examining these trade-offs to generalize data decomposition strategies for other numerical methods. Performance results are presented for a range of input data.

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#110/2:00 PM

Basic Linear Algebra on the FPS T Series

The FPS T Series is a parallel vector supercomputer. Each T Series system contains from 16 to 1024 nodes with a hypercube interconnect structure and a peak speed of 16 million floating point operations per second from each node. This paper describes the implementation of the basic operations of computational linear algebra on the FPS T Series. Basic operations include matrix multiplication and factorizations, eigenvalue and singular value decompositions. Timings will be compared with scalar systems.

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#83/2:15 PM

Solution of Fixed Cauchy Singular Integral Equations in Parallel using Product Integration

Singular integral equations with fixed Cauchy singularities, such as

$$x(s)=y(s) + \fint_a^b [K(s,t)x(t)/(\mu-t)dt \text{ with } a < \mu < b$$

and μ fixed, occur frequently in science, e.g., the one dimensional Lippmann-Schwinger equation in momentum space or the K-matrix form of the Chandler-Gibson equations for N-body quantum mechanical scattering problems. This paper demonstrates the use of product integration in a parallel setting (Intel iPSC Hypercube, model d4) for the solution of such equations. The parallel method is then compared with a similar serial method.

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TUESDAY, MAY 24

1:30 - 2:30 PM
State A

CONTRIBUTED PRESENTATIONS 11
Gaussian Elimination

#127/1:30 PM

Unraveling Some Mysteries of Gaussian Elimination Part I

A complete geometric analysis of each step in Gaussian Elimination (GE) has revealed a previously undetected nemesis in the back-substitution phase. Studying this nemesis has lead to a much better understanding of the stability (and occasional instability) of this remarkable algorithm. This presentation will describe the hyperplane geometry associated with each step in both the sweep-out and back-substitution phase of GE. The consequences of ignoring potential problems in the back-substitution phase when selecting pivots during the sweep-out phase will be addressed. This presentation is continued in Part II.

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#128/1:45 PM

Unraveling Some Mysteries of Gaussian Elimination Part II

Partial pivoting has long been used to control numerical error incurred during the sweep-out phase of Gaussian elimination (GE). It does not explicitly address errors which may occur in the back-substitution phase. Scaling used with partial pivoting often yields better results. The geometry presented in Part I will reveal that scaling with partial pivoting actually does more to avoid numerical instability than previously thought. This accepted technique devised to control numerical errors during the sweep-out phase of GE actually helps to avoid the hidden nemesis in back-substitution. Ramifications with regard to LU factorizations and condition numbers are discussed.

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#134/2:00 PM

Average-Case Stability of Gaussian Elimination

Gaussian elimination with partial pivoting is unstable in the worst case: the "growth factor" can be as large as 2^{n-1}, where n is the matrix dimension, resulting in a loss of n-1 bits of precision. We show that an average-case analysis can help explain why it is nevertheless stable in practice. We find that for many distributions of matrices, the matrix elements after the first few steps of elimination are very close to normally distributed. This observation is the basis of a statistical model that closely matches the experimental result: the growth factor, normalized by the standard deviation of the initial elements, is about $n^{2/3}$ on average.

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Lloyd N. Trefethen
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#139/2:15 PM

Solution of Linear Systems by Tearing

In some circumstances, linear systems can be solved by a direct solution method called tearing (in engineering applications this is called diakoptics or substructuring). A numer of smaller linear systems are first solved and these solutions are processed to give a solution of the original system. A new approach to tearing is introduced here which has computational advantages. Comparisons are given between the new method and other fast solution methods.

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ABSTRACTS: CONTRIBUTED PRESENTATIONS

TUESDAY, MAY 24

4:15 - 6:15 PM
State B-C

CONTRIBUTED PRESENTATIONS 12
Core Linear Algebra 2

#2/4:15 PM

Tame Matrix Problems and Representations of Pairs of Partially Ordered Sets

We study the problem of finding a canonical form for a rectangular matrix dissected by a finite number of horizontal and vertical lines, where the admissible row and column elementary operations are given by two finite posets. The main result is a complete description of the pairs of posets for which the problem is tame - the non-equivalent indecomposable matrices in each dimension can be parametrized by a finite number of parameters. The method consists in reducing the problem to the case when one of the two posets consists of one element and then applying the result of Nazarova and Zavadsky.

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#32/4:30 PM

UNCOUPLING THE PERRON EIGENVECTOR PROBLEM

For a nonnegative irreducible matrix $\mathbf{A}_{m\times m}$ with spectral radius ρ, a fundamental problem concerns the determination of the unique normalized Perron vector $\pi_{m\times 1}$ which satisfies $\mathbf{A}\pi = \rho\pi$, $\pi > 0$, $\sum_{i=1}^{m} \pi_i = 1$. It is explained how to uncouple a large matrix $\mathbf{A}$ into two or more smaller matrices — say $\mathbf{P}_1, \mathbf{P}_2, \cdots, \mathbf{P}_k$ — of orders $r_1, r_2, \cdots, r_k$, respectively, where $\sum_{i=1}^{k} r_i = m$. This sequence of smaller matrices has the following properties.

- Each $\mathbf{P}_i$ is also nonnegative and irreducible so that each $\mathbf{P}_i$ has a unique Perron vector $\pi^{(i)}$.
- Each $\mathbf{P}_i$ has the same spectral radius, ρ, as $\mathbf{A}$.
- It is possible to determine the $\pi^{(i)}$'s completely independent of each other so that one can execute the computation of the $\pi^{(i)}$'s in parallel.
- It is possible to easily couple the smaller Perron vectors $\pi^{(i)}$ back together in order to produce the Perron vector π for the original matrix $\mathbf{A}$.

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#27/4:45 PM

The Jordan 1-Structure of a Matrix of Redheffer

Let $\varepsilon_1 = (1,0,\ldots,0)$ and $\gamma_n = (c(1),c(2)\ldots c(n))$ be vectors of $\mathbb{C}^n$. Let $b = [\log_2 n]$ and let $\tau(\gamma_n) = c(2^b) + b\cdot c(3\cdot 2^{b-1})$, where $c(3\cdot 2^{b-1}) = 0$ if $n < 3\cdot 2^{b-1}$. Let $C_n = \gamma_n^T \varepsilon_1$, $D_n = (d_{ij})$ with $d_{ij} = 1$ if $i|j$ and 0 otherwise, and $A_n = C_n + D_n$ be $n\times n$ complex matrices. The Segre characteristic of A_n associated with the eigenvalue 1 is $([\log_2(n/3)] + 1,\ldots,[\log_2(n/\{n\})] + 1)$ where $\{n\} = 2[(n-1)/2] + 1$ iff $\tau(\gamma_n) \neq 0$.

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#133/5:00 PM

The Inverse Eigenvalue Problem for Real Symmetric Toeplitz Matrices: Consistency Conditions for the Eigenvectors

Our inverse problem is: Given preassigned real eigenvalues $\lambda_1 \leq \lambda_2 \leq \ldots \leq \lambda_n$, find a real symmetric Toeplitz matrix having these eigenvalues. Our main result is a family of consistency conditions on the eigenvectors. It is well known that symmetric Toepliz matrices, like all other centrosymmetric matrices, can be block diagonalized into two half-size matrices by a similarity transformation. The eigenvectors of the original problem are given by the symmetric and anti-symmetric extensions of the unitary matrices of eigenvectors U and V of the half size matricies. For Toeplitz matrices, unlike general centrosymmetric matrices, we find that the choice of U and V is highly constrained in that a family of consistency conditions must be satisfied. The simplest example is in the 4×4 case, where 2×2 unitary U and V can be characterized as rotations through angles θ and ϕ: we find that $(\lambda_1-\lambda_3)\cos(2\theta) = (\lambda_2-\lambda_4)\cos(2\phi)$.

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#81/5:15 PM

Scaling of Matrices having given Row and Column Sums

The problem of scaling a matrix so that it has given row and column sums is transformed into a convex minimization problem. In particular, we use this transformation to characterize the existence of such scaling or corresponding approximation. We obtain new results and new and streamlined proofs of known results.

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Hans Schneider
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#89/5:30 PM

Linear Complementarity Problems

The Linear Complementarity Problem, LCP(T,K,q), is to find an x in K such that Tx+q is in the polar of K and $\langle Tx+q\ ,\ x\rangle = 0$. Here, T is an n by n real matrix, K is a closed convex cone in R^n and q is in R^n. We show that if T is copositive on K and $\langle q,x\rangle > 0$ for any nonzero x in K with Tx in K^* and $\langle Tx,x\rangle=0$, then LCP(T,K,q) has nonempty compact solution set. Also, for T in M(K) (i.e., T is copositive and $-T^*x$ belongs to K^* for any x in S), LCP(T,K,q) is solvable for all q iff $S=\{0\}$. Here, $S:=\{\ x\in K\ :\ Tx\in K^*$ and $\langle Tx,x\rangle=0\ \}$. In particular, this result holds for matrices which are either copositive plus on K or (strongly) pseudomonotone on K.

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#115/5:45 PM

Convergent Splittings of Singular Matrices

Let A be a singular $n \times n$ real or complex matrix of rank r. An elementary argument is used to show that there exist $d = n - r$ linearly independent matrices $E_1, E_2, \ldots, E_d$ such that for all matrices of the form $E = c_1E_1 + c_2E_2 + \ldots + c_dE_d$, where $c_1,c_2,\ldots,c_d$ are nonzero scalars, $A = (A + E) - E$ is a convergent splitting of A, that is, $A + E$ is nonsingular and $((A + E)^{-1}E)^k$ converges as k approaches infinity. Related results and questions that arose from an investigation into the use of solutions of systems of linear equations obtained by analog optics in an iterative refinement procedure are also discussed.

