Second SIAM Conference on Applied Linear Algebra

April 29–May 2, 1985
Mission Valley Inn
Raleigh, North Carolina

- Core Linear Algebra
- Industrial Applications
- Computer Demonstrations
- Numerical Methods
- Parallelism
- Matrix Methods in Partial Differential Equations
- Perturbation Theory of Operators
- Matrix Polynomials
- Applications of Linear Algebra in Discrete Mathematics, Statistics, Population Biology, Engineering, and Control and Systems Theory

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CONFERENCE COMMITTEE

Richard A. Brualdi (Co-chairman),
  University of Wisconsin—Madison
Hans Schneider (Co-chairman), University of
  Wisconsin—Madison
Gene H. Golub, Stanford University
Carl D. Myer, Jr., North Carolina State
  University
Robert J. Plemmons, North Carolina State
  University
Donald Rose, Duke University

FUNDING SOURCES

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partial support of the Air Force Office of Sci-
entific Research, the Army Research Office,
the Department of Energy and the National
Science Foundation.

*Cover photograph graciously provided by
the Information Service Department of North
Carolina State University and the Raleigh
Convention and Visitors Bureau.*

MEETING HIGHLIGHTS

INVITED PRESENTATIONS

Monday, April 29, 9:30 AM
Invited Presentation 1
PERTURBATION THEORY OF OPERATORS

In numerical analysis and in physics it is often
necessary to estimate the difference between cor-
responding eigenvalues and corresponding eigen-
vectors of two operations, in terms of the norm of
their difference. In recent years our knowledge
has grown markedly: the class of operators admit-
ted has been extended, hypotheses have been
weakened in other respects, and constants have
been improved. In this presentation the focus will
be on exact perturbation theory, where explicit in-
equalities are sought (vis-a-vis asymptotic pertur-
bation theory, which concerns rate of convergence
to zero only).

Chandler Davis
Department of Mathematics
University of Toronto
Toronto, Ontario, Canada

Monday, April 29, 11:00 AM
Invited Presentation 2
MATRIX POLYNOMIALS

Problems concerning matrix polynomials fre-
quently arise in systems theory and applied mathe-
matics, and many of these problems are clarified
by the application of spectral theory.
  The speaker will focus on basic ideas of spectral
theory as they apply to these problems—canonical
forms, least common multiples and greatest com-
mon divisors, factorization problems, inverse
spectral problems, and the special structure and
problems associated with hermitian matrix poly-
nomials.

Peter Lancaster
Department of Mathematics and Statistics
University of Calgary
Calgary, Alberta, Canada

Monday, April 29, 3:00 PM
Invited Presentation 3
**MATRIX METHODS IN THE NUMERICAL
SOLUTION OF PARTIAL DIFFERENTIAL
EQUATIONS**

The numerical solution of partial differential equa-
tions leads to the study of the eigenvalues of fami-
lies of matrices. These matrices may arise in
boundary value problems and in evolution equa-
tions. In both cases the "stability" and "rapidity
of convergence" of the numerical methods are
governed by the asymptotic behavior of their spec-
tra. In some problems it is sufficient to estimate
the spectral radius, for others a more detailed
knowledge of the distribution of the eigenvalues is
required. In this presentation the speaker will de-

scribe how these matrix problems arise and how
results of matrix theory can be applied.

Seymour V. Parter
Department of Mathematics and Mathematics
Research Center
University of Wisconsin—Madison
Madison, WI

Tuesday, April 30, 11:00 AM
Invited Presentation 4
**NUMERICAL AND COMPUTATIONAL
METHODS IN LINEAR ALGEBRA**

One problem of fundamental importance in control
theory is to compute a matrix function f(A) in an
effective and stable manner. In carrying out the
computation, it is necessary to determine invariant
subspaces of dimensions as low as possible consis-
tent with their being relatively insensitive to per-
turbations in A. The grouping of the eigenvalues
for this purpose involves very delicate considera-
tions which are closely related to those involved in
determining neighboring defective matrices. The
speaker will cover both of these numerical prob-
lems and highlight their relationships.

James H. Wilkinson
National Physical Laboratory
United Kingdom

Tuesday, April 30, 3:00 PM
Invited Presentation 5
**WHY I AM CARRYING A TORCH
FOR MATRIX THEORY**

It is planned to discuss the manner in which ma-
trices as a subject in itself came to the speaker, not
only attached to groups, or used in physics or
statistics. A few instances are: the Gersgorin the-
orem that came to her from algebraic number
theory, the Stein theorem and hence also the
Lyapunov theorem that came from topological al-
gebra. Suddenly numerical analysis and hence ap-
plied mathematics were swarming with non-trivial
applications of matrices. Some strange circum-
stances brought her to the Shoda theorem con-
cerning commutators of matrices and others to the
application of matrices in algebraic number the-
ory. There, she was able to use the eigenvectors of
matrices as bases for ideals.

Olga Taussky-Todd
Department of Mathematics
California Institute of Technology
Pasadena, CA

Wednesday, May 1, 9:30 AM
Invited Presentation 6
**PARALLEL ALGORITHMS IN
LINEAR ALGEBRA**

In spite of some earlier interesting research com-
puters at universities, we are just beginning to
have readily available machines of MIMD type

where each processor may execute its own inde-
pendent instruction stream in an asynchronous
fashion. Unfortunately, very few algorithms have
been developed to take advantage of this poten-
tially powerful approach to computing.
  This talk will focus on three techniques that can
be useful in developing parallel algorithms and one
that can be misleading. The three useful para-
digms are: changing the order of the computation,
computing asynchronously, and applying the
divided and conquer concept. These will be illus-
trated with examples from linear algebra.
  Unfortunately, computation complexity, a power-
ful tool for the numerical analyst, can lead to the
development or selection of algorithms that are
not optimal in a parallel computing environment.
This weakness will also be demonstrated by an ex-
ample from linear algebra.

Robert G. Voigt
ICASE, NASA Langley Research Center
Hampton, VA

Wednesday, May 1, 11:00 AM
Invited Presentation 7
**LINEAR ALGEBRA INDISCRETE
MATHEMATICS AND COMBINATORICS**

Combinatorics and linear algebra have had a long
history of fruitful interaction. A classical case of
this is the Perron-Frobenius theory of non-negative
matrices where the diagraph associated with a ma-
trix gives information on the spectrum. Another
comprises the graph-theoretic methods which are
important for the analysis of large sparse matrices
and in developing optimal pivoting strategies in
Gaussian elimination. Conversely, linear algebra
has been useful in solving combinatorial problems,
in particular the field of algebraic graph theory is
partly concerned with linear algebraic techniques
in graph theory.
  In this presentation, the speaker will describe
some recent developments in several combinatorial
areas where linear algebra plays a significant role.
One topic of particular focus will be that of
representing the distance structure in a graph by
means of vectors in R^n.

Ronald L. Graham
Mathematical Sciences Research Center
AT&T Bell Laboratories
Murray Hill, NJ

Wednesday, May 1, 3:00 PM
Invited Presentation 8
**LINEAR ALGEBRAIC METHODS IN
MULTIVARIATE STATISTICAL ANALYSIS**

Because multivariate statistical analysis is based
on observations of vector quantities, it is natural to
expect the tools of linear algebra to provide the
relevant mathematical techniques. The speaker
will examine the connections between multivariate
analysis and linear algebra: (1) multivariate distri-

bution theory including Jacobians of matrix transformations, functional equations with matrix arguments, and matrix representations and (2) multivariate inequalities including stochastic inequalities, eigenvalue inequalities, and partial ordering.

Ingram Olkin
Department of Statistics
Stanford University
Stanford, CA

Thursday, May 2, 9:30 AM
Invited Presentation 9
LINEAR ALGEBRA IN ENGINEERING, CONTROL AND SYSTEMS THEORY

From one point of view, the Schubert calculus is a tool for understanding certain families of simultaneous equations which involve determinants. It makes substantial contact with linear algebra and combinatorics and, potentially, is of interest in a wide variety of applied problems. Recently, it has been used to understand the inverse eigenvalue problems which arise in control theory and in this context, some computational experience has been gained. In this talk we will survey recent progress in this area.

Roger W. Brockett
Division of Engineering and Applied Physics
The Aiken Computation Laboratory
Harvard University
Cambridge, MA

Thursday, May 2, 11:00 AM
Invited Presentation 10
LINEAR ALGEBRA IN POPULATION BIOLOGY

The purpose of this talk is to show how thinking about population biology leads to new questions in linear algebra (and, of course, other parts of mathematics). I aim to give three examples of linear algebraic problems raised by models in population biology which are now solved and at least three such questions that are still open. Audience participation in answering the questions is invited.
   The solved problems involve the perturbation theory of nonnegative matrices, the combinatorics of multiplying different nonnegative matrices, and eigenvalue inequalities for products of matrix exponentials. Some unsolved problems involve more eigenvalue inequalities for products of matrix exponentials, discontinuities in ergodic behavior of inhomogeneous matrix products, and additive decompositions of nonnegative matrices. Time permitting, I will mention some recent developments in areas such as random matrices and nonlinear models.

Joel E. Cohen
Laboratory of Populations
Rockefeller University
New York, NY

MINISYMPOSIA

Tuesday, April 30, 4:00 PM
Minisymposium 1
EXACT COMPUTATION IN LINEAR ALGEBRA

We will survey the activity that has become known as "Computer Algebra." The capabilities of existing computer algebra systems for computation with matrices over the integers, rational numbers, polynomials and other domains will be discussed and demonstrated. The role of a computer algebra package as a research tool, as a teaching tool, and as a source of research problems in linear algebra will be shown.

CHAIRMAN AND ORGANIZER
B. David Saunders
Computer Science Department
Rensselaer Polytechnic Institute, Troy NY
Currently visiting:
Computer and Information Sciences Department
University of Delaware, Newark, DE

A Symbolic Computation Package for *-Semirings in REDUCE
S. Kamal Abdali
Computer Research Laboratory
Tektronix, Inc., Beaverton, OR

Exact Linear Algebra with a PC
William Squire
Department of Mechanical and Aerospace Engineering
West Virginia University, Morgantown, WV

MAPLE: A New Computer Algebra System
Bruce W. Char
Computer Science Department
University of Waterloo, Waterloo Ontario, Canada

Fast Computation of Invariant Factors: Probabilistic and Modular Methods
Erich L. Kaltofen
Mukkai S. Krishnamoorthy
Department of Computer Science
Rensselaer Polytechnic Institute, Troy, NY
and
B. David Saunders

Demonstrations of computer algebra systems such as MuMath, MAPLE and REDUCTION.

Wednesday, May 1, 4:00 PM
Minisymposium 2
INDUSTRIAL APPLICATIONS OF LINEAR ALGEBRA

Matrix computation is at the heart of many mathematical modeling problems. In this session we will examine some of these matrix problems for modeling in electronics, geology, and structural analysis. The speakers will review the physical motivation, matrix characteristics, and computational approaches to these diverse problems. Though the matrix problems have similar characteristics (generally large and sparse) they are also very different in other ways (e.g. sparsity pattern, numerical properties, symmetry, solution objectives) and these differences give rise to different solution approaches.

CHAIRMAN AND ORGANIZER
Al Erisman
Boeing Computer Services
Tukwila, WA

Matrix Computation in Electronics CAD Software
A. E. Ruehli
Computer Science Department
F. Odeh
Mathematical Science Department
IBM—T. J. Watson Research Center
Yorktown Heights, NY

The Linear Algebra of Seismic Modeling
R. P. Bording
K. R. Kelly
K. J. Marfurt
Amoco Production Company
Research Center
Tulsa, OK

Symmetric Generalized Eigenproblems in Structural Engineering
Roger G. Grimes
John G. Lewis
Horst D. Simon
Applied Mathematics Department
Boeing Computer Services Co.
Tukwila, WA
Louis Komzsik
The MacNeal Schwendler Corporation
Los Angeles, CA
David S. Scott
Department of Computer Science
The University of Texas
Austin, TX

Some Sparse Matrix Problems in Structural Analysis
Michael T. Heath
Oak Ridge National Laboratory
Oak Ridge, TN

COMPUTER DEMONSTRATIONS

Garry Helzer of the Mathematics Department of the University of Maryland will demonstrate the computer language APL and its use in performing matrix calculations. Cleve Moler of The Mathworks will demonstrate PC MATLAB, a new version of the "Matrix Laboratory." There will be computer demonstrations in connection with the minisymposium on Exact Computations in Linear Algebra, organized by B. David Saunders of the Computer Science Department of Rensselaer Polytechnic Institute.

SPECIAL FUNCTIONS

Welcoming Reception
Sunday, April 28, 8:00 PM
Location to be announced at Registration Desk
Wine and beer courtesy of North Carolina State University

Cocktails and Hors d' Oeuvres
Monday, April 29, 6:30 PM
Mission Valley Inn, Poolside
Open Bar: $10.00

Wine and Cheese Party
Tuesday, April 30, 6:30 PM
North Carolina State University
Wine and cheese courtesy of North Carolina State University

Banquet
Wednesday, May 1, 7:00 PM
North Carolina State University
BANQUET SPEAKER:
William M. Kahan, University of California, Berkeley
Dinner and Wine: $10.00

INVITED PRESENTATIONS, MINISYMPOSIA AND CONTRIBUTED PAPERS

MONDAY, APRIL 29

TIME A.M.	I/S (Cameron-Mordecai Rm.)		TIME P.M.	I/S (Cameron-Mordecai Rm.)
9:30	C. Davis		3:00	S. V. Parter
11:00	P. Lancaster			

P.M.	C/P 1 (Cameron Rm.)	C/P 2 (Haywood Rm.)	C/P 3 (Hinsdale Rm.)
1:00	M. T. Heath* / A. George / J. Liu	C. R. Johnson / D. D. Olesky* / P. van den Driessche	S. Demko
1:15	L. L. Scharf* / C. Demeure	A. A. Ahac* / D. D. Olesky	E. J. Brunelle
1:30	G. A. Geist* / R. E. Funderlic	H. Schneider / J. L. Stuart*	R. O. Hill
1:45	F. T. Luk* / S. Qiao	E. Deutsch / M. Neumann*	C. C. Blackwell
2:00	D. C. Fisher	J. J. Buoni	F. Chatelin
2:15	B. N. Datta* / K. Datta	R. DeMarr	L. Kaufman

	C/P 4 (Cameron Rm.)	C/P 5 (Hinsdale Rm.)	C/P 6 (Haywood Rm.)
4:00	J. H. Bramble / A. H. Schatz / J. E. Pasciak*	R. A. Horn* / Y. Hong	D. D. Warner / K. L. Fox*
4:15	S. Gupta / J. L. Barlow*	Y. Hong* / R. A. Horn	B. E. Cain* / E. H. Johnston
4:30	A. Genz / D. A. Swayne*	D. Choudhury* / R. A. Horn	R. K. Yedavalli
4:45	M. M. Gupta	A. R. Sourour	R. Beatson

TUESDAY, APRIL 30

TIME A.M.	C/P 7 (Cameron Rm.)	C/P 8 (Hinsdale Rm.)	C/P 9 (Haywood Rm.)
8:30	S. Pierce	R. E. White	R. Manber* / J. Shao
8:45	A. Berman / M. Neumann / R. Stern*	C. Beattie* / J. Schug / J. Viers / L. Watson	J. S. Maybee / G. M. Wiener*
9:00	W. N. Anderson / G. E. Trapp*	Y. Saad	W. W. Barrett* / C. R. Johnson
9:15	W. N. Anderson* / G. E. Trapp	M. W. Berry	S. Ursic
9:30	C. R. Johnson	V. B. Aggarwall / S. K. Dhall / J. C. Diaz* / S. Lakshmivarahan	T. F. Coleman* / J. Cai
9:45	C. R. Johnson / H. Shapiro*	J. M. Delosne* / I. C. F. Ipsen	T. F. Coleman / A. Pothen*
10:00	D. Hershkowitz* / H. Schneider		J. J. Cade
10:15	U. G. Rothblum* / C. P. Tan		R. Palazzo
11:00	I/S (Cameron-Mordecai Rm.) J. H. Wilkinson		

P.M.	C/P 10 (Cameron Rm.)	C/P 11 (Hinsdale Rm.)	C/P 12 (Haywood Rm.)
1:00	P. G. Coxson	K. Datta	D. M. Gay
1:15	S. J. Fu / M. E. Sawan*	L. J. Gerstein	F. T. Luk / S. Qiao*
1:30	J. Gregory* / R. Dalpatadu	J. Jones	C. Ashcraft
1:45	V. Mehrmann* / A. Bunse-Gertsner	J. T. B. Beard	F. J. Servedio
2:00	R. E. Fennell* / J. A. Reneke / S. B. Black	H. K. Wimmer	E. M. Borasky
2:15	C-C. Tsui	L. G. Sweet* / J. A. MacDougall	E. R. Ducot / V. C. Klema*

I/S

(Cameron-Mordecai Rm.)

3:00 Olga Taussky-Todd

Codes: I/S = Invited Speaker   C/P = Contributed Paper

* = Indicates the presenter of the paper when more than
one author is given.

INVITED PRESENTATIONS, MINISYMPOSIA AND CONTRIBUTED PAPERS

TUESDAY, APRIL 30 (continued)

M/S 1 (Cameron Rm.)	TIME P.M.	C/P 13 (Hinsdale Rm.)		
4:00 PM	4:00	W. B. Gragg* / W. J. Harrod	5:00	D. R. Phillips
S. K. Abdali	4:15	A. Bunse-Gertsner	5:15	E. L. Wachpress
W. Squire	4:30	M. A. Brebner	5:30	D. S. Watkins
B. W. Char	4:45	C. R. Vogel	5:45	D. R. Phillips
B. D. Saunders				

TIME P.M.	C/P 14 (Haywood Rm.)		
4:00	P. J. Kempthorne	5:00	W. W. Piegorsch* / G. Casella
4:15	C. L. Stunkard	5:15	E. Stallard* / M. A. Woodbury / K. G. Manton
4:30	J. Cabrera / G. S. Watson*		
4:45	K. S. Arun* / S-Y. Kung	5:30	M. Haviv

WEDNESDAY, MAY 1

TIME A.M.	C/P 15 (Cameron Rm.)	C/P 16 (Hinsdale Rm.)	C/P 17 (Haywood Rm.)
8:30	D. W. Sharp	O. Yamano* / K. Furuta	R. Kittappa
8:45	H. C. Elman	M. Togai	C. Beattie* / M. Boisen / L. Johnson
9:00	L. T. Watson	D. W. Tufts* / S. Parthasarathy	N. Bebiano
9:15	R. E. Parkin	J. M. Speiser	J. P. Milaszewicz* / L. Moledo

	I/S (Cameron-Mordecai Rm.)
9:30	R. G. Voigt
11:00	R. L. Graham

	C/P 18 (Cameron Rm.)	C/P 19 (Hinsdale Rm.)	C/P 20 (Haywood Rm.)
1:00	V. Pan	B. F. Wyman	P. N. Brown* / A. C. Hindmarsh
1:15	D. Boley	S-Y. Zhang	B. E. Howard
1:30	R. E. Benner* / D. K. Gartling / G. G. Weigand	S. J. Fu / M. E. Sawan*	G. H. Guirguis
1:45	V. Pan* / J. Reif	S. Mittnik	P. N. Shivakumar
2:00	P. J. Eberlein	R. Byers	
2:15	D. Bini* / V. Pan	G. A. Hewer* / C. Kenney	

TIME P.M.	I/S (Cameron-Mordecai Rm.)
3:00	I. Olkin

M/S 2 (Cameron Rm.)	TIME P.M.	C/P 21 (Hinsdale Rm.)	C/P 22 (Haywood Rm.)
4:00			
A. Ruehli* / F. Odeh	4:00	B. W. Peyton	L. Kaufman
	4:15	S. Chaiken	H. Lev-Ari
R. P. Bording / K. R. Kelly / K. J. Marfurt*	4:30	X. Lin	S. K. Abdali / B. D. Saunders*
R. G. Grimes / J. G. Lewis* / H. D. Simon / L. Komzsik / D. S. Scott	4:45	M. McAllister	D. Summers
	5:00	S. J. Dow / P. M. Gibson*	J. Doyle
M. T. Heath	5:15	S. Friedland	F. Uhlig
	5:30		G. P. Barker / M. Laidacker / G. D. Poole*

Codes: I/S = Invited Speaker
M/S = Minisymposium
C/P = Contributed Paper
* = Indicates the presenter of the paper when more than one author is given.

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INVITED PRESENTATIONS, MINISYMPOSIA AND CONTRIBUTED PAPERS

THURSDAY, MAY 2

TIME A.M.	C/P 23 (Cameron Rm.)	C/P 24 (Hinsdale Rm.)	C/P 25 (Haywood Rm.)
8:30	D. W. Robinson	J-S. Pang	B. N. Parsons
8:45	R. Merris	D. B. Szyld	M. Eiermann
9:00	L. B. Beasley	M. Frank	G. Sewell
9:15	D. Carlson* D. Hershkowitz	R. E. Funderlic* C. D. Meyer	B. J. Philippe

I/S (Cameron-Mordecai Rm.)

TIME A.M.	
9:30	R. W. Brockett
11:00	J. E. Cohen

TIME P.M.	C/P 26 (Cameron Rm.)	C/P 27 (Hinsdale Rm.)	C/P 28 (Haywood Rm.)	C/P 29 (Mordecai Rm.)
1:00	E. Moore	T. F. Chan D. C. Resasco*	S. K. Dey	B. N. Datta D. Pierce*
1:15	M. Artzrouni	M. T. Chu	L. J. Senechal	K. P. S. Bhaskara Rao
1:30	J. R. Weaver* D. L. Sherry	W. Squire	J. S. Weber	J. L. Goldwasser
1:45	H. Robert van der Vaart	S. J. Leon	D. W. F. Wendt	B. Grone
2:00		D. St. Clair Scott	W. F. Moss* P. W. Smith J. D. Ward	J. F. Queiro
2:15		E. Zmijewski* J. R. Gilbert	J. A. Ball	J. G. Lewis* H. D. Simon
2:30		D. R. Phillips	E. L. Yip	M. Jeter* W. C. Pye
2:45		V. Pan* J. Reif	A. Paulraj* T. Kailath	C. E. Robinson

Codes: I/S = Invited Speaker
C/P = Contributed Paper
* = Indicates the presenter of the paper when more than one author is given.

FINAL PROGRAM

Sunday, April 28 / PM

5:00 PM
Registration Opens
Prefunction Area

8:00 PM
Welcoming Reception

10:00 PM
Registration Closes

Monday, April 29 / AM

8:00 AM
Registration Opens
Prefunction Area

9:00 AM/Cameron-Mordecai Room
Opening Remarks

Richard A. Brualdi, Department of Mathematics, University of Wisconsin-Madison; Garrett Briggs, Dean of the School of Physical and Mathematical Sciences, North Carolina State University; and Gene H. Golub, SIAM President, Department of Computer Science, Stanford University

9:30 AM/Cameron-Mordecai Room
Invited Presentation 1
Richard A. Brualdi, CHAIRMAN
Department of Mathematics
University of Wisconsin—Madison, Madison, WI

PERTURBATION THEORY OF OPERATORS
Chandler Davis
Department of Mathematics
University of Toronto, Toronto, Ontario, Canada

10:30 AM/Coffee

11:00 AM/Cameron-Mordecai Room
Invited Presentation 2
Robert J. Plemmons, CHAIRMAN
Department of Mathematics
North Carolina State University, Raleigh, NC

MATRIX POLYNOMIALS
Peter Lancaster
Department of Mathematics and Statistics
University of Calgary, Calgary, Alberta, Canada

Monday, April 29 / PM

12:00 Noon/Lunch

Monday, April 29/**1:00–2:30 PM**
Contributed Papers 1/Cameron Room

PARALLEL MATRIX COMPUTATIONS
CHAIRMAN: Robert C. Ward, Mathematics & Research Section, Engineering Physics and Mathematics Division, Oak Ridge National Laboratory, Oak Ridge, TN

1:00
Parallel Cholesky Factorization on a Multiprocessor
Michael T. Heath, Oak Ridge National Laboratory, Oak Ridge, TN; Alan George, Faculty of Mathematics, University of Waterloo, Waterloo, Ontario, Canada; Joseph Liu, Department of Computer Science, York University, Downsview, Ontario, Canada

1:15
Vectorizing the Computation of Cholesky Factors, Reflection Coefficients, and Kalman Gains in Toeplitz Systems
Louis L. Scharf, Electrical and Computer Engineering, University of Colorado, Boulder, CO; Cedric Demeure, Electrical Engineering, University of Rhode Island, Kingston, RI

1:30
Torus Data-Flow for Parallel Computation of Missized Matrix Problems
George A. Geist, R. E. Funderlic, Oak Ridge National Laboratory, Oak Ridge, TN

1:45
A Linear Time Method for Computing the CS-Decomposition
Franklin T. Luk, School of Electrical Engineering, Cornell University, Ithaca, NY; Sanzheng Qiao, Center for Applied Mathematics, Cornell University, Ithaca, NY

2:00
Fast Matrix Multiplication on Square and Cubic Grids of Processors
David C. Fisher, Applied Mathematics Program, University of Maryland, College Park, MD

2:15
Efficient Parallel Algorithms for Inertia, Stability, Relative Primeness and Lyapunov Equation
B. N. Datta and Karabi Datta, Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL

Monday, April 29/**1:00–2:30 PM**
Contributed Papers 2/Haywood Room

M—MATRICES
CHAIRMAN: Hans Schneider, Department of Mathematics, University of Wisconsin—Madison, Madison, WI

1:00
Stability of M-matrix Products
Charles R. Johnson, Department of Mathematical Sciences, Clemson University, Clemson, SC; D. D. Olesky, Department of Computer Science, University of Victoria, Victoria, B.C., Canada; P. van den Driessche, Department of Mathematics, University of Victoria, Victoria, B.C., Canada

1:15
Solving Ax = b when A is a Nonsingular M-matrix
Alan A. Ahac and D. D. Olesky, Department of Computer Science, University of Victoria, Victoria, B.C., Canada

1:30
Products of Commuting MMA-matrices
Hans Schneider and Jeffrey L. Stuart, Department of Mathematics, University of Wisconsin—Madison, Madison, WI

1:45
Second Order Derivatives of the Perron Vector
Emeric Deutsch, Department of Mathematics, Polytechnic Institute of New York, Brooklyn, NY; Michael Neumann, Department of Mathematics and Statistics, University of South Carolina, Columbia, SC

2:00
Incomplete Factorization of Singular M-matrices
John J. Buoni, Department of Mathematical and Computer Sciences, Youngstown State University, Youngstown, OH

2:15
Singular M-matrices
Ralph DeMarr, Department of Mathematics, University of New Mexico, Albuquerque, NM

Monday, April 29/**1:00–2:30 PM**
Contributed Papers 3/Hinsdale Room

NUMERICAL ANALYSIS 1
CHAIRMAN: Richard Painter, Department of Mathematics, Colorado State University, Fort Collins, CO

1:00
Condition Numbers of Rectangular Systems and Bounds for Generalized Inverses
Stephen Demko, School of Mathematics, Georgia Institute of Technology, Atlanta, GA

1:15
Some New Ill-Conditioning Numbers via Differential Geometry
E. J. Brunelle, Department of Aeronautics and Astronautics, Air Force Institute of Technology, Wright-Patterson AFB, OH

1:30
Purcell's Method and Projective n-Space
Richard O. Hill, Jr., Department of Mathematics, Michigan State University, East Lansing, MI

1:45
Linear Algebra Problems in the Use of the Repeated Integration Parameter Estimation Basis
Charles C. Blackwell, Jr., Department of Mechanical Engineering, University of Texas at Arlington, Arlington, TX

2:00
Perturbation Theory for a Group of Eigenvalues
Francoise Chatelin, IBM Developpement Scientifique, Paris, France

2:15
The Generalized Householder Transformation
Linda Kaufman, AT&T Bell Laboratories, Computing Mathematics Research, Murray Hill, NJ

2:30 PM/Coffee

3:00 PM/Cameron-Mordecai Room
Invited Presentation 3
Gene H. Golub, CHAIRMAN
Department of Computer Science
Stanford University, Stanford, CA

MATRIX METHODS IN THE NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS
Seymour V. Parter,
Department of Mathematics and Mathematics Research Center
University of Wisconsin—Madison, Madison, WI

Monday, April 29/**4:00–5:00 PM**
Contributed Papers 4/Cameron Room

MATRIX METHODS IN DIFFERENTIAL EQUATIONS 1
CHAIRMAN: Richard S. Varga, Department of Mathematics, Kent State University, Kent, OH

4:00
A Parallelizable Preconditioning Algorithm for the Fast Solution of Elliptic Problems
J. H. Bramble and A. H. Schatz, Cornell University, Ithaca, NY; J. E. Pasciak, Applied Mathematics Department, Brookhaven National Laboratory, Upton, NY

4:15
Matrix Splittings for the Solution of Higher Order Boundary Value Problems
Suchitra Gupta and Jesse L. Barlow, Department of Computer Science, The Pennsylvania State University, University Park, PA

4:30
Incorporating Time-Dependent Forcing in Locally One-Dimensional Methods
Alan Genz and D. A. Swayne, Computer Science Department, Washington State University, Pullman, WA and Department of Computing and Information Science, University of Guelph, Guelph, Ontario, Canada

4:45
A Spectrum Enveloping Algorithm for Solving Central Difference Approximations of Convection Diffusion Equations
Murli M. Gupta, Department of Mathematics, The George Washington University, Washington, DC

Monday, April 29/4:00–5:00 PM
Contributed Papers 5/Hinsdale Room

CORE LINEAR ALGEBRA 1
CHAIRMAN: R. C. Thompson, Department of Mathematics, University of California, Santa Barbara, CA

4:00
Consimilarity: A Survey of Results
Roger A. Horn and Yoopyo Hong, Department of Mathematical Sciences, The Johns Hopkins University, Baltimore, MD and Department of Mathematics and Computer Science, University of Maryland, Baltimore, MD

4:15
Applications of a Cononical Form under Consimilarity
Yoopyo Hong and Roger A. Horn, Department of Mathematical Sciences, The Johns Hopkins University, Baltimore, MD and Department of Mathematics and Computer Science, University of Maryland, Baltimore, MD

4:30
An Analog of the Singular Value Decomposition for Orthogonal Equivalence
Dipa Choudhury and Roger A. Horn, Department of Mathematical Sciences, The Johns Hopkins University, Baltimore, MD and Department of Mathematical Sciences, Loyola College, Baltimore, MD

4:45
Spectral Factorization of Matrices
A. R. Sourour, Department of Mathematics, University of Victoria, Victoria, B.C., Canada

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Monday, April 29/4:00–5:00 PM
Contributed Papers 6/Haywood Room

MATRIX ANALYSIS 1
CHAIRMAN: B. N. Datta, Department of Mathematical Sciences, Northern Illinois University, Dekalb, IL

4:00
Least Squares Approximation with Smoothed Spline Functions
Daniel D. Warner and Kevin L. Fox, Department of Mathematical Sciences, Clemson University, Clemson, SC

4:15
Stabilizing Certain Iterative Processes
Bryan E. Cain and Elgin H. Johnston, Department of Mathematics, Iowa State University, Ames, IA

4:30
Stability Analysis of Interval Matrices— Another Sufficient Condition
Rama K. Yedavalli, Department of Mechanical Engineering, Stevens Institute of Technology, Hoboken, NJ

4:45
On Cubic Spline Interpolants and Postprocessing for Monotonicity Preservation
Rick Beatson, Department of Mathematics, University of Connecticut, Storrs, CT

5:00 PM/Cameron Room
MEETING OF THE SIAM ACTIVITY GROUP ON LINEAR ALGEBRA
Robert J. Plemmons, CHAIRMAN
Department of Mathematics
North Carolina State University, Raleigh, NC

6:30 PM/Poolside
Cocktails and Hors d'oeuvres

Tuesday, April 30 / AM

Tuesday, April 30/8:30–10:30 AM
Contributed Papers 7/Cameron Room

CORE LINEAR ALGEBRA 2
CHAIRMAN: David Carlson, Department of Mathematics, San Diego State University, San Diego, CA

8:30
Quasi-Positive Definite Maps
Stephen Pierce, Department of Mathematics, University of Toronto, Toronto, Canada and Department of Mathematics, San Diego State University, San Diego, CA

8:45
More on Cone Reachability
Avi Berman, Department of Mathematics, Technion, Haifa, Israel; Michael Neumann, Department of Mathematics, University of South Carolina, Columbia, SC; Ron Stern, Department of Mathematics, Concordia University, Montreal, Canada