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Mustafa A. G. Abushagur
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H. John Caulfield
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#105/6:00 PM

Matrices Whose Powers Are Completely Reducible Z-Matrices or M-Matrices

A ZM-matrix (MM-matrix) is a matrix all of whose positive powers are Z-matrices (M-matrices). Recently, the ZM- and MM-matrices with all positive powers irreducible were characterized in terms of the existence of a single irreducible power. We present an analogous characterization for ZM- and MM-matrices all of whose powers are completely reducible in terms of the existence of a single completely reducible power. Unlike the irreducible case, special restrictions must be imposed when the matrices are not invertible M-matrices.

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TUESDAY, MAY 24

4:15 - 6:15 PM
State A

CONTRIBUTED PRESENTATIONS 13
Applications 2

#17/4:15 PM

A RATE-DISTORTION THEORETIC APPROACH TO PATTERN RECOGNITION-VECTOR RECOGNITION

The fields of information theory, in particular, the area of rate-distortion theory, and pattern recognition stand as well developed disciplines. While the areas of interest to engineering and applied mathematics researchers in the two fields have overlapped in the past, up to now no comprehensive effort has been made to relate the philosophy, goals, and analytical techniques of these two disciplines. This paper is motivated by the belief that such an examination would uncover a number of interesting new research questions; would add to the understanding of the fields, both separately and together; and would provide a basis for increased collaboration. Emphasis is placed on the concept of vector recognition, a process which may impact the manner in which we view problems in computer vision and artificial intelligence.

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#5/4:30 PM

Adaptive Stochastic Algorithms: Open Issues

This paper summarizes the new adaptive stochastic algorithms introduced by the author and others and the applications of these algorithms to the problem of adaptive line enhancement, sinusoidal detection and adaptive spectral estimation. This summary will lead to a discussion of several open issues with regard to the stochastic adaptive algorithms. The issues chosen for discussion in this paper are the strict positive real condition satisfaction, the effects of debiasing parameters and dither signals on the rate of convergence and the bias in the estimated parameters and the alternative multi-stage algorithms.

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#29/4:45 PM

Mason's Unistor, Hill and King-Altman Diagrams and Network Thermodynamics. An Application to Dynamic Kinetic Systems Analysis

Appropriately defined experimental constraints enable physical systems to be represented as linear digraphs in the steady state. These digraphs are equivalent to a set of linear equations. Solutions yield state populations and flow-force relations. Mason developed the unistor to represent electronic systems of this kind. Here the unistor concept is generalized to a broader class of systems and used to provide a set of real experiments which give physical interpretations to the relation between solutions to sets of linear equations and their generation by graph theoretical methods by use of the superposition principle.

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#4/5:00 PM

The Mathematical Foundations of Unified Field Potential Theory

The unification of gravity with the electric and magnetic fields as described by Maxwell have eluded physicists and mathematicians for over a century. Proposed and empirically proved to the right are the field equations; named and dedicated by this author, The Olof Palme Equations.

$\nabla \times \vec{H} = \frac{1}{c^2} \partial \vec{E}/\partial t$	Ampere's Law
$\nabla \times \vec{H} = k_1 \partial \vec{M}/\partial t$	Earth's Magnetic Field
$\nabla \times \vec{M} = k_2 \partial \vec{H}/\partial t$	Elementary Particles: n^o, Λ^o.
$\nabla \times \vec{M} = k_3 \partial \vec{E}/\partial t$	Lorentz Transformations
$\nabla \times \vec{E} = -\partial \vec{H}/\partial t$	Lorentz Force
$\nabla \times \vec{E} = k_4 \partial \vec{M}/\partial t$	Van Allen Radiation Belt
$\nabla \cdot \vec{H} = \chi$	Monopole Density
$\nabla \cdot \vec{M} = m$	Mass Density
$\nabla \cdot \vec{E} = \rho$	Charge Density

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The mathematical foundations from which these relationships originate will be proved.

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#53/5:15 PM

Matrix Group Representations in Parallel Algorithms for Digital Filter Bank Structures

Convenient forms for shift operators which occur in the design of multi-rate digital filters have been derived by use of similarity transforms over polynomial domains (T.G.Marshall, Application of the Polyphase Transform to Digital Filter Bank Design, Asilomar, 1987). In the current work it is shown that the shift operators which occur in block convolution processing form a dihedral group, and that the irreducible representations of this group are useful in the determination of forms for on-the-fly data processing schemes which use block convolution. These forms suggest useful implementations for parallel algorithms in digital signal processing.

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#94/5:30 PM

Factorization Methods for Sequential Data Estimation with Arbitrary Given Gain Matrix

The Kalman filter equation for updating the estimation error covariance

$$P(+) = (I - KH)\, P(-)\, (I - KH)^t + KRK^t,$$

there exits a square root matrix, S, such that $P(+) = SS^t$. This paper presents an efficient orthogonal transformation to transform S into a square matrix, so that the data can be processed recursively. Using this procedure, the gain matrix K, need not depend on P(-). If the gain matrix is given, then the total computation of the factored P(+) will be on the order of 2.5 times the dimension of P squared. Furthermore, this special orthogonal transformation can also be applied to P(-), resulting in an efficient square root Kalman filter.

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#138/5:45 PM

Time Domain Radar Processing

The target and clutter response in slant-range and cross-range are expressed mathematically as a time-variant impulse response. The time-variant impulse response is convolved with a stepped-frequency Fourier Kernel waveform to form the transmitted wave in a High Resolution Radar-Inverse Synthetic Aperture Radar format. An LMS algorithm is developed for identifying and classifying the target. The LMS algorithm is based on minimizing the error between a reference waveform and the received time series. The clutter response is modeled as the deterministic scattering from wind driven gravity waves on the sea. Experimental results support the mathematical development identifying individual target features.

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#141/6:00 PM

Data Compression of Multispectral Images

The trend in satellite and other remote sensing imagery is toward the use of more and more regions of the spectrum. In addition to multiple color bands, data is being collected simultaneously in a wide range of infrared, ultraviolet, and microwave bands. Each image provides its own unique set of information about the scene being imaged, but much of the information is redundant. For example, edges may be identical in some or all of the images. We investigate the use of principal component images to reduce the amount of data that must be stored and transmitted to retain the useful information in these images.

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ABSTRACTS: CONTRIBUTED PRESENTATIONS

WEDNESDAY, MAY 25

8:30 - 10:30 AM
State B-C

CONTRIBUTED PRESENTATIONS 14
Combinatorial Matrix Analysis

#71/8:30 AM

Jordan Structure and Singular Graph of a Non-Negative Matrix

In this work we generalize some well-known results on the relation between the structure of a singular graph S(A) of a nonnegative matrix A and the Weyr characteristic of A associated with the spectral radius of A (the Jordan structure). Thus, we partially answer the question put by Schneider: "Given a singular graph S(A) what are the possible Jordan structure of nonnegative matrices such that have the same singular graph S(A)"?. In this way, we give lower bounds of the Weyr characteristic of A.

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#41/8:45 AM

Regular matrices and prime matrices in the Hall matrix semigroups H_n.

Let B_n denote the Boolean semigroup of n×n (0,1)-matrices, and let H_n denote the subsemigroup of B_n consisting of those matrices with positive permanent. In this paper we describe the regular matrices and the prime matrices in H_n. First, we characterize the regular matrices in H_n in terms of idempotent matrices, adjoint matrices, and identifying permutation matrices. Then we consider the Boolean ranks and permanents of prime matrices in H_n. Finally, we compare the properties of regularity and primeness in H_n with the corresponding properties in other semigroups such as B_n, the semigroup of n×n doubly stochastic matrices, and the semigroup of n×n nonnegative matrices.

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#80/9:00 AM

Positive Semiefinite Matrices with Given Sparsity Pattern

Let G be a simple undirected connected graph on n vertices {1,...,n}. Let M(G) be the set of all positive semidefinite hermitian matrices A satisfying $a_{ij} = 0$ if (i,j) is not an edge of G. Obviously M(G) is a convex cone. We discuss the possible values for the ranks of the extreme points of M(G) in relation to the structure of G.

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#95/9:15 AM

Determinantal Identities and Inequalities Induced by Chordal Graphs

Suppose A is a positive definite symmetric matrix and that the diagonal elements and some off-diagonal elements of A are specified. We consider the question: What is the sharpest possible upper bound for the determinant of A in terms of these elements? (For example, if no off-diagonal elements are known, the best bound is the product of the diagonal elements by Hadamard's inequality.) When the undirected graph G corresponding to the specified entries is chordal, a complete answer is obtained in terms of the principal submatrices corresponding to the maximal cliques of G.

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#111/9:30 AM

Multigraphs and Structure Matrices

With each positive integer r and each non-increasing sequence D of n nonnegative integers we associate a structure matrix T of order n+1. We introduce the structure matrix T to study the class G(D;r) of all r-multigraphs with the prescribed degree sequence D. We show that necessary and sufficient conditions for the class G(D;r) to be nonempty are that the terms of the sequence D have an even sum and that the structure matrix T be nonnegative. From this result we deduce Chungphaisan's generalization to r-multigraphs of the Erdős-Gallai existence theorem for graphs with a prescribed degree sequence.

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#131/9:45 AM

On the Ranks of Matrix Completions

Given a subset Ω of (1,...n)x(1,...,m) and numbers a_{ij} ((i,j)∈Ω) we wish to find the interval [a,b]∈Ω occupied by the ranks of all the nxm matrices A for which $A_{ij}=a_{ij}$ ((i,j)∈Ω). This problem has an easy solution if Ω looks like a triangle, but is numerically difficult for large and more complex patterns. By considering triangular subsets of Ω we obtain lower and upper bounds $a' \le a$ and $b' \ge b$ of a and b, which are quite tight in most cases, and are much easier to compute. It is also possible to identify many classes of matrices for which a=a' and/or b=b'.