9:00
Inverse Problems For Means of Matrices
William N. Anderson, Jr., Department of Mathematics and Computer Science, Fairleigh Dickinson University, Teaneck, NJ; George E. Trapp, Department of Statistics and Computer Science, West Virginia University, Morgantown, WV

9:15
The Cascade Sum and Difference of Matrices
William N. Anderson, Jr., Department of Mathematics and Computer Science, Fairleigh Dickinson University, Teaneck, NJ; George E. Trapp, Department of Statistics and Computer Science, West Virginia University, Morgantown, WV

9:30
Recent Progress of Linear Transformation which Preserve Certain Classes of Matrices
Charles R. Johnson, Mathematical Sciences Department, Clemson University, Clemson, SC

9:45
Mathematical Aspects of the Relative Gain Array (AOA-T)
Charles R. Johnson, Department of Mathematical Sciences, Clemson University, Clemson, SC; Helene Shapiro, Department of Mathematics, Swarthmore College, Swarthmore, PA

10:00
Semistability Factors and Semifactors
Daniel Hershkowitz and Hans Schneider, Mathematics Department, University of Wisconsin— Madison, Madison, WI

10:15
Upper Bounds on the Maximum Modulus of Subdominant Eigenvalues of Nonnegative Matrices
Uriel G. Rothblum, School of Organization and Management, Yale University, New Haven, CT; Choon Peng Tan, Department of Mathematics, University of Malaya, Kuala Lumpur, Malaysia

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Tuesday, April 30/8:30–10:15 AM
Contributed Papers 8/Hinsdale Room

PARALLEL MATRIX COMPUTATIONS 2
CHAIRMAN: B. N. Datta, Department of Mathematical Sciences, Northern Illinois University, Dekalb, IL

8:30
Parallel Nonlinear Algorithms
R. E. White, Mathematics Department, North Carolina State University, Raleigh, NC

8:45
A Vector Approach to Large Scale Configuration Interaction Calculations
Christopher Beattie, Mathematics Department, John Schug and Jimmy Viers, Chemistry Department, and Layne Watson, Computer Science Department, Virginia Polytechnic Institute and State University, Blacksburg, VA

9:00
Communication Complexity of Gaussian Elimination on Multiprocessors
Youcef Saad, Computer Science Department, Yale University, New Haven, CT

9:15
Parallel Matrix Algorithms for Structural Analysis
Michael W. Berry, Department of Mathematics, North Carolina State University, Raleigh, NC

9:30
Parallelism of Block-Preconditioned-Conjugate-Gradient Method on HEP-like MIMD Machines
V. B. Aggarwall, S. K. Dhall, J. C. Diaz, and S. Lakshmivarahan, School of Electrical Engineering and Computer Sciences, The University of Oklahoma, Norman, OK

9:45
Efficient Parallel Solution of Linear Systems with Hyperbolic Rotations
Jean-Marc Delosme, Department of Electrical Engineering; Ilse C. F. Ipsen, Department of Computer Science, Yale University, New Haven, CT

10:00
DISCUSSION: Proposals for the Extension of the Basic Linear Algebra Subprograms; Jack Dongarra, Argonne National Laboratory, Group Leader

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Tuesday, April 30/8:30–10:30 AM
Contributed Papers 9/Haywood Room

DISCRETE METHODS IN LINEAR ALGEBRA
CHAIRMAN: C. T. Kelly, Department of Mathematics, North Carolina State University, Raleigh, NC

8:30
Sign Nonsingularity and the Odd Cycle Property
Rachel Manber, Department of Computer Sciences, University of Wisconsin, Madison, WI; Jai-yu Shao, Tongji University, Shanghai, China

8:45
L-functions and Their Inverses
Johns S. Maybee, Department of Mathematics, University of Colorado, Boulder, CO; Gerry M. Wiener, Department of Mathematics, University of Colorado at Denver, Denver, CO

9:00
Formulae for det A Corresponding to Zero Patterns of A−1
Wayne W. Barrett, Department of Mathematics, Brigham Young University, Provo, UT; Chares R. Johnson, Department of Mathematical Sciences, Clemson University, Clemson, SC

9:15
Linear Characterizations for NP-complete and Number Complete Problems
S. Ursic, Madison, WI

9:30
The Cyclic Coloring Problems and Estimation of Sparse Hessian Matrices
Tom F. Coleman and Jin-yi Cai, Computer Science Department, Cornell University, Ithaca, NY

9:45
The Sparse Null Space Basis Problem
Thomas F. Coleman, Computer Science, Cornell University, Ithaca, NY; Alex Pothen, The Pennsylvania State University, Computer Science Department, Whitmore Laboratory, University Park, PA

10:00
A New Public-key Cipher Which Allows Signatures
John J. Cade, Winchester, MA

10:15
Unit-Memory Convolutional Codes as a Mean in Cryptographic Systems
Reginaldo Palazzo, Jr., Los Angeles, CA

10:30 AM/Coffee

11:00 AM/Cameron-Mordecai Room
Invited Presentation 4
Carl D. Meyer, Jr., CHAIRMAN
Department of Mathematics
North Carolina State University, Raleigh, NC

NUMERICAL AND COMPUTATIONAL METHODS IN LINEAR ALGEBRA
James H. Wilkinson
National Physical Laboratory, United Kingdom

Tuesday, April 30 / PM

12:00 Noon/Lunch

Tuesday, April 30/*1:00–2:30 PM*
Contributed Papers 10/Cameron Room

SYSTEMS THEORY 1
CHAIRMAN: Nicholas J. Rose, Department of Mathematics, North Carolina State University, Raleigh, NC

1:00
Controllability of Positive Systems
Pamela G. Coxson, Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA

1:15
Linear Quadratic Regulator Problem under Equivalence Transformation
S. J. Fu and M. E. Sawan, Electrical Engineering Department, Wichita State University, Wichita, KS

1:30
New Numerical Methods of Optimal Control Problems
John Gregory and Rohan Dalpatadu, Department of Mathematics, Southern Illinois University, Carbondale, IL

1:45
Numerical Solution of General Linear Quadratic Gaussian Control Problems
Volker Mehrmann, Department of Mathematics, University of Wisconsin, Madison, WI; Angelika Bunse-Gerstner, Fakultat fur Mathematik, Universitat Bielefeld, Bielefeld I, Federal Republic of Germany

2:00
Control Coordination for Large Scale Linear Systems
Robert E. Fennell and James A. Reneke, Department of Mathematical Sciences, Clemson University, Clemson, SC: S. B. Black, Government Information Systems Division, Harris Corporation, Melbourne, FL

2:15
Numerical Examples of State Feedback Design Algorithms
Chia-Chi Tsui, Department of Electrical & Computer Engineering, Northeastern University, Boston, MA

Tuesday, April 30/*1:00–2:30 PM*
Contributed Papers 11/Hinsdale Room

MATRIX EQUATIONS AND ALGEBRAS
CHAIRMAN: Charles R. Johnson, Department of Mathematics, Clemson University, Clemson, SC

1:00
The Matrix Equation XA − BX = C and its Applications
Karabi Datta
Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL

1:15
Roth's Theorem on the Matrix Equation AX + BY = C
Larry J. Gerstein, Department of Mathematics, University of California, Santa Barbara, CA

1:30
Matrix Equations Over Rings
John Jones, Jr., Mathematics Department, School of Engineering, Air Force Institute of Technology, Wright-Patterson AFB, OH

1:45
Similarity Over F[×]
Jacob T. B. Beard, Jr., Department of Mathematics and Computer Science, Tennessee Technological University, Cookeville, TN

2:00
Realization of Rational Matrices
Harald K. Wimmer, Mathemat. Institut d. Universitat, Wirzburg, W. Germany

2:15
On Homogeneous Algebras
Lowell G. Sweet and James A. MacDougall, Department of Mathematics and Computer Science, University of Prince Edward Island, Charlottetown, P.E.I., Canada

Tuesday, April 30/*1:00–2:30 PM*
Contributed Papers 12/Haywood Room

COMPUTER SCIENCE
CHAIRMAN: Roger Horn, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD

1:00
Sparse Projections in Karmarkar's Linear Programming Algorithm
David M. Gay, AT&T Bell Laboratories, Murray Hill, NJ

1:15
A Fast but Unstable Orthogonal Triangularization Technique for Toeplitz Matrices
Franklin T. Luk, School of Electrical Engineering, Cornell University, Ithaca, NY; Sanzheng Qiao, Center for Applied Mathematics, Cornell University, Ithaca, NY

1:30
The Solution of Banded Systems in Block Tridiagonal Form Using Odd-Even Reduction
Cleve Ashcraft, Computer Science Department, General Motors Research Laboratory, Warren, MI

1:45
Storage Versus RUN-TIME Step Preserving Programs
Frank J. Servedio, Department of Mathematics and Computer Science, Montclair State College, Upper Montclair, NJ

2:00
Max and the Singular Value Decomposition
Edward M. Borasky, Sr. Applications/Systems Analyst, Floating Point Systems Inc., Rockville, MD

2:15
Basic Linear Algebra Models for a Concurrent Computing Environment with IEEE Floating Point Arithmetic
Elizabeth R. Ducot and Virginia C. Klema, Massachusetts Institute of Technology Statistics Center, Cambridge, MA

2:30 PM/Coffee

3:00 PM/Cameron-Mordecai Room
Invited Presentation 5
Hans Schneider, CHAIRMAN
Department of Mathematics
University of Wisconsin—Madison, Madison, WI

WHY I AM CARRYING A TORCH FOR MATRIX THEORY
Olga Taussky-Todd
Department of Mathematics
California Institute of Technology, Pasadena, CA

4:00 PM/Minisymposium 1
Cameron Room
EXACT COMPUTATIONS IN LINEAR ALGEBRA
B. David Saunders, CHAIRMAN AND ORGANIZER
Computer Science Department
Rensselaer Polytechnic Institute, Troy, NY
Currently visiting:
Computer and Information Sciences Department
University of Delaware, Newark, DE

Tuesday, April 30/*4:00–6:00 PM*
Contributed Papers 13/Hinsdale Room

NUMERICAL ANALYSIS 2
CHAIRMAN: Jack Dongarra, Applied Mathematics Division, Argonne National Laboratory, Argonne, IL

4:00
The QR and Inverse QR Algorithms for Unitary Hessenberg Matrices
William B. Gragg and William J. Harrod, Department of Mathematics, University of Kentucky, Lexington, KY

4:15
On Symplectic QR like Methods
Angelika Bunse-Gerstner, Fakultat fur Mathematik, Universitat Bielefeld, Federal Republic of Germany

4:30
Analogues of Givens and Lanczos Methods for Pseudosymmetric Matrices
Michael A. Brebner, Department of Computer Science, University of Calgary, Calgary, Alberta Canada

4:45
Optimal Choice of Truncation Level for Truncated SVD For Linear Ill-posed Problems
C. R. Vogel, Department of Mathematics and Ames Laboratory, Iowa State University, Ames, IA

5:00
Resolvent Bounds and Eigenvalue Estimates' Error Bounds
Dennis R. Philips, Middleton, WI

5:15
Estimating the SOR Extrapolation Parameter
Eugene L. Wachspress, Department of Mathematics, University of Tennessee, Knoxville, TN

5:30
Singularities in Isospectral Flows
David S. Watkins, Department of Pure and Applied Mathematics, Washington State University, Pullman, WA

5:45
Transforming Residual Bounds into Error Bounds for Eigenvalue Estimates
Dennis R. Phillips, Davis Hibbard Mayer Norton & Phillips, Inc., Middleton, WI

Tuesday, April 30/*4:00–5:30 PM*
Contributed Papers 14/Haywood Room

LINEAR ALGEBRA IN STATISTICS
CHAIRMAN: Peter Gibson, Department of Mathematics, University of Alabama, Huntsville, AL

4:00
Identifying Rank-Influential Groups of Observations in Generalized Linear Regression Models
Peter J. Kempthorne, Department of Statistics, Harvard University, Cambridge, MA

8

4:15
Multivariate and Other Forms of the Pitman-Welch Permutation Test for Randomized Blocks
Clayton L. Stunkard, Department of Measurement, Statistics, and Evaluation, University of Maryland, College Park, MD

4:30
The Algebra of Hyperboloids of Revolution
Javier Cabrera, Department of Statistics, Rutgers University, New Brunswick, NJ; Geoffrey S. Watson, Department of Statistics, Princeton University, Princeton, NJ

4:45
An SVD-Based Algorithm for Stochastic System Identification
K. S. Arun, Coordinated Science Laboratory, University of Illinois at Urbana-Champaign, Urbana, IL; Sun-Yuan Kung, Department of Electrical Engineering Systems, University of Southern California, Los Angeles, CA

5:00
The Early Use of Matrix Diagonal Increments in Statistical Problems
Walter W. Piegorsch, Biometry and Risk Assessment Program, National Institute of Environmental Health Science, Research Triangle Park, NC; George Casella, Biometrics Unit, Cornell University, Ithaca, NY

5:15
Estimating the Parameters of a Positive Semidefinite Quadratic Form Using a Cholesky Decomposition
Eric Stallard, Max A. Woodbury and Kenneth G. Manton, Center for Demographic Studies, Duke University, Durham, NC

5:30
A Probabilistic Approach in Approximating the Stationary Distribution of A Nearly Completely Decomposable Markov Chain
Moshe Haviv, Department of Statistics, The Hebrew University, Jerusalem, Israel

6:30 PM
Wine and Cheese Party
Sponsored by North Carolina State University

Wednesday, May 1 / AM

Wednesday, May 1/*8:30–9:30 AM*
Contributed Papers 15/Cameron Room

NUMERICAL ANALYSIS 3
CHAIRMAN: Michael Neumann, Department of Mathematics and Statistics, University of South Carolina, Columbia, SC

8:30
Newton-Hankel and Newton-Toeplitz Matrices: Theory and Applications
Daniel W. Sharp, Department of Mathematical Sciences, Clemson University, Clemson, SC

8:45
A Stability Analysis of Incomplete LU Factorizations
Howard C. Elman, Department of Computer Science, Yale University, New Haven, CT

9:00
The Linear Algebra Challenge of Globally Convergent Homotopy Methods
Layne T. Watson, Department of Computer Science and Spatial Data Analysis Laboratory, Virginia Polytechnic Institute and State University, Blacksburg, VA

9:15
An Efficient Method for Determining Symbolically the Characteristic Polynomial of a Matrix
Robert E. Parkin, Electrical Engineering Department, University of Lowell, Lowell, MA

Wednesday, May 1/*8:30–9:30*
Contributed Papers 16/Hinsdale Room

APPLICATIONS OF LINEAR ALGEBRA
CHAIRMAN: Robert Ward, Mathematics & Research Section, Engineering Physics and Mathematics Division, Oak Ridge National Laboratory, Oak Ridge, TN

8:30
Design of Extended Model Following Servo Controller
Osamu Yamano, Robotics Systems Research Laboratory, AT&T Bell Laboratories, Holmdel, NJ; Katsuhisa Furuta, Department of Control Engineering, Tokyo Institute of Technology, Tokyo, Japan

8:45
An Application of the Singular Value Decomposition to Manipulability and Sensitivity of Industrial Robots
Masaki Togai, AT&T Bell Laboratories, Holmdel, NJ

9:00
Statistical Analysis of the Effects of Matrix Perturbations in Some Least Squares Problems
Donald W. Tufts and S. Parthasarathy, Department of Electrical Engineering, University of Rhode Island, Kingston, RI

9:15
Linear Algebra in Modern Signal Processing
Jeffrey M. Speiser, Naval Ocean Systems Center, San Diego, CA

Wednesday, May 1/*8:30–9:30 AM*
Contributed Papers 17/Haywood Room

MATRIX ANALYSIS 2
CHAIRMAN: Robert Hartwig, Department of Mathematics, North Carolina State University, Raleigh, NC

8:30
Some Special Function Matrices and Identities Derived From Them
Rethinasamy Kittappa, Department of Mathematics and Computer Science, Millersville University, Millersville, PA

8:45
A Characterization of Inertia-preserving Secant Updates
Christopher Beattie, Monte Boisen and Lee Johnson, Mathematics Department, Virginia Polytechnic Institute and State University, Blacksburg, VA

9:00
On Certain Strictly Dissipative Matrices
Natalia Bebiano, Departamento de Mathematica, Faculdade de Ciencias e Technologia Universidade de Coimbra, Coimbra, Portugal

9:15
On Nonnegative Matrices
J. P. Milaszewicz and L. Moledo, Buenos Aires University, and National Research Council, Argentina

9:30AM/Cameron-Mordecai Room
Invited Presentation 6
Stephen Campbell, CHAIRMAN
Department of Mathematics
North Carolina State University, Raleigh, NC
PARALLEL ALGORITHMS IN LINEAR ALGEBRA
Robert G. Voigt
ICASE, NASA Langley Research Center
Hampton, VA

10:30 AM/Coffee

11:30 AM/Cameron-Mordecai Room
Invited Presentation 7
Richard A. Brualdi, CHAIRMAN
Department of Mathematics
University of Wisconsin—Madison, Madison, WI
LINEAR ALGEBRA IN DISCRETE MATHEMATICS AND COMBINATORICS
Ronald L. Graham
Mathematical Sciences Research Center
AT&T Bell Laboratories, Murray Hill, NJ

Wednesday, May 1 / PM

12:00 Noon/Lunch

Wednesday, May 1/*1:00–2:30 PM*
Contributed Papers 18/Cameron Room

PARALLEL MATRIX COMPUTATIONS 3
CHAIRMAN: Roger Horn, Department of Mathematical Sciences, Johns Hopkins University, Baltimore, MD

1:00
Some New Efficient Algorithms Related to Cayley-Hamilton Theorem
Victor Pan, Computer Science Department, State University of New York at Albany, Albany, NY

1:15
A Parallel Method for the Generalized Eigenvalue Problem
Daniel Boley, Computer Science Department, University of Minnesota, Minneapolis, MN

1:30
Design of and Experience with Frontal and Skyline Solvers for Vector and Parallel Processing of Finite Element Codes
R. E. Benner, D. K. Gartling, and G. G. Weigand, Fluid and Thermal Sciences Department, Sandia National Laboratories, Albuquerque, NM

1:45
Direct Parallel Algorithms for Exact Solution of Sparse Symmetric Linear Systems
Victor Pan, Computer Science Department, State University of New York at Albany, Albany, NY; John Reif, Laboratory of Computer Science, Massachusetts Institute of Technology, Cambridge, MA and Aiken Computation Laboratory, Division of Applied Sciences, Harvard University, Cambridge, MA

2:00
A Program for the Parallel Computation of the Schur Decomposition of an Arbitrary Matrix
Patricia J. Eberlein, Department of Computer Science, Cornell University, Ithaca, NY

2:15
Fast Division of Polynomials via Triangular Toeplitz Matrix Inversion
Dario Bini, Department of Informatica, University of Pisa, Pisa, Italy; and Victor Pan, Computer Science Department, State University of New York at Albany, Albany, NY

Wednesday, May 1/*1:00–2:30 PM*
Contributed Papers 19/Hinsdale Room

SYSTEMS THEORY 2
CHAIRMAN: Richard Painter, Department of Mathematics, Colorado State University, Fort Collins, CO

1:00
Prolegomena to Numerical Homological Algebra
Bostwick F. Wyman, Mathematics Department, The Ohio State University, Columbus, OH

1:15
Algorithms for Polynomial Matrix Operations
Shou-Yuan Zhang, Department of Electrical Engineering, State University of New York at Stony Brook, Stony Brook, NY

1:30
On the Computation of State Transition Matrices
S. J. Fu and M. E. Sawan, Electrical Engineering Department, Wichita State University, Wichita, KS

1:45
Approximate Linear Realization from Finite Time-Series Data
Stefan Mittnik, Department of Systems Science and Mathematics, and Department of Economics, Washington University, St. Louis, MO

2:00
Using Symplectic Structure in Algorithms for Solving the Discrete Riccati Equation
Ralph Byers, Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL

2:15
The Sensitivity of the Stable, Non-negative Definite Lyapunov Equation
Gary A. Hewer, RF Missle Systems Branch, Weapons Synthesis Division, Naval Weapons Center, China Lake, CA; Charles Kenney, Numerical Software for Scientific Engineering, Naval Weapons Center, China Lake, CA

Wednesday, May 1/1:00–2:00 PM
Contributed Papers 20/Haywood Room

MATRIX METHODS IN DIFFERENTIAL EQUATIONS 2
CHAIRMAN: Stephen Campbell, Department of Mathematics, North Carolina State University, Raleigh, NC

1:00
Matrix-Free Methods for Stiff Systems of ODE's
Peter N. Brown, Mathematics Department, University of Houston, Houston, TX; Alan C. Hindmarsh, Mathematics and Statistics Division, Lawrence Livermore National Laboratory, Livermore, CA

1:15
Linear Algebra in Phase Space Analysis of Ordinary Differential Equations
Bernard E. Howard, Department of Mathematics and Computer Science, University of Miami, Coral Gables, FL

1:30
Solution of Linear Systems of Equations of Saddle Point Type By Domain Decomposition Techniques
Georges H. Guirguis, Department of Mathematics, North Carolina State University, Raleigh, NC

1:45
Infinite Matrices and Some Applications
P. N. Shivakumar, Department of Applied Mathematics, University of Manitoba, Winnipeg, Manitoba, Canada

2:30 PM/Coffee

3:00 PM/Cameron-Mordecai Room
Invited Presentation 8
Hans Schneider, CHAIRMAN
Department of Mathematics
University of Wisconsin—Madison, Madison, WI
LINEAR ALGEBRAIC METHODS IN MULTIVARIATE STATISTICAL ANALYSIS
Ingram Olkin
Department of Statistics
Stanford University, Stanford, CA

4:00 PM/Minisymposium 2
Cameron Room
INDUSTRIAL APPLICATIONS OF LINEAR ALGEBRA
Al Erisman. CHAIRMAN AND ORGANIZER
Boeing Computer Services
Tukwila, WA

Wednesday, May 1/4:00–5:30 PM
Contributed Papers 21/Hinsdale Room

GRAPH THEORY
CHAIRMAN: Gil Koh, Department of Mathematics, North Carolina State University, Raleigh, NC

4:00
Maximum Chordal Subgraphs of Grid Graphs
Barry W. Peyton, Department of Mathematical Sciences, Clemson University, Clemson, SC

4:15
On the Use of Electrical Network Equations to Draw Graphs in the Plane
Seth Chaiken, Department of Computer Science, State University of New York at Albany, Albany, NY

4:30
Spectra of the Extended de Bruijn-Goods Graphs
Xin-ding Lin, Department of Mathematics, North Carolina State University, Raleigh, NC and Mathematics Department, China University of Science and Technology, Hafei, China

4:45
Where are the Cycles?
Marialuisa N. McAllister, Department of Mathematics, Moravian College, Bethlehem, PA

5:00
Hypergraphs of k-Dimensional Matrices
Stephen J. Dow and Peter M. Gibson, Department of Mathematics, University of Alabama, Huntsville, Al

5:15
A Probabilistic Algorithm for Graph Isomorphism
Shmuel Friedland, Department of Mathematics, Cornell University, Ithaca, NY

Wednesday, May 1/4:00–5:45 PM
Contributed Papers 22/Haywood Room

COMPUTER SCIENCE AND SYSTEMS THEORY
CHAIRMAN: John Todd, Department of Mathematics, California Institute of Technology, Pasadena, CA

4:00
Squeezing the Most Out of Eigenvalue Solvers on High-Performance Computers
Linda Kaufman, Computing Mathematics Research, AT&T Bell Laboratories, Murray Hill, NJ

4:15
Cholesky Factorization of Structured Matrices
Hanoch Lev-Ari, Information Systems Laboratory, Stanford University, Stanford, CA

4:30
Transitive Closure and Related Semiring Properties Via Eliminants
S. Kamal Abdali, Computer Research Laboratory, Tektronix, Inc., Beaverton, OR; and B. David Saunders, Department of Computer Science, Rensselaer Polytechnic Institute, and Department of Computer and Information Sciences, University of Delaware, Newark, DE

4:45
Lyapunov Approximation of Reachable Sets for Controlled Linear Systems
Danny Summers, Department of Mathematics and Statistics, Memorial University of Newfoundland, St. John's, Newfoundland, Canada

5:00
Linear Algebra in Robust Multivariable Control Theory: The Structured Singular Value
John Doyle, Department of Electrical Engineering, California Institute of Technology, Pasadena, CA

5:15
On the Generators of a Controllability Matrix
Frank Uhlig, Department of Mathematics, Auburn University, Auburn, AL

5:30
Projectionally Exposed Cones in Convex Programming
George P. Barker, Department of Mathematics, University of Missouri, Kansas City, MO; Michael Laidacker and George D. Poole, Department of Mathematics, Lamar University, Beaumont, TX

7:00 PM
Banquet
North Carolina State University
William M. Kahan, BANQUET SPEAKER
Department of Electrical Engineering and Computer Science
University of California—Berkeley, Berkeley, CA
"If At First You Don't Succeed, Try and Try and Try Again." How Hard?
The Perron-Frobenius theory of non-negative matrices and their dominant eigenvalues illuminates this question.

Thursday, May 2 / AM

Thursday, May 2/8:30–9:30 AM
Contributed Papers 23/Cameron Room

CORE LINEAR ALGEBRA 3
CHAIRMAN: Daniel Hershkowitz, Department of Mathematics, University of Wisconsin—Madison, Madison, WI

8:30
Nullities of Submatrices of Generalized Inverses
Donald W. Robinson, Department of Mathematics, Brigham Young University, Provo, UT

8:45
The Second Immanant and the Moment Sum of a Graph
Russell Merris, Department of Mathematics and Computer Science, California State University, Hayward, CA

9:00
On the Null Space of a Subspace of Singular Matrices
LeRoy B. Easley, Department of Mathematics, Utah State University, Logan, UT

9:15
Null Vectors and Singularity of Acyclic Matrices
David Carlson, Mathematical Sciences Department, San Diego State University, San Diego, CA; Danny Hershkowitz, Mathematics Department, University of Wisconsin-Madison, Madison, WI

Thursday, May 2/8:30–9:30 AM
Contributed Papers 24/Hinsdale Room

APPLICATIONS TO ECONOMICS AND DECISION SCIENCE
CHAIRMAN: Charles R. Johnson, Department of Mathematics, Clemson University, Clemson, SC

8:30
A Polynomially Bounded Pivoting Algorithm for a Linear Complementarity Problem with a Quasi-Diagonally Dominant Matrix
Jong-Shi Pang, School of Management, University of Texas at Dallas, Richardson, TX

8:45
Existence of Nonnegative Solutions for Leontief's Closed Dynamic Input-Output Model
Daniel B. Szyld, Institute for Economic Analysis, New York University, New York, NY

9:00
Path Addition and Marginal Cost on User-optimized Transportation Networks
Marguerite Frank, Department of Decision Science and Computers, Rider College, Lawrenceville, NJ

9:15
Sensitivity of the Stationary Distribution Vector for an Ergodic Markov Chain
R. E. Funderlic, Oak Ridge National Laboratory, Oak Ridge, TN; C. D. Meyer, Jr., Department of Mathematics, North Carolina State University, Raleigh, NC

Thursday, May 2/8:30–9:30 AM
Contributed Papers 25/Haywood Room

ITERATIVE METHODS
CHAIRMAN: Volker Mehrmann, Department of Mathematics, University of Wisconsin, Madison, WI

8:30
K-part Iterative Solutions to Linear Systems
Bradley N. Parsons, Systems Engineering and Analysis, Hughes Aircraft Company, Fullerton, CA

8:45
Semiiterative Methods for Nonsymmetric Linear Systems
Michael Eiermann, Institut fur Praktische Mathematik, Universitat Karlsruhe, Karlsruhe, West Germany, and Institute for Computational Mathematics, Kent State University, Kent, OH

9:00
Preconditioned Lanczos—A Robust Iterative Method
Granville Sewell, Mathematics Department, University of Texas at El Paso, El Paso, TX.

9:15
An Iterative Method for Computing the Square Root of the Inverse of a Matrix
Bernard Jacques Philippe, Visiting the Department of Computer Science, University of Illinois at Urbana-Champaign, Urbana, IL

9:30 AM/Cameron-Mordecai Room
Invited Presentation 9
Donald J. Rose, CHAIRMAN
Department of Computer Science
Duke University, Durham, NC
LINEAR ALGEBRA IN ENGINEERING, CONTROL AND SYSTEMS THEORY
Roger W. Brockett
Division of Applied Sciences
Harvard University, Cambridge, MA

10:30 AM/Coffee

11:00 AM/Cameron-Mordecai Room
Invited Presentation 10
Nicholas J. Rose, CHAIRMAN
Department of Mathematics
North Carolina State University, Raleigh, NC
LINEAR ALGEBRA IN POPULATION BIOLOGY
Joel E. Cohen
Laboratory of Populations
Rockefeller University, New York, NY

Thursday, May 2 / PM

12:00 Noon/Lunch

Thursday, May 2/1:00–2:00 PM
Contributed Papers 26/Cameron Room

LINEAR ALGEBRA IN POPULATIONS AND BIOLOGY
CHAIRMAN: Robert Hartwig, Department of Mathematics, North Carolina State University, Raleigh, NC

1:00
A Matrix Model of the Population Dynamics of the Pacific Salmon
Elmo Moore, Mathematics Department, Humboldt State University, Arcata, Ca

1:15
Conditions for Asymptotically Exponential Solutions of Linear Difference Equations with Variable Coefficients
Marc Artzrouni, Department of Biostatistics, School of Public Health, University of North Carolina, Chapel Hill, NC

1:30
Centrosymmetric Generalized Wright Model
James R. Weaver and David L. Sherry, Department of Mathematics/Statistics, The University of West Florida, Pensacola, FL

1:45
An Assessment of the Customary Linear Model for Tracer Kinetics in a Nonlinear Environment
H. Robert van der Vaart, Department of Statistics, Biomathematics Division, North Carolina State University, Raleigh, NC

Thursday, May 2/1:00–3:00 PM
Contributed Papers 27/Hinsdale Room

NUMERICAL ANALYSIS 4
CHAIRMAN: Robert J. Plemmons, Department of Mathematics, North Carolina State University, Raleigh, NC

1:00
Generalized Deflated Block-Elimination
Tony F. Chan, and Diana C. Resasco, Department of Computer Science, Yale University, New Haven, CT

1:15
Curves on S^{n-1} That Lead to Eigenvalues or Their Means of a Matrix
Moody T. Chu, Department of Mathematics, North Carolina State University, Raleigh, NC

1:30
Some Applications of Vandermonde Systems
William Squire, Department of Mechanical and Aerospace Engineering, West Virginia University, Morgantown, WV

1:45
The Conjugate Gradient Method with Element by Element Preconditioners: Preliminary Report
Steven J. Leon, Department of Mathematics, Southeastern Massachusetts University, North Dartmouth, MA

2:00
Parallel Block Jacobi Algorithms
David St. Clair Scott, Computer Sciences Department, University of Texas at Austin, Austin, TX

2:15
Wide Quotient Trees for Finite Element Problems
Earl Zmijewski and John R. Gilbert, Computer Science Department, Cornell University, Ithaca, NY

2:30
Numerical Algorithms for Determining an Invariant Subspace of a Matrix
Dennis R. Phillips, Scientific Programming and Applied Mathematics, Inc. Middleton, WI

2:45
Efficient Parallel Matrix Inversion
Victor Pan, Computer Science Department, State University of New York at Albany, Albany, NY; John Reif, Laboratory of Computer Science, Massachusetts Institute of Technology, Cambridge, MA and Aiken Computation Laboratory, Division of Applied Sciences, Harvard University, Cambridge, MA

Thursday, May 2/1:00–3:00 PM
Contributed Papers 28/Haywood Room

MATRIX ANALYSIS 3
CHAIRMAN: Nicholas J. Rose, Department of Mathematics, North Carolina State University, Raleigh, NC

1:00
Analysis of Convergence of Nonlinear Nonstationary Functional Iterations
Suhrit K. Dey, Department of Mathematics, Eastern Illinois University, Charleston, IL

1:15
Functions of Perturbed Matrices
Lester J. Senechal, Department of Mathematics, Mount Holyoke College, South Hadley, MA

1:30
Derivatives of D_1AD_2 Matrices
James S. Weber, Department of Management, Roosevelt University, Chicago, IL