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WEDNESDAY, MAY 25

8:30 - 10:30 AM
State A

CONTRIBUTED PRESENTATIONS 15
Parallel Matrix Computations 2

#47/8:30 AM

Parallel Nested Iterations

We consider parallel implementation of nested iterative and block methods for solving linear systems of the form Ax=b. The outer iteration is defined by the splitting A=M-N where M is a non-singular matrix (i.e. $Mx^{k+1}=b+Nx^k$). This linear system is solved either by Gaussian elimination or by an inner iterative method. We investigate convergence properties of the latter and in particular we explore the question of what is the optimal number of inner iterations per outer. To that end we present two heuristic methods which dynamically choose the number of inner iterations to perform at each outer iteration. We present results of numerical experiments on a 64 node BBN Butterfly.

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#107/8:45 PM

Efficient Parallel Algorithm for Solving Positive Definite Systems

We present a new parallel scheme for Cholesky Decomposition of a given symmetric positive definite matrix A. Some of its important features are: (1) Its design is insensitive to any number of processors, and its performance grows monotonically with them. (2) It is especially good for large matrices, with dimensions large relatively to the number of processors in the system. In this case, it achieves the optimal speed up. optimal efficiency and very low communication complexity. (3) It can be used in both distributed parallel computing system. Combining this algorithm with the parallel algorithm for linear triangular systems presented recently by Lin and Zhang, we can easily get an efficient parallel algorithm for Ax = b.

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#91/9:00 PM

On the Parallelization of a Block Toeplitz Solver

Block Toeplitz matrices have important applications in such areas as time series analysis and the numerical solution of two-dimensional integral equations with difference kernels.
We shall outline the parallelization of an algorithm for the numerical solution of a (real or complex) linear system Tx = b with T an mn x mn block Toeplitz matrix, where each block $T_{i,j}=T_{i-j}$, i,j = 0,1,...,n-1, is a general matrix of size m x m. The serial algorithm, from the Toeplitz package by Arushanian et al. (Argonne National Labs Tech. Rep. ANL-83-16), incorporates a recurrent process which, in step k, k = 0,1,...,n-1, determines a block multiple of the first and last block column of C_k^{-1} where C_k is the principal minor of order (k+1)m of T.
An efficient parallelization for the Sequent Balance and the Alliant FX-8 is obtained by parallelizing the operations done within each step. Alternatives are studied and the speedups analyzed.

Elise de Doncker
John Kapenga
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#66/9:15 AM

Displacement Structure and Improved Parallel Computations with Dense Structured Matrices

We exactly compute the coefficients of the characteristic polynomial and the inverse of Toeplitz and other structured $n \times n$ integer matrices T using $O(\log^2 n)$ parallel arithmetic steps and n^2 processors and the precision of computations of $O(n \log(n \|T\|))$ binary bits. We also use $O(\log^2 n)$ steps and n processors for a rapid improvement of an initial approximation to the Toeplitz inverse via modified Newton's iteration. The results substantially improve the processor efficiency of the known fast parallel algorithms; they are extended to many parallel polynomial and rational computations.

Victor Pan
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and
John Reif
Computer Science Dept.
Duke University
Durham, NC 27706

#82/9:30 AM

A Parallel Algorithm for Computing the QR Factorization of a Rectangular Matrix

A parallel algorithm for computing the QR factorization on a shared memory multiprocessor will be presented. The basic step is a divide and conquer step based upon block Householder transformations. Performance limitations associated with the Householder transformation are avoided by overlapping the construction of the block Householder transformations with the application of the transformation to the matrix. A nearly linear speedup is predicted theoretically, and demonstrated experimentally on a 30 processor Sequent Balance 21000.

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and

Bruce W. Suter
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#125/9:45 AM

Numerical Factorization of Matrices Into Products of Local Matrices

A fine-grained parallel architecture, such as a mesh-connected array, can be modeled as a graph with the nodes representing processing elements and the edges representing communication links. A local matrix with respect to a graph reflects the structure of a graph, e.g, a tridiagonal matrix is local with respect to a linear graph. Factoring matrices into products of local matrices yields methods for computing linear transforms locally, either by iterating local transforms or by parallel-pipelining. Numerical algorithms for factoring matrices are discussed, conditions under which they can be applied are given, and results of computer implementations are described.

Dr. Paul D. Gader
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#129/10:00 AM

Parallel VLSI Computing Array for Updating Principal Eigen-subspace

A VLSI parallel conmputing structure is developed which is able to compute rank-one update of principal component eigen-subspace of a real symmetric matrix. The algorithm is based on the adaptive version of a Block Gradient Subspace Iteration (BGSI) algorithm developed by the author earlier. The main contribution of this paper is a new procedure to bidiagonalize a structured sparse matrix which uses $O(N^2)$ rather than $O(N^3)$ operations as required in general cases. Then a linear array structure of VLSI rotation processor is proposed to implement this procedure in parallel.

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WEDNESDAY, MAY 25

1:30 - 2:30 PM
Ballroom A-B

CONTRIBUTED PRESENTATIONS 16
Sparse Matrix Computations 1

#123/1:30 PM

Finding Separators for Sparse Matrix Partitioning

The notion of separators is useful in partitioning sparse symmetric matrices for fill reduction and for parallel elimination. An algorithm is presented to determine effective separators for undirected graphs. The scheme is related to the fill-reducing minimum degree ordering and is also based on some known results in bipartite graph matching. This results in an overall practical scheme for finding separators appropriate for sparse matrix partitioning. Experimental results are also presented to demonstrate the effectiveness of this heuristic algorithm.

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#135/1:45 PM

Parallelizing an Efficient Partial Pivoting Algorithm

A sparse matrix can be factored by Gaussian elimination with partial pivoting in time proportional to the number of nonzero arithmetic operations, using an algorithm of Gilbert and Peierls. A sequential implementation of that algorithm is quite efficient in practice.

We obtain a shared-memory parallel version of the algorithm by using two ideas: Elimination trees are used to identify parts of the factorization that can be performed independently in parallel, and the graph-theoretic structure prediction step in the original algorithm is modified to allow pipelining of consecutive columns. We present numerical results from an implementation on an Alliant FX/8 multiprocessor.

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Norway

#46/2:00 PM

A Linear-time Method for Block Ordering of Sparse Matrices

Block iterative methods used for the solution of linear systems of algebraic equations can perform better when the diagonal blocks of the corresponding matrix are carefully chosen. We present a method based on combinatorial considerations which symmetrically permutes the rows and columns of a general matrix in such a way that relatively dense blocks of various sizes appear along the diagonal. Two parameters indirectly determine the quantity and the density of the diagonal blocks. The algorithm is O(n+r) in time and space, where n is the order of the matrix and r is the number of nonzeros in the matrix. Numerical test results are presented which illustrate the performance of both the ordering algorithm and the block iterative methods with the resulting orderings.

James O'Neil
Donald J. Rose
Daniel B. Szyld
Department of Computer Science
Duke University
Durham, NC 27706

#45/2:15 PM

Orderings for Threshold Incomplete Factorizations

Conjugate-gradient-type methods for the solution of large sparse pattern-symmetric systems are efficient when incomplete LU factorization is used as a preconditioner. In those cases, the location of the nonzeros in the factors is prescribed; typically, the factors will have the same nonzero structure as the original matrix. We explore the use of another criterion for the location of the nonzeros in the factors: only the nonzeros whose absolute value is above a prescribed threshold is kept. We further explore the influence of different orderings of the variables in the original matrix on the efficiency of the method. Numerical experiments are reported.

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ABSTRACTS: CONTRIBUTED PRESENTATIONS

WEDNESDAY, MAY 25

1:30 - 2:30 PM
Empire Room

CONTRIBUTED PRESENTATIONS 17
Signals and Systems 2

#69/1:30 PM

On the Problem of Robust Control of Linear Time Varying Systems

We consider discrete time linear time varying systems and characterize those that are Bounded Input Bounded Output stable. We parameterize the space of time varying linear systems of unbounded lag and show that the parameterization is robust with respect to stability. We also pose and analyze a new simultaneous identification problem and describe a stochastic algorithm to solve it. This opens up some new opportunities in expert system design.

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#122/1:45 PM

Robust Controller Design for Linear Discrete-time Systems

This paper presents an efficient numerical algorithm for robust controller design of linear discrete-time systems. The quantified bounds on the structural properties such as controllability, stability and sensitivity are given based on which the objective function for robust controller is obtained. A new numerical algorithm by using Gram-Schmidt orthogonalization and linear least square method is constructed which is prooved by the numerical examples to be efficient in robust controller design.

Yiren Huang
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Houghton, MI 49931

#72/2:00 PM

ROBUST CONTROLLER DESIGN FOR A CLASS OF DISCRETE-TIME INTERCONNECTED SYSTEMS

An interconnected discrete-time system is considered. It is assumed that the large-scale system consists of three interconnected discrete-time subsystems: x_1, x_2, and x_3 where x1 is the main subsystem and is controlled through subsystems x2 and x3. x2 and x3 subsystems are being controlled by u2 and u3 respectively. Since x1 subsystem is the main subsystem, the order is usually larger than the other subsystems and it could be assumed that there is an uncertain parameter in this subsystem. In this paper controls u2 and u3 are designed such that a desired cost functional is minimized and the system trajectory sensitivity is reduced with respect to the uncertain parameter.

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#84/2:15 PM

Robust Optimal Model Matching Control of Discrete-Time Singularly Perturbed Systems

Singular perturbation analysis is proposed to study the robustness of optimal feedback control. A class of linear shift-invariant discrete-time singularly perturbed system is considered. A method of designing control strategy involves minimization of performance index which includes matching of the prespecified model.