1:45
Rationalization of Fractions
Dieter W. F. Wendt, Phoenixville, PA

2:00
Nonlinear Eigenvalue Approximation
William F. Moss, Department of Mathematical Sciences, Clemson University, Clemson, SC; Philip W. Smith, Department of Mathematical Sciences, Old Dominion University; and Joseph D. Ward, Department of Mathematics, Texas A&M University, College Station, TX

2:15
Unitary Completions and Noncanonical LU Factorization
Joseph A. Ball, Department of Mathematics, Virginia Polytechnic Institute and State University, Blacksburg, VA

2:30
Inexact One-Step Method
Elizabeth L. Yip, Boeing Computer Services Company, Tukwila, WA

2:45
The Role of the Schur Product in the Eigenstructure Approach to Parameter Estimation
A. Paulraj and T. Kailath, Information Systems Laboratory, Stanford University, Stanford, CA

Thursday, May 2/1:00–3:00 PM
Contributed Papers 29/Mordecai Room

CORE LINEAR ALGEBRA 3
CHAIRMAN: Joe Marlin, Department of Mathematics, North Carolina State University, Raleigh, NC

1:00
A Numerical Comparison of Methods for Computing the Inertia of a General Matrix
B. N. Datta Department of Mathematics, Northern Illinois University, DeKalb, IL; and Daniel Pierce, Department of Mathematics, North Carolina State University

1:15
Generalized Inverses of Matrices Over Rings
K. P. S. Bhaskara Rao, Department of Mathematical and Computer Sciences, Michigan Technological University, Houghton, MI

1:30
Monotonicity of Permanents in Ω_n
John L. Goldwasser, Department of Mathematics, Iowa State University, Ames, IA

1:45
An Inequality for the Second Immanant
Bob Grone, Department of Mathematics, Auburn University, Auburn, AL

2:00
Some Generalizations of the Singular Value Concept
J. F. Queiró, Departamento de Matematicá, Universidade de Coimbra, Coimbra, Portugal

2:15
Platzman's Problem Revisited
John G. Lewis and Horst D. Simon, Boeing Computer Services Company, Applied Mathematics Division, Tukwila, WA

2:30
Some Comments About Semimonotone and Copositive Matrices
Melvyn W. Jeter and Wallace C. Pye, Department of Mathematics, University of Southern Mississippi, Hattiesburg, MS

2:45
Some Comments on Substochastic Matrices
Cecil Eugene Robinson, Jr., Department of Mathematics, University of Southern Mississippi, Hattiesburg, MS

AUTHOR INDEX

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A Symbolic Computation Package for *-Semirings in REDUCE

*-Semirings are algebraic structures that provide a unified approach to several problems of computer science and operations research. The theory of matrices over *-semirings has a number of similarities to the theory of matrices over fields. For example, eliminants and asterates behave analogously to determinants and matrix inverses. Since *-semirings lack additive and multiplicative inverses, the expressions resulting from various computations are often quite complex and thus provide an opportunity for symbolic manipulation by computers. We describe a set of REDUCE procedures for symbolic eliminant computation, asteration, and solution of systems of linear equations over *-semirings.

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Exact Linear Algebra With A PC

The muMATH/muSIMP computer algebra system for microcomputers provides an exact rational arithmetic and the capability of evaluating determinants, solving systems of numerical or symbolic elements. We will review these capabilities and explore the application of the extended arithmetic capabilities to such procedures as the method of conjugate gradients (which is exact in the absence of round-off) and the Bareiss division free procedure which normally requires rescaling to eliminate large or small numbers.

William Squire
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Maple: A New Computer Algebra System

Maple is a system for symbolic computation in development at the University of Waterloo since 1980, distributed to a variety of systems and sites since 1982. A brief overview of the system's features and design philosophy will be given, illustrated by discussion of library software such as Maple's equation solver, Taylor series computations, and its package for matrices and vectors. The accomplishments and future plans of the Maple project will be placed in perspective with other symbolic computation systems. The Waterloo experience with Maple's usage by introductory calculus classes will be detailed.

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Fast Computation of Invariant Factors: Probabilistic and Modular Methods

Algorithms for the exact computation of the Hermite normal form and Smith normal form - and hence the invariant factors - of a martrix over F [x] are discussed. While seeking limits to the speedup possible through parallel computation, we have found new algorithms which perform well in practice on current non-parallel computers. Some of the algorithms achieve speed at the cost of introducing a minute probability of incorrect results. Theoretical complexity results and experimental findings are reported.

Erich L. Kaltofen
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B. David Saunders*

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Matrix Computation in Electronics CAD Software

The modeling and analysis of electronic system is accomplished via lumped as well as distributed models. The solution techniques which give the designer the quantities of interest involve matrix computations.

A variety of important problems need to be solved like circuit analysis, capacitance and resistance computations and semiconductor device analysis.

In this talk we plan to outline the mathematical formulation of such problems, the solution technique involved and what some of the results are. All these problems involve matrix computation. We plan to give examples of matrices, what their properties are and what the conventional solution techniques in common use are.

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Some Sparse Matrix Problems in Structural Analysis

The well-known stiffness method of finite element structural analysis leads to the well-studied problems of solving overdetermined and symmetric positive definite systems of linear equations. The lesser-known flexibility (or force) method leads to the less well-studied, but equally interesting problem of solving underdetermined linear systems, and the related problems of computing a basis matrix for the null space of the equilibrium matrix and solving generalized least squares problems. In this talk we review recent work on solving these problems for large sparse matrices.

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The Linear Algebra of Seismic Modeling

Seismic modeling codes can be used both to simulate seismic exploration and to process seismic data. Numerical approximation of the visco-elastic Helmholtz equations using a finite element method are characterized by large ($10^6 \times 10^6$), sparse (block tri-tridiagonal) non-positive definite complex symmetric systems of linear equations for 2-dimensional geologies. One wishes to obtain the solution at a restricted (10^3) number of nodes due to multiple (10^2) source locations (right hand sides). Unlike reservoir simulation, conventional iterative equation solvers perform poorly for models many wavelengths in size. Multifrontal direct methods perform well.

Totally direct methods that we know of will not be able to solve the 3-dimensional problem ($10^9 \times 10^9$ matrices) on machines of the next five years.

We solicit from the linear algebra community the proper mix of direct/iterative solution techniques and machine architectures that will allow us to solve the 3-dimensional seismic modeling problem.

R. P. Bording, Amoco Production Company Research Center, Tulsa, Oklahoma 74102 (Geophysics)

K. R. Kelly, Amoco Production Company Research Center, Tulsa, Oklahoma 74102 (Geophysics)

K. J. Marfurt, Amoco Production Company Research Center, Tulsa, Oklahoma 74102 (Geophysics)

SYMMETRIC GENERALIZED EIGENPROBLEMS IN STRUCTURAL ENGINEERING

Vibration and buckling analyses of structures give rise to symmetric generalized eigenproblems of large order. Standard sparse algorithms, such as the shifted Lanczos algorithms by Ericsson and Ruhe, and Nour-Omid and Parlett, provide a sound basis for solving such problems in isolation. Incorporating such an algorithm into an existing structural engineering package, as a "user-friendly" black box eigensolver, adds substantially to the complexity of the algebraic problem. We shall discuss the implementation of a shifted block Lanczos algorithm into MSC NASTRAN to illustrate the practical problems that must be faced.

Structural engineering eigenproblems have numerical characteristics that pose further difficulties. Typical sparse algorithms require, as a key subproblem, solution of linear equations with one or more matrices. The matrices in the eigenproblem may be very poorly conditioned. The eigenvalue problems may, in fact, be ill-posed. We shall discuss some of the effects of ill-conditioning and ill-posedness on the numerical solution of these problems.

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ABSTRACTS: CONTRIBUTED PAPERS

Parallel Cholesky Factorization on a Multiprocessor

A parallel algorithm is developed for Cholesky factorization on a multiprocessor. The algorithm is based on self-scheduling of a pool of tasks. The subtasks in several variants of the basic elimination algorithm are analyzed for potential concurrency in terms of precedence relations, work profiles, and processor utilization. This analysis is supported by simulation results. The most promising variant, which we call column-Cholesky, is identified and implemented for the Denelcor HEP multiprocessor. Experimental results are given for this machine.

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Joseph Liu
Department of Computer Science
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Canada

Vectorizing the Computation of Cholesky Factors, Reflection Coefficients, and Kalman Gains in Toeplitz Systems

Let $R=(r_{|i-j|})$ denote a Toeplitz correlation matrix and $r=(r_0 \ldots r_{t-1})$ the corresponding correlation sequence. This sequence is used to initialize a fixed point vector recursion for computing reflection coefficients, Kalman gains, and triangular Cholesky factors of R. The recursion is presented in a form that makes it suitable for implementation on a vector processing machine. This provides an alternative to the nested scalar recursions and to the lattice algorithms usually advocated for these computations. The results are applicable to the analysis and synthesis of stationary time series.

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Cedric Demeure
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University of Rhode Island
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Torus Data-Flow for Parallel Computation of Missized Matrix Problems

A data-flow approach can be used to solve large dense systems of equations on a processor array with only nearest-neighbor communication. Although this approach requires no global synchronization, the development of our simulator provided additional understanding of the necessity of local synchronization of data movement when there are more computational nodes than processors (missized). New definitions for missized problems and parallel algorithm efficiency are given. For the Cholesky decomposition the lower triangle was mapped onto a torus configuration of processors. Various time step, efficiency, and processor utilization plots are given.

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A Linear Time Method for Computing the CS-Decomposition

We describe a new parallel algorithm for computing the CS-decomposition, and compare it against a recently published procedure due to Kaplan and Van Loan. For a $2n \times n$ orthonormal matrix that is partitioned into two square blocks, their procedure needs $O(n^2)$ time and $O(n^2)$ processors (probably in the form of two distinct arrays), whereas our new procedure requires only $O(n)$ time and one triangular array of $O(n^2)$ processors.

Franklin T. Luk, School of Electrical Engineering, Cornell University, Ithaca, New York 14853

Sanzheng Qiao, Center for Applied Mathematics, Cornell University, Ithaca, New York 14853

Fast Matrix Multiplication on Square and Cubic Grids of Processors

Parallel processing algorithms are given for these three problems:
(a) Multiply an nxn matrix by an n vector on a square grid in time = $O(n^{2/3})$.
(b) Multiply an nxn matrix by an n vector on a cubic grid in time = $O(n^{1/2})$.
(c) Multiply two nxn matrices on a cubic grid in time = $O(n^{3/4})$.
These algorithms use only communications between adjacent processors. At the start of computation, only one copy of each input is needed.

David C. Fisher
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Efficient Parallel Algorithms for Inertia, Stability, Relative Primeness and Lyapunov Equation.

The design and analysis of time-invariant linear control systems give rise to a variety of interesting linear algebra problems. In an invited talk at the last Gatlinburg meeting in Waterloo, one of the authors, B. Datta, presented efficient parallel algorithms for some of these problems. The present talk is a sequel to the Gatlinburg talk. In this talk, after reviewing briefly the state of art in parallel matrix algorithms relevant to the talk, efficient parallel algorithms will be presented for three important problems, namely, the problem of determining the inertia and stability of matrix, finding the relative primeness of two matrices, and solving Lyapunov equation. These algorithms have parallel efficiency of $O(\frac{1}{\log n})$ and can be implemented in $O(n\log_2 n)$ steps using atmost $O(n^2)$ processors. A desireable feature of these algorithms is that they are composed of basic linear algebraic operations such as vector matrix multiplication, matrix multiplications and QR factionzations, for which efficient parallel algorithms already do exist. Thus, these algorithms have potentials for implementations on the existing and future parallel machines.

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Stability of M-matrix Products

Various types of stability for powers and products of nonsingular M-matrices are discussed. Stability of the matrix powers is categorized according to the length of the longest simple circuit in the digraph of the matrix, while stability of the general products is categorized by the order of the matrices. Additional results are given regarding stability of the Hadamard product of M-matrices.

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P. van den Driessche
Department of Mathematics
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Solving Ax=b when A is a Nonsingular M-matrix

Various types of pivoting and diagonal scaling strategies are considered for solving a system of linear equations Ax=b using Gaussian elimination, where A is a nonsingular M-matrix. The numerical stability of such algorithms is analyzed, and bounds are given for the growth factor which occurs in a backward error analysis of the LU decomposition.

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SECOND ORDER DERIVATIVES OF THE PERRON VECTOR

In a previous work the authors ceveloped formulas for the second partial derivatives of the Perron root as a function of the matrix entries at an essentially nonnegative and irreducible matrix. These formulas, which involve the group generalized inverse of an associated M-matrix, were used to investigate the concavity and convexity of the Perron root as a function of the entries.

The authors now combine the above results together with an approach taken in an earlier joint paper of the second author with L. Elsner and C. Johnson and they develop formulas for the second order derivative of an appropriately normalized Perron vector, which again are given in terms the group gener-

alized inverse of an associated M-matrix. Convexity and concavity properties of the Perron vector as a function of the entries of the matrix are then examined. Moreover, some further properties of the group generalized inverse of a singular and irreducible M-matrix are also determined.

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  and

Michael Neumann
Department of Mathematics and Statistics
University of South Carolina
Columbia, SC 29208

Products of Commuting MMA-matrices

An irreducible M-matrix (possibly singular) is called MMA if all of its positive integral powers are irreducible M-matrices. It is known that if A is MMA, then $A = \sum_{i=1}^{k} \lambda_i E_i$ where λ_i are the distinct nonnegative eigenvalues and the E_i are certain projectors. We show there is a combinatorially-generated partial order $\preceq$ on the set $\{E_i : 1 \le i \le k\}$.

THEOREM 1: If the E_i are as above, and if $\beta_1, \cdots, \beta_k$ are distinct nonnegative reals, then the following are equivalent: (1) $B = \sum_{i=1}^{k} \beta_i E_i$ is MMA, (2) $E_i \prec E_j \Rightarrow \beta_i < \beta_j$.

THEOREM 2: Let A and B be MMA with B nonderogatory. If AB = BA, then AB is MMA.

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Jeffrey L. Stuart
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Incomplete Factorization of Singular M-matrices

In 1981, Varga and Cai characterized those M-matrices A (perhaps singular) which admit a factorization into M-matrices L and U (A = L U) where L is required to be non-singular, lower triangular M-matrix and U is required to be upper triangular M-matrix a result that was first proved by Fiedler and Ptak (1962) in the non-singular case. Because this factorization may produce a lower triangular matrix which is considerably less sparse than A, one attempts to control the fill-in of the factorization of A by means of a graph. This method leads to the concept of Incomplete Factorizations of A. Meijerink and van der Vorst (1977) have shown that Incomplete Factorizations of non-singular M-matrices are possible. The purpose of this paper is to give a condition on a singular M-matrix which guarantee the Incomplete Factorization of a singular M-matrix.

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Singular M-matrices

We discuss various inequalities involving a singular M-matrix A and its generalized inverse B. We show how these inequalities determine the structure of both A and B. We also give a simpler and more general proof of a theorem of I. Kuo (Linear Algebra and its Applications, 1977).

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Condition Numbers of Rectangular Systems and Bounds for Generalized Inverses

A natural extension of the notion of condition number of a matrix to the class of all finite matrices is shown to enjoy properties similar to the classical condition number. For example, the relative distance to the set of all matrices of smaller rank is just the reciprocal of this generalized condition number. The question of whether a matrix with a small generalized condition number must also have a generalized inverse of small norm is then studied. The answer turns out to be norm dependent. In particular, only if p is 1 or 2, must an intrinsically well conditioned full rank matrix in the ℓ_p sense have a nicely bounded generalized inverse; in particular in the ℓ_∞ norm this need not be true. These facts are consequences of recent results in Banach space theory.

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PURCELL'S METHOD AND PROJECTIVE n-SPACE

A new look at Purcell's method via real projective n-space leads to a new encoding technique and a reasonable error analysis. The results shows promise for some sparse systems and a new approach to estimating condition numbers.

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Linear Algebra Problems in the Use of the Repeated Integration Parameter Estimation Basis

Attempts to apply the Repeated Integration Parameter Estimation Basis (RIPEB) successfully have been thwarted by failure to account for certain fundamental profound effects, by difficulties in executing certain operations of linear algebra, and by integration algorithm inaccuracy. The source and nature of the two former difficulties are described, as are strategies to overcome them. Also described is an apparently previously unreported property of a certain determinant which is crucial to the successful use of the RIPEB.