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WEDNESDAY, MAY 25

1:30 - 2:30 PM
State B-C

CONTRIBUTED PRESENTATIONS 18
Approximations

#38/1:30 PM

A Generalized Rational Approximation Problem and Generalized Toeplitz and Hankel Matrices

In the Newton-Padé Approximation Problem (rational Hermite interpolation), a function f(z) is approximated by a ratio of polynomials p(z)/q(z) such that p(z) - f(z)q(z) has as many leading coefficients of zero in its Newton series representation as possible. Consider a more general approximation problem where a basis of Lanczos orthogonal polynomials is used instead. The relevant linear algebra results in the study of very generalized versions of Toeplitz and Hankel matrices. These matrices can be characterized in terms of Comrade matrices, which leads to generalized Trench formulas for their inverses. Other properties of these matrices are also shown.

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#76/1:45 PM

Polynomial Approximation of Functions of Matrices and Applications

In solving a mathematical problem numerically, we frequently need to operate on a vector V by an operator F(A), where A is a NxN matrix (e.g., exp(A)). In the present research we develop an algorithm based on polynomial approximation to F(A). First the problem is reduced to a problem of approximating F(z) by a polynomial in z where z belongs to a domain D which includes all the eigenvalues of A. This approximation problem is treated by interpolating F(z) in a certain set of points which is known to have some maximal properties. Since a solution to Ax = b is x = f(A)b where $f(z) = z^{-1}$, an iterative solution can be regarded as polynomial approximation to A^{-1}. We give special attention to this important problem.

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#65/2:00 PM

New Progress in Computing Polynomial Zeros and Its Impact on Matrix Eigenvalue Computation

New algorithms use $O(n^2 \log b \log n)$ arithmetic operators to approximate with errors $< 2^{m-b}$ to all the zeros of an n-th degree polynomial having moduli of coefficients $< 2^m$. Near optimum O(n log b log n) suffice for a single zeros. Fully efficient parallelization is possible with p processors if $p < n$. The precision of computations is on the order of the input precision. The progress may suggest revitalization of computing matrix eigenvalues as the zeros of its characteristic polynomial.

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#61/2:15 PM

An Asymptotically Superior Algorithm for Computing the Characteristic Polynomial of a Tridiagonal Matrix

In this work, we study the design of algorithms for computing the characteristic polynomial of a tridiagonal matrix. Such a problem arises in many areas of applied mathematics and engineering. Based on the well-known divide-and-conquer technique, a new algorithm is derived. First, the three-term recurrence relation is cast into a matrix-vector product form, and then the divide-and-conquer technique is employed. The various polynomial products are computed using the Fast Fourier Transform (FFT) algorithms. This leads to a new algorithm that requires $O(n\log^2 n)$ arithmetic operations (multiplications and additions) as compared to the classical algorithm requiring $O(n^2)$ arithmetic operations. Thus the new algorithm is computationally superior asymptotically to the classical algorithm.

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THURSDAY, MAY 26

8:30 - 9:30 AM
Ballroom A-B

CONTRIBUTED PRESENTATIONS 19
Matrix Algorithms 2

#8/8:30 AM

Homotopy Algorithm for Symmetric Eigenvalue Problems

Homotopy method can be used to solve the eigenvalue-eigenvector problems. This paper gives a new fast algorithm for following the homotopy continuation curves when we have symmetric matrices. We show how to decouple the problem and separate out the eigenvalue curve. Thus the predictor part of the usual continuation curve followers is reduced to a one-dimensional problem and leads to great economy. For the corrector Rayleigh quotient iteration can be applied. Our numerical results show that homotopy algorithm may outperform QR-algorithm for matrices which have well-separated eigenvalues.

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Noah Rhee
Department of Mathematics
University of Missouri-Kansas City
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#39/8:45 AM

Reconstructing ALL Jacobi Matrices from Spectral Data by the Homotopy Method

A homotopy approach to solving the additive inverse eigenvalue problem for Jacobi matrices is proposed. The expected advantages are that it offers a global method without requiring the knowledge of an additional set of eigenvalues associated with a corresponding principal submatrices, that it can be used to find all possible solutions independently and that it does not need the calculation of the eigensystems. The computational tasks are discussed.

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#10/9:00 AM

Leverrier's Algorithm: A New Proof and Extensions

A new derivation is given of the Leverrier-Fadeev algorithm for simultaneous determination of the adjoint and determinant of the n × n characteristic matrix $\lambda I_n - A$. The proof uses an appropriate companion matrix, and is of some interest in its own right. The method is extended to produce a corresponding scheme for the inverse of the polynomial matrix $\lambda^2 I_n - \lambda A_1 - A_2$, and indeed can be generalized for a regular polynomial matrix of arbitrary degree. The results have application to linear control systems theory.

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#102/9:15 AM

An Algorithm for Matrix Optimization Problems

We present an algorithm for solving maximization problems where the objective function is matrix valued and the maximum is with respect to the partial order determined by the positive semidefinite matrices. Examples include computing the geometric mean of matrices, and solving matrix Ricatti equations.

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George E. Trapp
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THURSDAY, MAY 26

8:30 - 9:30 AM
Empire Room

CONTRIBUTED PRESENTATIONS 20
Iterative Techniques 2

#113/8:30 AM

Application of Contractor Directions to Linear Algebra

The method of contractor directions is an iterative method with variable step-size at each iteration, $0 < \epsilon_n \leq 1$, designed to solve general nonlinear operator equations in Banach spaces. We have already applied this method successfully for solving systems of nonlinear equations.

The aim of this talk is to show how to apply the method of contractor directions for solving systems of linear algebraic equations. In particular, the method of steepest descent and the least square method for general operator equations are investigated with variable (contractor direction) step-size.

Tom Altman
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#103/8:45 AM

A General Theory for the Iterative Solution of BX + XA + C = 0.

The matrix equation (*)$BX + XA + C = 0$ appears often in linear systems theory and optimal control theory (where usually $B = A^T$). Both iterative and factorization based schemes have been developed for its numerical solution. Iterative techniques recursively generate sequences of matrices X_k converging to the solution X of (*) as $k \to \infty$. Generally speaking, these techniques require A and B to be stable matrices. This paper presents a comprehensive theory for the iterative solution of (*), provided only that (*) has a unique solution. The known iterative techniques mentioned above follow as special cases of this more general formulation.

David F. Miller
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#64/9:00 AM

Iterative Improvement of the Singular Value Decomposition

We give a derivation, an error analysis, and applications of a numerical method for improving the accuracy of an approximate singular value decomposition of a matrix. Suppose matrix A is approximately $U\Sigma V^T$ where Σ is diagonal and U and V are approximately orthogonal. We seek correction terms $\Delta\Sigma$, ΔU, and ΔV to improve these approximations. With $\Delta X = U^T(\Delta U)$ and $\Delta Y = V^T(\Delta V)$, linearizations of certain defining equations for $\Delta\Sigma$, ΔU, and ΔV yield equations for $\Delta\Sigma$, ΔX, and ΔY which decouple into systems of order 4 or smaller. Under mild conditions on Σ these small systems are all nonsingular. Ultimate convergence is quadratic. Numerical instabilities may occur if A is ill-conditioned or has nearly equal singular values. Possible applications include correcting an SVD after a small perturbation; or using an initial low precision SVD to find a high precision SVD of A.

Daniel P. Giesy
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#56/9:15 AM

Numerical Solution of the Eigenvalue Problem for Hermitian Toeplitz Matrices

An iterative procedure is proposed for computing the eigenvalues and eigenvectors of Hermitian Toeplitz matrices. The computational cost per eigenvalue-eigenvector for a matrix of order n is $O(n^2)$ in serial mode. Results of numerical experiments on Kac-Murdock-Szegö matrices and randomly generated real symmetric Toeplitz matrices of orders 100, 150, 500 and 1000 are included.

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THURSDAY, MAY 26

8:30 - 9:30 AM
State B-C

CONTRIBUTED PRESENTATIONS 21
Core Linear Algebra 3

#70/8:30 AM

Nonnegative Centrosymmetric Matrices

Examples of nxn nonnegative centrosymmetric matrices are given which have 2 real eigenvalues if n=4m or n=4m+2, 1 real eigenvalue if n=4m+1, and 3 real eigenvalues if n=4m+3 for m a nonnegative integer.

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#68/8:45 AM

Points, Bases, and Norms in Fuzzy Linear Spaces

Fuzzy linear spaces and fuzzy convex sets in $\mathbb{R}_n$ are investigated as a first step toward developing the theory of fuzzy optimization. The concepts of fuzzy bases and fuzzy linear independence are defined, and techniques from "crisp" optimization are used to give a constructive proof of the existence of a base for every fuzzy linear subspace. A fuzzy norm is defined, and it is shown that the fuzzy topology of this norm is the usual fuzzy topology of $\mathbb{R}_n$. Closures and interiors of fuzzy convex sets are investigated with the aid of this norm.

Dr. Godfrey C. Muganda
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#104/9:00 AM

Inflation Matrices That Commute with a Permutation Matrix

Centrosymmetric matrices are matrices that commute with the permutation matrix with ones on its cross diagonal. The concept of centrosymmetry naturally generalizes to the study of matrices that commute with an arbitrary permutation matrix P. We address this latter property for two related classes of matrices: inflation matrices and ZME-matrices (Matrices all of whose odd powers are irreducible Z-matrices). The structure of P-commutative inflators is determined, and then this is used to characterize the P-commutative ZME-matrices. Centrosymmetric matrices in these classes are presented as a special case.

Jeffrey L. Stuart
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#145/9:15 AM

Certain isometries and set preservers on matrix spaces

We study different isometries on matrix spaces and show that they are the dual transformations of linear operators that preserve different matrix sets. The structures of these linear operators are then determined. These extend and link up various existing results of linear preservers problems.

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THURSDAY, MAY 26

8:30 - 9:30 AM
State A

CONTRIBUTED PRESENTATIONS 22
Sparse Matrix Computations 2

#18/8:30 AM

A Connectivity Coordinate System for Ordering

Much of modern engineering practice requires the analysis of large and complex problems which are defined by sets of linear equations, having several thousands of variables. An effiecient solution using the Gaussian elimination method or frontal approach requires ordering the variables of the problem. In this article a new connectivity coordinate system is defined for skeletal structures and employed in their nodal ordering to reduce the bandwidth of the corresponding stiffness matrices. The application is extended to cycle ordering and generalized cycle ordering to reduce the bandwidth of the corresponding flexibitity matrices. A method for finite element ordering is provided for frontwidth optimization.

Ali Kaveh
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Iran University of Science and Technology
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#100/8:45 AM

Stretching of Linear Equations

A new sparse matrix method, stretching, allows Gaussian elimination to be performed efficiently (with pivoting) on matrices that are sparse but for a few dense rows and columns. The method generalizes techniques long used in the numerical solution of two point boundary value problems to other areas, in particular to (pseudo-arclength) continuation methods.

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#136/9:00 AM

Proposal for a benchmark package for sparse computations.

We examine the problem of evaluating performance of modern supercomputers on sparse computations and propose a benchmark package dedicated to sparse matrix computations. Evaluating the performance of a given architecture on sparse matrix computations presents many challenges. Some of the obstacles are due to the different natures of the basic computations that comprise sparse matrix techniques. Others are related to the role of such a benchmark: what information should we expect from it? With this in mind we propose a benchmark package consisting of three independent modules, each of which has a distinct role. The first module executes a representative set of the most common loops arising in sparse matrix computations. It is similar in nature to the Livermore loops and the Los Alamos benchmark. The loops are run under different conditions to test specific features of the architecture, such as its sensitivity to data locality and the degree of randomness. The second module comprises loops with no floating point arithmetic while the third combines a few sample application programs. Results of a preliminary version run on an Alliant FX-8 and a Cray X-MP will be presented.

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THURSDAY, MAY 26

1:45 - 3:45 PM
State B-C

CONTRIBUTED PRESENTATIONS 23
Statistics 2

#52/1:45 PM

Computer-aided Illustration of Regression Diagnostics

The recent growth of the computational capacity has activated lots of matrix formulas, related to regression diagnostics, which earlier were merely of theoretical interest. The availability of possible diagnostics (leverages, Cook's distance...), whose number is almost confusingly high, causes no problems for most users. The interpretation and practical meaning, however, may not be that clear. This paper describes a micro computer program developed by the authors for illustration of these concepts. For example, the user can "perturbe" the data in various ways and observe the consequences. The user can e.g. move an observation on the screen and simultaneously see the effect on the diagnostics.
Though life is short (according to the book of Cook & Weisberg 1982, p.8) it seems fair to devote a part of it to regression diagnostics.

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#51/2:00 PM

Robustness to Missing Data under the Growth Curve Model

In this paper we propose an influence measure for detecting influential observations under the growth curve model. The proposed measure can be easily interpreted as a distance measure and it has close relations to well known Cook's distance popular in regression analysis. The measure envisaged serves as a means for comparing the robustness of various models to missing measurement and to different study design. The paper contains the examination of the robustness of the three best model found. Such an examination is done using various simulation techniques. The models are applied to a sample of the data set of the 2712 bulls tested at an experimental station in Finland between the years 1965 and 1977.

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#50/2:15 PM

On the Canonical Correlations between the OLS Fitted Values and the Residuals in the General Linear Model

The relative goodness of the ordinary least squares estimator of $X\beta$ in the general linear model $Ey = X\beta$, $cov\ y = V$, can be expressed as a function of the canonical correlations between the OLS fitted values and the residuals. In this paper we survey some properties of these canonical correlations. The covariance matrix V is allowed to be singular and the model matrix X may not have a full column rank. Special attention is paid to the number u of unit canonical correlations between the fitted values and the residuals. We introduce several equivalent formulas for u. In particular, we study the effect of the condition $u = 0$, i.e., there are no unit canonical correlations between the fitted values and the residuals.

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#48/2:30 PM

Variance Inflation and Collinearity in Regression

The variance inflation factors associated with the parameters in a linear regression model can be interpreted as variance ratios. This approach leads naturally to factorizations of the variance inflation factors into marginal and partial variance inflation factors. Specifically, components can be isolated which relate respectively to the centered and uncentered data. Generalizations follow, which can be related to multivariate test statistics. The generalized variance inflation factors lead to a full set of collinearity indices for a linear regression model. Thus the diagnostics defined by Stewart (1987) can be extended, to provide a fairly omnibus approach to the identification of collinearity, variance inflation, ill-conditioning, and errors in variables problems in linear regression. A statistic for collinearity-influential points, and more generally, for collinearity-influential variables is suggested.

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#43/2:45 PM

A Usable Criterion of Multivariate Model Stationarity

The time-dependence of a multivariate regression model can best be measured as the movement of the ellipsoid corresponding to the second moment's quadratic risk form. The time dependence of the joint probability distribution can be reduced by three criteria of model stationarity to the fluctuation of a single geometric object: the hyperellipsoid of non-clustered principle components.

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#25/3:00 PM

Statistics on a Parallel Computer: All-Subsets Regression

All-subsets regression (that is, computing linear regressions for all subsets of k predictors) is an inherently parallel problem, suitable for exploring the use of hypercube multiprocessors in statistical computation. The algorithm described here uses the sweep operator for introducing or removing variables; the load is apportioned among processors in a nearly optimal way, based on the Gray code embedding of a hypercube into a torus. The algorithm is implemented in FORTRAN on an Intel iPSC d5; its performance is discussed both in terms of speed-up factors, and by comparison with commercial statistical packages.

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THURSDAY, MAY 26

1:45 - 3:45 PM
State A

CONTRIBUTED PRESENTATIONS 24
Core Linear Algebra 4

#57/1:45 PM
The Matrix Equation $A\bar{X} - XB = C$ and Its Special Cases

The consistency and solutions of the matrix equations $A\bar{X} - XB = C$, $A\bar{X} \pm XA^T = C$, and $A\bar{X} \pm XA^* = C$ are characterized. As a consequence it is shown that A^T (resp. A^*) may be obtained from A by a consimilarity transformation using a Hermitian (resp. symmetric) matrix.

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Robert E. Hartwig
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#9/2:00 PM
Extraction of *m*th Roots in Matrix Rings over Fields

Criteria are developed to determine whether an $n \times n$ matrix M with entries in an arbitrary field F is an mth power in the ring $M_n(F)$. These criteria are described in terms of the elementary divisors of M and fall into the three cases: (1) M is nilpotent; (2) M is not nilpotent, and the characteristic of F is zero or does not divide m; (3) M is not nilpotent, and m is a power of the nonzero characteristic of F. In cases (1) and (3), it is possible to describe "all" mth roots of M, i.e., all distinct similarity classes of the mth roots of M.

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#13/2:15 PM
Co-Solutions of Algebraic Matrix Equations of Polynomial type and Applications.

In recent papers |1,2| a method for solving matrix differential equations of polynomial type without increasing the dimension of the problem is given in terms of an appropriate set of solutions of the corresponding characteristic algebraic matrix equation. In this paper we introduce the concept of co-solution for an algebraic matrix equation of polynomial type. This concept allows us to extend the above method when the required set of solutions for the algebraic matrix equation is not available. A method for obtaining co-solutions and its application to solve matrix differential equations is presented.

1. L. Jódar, Linear Algebra and its Appls., 83: 29-38(1986).
2. L. Jódar, Algebraic and Differential Operator Equations, Linear Algebra and its Appls., to appear in 1988.

Lucas Jódar

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#87/2:30 PM
Symmetric Bilinear Form and its Application in Matrix Theory

Let $A = (a_{ij}) \in M_n$ be a complex matrix and consider the bilinear form $Q(x, y) = y^T Ax = \sum_{i,j=1}^{n} a_{ij}\, y_i\, x_j$, $x, y \in \mathbb{C}^n$. If we want to have $Q(x, y) = Q(y, x)$ for all x,y then it is necessary and sufficient that $a_{ij} = a_{ji}$ for all $i, j = 1, \ldots n$. Thus, symmetric bilinear forms are naturally associated with symmetric matrices. A complex symmetric matrix is not always diagonalizable but when it is diagonalizable it can be diagonalized by a complex orthogonal matrix. In this paper we study the role of symmetric and orthogonal matrices in various reduction of a complex matrix.

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ADDENDUM*

#L-1/5:15 PM (Cont. Pres. 7; Mon., May 23)
The Matrix Foundations for Combining Vector Estimators and Evaluating Shrinkage Estimator Models

A unified theory of combining vector estimators of a parameter is developed using a matrix valued expected mean square criteria and an affine form of a linear matrix weighted combination of the vector estimators. The theory developed is then related to the problem of shrinkage estimators. Several numerical examples are presented to exemplify effeciencies.

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#L-2/3:15 PM (Cont. Pres. 4; Mon., May 23)
Refining Invariant Subspaces of Integral and Partial Differential Operators with Newton's Method

Newton's method is applied to a formulated quadratic mapping to refine invariant subspaces of discrete approximation equations to both integral operators and elliptic partial differential operators. This approach achieves quadratic convergence and employs efficient multi-grid methods to find the inverse of the resulting Frechet derivative at each iteration step. This generalized methods previously limited to linear algebra. Numerical examples are provided.

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#L-3/2:00 PM (Cont. Pres. 18A; Wed., May 25)
On the Invariant Factors of Block Triangular Matrices

Let $\mathbb{F}$ be an arbitrary field, and A and B nxn and mxm matrices with elements in $\mathbb{F}$. This paper is devoted to present some new results on the relationship between the invariant factors of the matrices A, B and

$$G = \begin{bmatrix} A & 0 \\ * & B \end{bmatrix}$$

If $\tilde{\alpha}$ and $\tilde{\gamma}$ are the sequences of invariant factors of A and G, respectively, then the minimal polynomial path from $\tilde{\alpha}$ to $\tilde{\gamma}$ plays a fundamental role in the solution of this problem.