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Some New Ill-Conditioning Numbers via Differential Geometry

A simple method is posed that permits an answer to the question, "when can linear algebraic equations be solved accurately/not be solved accurately." Appealing to differential geometry one reasons that when any two (or more) hyperplanes have nearly identical unit hypernormals then "sensitivity of solution" occurs just as in the special case of 2-space when two lines have nearly equal slopes (i.e. nearly equal unit normals). Thus if all the inner products of the unit hypernormals associated with the hypersurfaces are sufficiently less than unity then the associated linear equations are well-conditioned. These ideas and corollary results are presented and illustrated with diverse examples.

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A Parallelizable Preconditioning Algorithm for the Fast Solution of Elliptic Problems

A "good" preconditioner for elliptic problems is defined which can be efficiently solved by using substructuring and/or block Gaussian elimination techniques. The mesh domain is decomposed into a union of subdomains on which "good" preconditioners are available. These subdomains need not be rectangles and can be joined in a rather general fashion. The proposed preconditioner is such that when substructuring techniques are applied to obtain its solution, the resulting boundary system decouples into many independent systems which can be solved in parallel. Theoretical estimates for the condition number of the preconditioned system will be given. Implementation of the algorithm in serial and parallel architectures will be discussed. Numerical results for the model problem will also be presented.

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Matrix Splittings for the Solution of Higher Order Boundary Value Problems

Butcher, Hairer, and Wanner have developed a calculus which can be used for developing Runge-Kuth processes. Hairer has also developed a calculus for higher order differential equations. We use a variation of this calculus to develop a class of processes for the second order boundary value problems of the form $y''=f(x,y)$, $y(a)=A$, $y(b)=B$. These processes do not require derivatives of f and lead to systems of nonlinear equations with block tridiagonal Jacobians.

However, these Jacobians are expensive to form and factor. Hence, the use of quasi-Newton methods based upon a matrix splitting or approximate LU factorization technique is used. We give bounds for the rate of convergence of these iterations. Computational experiments showing that the rate of convergence is fast. One important special case of this class of matrix splitting is the method of deferred correction.

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Incorporating Time-Dependent Forcing in Locally One-Dimensional Methods

When a partial differential equation of parabolic type is discretized in space, a system of ordinary differential equations is defined. It is frequently possible to split the resulting matrix operator into two or more components and to proceed in a locally one-dimensional fashion. That is, the solution of $\frac{d}{dt}u = (L_1+L_2)u$ is replaced by an appropriate linear combination of $\frac{d}{dt}u_1 = 2L_1u_1$ and $\frac{d}{dt}u_2 = 2L_2u_2$.

One such locally one-dimensional scheme utilizes
$$\frac{1}{2}(\exp(\tau L_1)\ \exp(\tau L_2)+\exp(\tau L_2)\exp(\tau L_1))= \exp\ \tau(L_1+L_2)+ + O(\tau^3).$$
The methods based on this splitting are well-suited to parallel computation.

One drawback to LOD schemes has been the inability to incorporate, to full accuracy, time-dependent boundary conditions. This paper describes the way this problem has been solved for a number of LOD schemes. A by-product of the research has been a method to incorporate interior source terms at main (unsplit) time-points, either in predictor-corrector fashion or/and with variable stepsize. Nonlinearities may be locally linearized, as with unsplit methods.

Various numerical experiments are also reported.

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A Spectrum Enveloping Algorithm for Solving Central Difference Approximations of Convection Diffusion Equations

When a convection-diffusion equation is discretized using central difference scheme, the resulting coefficient matrix loses diagonal dominance whenever the convection terms are large and the conventional iterative procedures often fail to converge. The eigenvalue spectrum of some iteration matrices can be enveloped by an ellipse with major axis on the imaginary axis and minor axis in the real interval (-1,1). This ellipse is used to define a convergent iteration scheme. A computational algorithm is described. Numerical examples show that the spectrum enveloping   technique works well when the original iterations diverge. When the original iterations converge, the spectrum enveloping technique converges even faster.

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Consimilarity: A Survey of Results

Two square complex matrices A and B are consimilar if $A = \overline{S}BS^{-1}$ for some nonsingular square complex matrix S of the same size. This concept arises naturally from a classical problem in the theory of univalent analytic functions, in which one wants to diagonalize simultaneously two quadratic forms, one symmetric and one Hermitian. We survey the consimilarity analogs of basic matrix theoretic notions such as invariant subspaces, triangularization, diagonalization, normality, simultaneous reduction, and canonical forms. Complex symmetric matrices play a role in the theory of consimilarity that is analogous to the role played by normal matrices in the theory of ordinary similarity. Consimilarity is a natural extension to matrices of the notion of rotation in the complex plane.

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Applications of a Canonical Form under Consimilarity

Complex square matrices A and B are consimilar if there exists a nonsingular complex square matrix S such that $A = S^{-1}B\overline{S}$, where $\overline{S}$ denotes the componentwise complex conjugate of S. We establish a canonical form under consimilarity that is analogous to the Jordan canonical form for ordinary similarity. A and B are consimilar if and only if $A\overline{A}$ is similar to $B\overline{B}$ and a rank condition is satisfied. Every complex square matrix A is consimilar to its conjugate, transpose, and adjoint, as well as to a real matrix and a Hermitian matrix. The Witt cancellation property extends to consimilarity.

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Spectral Factorization of Matrices

We prove that a nonscalar invertible square matrix can be written as a product of two matrices with preassigned eigenvalues subject only to the obvious determinant condition. As corollaries, we give short proofs of some known results such as Ballantine's characterization of products of four or five positive definite matrices.

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An Analog of the Singular Value Decomposition for Orthogonal Equivalence

Let A be a given m-by-n complex matrix. We give necessary and sufficient conditions for the existence of square complex orthogonal matrices P and Q such that $A = P \Lambda Q^T$, where $\Lambda = (\lambda_{ij})$ is an m-by-n complex matrix such that $\lambda_{ij} = 0$ for $i \neq j$. We also give necessary and sufficient conditions for the simultaneous reduction of a family of matrices to the above form, which may be thought of as an analog of the ordinary (unitary) singular value decomposition. As an application of these results we show that, subject to certain restrictions, a complex square matrix A such that $AA^T = A^TA$ can be reduced to an analog of the real normal form by complex orthogonal similarity.

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Least Squares Approximation with Smoothed Spline Functions

In 1967 Christian Reinsch developed an algorithm for finding the smoothest Natural Cubic Spline function whose weighted square error was less than a prescribed bound. The authors present an algorithm which generalizes Reinsch's algorithm to B-spline functions of arbitrary order. In addition the knot sequence is independent of the data points and the inner product used in the constraint is generalized. The complexity of each Newton iteration is only $O(n)$, where n is the dimension of the space of B-splines. In those cases where the number of data points is significantly larger than n the use of B-splines is significantly more efficient than Natural splines.

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Stabilizing certain iterative processes.

Let A be an $n \times n$ matrix and x_0 an $n \times 1$ column vector. We try to stabilize (i.e. cause to be bounded) the sequence $x_0, Ax_0, A^2x_0, \ldots$ by subtracting a fixed vector y at times $t_1 < t_2 < \ldots$ during its evolution. Thus a typical term of the new sequence is

$$A^n(A^{t_{m+1}-t_m}(\ldots(A^{t_2-t_1}(A^{t_1}x_0-y)-y)\ldots)-y)$$

where $0 \leqslant n < t_{m+1}-t_m$. We modify and extend results of U. Abel which characterized those

real diagonalizable A such that $x_0, Ax_0, A^2x_0,$ ... can be stabilized whatever the choice of x_0 and $t_1 < t_2 < \ldots$. For example our results include all compact operators on a complex Banach space.

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Stability Analysis of Interval Matrices – Another Sufficient Condition

A sufficient condition for the stability of interval matrices is presented based on Liapunov approach. The condition, while requiring the solution of a Liapunov matrix equation, removes the restrictions imposed in a previous paper by Heinen. Examples given illustrate the improvement of the proposed condition over the previously published results.

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On cubic spline interpolants and postprocessing for monotonicity preservation

The main purpose of this talk is to discuss algorithms for postprocessing spline interpolants in order to impose monotonicity constraints while retaining optimal order approximation. One such algorithm will be presented. A secondary purpose is to obtain error estimates for some "practical" unconstrained spline interpolation schemes. Here "practical" means that derivative values are not needed in order to fit the interpolant. One result of the latter type is a different proof of de Boor's recent error estimate for the not-a-knot cubic spline. The proofs of these results are essentially estimates for the inverses of certain band matrices.

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Quasi-Positive Definite Maps

Let V be an n-dimensional unitary space. Let W be the mth tensor product of V. Suppose T is a hermitian transformation on W satisfying $(Tw,w) \geq 0$ for every rank one (decomposable) tensor w in W. Then T is called quasi-positive semi-definite (qpsd). Such a map need not be positive semi-definite and in fact we show that its negative signature can be quite large. If the largest eigenvalue of T is 1, we discuss lower bounds for the smallest eigenvalue and compute the lower bound explicity if m = 2.

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More on Cone Reachability

In recent years, there has been a good deal of research on positively invariant cones; e.g. Elsner (Arch. Rat. Mech. Anal. 1970) and Schneider and Vidyasagar (SIAM Num. Anal. 1970). The present work continues this study.

Given the linear system of o.d.e.'s $\dot{x} = Ax$ $(A \in R^{nn})$, a problem of interest in economics and engineering is to determine those initial states $x(0)$ whose trajectories become and remain non-negative with respect to a positively invariant simplicial cone K. That is, we want to characterize the set $X_A(K) := \cup \{e^{-tA}K: t \geq 0\}$. We do this in case A has a real spectrum, generalizing results of the second and third author (Applic. Anal., to appear), in which diagonability was assumed.

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2) Michael Neumann, Dept. of Mathematics, University of South Carolina.

3) Ron Stern, Dept. of Mathematics, Concordia University, Montreal.

Inverse Problems For Means of Matrices

Given two hermitian positive semidefinite (HSD) matrices A and B, there are natural definitions for their arithmetic and harmonic means. This work considers and answers the following question: Given HSD C and D, when do there exist HSD A and B so that C is the arithmetic mean of A and B and D is the harmonic mean of A and B? The question of the uniqueness of A and B is also answered. A third classical mean is the geometric mean. Similar representational results are presented for the arithmetic and geometric means. All of the results presented are generalizations of results obtained by Gauss in the Scalar Case.

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The Cascade Sum and Difference of Matrices

Whenever a physical system can be described as a function from inputs to outputs it is natural to consider the cascade connection of two or more systems. That is, the outputs of one system furnish the inputs for the next. In the linear case the systems are described by matrices, and the connection gives rise to the cascade sum of matrices. We develop various properties of the cascade sum, and also give conditions for the existence of a cascade difference. This latter problem is closely related to classical problems of electrical network systhesis.

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Recent Progress on Linear Transformations which Preserve Certain Classes of Matrices

Let S be a given class of n-by-n matrices. We say that a linear transformation T on n-by-n matrices preserves S (in an onto sense) if
$$T(S)=S$$
and preserves S (in an into sense) if
$$T(S) \subset S.$$
Characterization of such T has been of classical interest and is of potential practical import for two reasons: (1) such study may be a good way to gain insight into structure of the class S; and (2) full knowledge of such T may be useful in "normalizing" matrices from S for a particular problem. Generally characterizing all the preservers in an into sense is much harder, and we report here on two lines of work in this area which include some of the first into preserver results. In one, joint with Stephen Pierce, S is a subclass of the Hermitian matrices with fixed inertia. In the other, joint with A. Berman and D. Hershkowitz, S is a positivity class, such as the M-matrices, P-matrices, totally positive matrices, etc.

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Mathematical Aspects of the Relative Gain Array ($A \circ A^{-T}$)

The relative gain array (RGA) associated with a nonsingular matrix A is the Hadamard product $A \circ A^{-T}$, where A^{-T} abbreviates $(A^{-1})^T$. Bristol (IEEE Trans. Autom. Control AC-11, 1961) introduced the RGA in connection with control theory in chemical engineering design problems. The matrix $A \circ A^{-T}$ also appears in a matrix theoretic problem and perhaps has other uses.

We study the map $A \to \Phi(A) \equiv A \circ A^{-T}$. We show the sequence of iterates $\Phi^K(A)$ converges to I when A is a positive definite symmetric matrix, and also when A is an H-matrix. We also investigate some intriguing questions about the range of Φ and the fixed points of Φ.

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Semistability Factors and Semifactors

A (semistability) factor [semifactor] of a matrix $A \in \mathbb{C}^{nn}$ is a positive definite [positive semidefinite] matrix H such that $AH + HA^*$ is positive semidefinite. We give three proofs to show that if A has a semistability factor then it cannot be unique. We give necessary and sufficient conditions for a matrix H to be a (semi)factor of a given matrix and we determine the dimension of the cone of semistability factors. We also discuss the relation of rank H to rank $(AH+HA^*)$, when H is a semifactor of A.

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Upper Bounds on the Maximum Modulus of Subdominant Eigenvalues of Nonnegative Matrices

Upper bounds for the maximum modulus of the subdominant roots of square nonnegative, matrices are obtained. We provide a unified approach that yields or improves upon most of the bounds that have been obtained so far.

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Parallel Nonlinear Algorithms

This talk will describe some iterative linear and nonlinear algorithms whose parts may be executed simultaneously. Parallel versions of the nonlinear Gauss-Seidel method, and the Newton-SOR method will be presented. The convergence of these algorithms will be discussed, and applications to some elliptic and parabolic partial differential equation will be given.

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A Vector Approach to Large Scale Configuration Interaction Calculations

A computational scheme is offered for resolving the extremely large matrix eigenvalue problems arising frequently in quantum chemistry. The primary feature of our approach is the use of the nearly separating character of the molecular Hamiltonian to form a Rayleigh-Ritz matrix expressible as a sum of Kronecker products of relatively small matrices. This special structure provides an analog to sparsity in formulating a vector algorithm involving an inexpensive matrix-vector multiply which drives both a Lanczos-based procedure for eigenvalue extraction and a conjugate-gradient procedure for simultaneous eigenvector extraction.

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Communication complexity of Gaussian Elimination on multiprocessors

We propose a few lower bounds for communication complexity of the Gaussian Elimination algorithm implemented on three types of multiprocessor architectures: a bus architecture, a nearest neighbor ring network and a nearest neighbor grid network. It is shown that for the bus and the ring architectures, the minimum communication time is lower bounded by $O(N^2)$, independent of the number of processors, while for the grid this bound is reduced to $O(k^{-1/2}N^2) + O(k^{1/2}N)$, where k is the total number of processors. These bounds take into account both the total bandwidth of the system and latency times. An important consequence of these results is that the minimum time required to solve a linear system by a parallel Gaussian elimination algorithm using an arbitrary number of processors is of the order $O(N^2)$ for the broadcast bus architecture and the ring, and of the order $O(N^{3/5})$ for the grid array. We will discuss the practical implications of these results.

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Parallel Matrix Algorithms for Structural Analysis

A fundamental problem in linear elastic analysis is that of finding the vector of stresses and strains, given a finite element model of a structure and a set of external loads. To obtain the solution to this linear constrained minimization problem, a variety of methods such as the displacement method, the force method, the natural factor method, and the weighted least squares method may be used. While the advantages of implementing one of these methods over another on digital computers have been widely studied, the effects of parallelism in performing the matrix computations associated with each of these methods have not. In this talk, a comparative study of the use of serial and parallel versions of popular matrix methods in solving the fundamental problem of linear elastic analysis on MIMD multiprocessing machines such as the Denelcor HEP will be presented.

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Parallelism of Block-Preconditioned-Conjugate-Gradient Method on HEP-like MIMD Machines

Block-preconditioned-conjugate-gradient-like iterative schemes have found applications in large scale computations in areas such as oil reservoir simulation, numerical grid generation, and others. We discuss an efficient scheduling of these schemes for HEP-like MIMD machines. In particular, we consider matrices generated by 9-point operators with a natural order. We study parallel schedules for the block-diagonal-scaling and the block-incomplete-LU-decomposition preconditionings. With a processor utilization rate of 66%, we derive a speed up linear in the number of processors and proportional to the square root of the number of grid points.