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#L-4/1:45 PM (Cont. Pres. 18A; Wed., May 25)
Classification of Triples of Matrices and Determinantal Curves

Simultaneous classification of triples of matrices is a natural generalization of the classical theory of matrix pencils; it is equivalent to the classification of determinantal representations of algebraic curves. A determinantal representation U(x) of a complex algebraic curve $F(x_0, x_1, x_2)$ of order n is a matrix of order n, whose entries are linear in x_0, x_1, x_2, satisfying $\det U(x) \equiv cF(x)$ $(c \neq 0)$. For smooth irreducible curves (generic case) we obtain, via the class of divisors of the corresponding vector bundle, a parametrization of determinantal representations, up to equivalence, by the points on the Jacobian variety of the curve not on some exceptional subvariety. We obtain also a description of symmetrical and self-adjoint determinantal representations.

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* Abstracts submitted after deadline.

#L-5/5:30 PM (Cont. Pres. 7; Mon., May 23)

Fast Adaptive RLS Algorithms: A Generalized Inverse Unification

A generalized inverse unification of some important fast adaptive recursive least squares algorithms is presented. This unification reveals the inside view of those algorithms and also gives a new algorithm for the initial state in prewindowed signal case.

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#L-6/2:15 PM (Cont. Pres. 18A; Wed. May 25)

A SURVEY OF INFINITE MATRICES AND APPLICATIONS

Systems of linear equations involving infinite matrices occur frequently in a variety of topics. Advantage is taken of the structure of the matrix to establish the nature of the solutions complete with error bounds for their approximations. Systems of the form $A\underset{\sim}{x}=\underset{\sim}{b}$, $\underset{\sim}{x}=A\underset{\sim}{x}+\underset{\sim}{f}$, are considered. For $A\underset{\sim}{x}=\lambda\underset{\sim}{x}$, intervals are given for the eigenvalues and a simple but extremely efficient algorithm establishes upper and lower bounds to any required degree of accuracy. Boundary value problems on infinite intervals of the type $-y''+f(x)y=\lambda y, y(0)=y(\infty)=0$ are also discussed. Mathieu equation and Schrodinger's wave equation are used to illustrate the results.

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CANADA

#L-7/5:45 PM (Cont. Pres. 7; Mon., May 23)

Iterative Solution of Burgers Equation

A Sinc-Galerkin discretization of the Burgers equation gives rise to the linear system of equations

(1) $\varepsilon AU + UB = \alpha C(U) + F$.

In (1) the N x M matrices U, C(U) and F contain the sinc coefficients of the Galerkin solution of Burgers equation, the non-linearity, and point evaluations of f(x,t) at the sinc-nodes in Ω, respectively. The N x N matrix A is symmetric and positive definite and B is an M x M matrix that is perturbed skew-symmetric.

The solvability of (1) ($\alpha = 0$) follows from Roth's theorem (1952) (e.g. $\alpha(A) \cap \alpha(B) = \emptyset$). An iterative solution of (1) depends on a more precise location of the spectrums of A and B. There are theorems giving analytic bounds on this location, however numerical results indicate that the analytic bounds are quite conservative.

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#L-8/10:00 AM (Cont. Pres. 14; Wed. May 25)

Maximum Permanents on Certain Polytopes of Doubly Stochastic Matrices

Let Ω_n denote the set of all nxn doubly stochstic matrices and let $J_n = [1/n]_{n\times n}$. Let

$$\Omega_n^{(\theta)} = \{(1-\theta)J_n + \theta A \mid A \in \Omega_n\} .$$

Then $\Omega_n^{(\theta)}$ constitutes a polytope. We prove that, for any θ, $(-1/(n-1)) \leq \theta \leq 1$,

$$\max\{\mathrm{per}B \mid B\in\Omega_n^{(\theta)}\} = \frac{n!}{n^n}\sum_{k=0}^{n}\frac{(1-\theta)^{n-k}(n\theta)^k}{k!},$$

where the maximum is achieved uniquely at those matrices which are permutation equivalent to $(1-\theta)J_n + \theta I_n$. Particular values of θ give us some interesting corollaries some of which are known in the literature.

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ADDENDUM

#L-9/1:30 PM (Cont. Pres. 18A; Wed. May 25)

Nonlinear Factorization of Nonmonic Matrix Polynomials

We consider the problem of the factorization of nonmonic matrix polynomials $L(\lambda)=L_k(\lambda)\ldots L_1(\lambda)$, where $L_k(\lambda)$ has the same leading coefficient as $L(\lambda)$ and $L_i(\lambda)$ is monic for every $i=1,\ldots,k-1$. We prove that the existence of this factorization is related to the strict equivalence between the companion polynomial $C_L(\lambda)$ of $L(\lambda)$ and the pencil $F(\lambda)=\mathrm{diag}(I,\ldots,I,A_o)\lambda-F$. Matrix F is the block bidiagonal matrix with $C_1,\ldots,C_k$ forming the principal diagonal and $J_1,\ldots,J_{k-1}$ the upper diagonal, where C_i is the companion matrix of $L_i(\lambda)$ and J_i is a block matrix with the identity in the southwest corner and zeros elsewhere.

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#L-10/9:15 AM (Cont. Pres. 22; Thur. May 26)

On One-Way Dissection with Singular Diagonal Blocks

We present a procedure for performing one-way dissection on a sparse matrix that may have singular or nearly singular diagonal blocks. Our procedure is an improvement over a similar procedure recently advocated by Genzberger and Nicholaides.

An error analysis of our procedure is presented. This analysis extends to a class of similar procedures. We also present empirical tests which, along with the error analysis, show that our procedure has favorable numerical properties.

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#L-11/10:15 AM (Cont. Pres. 14; Wed. May 25)

Balancing Weighted Directed Graphs in l-Infinity Norm

Let G = (X,U,g) be a directed graph with a real-valued arch-weight function, g(u), for u in U. For a subset A of X, G is BALANCED at A if the maximum weight on arcs directed out of A equals the maximum weight on arcs directed into A. A graph is BALANCED if it is balanced at every subset A of X. We show that for strongly-connected graphs there exist unique (up to an additive constant) vertex weights p(x), for x in X, such that (X,U,f) is balanced where $f(u) = p(x) + g(u) - p(y)$, for u in U. We apply a variant of Karp's minimum cycle-mean algorithm to show that vertex weights which balance every strong component of G can be computed efficiently.

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#L-12/10:00 AM (Cont. Pres. 8; Tue. May 24)

Generalized Correlations in the Singular Case

A unified theory is given which provides appropriate formulae for various generalizations of canonical correlations in the singular case. This covers as special cases the results for multiple correlation due to Tucker, Cooper and Meredith (1972), and Khatri (1976), and for partial and canonical correlations due to Rao (1971, 1981). The numbers of zero, unit and other critical generalized correlations are given for the general case. Some examples are also presented.

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#L-13/5:00 PM (Cont. Pres. 6; Mon., May 23)

A New Preconditioner for Linear and Nonlinear Deconvolution Problems

This report considers computational methods for solving linear and nonlinear least-squares problems arising from deconvolution applications in elastic wave propagation. The normal equations are formed from a Toeplitz matrix. To take advantage of its structure, we propose a new preconditioner based on Cybenko's QR factorization of a circulant matrix. Our numerical results confirm that our preconditioner significantly speeds up the convergence of the conjugate gradient method when the Toeplitz matrix and its circulant approximation are close.

This preconditioner is applied to the linear subproblems which arise from the linearization of nonlinear problems. We investigate several algorithms which take advantage of the inherent Toeplitz structure. The scale degeneracy present in our nonlinear problems is also remedied.

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#L-14/2:45 PM (Cont.Pres. 24; Thurs. May 26)

On the Error Estimate for the Projection of a Point Onto a Linear Manifold

Suppose that the linear system $A^H x = b$ is consistent. The problem of finding the solution x to minimize $1/2\| x-p \|_2^2$ subject to $A^H x = b$ is studied, where $A \in C^{n\times m}$, $b \in C^m$, $x,p \in C^n$ and A, b, p are given. When A, b and p are perturbed, the error bound for the solution x is obtained. The results in this paper extend existed one to the case when A is not of full rank and either $m \leqslant n$ or $m > n$.

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#L-15/3:00 PM (Cont. Pres. 24; Thurs. May 26)

On the Spectral Radius of Functions of Nonnegative Matrices

Let A be a nonnegative square matrix and denote by r(A) the spectral radius of A. Let f(x) be a function that maps the set of all nonnegative numbers into itself. f(A) is defined to be the matrix whose entries are the images under f of the coreesponding entries of A. We characterize all such functions f for which r(f(A))t<tf(r(A)) for all square nonnegative matrices A. We also give a necessary condition and several sufficient conditions for f to satisfy r(f(A))t>tf(r(A)) for all square nonnegative matrices A.

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#L-16/3:15 PM (Cont. Pres. 5; Mon. May 23)

Iterative Solution of the Sylvester Equation

The generalized Sylvester equation and special cases like the Lyapunov matrix equation are all model - problems for ADI Iteration. One may reduce the systems to tridiagonal or upper Hessenberg form as in the direct solution methods. One may then replace the $O(n^3)$ reduction to diagonal or real Schur form by an $O(n^2)$ ADI iteration. Deficient - eigenvector subspace error not reduced by the ADI iteration may be removed by an appended block-Lanczos iteration. ADI convergence theory has been generalized to complex spectra for this application. Modular transformations of elliptic functions play a crucial role in the analysis.

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ADDENDUM

#L-17/3:15 PM Cont. Pres. 24; Thur. May 26

Multi-dimensional Levinson Recursions for Non-Causal Prediction

The problem addressed is the recursive computation of multi-dimensional, non-causal, prediction-error filters $a(\underline{k})$ that satisfy the normal equations

$$r(\underline{m}) - \sum_{\underline{k} \in N} a(\underline{k}) r(\underline{m} - \underline{k}) = 0 \qquad \text{for all } \underline{m} \in N,$$

where N is a finite neighborhood in the multi-dimensional integer lattice around but excluding the origin. The coefficient matrix in the above system of linear equations is a generalized Toeplitz matrix whose $(i,j)^{th}$ element is $r(\underline{f}(i) - \underline{f}(j))$, where f^{-1} is an arbitrarily chosen ordering of the indices in the neighborhood plus the origin. When the number of dimensions is 2, and the neighborhood is rectangular, the matrix is Toeplitz-block-Toeplitz, and the Levinson-Trench algorithm has been generalized to handle such matrices. Here, we deal with arbitrarily shaped, non-causal neighborhoods in several dimensions, and present a generalized Levinson algorithm for the recursive computation of the prediction error filters as the neighborhood is made to grow.

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#L-18/4:30 PM (Wed. May 25, Cont. Session 18B)

A Blocked Jacobi Method for the Symmetric Eigenproblem

A block matrix generalization of the Jacobi rotation method for computing the eigendecomposition of a symmetric matrix is presented. This Blocked Classical Jacobi (BCJ) algorithm selects for block rotation at each step the off-diagonal block(s) of largest mass. The BCJ algorithm exhibits substantially shorter runtimes than other Jacobi-like methods, even though it performs more work per iteration. Timings and other data are presented from experiments on random matrices.

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#L-19/4:15 PM (Wed. May 25, Cont. Session 18B)

Effectively Well-Conditioned Linear Systems

When solving the linear system Ax = b, the condition number $K(A) = \|A\| \cdot \|A^{-1}\|$ is a useful, albeit often overly conservative, measure of the sensitivity of the solution x under perturbations ΔA and Δb to A and b. We demonstrate how the projection of b onto the range space of A, in addition to K(A), can strongly affect the sensitivity of x in specific problem instances. Two practical cases are presented in which the sensitivity of x can be substantially smaller than that predicted by K(A) alone, a class of Vandermonde matrices and an FFT-based fast Poisson solver.

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#L-20/4:45 PM (Wed. May 25, Cont. Session 18B)

LAPACK - A Portable, High-performance Linear Algebra Library

LAPACK is a library of portable, high-performance linear algebra subroutines being designed for use on supercomputers and shared-memory parallel processors, and covering most of the facilities offered by EISPACK and LINPACK. High-performance and portability will be achieved by constructing the library from the Level 3 BLAS, a set of Basic Linear Algebra Subroutines for matrix-matrix operations. The library will also include recently devised parallel divide and conquer algorithms for the symmetric eigenproblem and SVD. This work is a collaboration among Argonne National Lab, Courant Institute and the Numerical Algorithms Group.

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Jack Dongarra - Argonne National Lab, Argonne IL
Jeremy Du Croz - Numerical Algorithms Group Ltd, Oxford, England
Anne Greenbaum - Courant Institute
Sven Hammarling - Numerical Algorithms Group
Danny Sorensen - Argonne National Lab

#L-21/4:15 PM (Wed. May 25, Cont. Session 18C)

A New, More Accurate Singular Value Decomposition

Computing the singular values of a bidiagonal matrix is the final phase of the standard algorithm for the singular value decomposition of a general matrix. We present a new algorithm which computes all the singular values of a bidiagonal matrix to high relative accuracy independent of their magnitudes. In contrast, the standard algorithm for bidiagonal matrices may compute small singular values with no relative accuracy at all. Numerical experiments show that the new algorithm is comparable in speed to the standard algorithm, and frequently faster. We also show how to accurately compute tiny eigenvalues of some classes of symmetric tridiagonal matrices using the same technique.

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#L-22/4:30 PM (Wed. May 25, Cont. Session 18C)

Solving Sparse Linear Systems With Sparse Backward Error

When solving sparse linear systems, it is desireable to produce the solution of a nearby sparse system with the same sparsity structure as the original. Theorems of Oettli, Prager and Skeel show that one step of iterative refinement, even with single precision accumulation of residuals, guarantees such a sparse backward error under certain conditions on the matrix and right hand side. We incorporate these results into a sparse matrix solver and experimentally verify the predicted performance. Corresponding to this backward error is a condition number which may be much smaller that the usual one; we present an inexpensive estimator for this new condition number.

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Iain Duff - Comp. Sci. and Sys. Div., Harwell Lab, Didcot, England

#L-23/5:45 PM (Tue. May 24, Cont. Session 12)

On Structured Singular Values

Let $T=[[A,B];[C,D]]$ be a square, nonsingular 2 by 2 block matrix. We give explicit bounds, accurate to within a factor of at most 5.2, for the distance from T to the nearest singular matrix when only 1, 2, or 3 of T's subblocks may be perturbed. The bounds are in terms of norms of subblocks of T^{-1}. These results hold for all p-norms, and we present an inexpensive algorithm for estimating these bounds without explicitly computing T^{-1}. We extend some of these results to block 3 by 3 matrices. These results have applications in H^∞ control theory and stability analysis of various problems in linear algebra.

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#L-24/5:00 PM (Wed. May 25, Cont. Session 18D)

On a Block Implementation of Hessenberg QR Iteration

The usual QR algorithm for finding the eigenvalues of a Hessenberg matrix H is based on vector-vector operations, e.g. adding a multiple of one row to another. The opportunities for parallelism in such an algorithm are limited. Based on work of C. C. Paige, we have reorganized the work of QR to permit either matrix-vector or matrix-matrix operations to be performed, both of which yield more efficient implementations on parallel and vector machines. The idea is to chase a k by k bulge rather than a 1 by 1 or 2 by 2 bulge as in the standard algorithm. We will report on preliminary numerical experiments.

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#L-25/5:00 PM (Wed. May 25, Cont. Session 18B)

The SAS Domain Decomposition Method

Domain decomposition techniques have recently become an active area of research due to its potential for parallel computations. In this presentation, a special domain decomposition method for the efficient and parallelizable numerical handling for structural analyses using finite element discretizations will be presented. This method, referred to as the SAS domain decomposition method, has its origin in the idea of the traditional symmetrical and antisymmetrical approach. It takes advantage of the symmetry or partial symmetry of a physical problem via some interesting properties possessed by two special classes of matrices.

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#L-26/4:30 PM (Wed. May 25, Cont. Session 18D)

Signal Processing Applications of Modified Matrix Eigenvalue Problem

We consider the problem of determining the eigenvalues and eigenvectors of a matrix which is modified by a matrix of lower rank. Specifically this problem is formulated in a signal processing context where it is desirable to update and downdate a data matrix simultaneously. A new efficient algorithm for successive eigenvalue decomposition (EVD) is proposed. The algorithm involves a deflation procedure and some approaches for solving the small size EVD problem. This algorithm can be useful in adaptive array processing and tracking of non-stationary sinusoids.

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ADDENDUM

#L-27/4:15 PM (Wed. May 25, Cont. Session 18E)

Introduction to Qualitative Matrix Theory and the Perron Property of Sign Pattern Matrices

The basic definitions, ideas and questions of qualitative matrix theory are introduced. Techniques used to locate eigenvalues are specified. A combinatorial equivalent of the Perron-Frobenius theorem, that is, the characterization of sign patterns that require the Perron property is discussed. In addition, a sufficient condition for sign patterns to allow the Perron property is presented. Finally, a summary of the four major open questions concerning eigenvalue distribution is given in the concluding table.

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#L-28/4:45 PM (Wed. May 25, Contributed Sess. 18C)

Principals for Mapping and Scheduling Sparse Matrix Computations

There exists substantial data level parallelism in many applications. We are developing an automated system that is intended to organize the data and computation required for solving data parallel problems in ways that optimize multiprocessor performance. By capturing and manipulating representations of a computation at run-time, we are able to explore and implement rather general heuristics for partitioning program data and control. These heuristics are directed towards dynamic identification and allocation of concurrent work in computations with irregular computational patterns. In problems which involve repetitive patterns of computation, such as iterative methods seen in scientific computations; we calculate an optimized static workload partitioning.

The system is structured as follows: An appropriate level of granularity is first selected for the computations. A directed acyclic graph representation of the program is generated. Parallelization is identified and various workload clustering or aggregation techniques are employed in order to generate efficient schedules. These schedules are then mapped onto the target machine. When computations are irregular, this graph and schedule generation can proceed throughout the course of the computation.

We describe some initial results from experiments conducted on the Intel Hypercube and the Encore Multimax that indicate the usefulness of our approach.

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#L-29/4:15 PM (Wed.May 25, Contributed Sess.18D)

One Generator Matrix Algebras Associated with a Commutative Set of (-1,0,1)-Matrices and the Klein-Gordon Equation

The commutative spaces $A=\sum_{s=1}^{n} a_s J_s$ were studied by Zellini, Chao, Zellini-Mack and Grone-Hoffman-Wall. In case when A happens to be a one generator matrix algebra genrated by H i.e. $A=R[H] \cong R[X]/\langle p(X)\rangle$, $R \in$ Reals, p(X) the minimal polynomial of the non-deregatory matrix H. It is possible to change the (0,1)-matrix into (-1,0,1)-matrix by simply changing an arbitrary number of +1's into -1's. This adds an extra advantage to the related algebra $\bar{A}=\sum^{n} a_s \bar{J}_s$ as regards its applications. Moreover if p(X) has distinct zeros over the complex field, the computation is easily done by breaking H into 'structure' and 'informal content'. Thus we approach a beautiful algebra providing best solutions.

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#L-30/4:45 PM (Wed. May 25, Contributed Sess. 18D)

A Procedure for Fast QR Factorization of Structured Matrices

A procedure is described to derive fast QR factorizations of the form $Y = QR$, for Toeplitz, Hankel, and Vandermonde matrices. The complexity is $O(mn)$. A low rank reduction is used to obtain recursions on the columns of the Cholesky factor of the inverse Grammian $(Y^{\#}Y)^{-1}$. In the Toeplitz case, this is the generalized Levinson's algorithm. These recursions are then used to derive independent recursions on the columns of Q and the rows of R. The special case of Toeplitz and Vandermonde matrices is presented in detail, as these matrices arise in least squares estimation problems in digital signal processing.