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Efficient Parallel Solution of Linear Systems with Hyperbolic Rotations

An algorithm based on hyperbolic rotations is presented for the solution of linear systems of equations,

$$Ax = b,$$

with symmetric positive definite coefficient matrix A. Forward elimination and backsubstitution are replaced by matrix vector multiplications, rendering the method most amenable to implementation on a variety of parallel and vector machines. The stability behaviour compares favourably with that of the best, known methods.

The method can be simplified and formulated without square roots if A is also Toeplitz; a corresponding systolic architecture (in VLSI) for the resulting recurrence equations is more efficient than previously proposed pipelined Toeplitz system solvers. The hardware count becomes independent of the matrix size if its inverse is banded.

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Sign Nonsingularity and the Odd Cycle Property

A nonsingular real matrix A is sign nonsingular if every matrix with the same sign-pattern as A is nonsingular. We give necessary and sufficient condition for the existence of sign nonsingular matrices with a given zero pattern. Our method and condition are graph-theoretic. In particular we study when does a given digraph D = (∇,E) contain a subset S of the edge set E such that every cycle in D has an odd number of edges from S. We also consider the analoguous question for undirected graphs.

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L-functions and Their Inverses

In 1969 Ortega introduced a class of M-functions, a generalization of the linear mappings induced by M-matrices. The convergence of Gauss-Seidel and Jacobi iteration for M-matrices naturally extends to M-functions

Similarly, we introduce a class of L-functions which generalize the linear mapping induced by L-matrices. A real nxn matrix is an L-matrix if it is the matrix of at least one sign solvable system. This implies that the diagonal of A is negative and all cycles in the signed digraph associated with A are negative. Since L-matrices are invertible, we examine the invertibility of L-functions and present an implicit function theorem for L-functions.

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Formulae for det A Corresponding to Zero Patterns of A^{-1}

We address the problem of expressing the determinant of a matrix A as a quotient p/q where p and q are products of principal minors of A. A broad class of such formulae is demonstrated in Barrett and Johnson, Determinantal Formulae for Matrices with Sparse Inverses, Linear Algebra and its Applications 56: 73-88 (1984), for various symmetric zero patterns in A^{-1}. Given any of these formulae, we consider the problem of finding all (asymmetric) zero patterns of A^{-1} for which the formula holds. The solution of this problem involves the notion of a directed spanning tree of the intersection graph of a collection of node sets each of which is an index set of one of the principal minors appearing in p.

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Linear Characterizations for NP-complete and Number Complete Problems

The problem of computing the number of solutions to many combinatorial problems is reduced to a linear program in a polynomial number of variables. The construction shows that a complete linear characterization would lead to both NP = CoNP and NP = #P. The construction uses techniques from: S. Ursic, A Linear Characterization of NP-complete Problems, Springer-Verlag Lecture Notes in Computer Science: 7th International Conference on Automated Deduction, ed.: R. E. Shostak, 170 (1984) 80-100. It shows that incomplete linear characterizations lead to imprecise counting. It gives a meaning to the fractional solutions we sometimes obtain when incomplete descriptions of the polytopes are used in linear programs. Known facets of the counting polytopes are boolean symmetric and partially symmetric functions.

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The Cyclic Coloring Problem and Estimation of Sparse Hessian Matrices

Numerical optimization algorithms often require the (symmetric) matrix of second derivatives of some smooth problem function. If this Hessian matrix is large and sparse then estimation by finite differences can be quite attractive since several schemes allow for estimation in relatively few gradient evaluations.

The purpose of this paper is to analyze, from a combinatorial point of view, a class of methods known as substitution methods. We present a concise characterization of such methods in graph-theoretic terms. Using this characterization, we develop a complexity analysis of the general problem and derive a roundoff error bound on the Hessian approximation. Moreover, the graph model immediately reveals procedures to effect the substitution process optimally (ie. using fewest possible substitutions given the differencing directions) in space proportional to the number of nonzeroes in the Hessian matrix.

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The Sparse Null Space Basis Problem

When optimization problems are solved by feasible point active set methods, an initial feasible approximation to the solution is iteratively improved in the null space of the matrix of constraints. Hence, algorithms to solve these problems require a representation for a basis of the null space of the constraint matrix. Further, in large-scale problems a sparse null basis is needed if these algorithms are to be practical. The sparse null basis problem can be formulated as a combinatorial optimization problem, under a non-degeneracy assumption on the constraint matrix.

This problem is solved by the theory of matchings in bipartite graphs to obtain a structural null basis (the positions of the nonzero elements in the basis). Numerically stable factorizations can then be used to compute the null basis. Our combinatorial approach constructs sparse null bases faster than conventionally used numerical techniques. This philosophy helps design algorithms that construct sparser null bases than the popular variable-reduction technique.

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A New Public-key Cipher Which Allows Signatures

A block substitution cipher is described which appears to be adequate for computer-implemented signed public-key encryption of messages given in the form of a sequence of binary digits. In this cipher, for a suitably large value of n, n-blocks of binary digits are identified with elements of the finite field $GF(2^n)$ and plaintext n-blocks are replaced by corresponding ciphertext n-blocks by using an enciphering permutation which is a sparse permutation polynomial of high degree defined on the field $GF(2^n)$.

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Unit-Memory Convolutional Codes as a Mean in Cryptographic Systems

In this paper we show that finding good unit-memory convolutional codes with rates r=b/n, b and n integers, is equivalent to solve a Knapsack Problem. For small values of b, this knapsack problem is easily solved whereas for large values it is a very difficult one. Since knapsack problems are known to be NP, unit-memory convolutional codes can be considered as good candidates for use in cryptographic systems. We show by a simple example how these codes are employed in such cryptographic systems.

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Controllability of Positive Systems

Positive systems are used to represent a wide range of applications for which the state vector is constrained to lie in the nonnegative orthant. We will discuss some implications of the positivity constraint for the purpose of control. The results will be illustrated by examples from pharmacokinetics and chemical process systems.

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Linear Quadratic Regulator Problem under Equivalence Transformation

The control input to minimize the cost functional of an infinite-time linear quadratic regulator (LQR) problem is given by

$$u = -R^{-1} B'Px$$

where x is the state vector, A is the system matrix, B is the control matrix, Q and R are the weighting matrices for the state and input respectively, and P is the solution of the algebraic matrix Riccati equation

$$A'P + PA - PBR^{-1} B'P + Q = 0 \qquad (1)$$

When the original system is transformed into an equivalent system, i.e., let x=Tz, and the weighting matrices for the state z and the input u are defined as $T'QT$ and R, the LQR problem for the equivalent system will be solved as

$$u = -R^{-1} B'(T^{-1})'Kz$$

where $K = T'PT$, and P satisfies equation (1). This result provides a convenient means to solve LQR problem for equivalent systems.

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New Numerical Methods for Optimal Control Problems

We present new numerical methods to solve optimal control problems. The basic idea is that the first variation and not a Hamiltonian type method is used. Examples are given which include the non linear-quadratic case.

For problems with "full-rank" our methods which include initial value problems are easy to apply and lead to convergence of order $O(h^2)$. For problems with less than full-rank an augmentation theory is used.

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CONTROL COORDINATION FOR LARGE SCALE LINEAR SYSTEMS

We consider the problem of choosing controls u_1 and u_2 which steer the system $x' = Ax + B_1u_1 + B_2u_2$ from a given initial position to a desired terminal position. A coordination strategy is presented which allows some independence in the choice of controls. The approach involves decomposition of the system into a controllable canonical form and the use of optimization techniques to solve component control problems.

Let $X_1 = [B_1,AB_1,\ldots,A^{n-1}B_1]$, $X_2 = [B_2,AB_2,\ldots, A^{n-1}B_2]$ and assume $X_3 = X_1 \cap X_2 \neq \phi$, $X_1 \not\subset X_2$, $X_2 \not\subset X_1$. The SVD is used to determine basis for the subspaces X_1, X_2, X_3. In this case transformation to controllable canonical form yields a two component system to which we can apply a coordination strategy. We show that component control problems can be solved independently provided certain side conditions are added to the component requirements. Component interactions necessitate the addition of these side conditions.

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Numerical Solution of General Linear Quadratic Gaussian Control Problems.

A new method is prescribed for the numerical solution of the linear quadratic Gaussian control problem: Minimize

$$J(x(t), u(t))=\tfrac{1}{2}\int_0^\infty x(t)^*Qx(t)+u(t)^*Ru(t)+u(t)^*Sx(t)$$
$$+x(t)^*S^*u(t)dt$$

subject to the constraint $\dot{x}(t)=Ax(t)+Bu(t)$, $x(0)=x_0$, where $A, Q \in \mathbb{C}^{n,n}$, $B, S \in \mathbb{C}^{n,m}$, $R \in \mathbb{C}^{m,m}$ Q is hermitian positive semidefinite and R is hermitian positive definite. The method is based on the computation of an invariant subspace of the hermitian pencil:

$$\begin{bmatrix} 0 & A & B \\ A^* & Q & S \\ B^* & S^* & R \end{bmatrix} - \lambda \begin{bmatrix} 0 & iI & 0 \\ -iI & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}.$$

Full use of the symmetry is made and the method is also applicable if R is almost singular. The connection to other algorithms for the solution of this problem is discussed.

CONTRIBUTED PAPERS

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The Matrix equation XA - BX = C and its applications

In this paper we study the well-known Sylvester equation $XA - BX = C$ in the case when A and B are given and C is known up to its first (n-1) rows. We prove new results on the existence and uniqueness of X. Our results essentially state that, in case A is a nonderogatory matrix, there always exists a solution to this equation; a solution is uniquely determined by its first row x_1; and there is an interesting relationship between x_1 and the rows of C. We also give a complete characterization of the non-singularity of X in this case. As applications of our results we develop direct methods for constructing symmetrizers, commuting matrices, computing the characteristic polynomial of a matrix and finding the numbers of common eigenvalues between A and B. Some well-known important results on symmetrizers, Bezoutian and inertia are recovered as special cases.

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Numerical Example of State Feedback Design Algorithms

There are three eigenvalue assignment state feedback design algorithms ([1] Miminis & Paige, 1982, Int. J. Contr.,[2] Tsui, 1983, A.C.C.,[3] Petkov et al, 1984, IEEE Trans. AC), all using Hessenberg form system matrices and orthogonal operations,and all claimed to have good numerical property. However, only algorithm 3 is claimed to be numerically stable using Wilkinson's analysis about deflation techniques. This note is to compare the algorithms 2 and 3 using a numerical example since the algorithm 2, which uses Hyman's method, is also very stable according to Wilkinson's analysis. The example used is an illconditioned 20x20 matrix of eigenvalues 1 to 20.

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Roth's Theorem on the Matrix Equation AX + BY = C

Let R be a principal ideal domain, and let A, B, $C \in M_n(R)$. Using determinantal divisors, W.E. Roth (Proc. Amer. Math. Soc. 3 (1952), 392-396) showed that the matrix equation $AX + YB = C$ is solvable in $M_n(R)$ if and only if the matrices $\begin{pmatrix} A & C \\ 0 & B \end{pmatrix}$ and $\begin{pmatrix} A & 0 \\ 0 & B \end{pmatrix}$ are equivalent over R. A new proof is now given that avoids determinantal divisors, using the local approach to matrix equivalance given in Lin. Alg. Applic. 16 (1977), 221-232.

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Matrix Equations Over Rings

The main purpose of this work is to establish necessary and sufficient conditions for the existence of solutions of matrix equations such as the Lyapunov and Riccati and higher order Riccati type matrix equations. The elements of the coefficient matrices belong to the polynomial domain $\mathcal{F}[\theta_1,\theta_2,\ldots,\theta_n]$ of polynomials in $(\theta_1,\theta_2,\ldots,\theta_n)$ having coefficients belonging to the field $\mathcal{F}$. Use is made of various generalized inverses of matrices over $\mathcal{F}[\theta_1,\theta_2,\ldots,\theta_n]$ to establish algorithms for obtaining solutions to such matrix equations which have applications in systems theory, control theory and elsewhere. Results obtained extend earlier results of W. E. Roth and others.

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Similarity Over F[x]

Let F be an arbitrary field having prime subfield F_p, p either zero or a prime, and let A be an n×n matrix of arbitrary rank over the polynomial domain F[x]. Whenever A lies in a subfield M of the complete matrix ring $(F[x])_n$ and M is a finite simple extension of its scalar interior, then the similarity invariants of A over the field F(x) of rational functions lie over F. I.e., the rational canonical form C of A over F(x) satisfies $C \in (F)_n$. Moreover, unless the field M is intrinsically irregular, it is shown that A is similar to C over F[x] whenever $[F:F_p] < \infty$. In particular, if F = $\mathbb{Q}$ or F = GF(p), then A is similar over F[x] to its rational canonical form over F(x). The conditions on M are equivalent to conditions on the canonical factorization of the minimal polynomial of A over F. Matrices A satisfying these conditions have been constructively characterized.

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Realizations of Rational Matrices

A matrix W of rational numbers can be expressed in the form $W = C(P-N)^{-1}B + D$ such that all matrices involved are integer matrices, the elementary divisors of P are primes and N is nilpotent. An analogon to the state space isomorphism theorem in linear system theory is proved. Duality of finite abelian groups and the concept of straight bases lead to a Jordan factorization of integer matrices.

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Sparse Projections in Karmarkar's Linear Programming Algorithm

The computationally expensive part of Karmarkar's linear programming algorithm is the projection of the cost vector onto null space of the constraint matrix. This projection must be (approximately) orthogonal with respect to the inner product determined by a diagonal matrix that is updated each iteration. Although the projection operator itself may change substantially during the course of the algorithm, the sparsity pattern behind it remains the same, and it may be worthwhile to spend some time on symbolic analysis at the beginning of the algorithm. For example, it may be worthwhile to choose a subset of the constraint matrix columns to be included in a sparse Cholesky or QR factorization (in the George-Heath style) that then serves as a preconditioner for conjugate gradient iterations. This talk discusses some of the heuristics we are trying and presents some preliminary computational experience.

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A Fast but Unstable Orthogonal Triangularization Technique for Toeplitz Matrices

D. Sweet's clever QR-decomposition algorithm for Toeplitz matrices is considered. It requires only $O(n^2)$ flops to factor an $n \times n$ matrix. We show why this novel algorithm is numerically unsound, and suggest techniques for its stabilization.

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The Solution of Banded Systems in Block Tridiagonal Form Using Odd-Even Reduction

The odd-even reduction algorithm is well known for the solution of block tridiagonal systems arising from finite difference problems. An important property is that by performing operations in parallel, the size of the system is reduced to half the previous. In previous work, the algorithm had been extended to give a greater reduction factor for special cases, and had been extended to banded systems in general.

We show that both these extensions are applications of odd-even reduction on block tridiagonal systems with suitably defined blocks. Proceeding in this direction, we define two block parameters which determine the reduction factor and the resulting degree of parallelism in the calculations. Through a suitable definition of these parameters, a solution algorithm for banded systems may be mapped onto a range of architectures which have little to massive parallelism. Accurate operation counts are given and computational results given for tridiagonal and pentadiagonal systems on the Cray 1-S.

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Storage Versus RUN-TIME Step Preserving Programs

Upper triangular unipotent matrices over a ring preserve the composition series $\langle C_i \rangle$ and induce the identity on $\langle C_i/C_{i+1} \rangle$. Two types of programs computing in stages $M=1$ to $n-1$ which preserve the quotient homomorphisms on $\langle C_i/C_{i+M} \rangle$ are given. One type requires duplicate storage but has RUN-TIME $O(n^3)$ whereas the other type works in place but has RUN-TIME $O(2^n)$. It is proved that the storage versus RUN-TIME relationship must hold for programs doing matrix inversion. The corresponding property is conjectured for programs which multiply matrices.

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MAX and the Singular Value Decomposition

The Floating Point Systems FPS-164/MAX is a scientific computer capable of a peak throughput of 341 megaflops. Up to 124 vector operations can be performed concurrently, obtaining high performance on large problems of numerical linear algebra. This paper describes the computational structure of the FPS-164/MAX, and documents work in progress towards highly efficient singular value decomposition routines in the FPS-164/MAX environment.

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The QR and Inverse QR Algorithms for Unitary Hessenberg Matrices.