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Liu, J. W. H.	Wed. PM	1:30	1:45	C/P 16	A38	BR A-B
Lund, John	Mon. PM	1:45	2:00	C/P 4	A18	State BC
Lund, John	Mon. PM	5:45	6:00	C/P 7	A48	State A
Lutz, Donald	Tue. AM	10:15	10:30	C/P 9	A28	State A
M						
Ma, Shing C.	Mon. PM	2:00	2:15	C/P 5	A20	State A
Maier, Robert	Mon. PM	1:45	2:00	C/P 5	A20	State A
Marcus, Marvin	Mon. AM	11:00	11:15	C/P 1	A15	Empire
Marshall, T.	Tue. PM	5:15	5:30	C/P 13	A34	State A
Mathias, R.	Mon. AM	11:30	11:45	C/P 1	A15	Empire
Maybee, John	Mon. PM	4:30	5:00	M/S 4	A3	BR A-B
McCormick, Steve	Thu. PM	2:45	3:15	M/S 15	A14	Empire
McCormick, Steve	Tue. AM	09:15	09:30	C/P 9	A27	State A
Mehrmann, Volker	Mon. PM	4:30	5:00	M/S 5	A4	Empire
Mehrmann, Volker	Mon. PM	5:00	5:30	M/S 5	A5	Empire
Meyer, Carl	Tue. PM	4:30	4:45	C/P 12	A31	State BC
Meza, Juan	Mon. PM	5:45	6:00	C/P 6	A23	State BC
Michael, T. S.	Wed. AM	09:30	09:45	C/P 14	A36	State BC
Mikulecky, D. C.	Tue. PM	4:45	5:00	C/P 13	A33	State A
Miller, David	Thu. AM	08:45	09:00	C/P 20	A42	Empire
Mittnik, Stefan	Tue. AM	09:00	09:15	C/P 8	A25	BR B-C
Moonen, Marc	Wed. AM	09:30	10:00	M/S 13	A12	Empire

C/P = Contributed Presentations
I/P = Invited Presentations
M/S = Minisymposium
S/C = Short Course

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NAME	DAY	TIME	ENDTIME	SESSION	ABSTPAGE	ROOM
Tsing, Nam-Kiu	Mon. AM	11:15	11:30	C/P 1	A15	Empire
Tsing, Nan-Kiu	Thu. AM	09:15	09:30	C/P 21	A43	State BC
U						
V						
van den Driessche, P.	Mon. PM	5:00	5:30	M/S 4	A4	BR A-B
Van Dooren, P.	Thu. AM	09:45	10:45	I/P 6	3	BR A-B
Van Huffel, S.	Wed. AM	09:30	10:00	M/S 13	A12	Empire
Van Loan, Charles	Mon. PM	3:00	3:30	M/S 3	A3	Empire
Vandewalle, Joos	Wed. AM	09:30	10:00	M/S 13	A12	Empire
Varga, Richard	Tue. AM	08:30	09:00	M/S 6	A5	BR A-B
Vavalis, E.	Thu. PM	3:15	3:45	M/S 15	A14	Empire
Vemulapati, U. B.	Thu. AM	09:15	09:30	C/P 22	A49	State A
Veselic, Kresimir	Thu. PM	3:15	3:45	M/S 14	A13	BR A-B
Vinella, Peter	Thu. PM	2:45	3:00	C/P 23	A45	State BC
Vinnikov, V.	Wed. PM	1:45	2:00	C/P 18A	A47	Director 6
Viswanathan, T.M.	Mon. AM	11:45	12:00	C/P 3	A17	State A
W						
Wachpress, E. L.	Mon. PM	3:15	3:30	C/P 5	A 50	State A
Wahba, Grace	Wed. AM	10:00	10:30	M/S 13	A12	Empire
Watkins, David	Tue. PM	4:15	4:45	M/S 11	A9	Empire
Weaver, James	Thu. AM	08:30	08:45	C/P 21	A43	State BC
Wei, Musheng	Thu. PM	2:45	3:00	C/P 24	A50	State A
Welstead, Stephen	Tue. AM	09:45	10:00	C/P 9	A28	State A
Wijshoff, Harry	Thu. AM	09:00	09:15	C/P 22	A44	State A
Willoughby, R.	Thu. PM	2:15	2:45	M/S 14	A13	BR A-B
Wolkowicz, Henry	Mon. PM	5:00	5:15	C/P 7	A24	State A
Wollan, Peter	Thu. PM	3:00	3:15	C/P 23	A45	State BC
Wood, David H.	Tue. PM	5:00	5:15	C/P 12	A31	State BC
X						
Y						
Yip, Elizabeth	Mon. PM	4:45	5:00	C/P 7	A24	State A
Z						
Zaballa, Ion	Wed. PM	2:00	2:15	C/P 18A	A47	Director 6
Zhang, He	Wed. AM	08:45	09:00	C/P 15	A36	State A

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ADDENDUM

Name	Day	Time	End-Time	Session	Abst. Page	Room
Budde, K.	Wed. PM	5:00	5:15	C/P 18E		State B-C
Chen, H-C.	Wed. PM	5:00	5:15	C/P 18B	A52	Empire
Demeure, C. J.	Wed. PM	4:45	5:00	C/P 18D	A53	State A
Demmel, J.	Wed. PM	5:00	5:15	C/P 18D	A52	State A
Demmel, J.	Tue. PM	5:45	6:00	C/P 12	A52	State B-C
Demmel, J.	Wed. PM	4:30	4:45	C/P 18C	A52	BR A-B
Demmel, J.	Wed. PM	4:15	4:30	C/P 18C	A52	BR A-B
Eschenbach, C.	Wed. PM	4:15	4:30	C/P 18E	A53	State B-C
Foulser, D. E.	Wed. PM	4:15	4:30	C/P 18B	A51	Empire
Foulser, D. E.	Wed. PM	4:30	4:45	C/P 18B	A51	Empire
Hammarling, S.	Wed. PM	4:45	5:00	C/P 18B	A51	Empire
Narang, P. D.	Wed. PM	4:15	4:30	C/P 18D	A53	State A
Overton, M.	Wed. PM	4:30	4:45	C/P 18E		State B-C
Saltz, Joel	Wed. PM	4:45	5:00	C/P 18C	A53	BR A-B
Usmani, R. A.	Wed. PM	5:00	5:15	C/P 18C		BR A-B
Yu, Kai-Bor	Wed. PM	4:30	4:45	C/P 18D	A52	State A

REGISTRATION INFORMATION

The registration desk will be open as listed below:

Saturday, May 21	5:00 PM–9:00 PM
Sunday, May 22	7:00 AM–9:00 PM
Monday, May 23	7:00 AM–6:00 PM
Tuesday, May 24	8:00 AM–6:00 PM
Wednesday, May 25	8:00 AM–5:30 PM
Thursday, May 26	8:00 AM–3:00 PM

Non SIAM Members
Non-member registrants are encouraged to join SIAM in order to obtain the member rate for meeting registration and enjoy all the other benefits of SIAM membership.

Special Note
There will be no prorated fees. No refunds will be issued once the meeting has started.

Credit Cards
SIAM is now accepting American Express, VISA, and MasterCard credit cards for the payment of registration fees and special functions.

SIAM CORPORATE MEMBERS
Non-member attendees who are employed by the following institutions are entitled to the SIAM member rate.

Aerospace Corporation
Amoco Production Company
AT&T Bell Laboratories
Bell Communications Research
Boeing Company
Cray Research, Inc.
Culler Scientific Systems Corporation
E.I. Du Pont de Nemours and Company
Eastman Kodak Company
Exxon Research and Engineering Company
General Electric Company
General Motors Corporation
Giers Schlumberger
GTE Laboratories, Inc.
Hollandse Signaalapparaten B.V.
IBM Corporation
Institute of Computer Applications in Science and Engineering (ICASE)
IMSL, Inc.
MacNeal-Schwendler Corporation
Marathon Oil Company
Martin Marietta Energy Systems
Mathematical Sciences Research Institute
Standard Oil Company of Ohio (SOHIO)
Supercomputing Research Center, a division of Institute for Defense Analyses
Texaco, Inc.
United Technologies Corporation

REGISTRATION FEES:

		SIAG/LA	SIAM Member	Non Member	Students
Short Course	Advance	$95	$95	$115	$50
	On-Site	$115	$115	$135	$65
Conference	Advance	$95	$100	$130	$20
	On-Site	$125	$130	$160	$20

Welcoming Reception
Sunday, May 22 8:00 PM–10:00 PM
Diplomat Rooms
Cash Bar

Beer Party
Monday, May 23 6:00 PM–8:00 PM
Diplomat Rooms
$12.00

Banquet
Wednesday, May 25, 6:00 PM
Memorial Union, University of Wisconsin
Speaker: Hans Schneider, University of Wisconsin, Madison "When Does Linear Algebra Become Applied?"
Cash Bar: 6:00 PM–7:00 PM
Buffet Dinner: 7:00 PM
$15.00

GENERAL INFORMATION

BOOK EXHIBITS

The exhibits will be in the Diplomat Rooms of the hotel. The exhibit times are as follows:

Sunday, May 22	8:00 PM–10:00 PM
Monday, May 23	10:00 AM– 8:00 PM
Tuesday, May 24	10:00 AM– 5:00 PM
Wednesday, May 25	10:00 AM– 4:00 PM

The exhibits setup time will begin at 12:00 noon, Sunday, May 22; dismantling will begin at 4:00 PM, Wednesday, May 25.

Special Notice To:
All Conference Participants

SIAM requests conferees to refrain from smoking in the session rooms during lectures. Thank you.