Let H be a unitary right Hessenberg matrix with positive subdiagonal elements. Using the "Schur-Szego parameterization" of H, and the shift strategy of Eberlein and Huang, the QR algorithm can be implemented to find the spectrum of H, and the weights of the associated Gauss-Szego quadrature formula, to machine precision, in $O(n^2)$ operations. The spectrum of H strictly interlaces, on the unit circle, that of H^1, obtained from H by negating the first row. The corresponding inverse problems will be treated by the "inverse QR algorithm". More generally, the forward algorithm can be used to find zeros of Szego polynomials.

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On Symplectic QR like Methods

In several applications one has to solve the matrix eigenvalue problem $Mx = \lambda x$, where M is a $2n \times 2n$ matrix with one of the following properties: for $J = \begin{bmatrix} 0 & I \\ -I & 0 \end{bmatrix}$, I the $n \times n$ identity, JM is Hermitian, symmetric, skew-Hermitian or skew-symmetric. Similarity transformations with symplectic matrices S , i.e. with matrices S for which $S^H JS = J$ or $S^T JS = J$, respectively, would preserve this special structure of M . Conditions are given under which a QR like method using symplectic transformations can be derived. It is shown why it is in general not possible to work with symplectic matrices which in addition are unitary or orthogonal. Connections with some known symplectic methods are pointed out.

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Basic Linear Algebra Modules for a Concurrent Computing Environment with IEEE Floating Point Arithmetic

IEEE Floating Point Arithmetic relaxes many of the programming constraints previously required to avoid the side-effects of arithmetic exceptions, particularly underflow, for matrix computations. However, the requirement for a minimal operating system on each node of a concurrent computing system reveals the need for floating point arithmetic exception handlers and associated communication primitives to access them.

The exception handlers and communication primitives designed and used on an Intel 8086/87 or 80286/287 microprocessor based concurrent computing system will be described.

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Analogues of Givens and Lanczos methods for Pseudosymmetric Matrices

A pseudosymmetric matrix A is defined as
$$A = BJ,$$
where $J = diag\{\pm 1\}$ and $B = B^T$.
An analogue of Givens method for pseudosymmetric matrices is discussed as described in (1) . The paper then shows that Lanczos method (2,p388-391) for reducing a general matrix to a tridiagonal matrix has a relatively simple form for pseudosymmetric matrices. A comparison of the special cases where these two methods breakdown is discussed.

REFERENCES
1. Brebner, M.A., and Grad, J., Eigenvalues of $Ax = \lambda Bx$ for Real Symmetric Matrices A and B Computed by Reduction to a Pseudosymmetric Form and the HR Process, Linear Algebra and Its Applications, 43;p99-118, 1982.
2. Wilkinson, J. H., The Algebraic Eigenvalue Problem, Oxford University Press, 1965.

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OPTIMAL CHOICE OF TRUNCATION LEVEL FOR TRUNCATED SVD FOR LINEAR ILL-POSED PROBLEMS

We apply the truncated singular value decomposition to solve linear ill-posed problems when the data are noisy. We define an optimal truncation level and apply generalized cross validation to choose an estimate for this optimal truncation level which depends on the data. Convergence rates and an example will be discussed.

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Resolvent bounds and eigenvalue estimates' error bounds

Majorants and accomanying norm bounds are found for the resolvent of a matrix on a closed curve consisting of segments of circles. These bounds are employed to transform residual norms into error bounds for an eigenvalue estimate close to a simple isolated eigenvalue and to count the number of eigenvalues contained in the curve.

A natural bound is found for the ℓ_∞ norm for the resolvent on a curve around a component of the Gerschgorin Disk set. This norm bound is calculated in n squared operations. Majorants are also found for the resolvent of a matrix close to a cluster of eigenvalue approximations that have been exposed through an application of the QR algorithm.

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Estimating the SOR Extrapolation Parameter

Effective use of any of a family of Successive OverRelaxation (SOR) methods requires estimation of an overrelaxation parameter. Several procedures have been used for adaptive refinement of an initial estimate. These often involve preliminary computation with parameters that are less than optimum. When insufficient iterations are performed between updates, a disastrous "creep" toward an erroneous value of two has been observed. In some cases, iteration for accurate update of the overrelaxation parameter consumes significant computation time. Some popular modern iteration programs use SOR as a component of a two-level procedure in which the SOR iteration is interrupted cyclically with a coarse-grid computation or a conjugate-gradient iteration. One variant involves periodic correction of the SOR iterate with a low-order polynomial correction. This reduces sensitivity to the overrelaxation parameter and in some cases reduces computation time by an order of magnitude. A procedure has been devised for using the polynomial correction equations to refine the extrapolation parameter for the next SOR cycle. Nearly-optimum parameters may be computed along with reasonable estimates of their accuracy. Theory and numerical results will be described for this new procedure.

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Singularities in Isospectral Flows

The Toda flow and its generalizations are related to the QR matrix decomposition and the QR algorithm. An analogous class of flows, the class of LU flows, is based on the LU matrix decomposition. These flows, unlike the QR flows, can have singularities in their solutions. We will examine these singularities and relate them to various subspace conditions, the existence of LU decompositions, and the LR eigenvalue algorithm.

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Transforming residual bounds into error bounds for eigenvalue estimates

Often researchers associate a pessimistic n'th root bound limitation with the use of residual norms for determining error bounds for eigenvalue estimates. For nonzero eigenvalues, we demonstrate that this pessimistic n can be replaced with the smallest integer greater than $M/|i.!|$ where M is the Frobenious norm of the matrix.

Applications are made to matrices generated by the QR algorithm to count the number of actual eigenvalues near a cluster of eigenvalue estimates and to create a function, locally valid, which maps residual norms onto error bounds for eigenvalue estimates.

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Group-invariant Covariance Models

A group-invariant covariance model may be described as a family of covariance matrices that remain invariant under the action of a finite group of orthogonal transformations. S. Andersson, H. Brons and S.T. Jensen have noted that all classical statistical hypothesis-testing problems for the covariance structure of a multivariate normal population reduce to that of testing one group-invariant model against another. We review the theory of such models and present several examples to illustrate their main features: maximum likelihood and least squares estimators coincide, and hypothesis-testing problems admit ANOVA-like decompositions.

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Identifying Rank-Influential Groups of Observations in Generalized Linear Regression Models.

When fitting a generalized linear regression model, deleting a small group of observations from the data may decrease the precision of parameter estimates substantially or worse, render certain parameters inestimable. These effects occur when the deletion of the group degrades the rank of the design matrix for the model. We present theory and methods for identifying such rank-influential groups of observations.

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The Algebra of Hyperboloids of Revolution

If we change the sign of $p \leqslant m$ columns (or rows) of a $m \times m$ positive definite symmetric matrix A, the resultant matrix B has p negative eigenvalues. We will give systems of inequalities for the eigenvalues of B and of the matrix obtained from B by deleting one row and column. To obtain these, we first develop characterizations of the eigenvalues of B which are the analogous to the minimum-maximum properties of the eigenvalues of a symmetric A, i.e. the Courant-Fischer theorem.

These results arose from studying probability distributions on the hyperboloid of revolution

$$x_1^2 + \ldots + x_{m-p+1}^2 - \ldots - x_m^2 = 1.$$

By contrast, the familiar results are associated with the sphere

$$x_1^2 + \ldots + x_m^2 = 1.$$

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Multivariate and Other Forms of the Pitman-Welch Permutation Test for Randomized Blocks

The objective of this paper is three-fold. First, the Pitman-Welch permutation test for the randomized blocks design is extended for analysis of multiple dependent variables. Next, this extension is shown to subsume the analysis of a design with a single multichotomous dependent variable. Cochran's test for homogeneity of proportions for multiple dichotomous variables, and McNemar's test for two correlated proportions are shown to be special cases. Lastly, the univariate design is also shown to subsume special cases, including Friedman's ranked data test and Fisher's randomization test for paired observations.

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An SVD-Based Algorithm for Stochastic System Identification

In this talk, we will present a new covariance approximation approach to stochastic identification. We will formulate the identification problem as one of selecting a partial-state to approximately span a state-space of higher dimension. Using a counter example, we will demonstrate the effect of the inherent normalization in Akaike's canonical-correlations approach. We introduce a new criterion for the partial-state-selection problem, that measures the error-variance in the prediction of the future. Using the predictive-efficiency criterion that was first used by C.R. Rao in multi-variate statistics, we will develop an SVD-based principal-components approximation method for estimating the ARMA model from estimates of the output covariance. We will relate the new method to the classical Hankel-approximation methods, and to balanced-model-reduction.

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The Early Use of Matrix Diagonal Increments in Statistical Problems

The early motivation for and development of diagonal increments to ease matrix inversion in least squares problems is discussed. It is noted that this diagonal incrementation evolved from three major directions: modification of methodology in non-linear least squares, additional information in linear regression, and improvement of the numerical condition of a matrix. The interplay among these factors, and the advent of ridge regression, are considered in an historical framework.

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Estimating the Parameters of a Positive Semidefinite Quadratic Form Using a Cholesky Decomposition

Maximum likelihood estimates of the parameters of a p.s.d. matrix B are obtained by reparameterization to the form $B=C^TC$, where C is an upper triangular matrix. The parameter matrix C is estimated using a Newton-Raphson search routine with variable step size. This procedure is a substantial improvement over the algorithm previously reported at the 1st SIAM Conference. The new algorithm is presented along with procedures for generating start values, imposing constraints, determining the rank of B, and developing standard errors of the estimates in B. We also deal with the problem that the empirical information (Hessian) matrix may not be p.d. and show that negative pivots should be treated separately from zero-valued pivots. Examples will be provided.

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Newton-Hankel and Newton-Toeplitz Matrices: Theory and Applications

Certain generalizations of Toeplitz and Hankel matrices, arising from the Hermite rational interpolation problem, are shown to be of interest in other contexts. As in the classical case, they provide an important connection between orthogonal polynomials, interpolation problems, control theory, and other areas. Some computational aspects of working with these matrices are also discussed.

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A Stability Analysis of Incomplete LU Factorizations

The combination of iterative methods with preconditionings based on incomplete LU factorizations constitutes an effective class of methods for solving the sparse linear systems arising from the discretization of elliptic partial differential equations. We show that there are some settings in which the incomplete LU preconditioners are not effective, and we demonstrate that their poor performance is due to numerical instability. Our analysis consists of an analytic and numerical study of a sample two-dimensional elliptic problem discretized by several finite difference schemes.

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The Linear Algebra Challenge of Globally
Convergent Homotopy Methods

Traditionally nonlinear systems of equa-
tions have been solved by locally conver-
gent iterative techniques, with global
algorithms considered the realm of topol-
ogists or impractical. Recent theoretical
work has developed some powerful global
theory, and some of the ensuing algorithms
have been shown to be indeed practical.
This talk will survey the unique numeri-
cal linear algebra problems of probabil-
ity one globally convergent homotopy
algorithms--the theory, algorithms and
their implementation, and applications
ranging from image processing to fluid
mechanics. The software package HOMPACK
will also be discussed.

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An Efficient Method for Determining
Symbolically the Characteristic
Polynomial of a Matrix.

A method is presented that determines
the characteristic polynomial of a real
matrix A of order n. The result is
presented in descending powers of λ
multiplied by real number coefficients.
The computation time involved is
approximately $5n^3 t_1/6 + 7n^3 t_2/6$ seconds,
where t_1 is the arithmetic time to
multiply or divide two numbers, and t_2
is the arithmetic time to add or sub-
tract two numbers. This compares favor-
ably to other methods. The method is

well behaved since most degenerate cases
simplify and speed the solution. If the
characteristic polynomial is illcondit-
ioned whilst A is well behaved, however,
the method should be avoided.

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Design of Extended Model Following Servo
         Controller

A servo controller is designed so that
the response of the plant is as close as
possible to that of a reference model
system, which has an arbitrary input
from a trajectory generating model.
The controller is named "the extended
model following servo" and its control
law is determined by discrete optimization.

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**An Application of the Singular Value Decomposition
to Manipulability and Sensitivity
of Industrial Robots**

In designing and evaluating industrial robots, it is important to find
optimal postures and locate optimum points in the workspace for
the anticipated tasks. In the talk the singular value decomposition
and the perturbation analysis are applied to the Jacobian of robot
kinematics; the condition number of the Jacobian is proposed to be
a measure of the "nearness" to degeneracy. Then qualitative
measures called "manipulability" and "sensitivity" are proposed.
Some properties of proposed measures are investigated and the
relation between these measures are investigated. Optimal postures
of various types of industrial robots are obtained.

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Statistical Analysis of the Effects of Matrix
Perturbations in Some Least Squares Problems

A central problem in many signal processing
techniques is the solution of a system of linear
equations. The coefficients are functions of
observed data. We examine two such problems;
(1) frequency estimation by linear prediction, and
(2) adaptive detection of a signal in Gaussian
noise. Low-rank approximation of the coefficient
matrix in solving systems of linear equations has
been shown to be useful in both problems. We
present a statistical analysis that relates the
accuracy of the frequency estimate in problem 1
and the detector performance in problem 2, to the
perturbations in the observed data and a suitably
defined coefficient matrix.

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Linear Algebra in Modern Signal Processing

This tutorial presentation surveys the role of
linear algebra in modern signal processing. The
discussion begins with the conceptual role of
linear algebra ideas and methods in the
formulation of signal processing methods for such
representative tasks as spectrum analysis,
beamforming, and data compression. Next, the
numerical stability of matrix algorithms needed
for several types of signal processing computations
is discussed. Finally, parallel algorithms and
architectures for matrix computations are surveyed,
with emphasis on systolic and related cellular
architectures.

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SOME SPECIAL FUNCTION MATRICES AND IDENTITIES DERIVED FROM THEM

For each $n=2,3,\cdots$ let r be an integer such that $\gcd(r,n)=1$ and $1\le r\le n-1$. Let A_r be the $n\times n$ circulant whose first row has a 1 in the $(r+1)$th place and zeros elsewhere. Then $\{zA_r : z\in\mathbb{C}\}$ is a Lie algebra. The exponential map yields a Lie group of unimodular matrices whose entries are $h_i(x)=\sum_{j=0}^{\infty}\left[(i+nj)!\right]^{-1}z^{i+nj}$. In the case of skew circulants we obtain $t_i(x)=\sum_{j=0}^{\infty}\left[(i+nj)!\right]^{-1}(-z)^{i+nj}$. These lead to identities for $h_i(x)$ and $t_i(x)$, the hyperbolic and trigonometric functions of order n. [vide A. Erdelyi et al, Higher Transcendental Functions, Vol. III, McGraw Hill, 1955]

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A Characterization of Inertia-preserving Secant Updates

A characterization is given for scale-invariant inertia-preserving secant updates expressible in real product form $(A_+ = FA_c F^t$ with $F = I + qr^t)$. This not only includes the BFGS and DFP updates but also provides distinct updates that may be of utility in resolving saddle point problems. The constructive nature of proof provides a new parameterized family of updates.

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ON CERTAIN STRICTLY DISSIPATIVE MATRICES

Let $A = H + iK$ be a strictly dissipative matrix such that H is semi-definite positive. Let $\alpha_1 \ge \cdots \ge \alpha_n$ and $\gamma_1 \ge \cdots \ge \gamma_n$ be the eigenvalues of H and K, respectively. We show that

$$\min_\sigma \sum_{j=1}^{n} |\alpha_j + i\gamma_{\sigma(j)}| \le |\det(A)| \le \max_\sigma \sum_{j=1}^{n} |\alpha_j + i\gamma_{\sigma(j)}|,$$

where $\sigma \in S_n$, S_n the symmetric group of degree n.
If $\alpha_1 \ge \cdots \ge \alpha_n > \gamma_1 \ge \cdots \ge \gamma_n$, then

$$\min_\sigma \sum_{j=1}^{n} \arg(\alpha_j + \gamma_{\sigma(j)}) \le \arg\det(A) \le$$
$$\le \max_\sigma \sum_{j=1}^{n} \arg(\alpha_j + i\gamma_{\sigma(j)}).$$

We present an example showing that the set of values attained by the determinant of a strictly dissipative matrix, whose real and imaginary parts have fixed eigenvalues, may not be simply connected.

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On Nonnegative Matrices

Let T be a nonnegative $n\times n$ matrix. We say that T is quasi-irreducible if (i) Its directed graph has a strongly connected component, which we call the kernel, such that any other node in the graph is connected by a path from it to the kernel; (ii) There are no directed paths from the kernel to any node outside it. Note that irreducible and semi-irreducible matrices are quasi-irreducible. In all that follows, T is quasi-irreducible. We call K the principal submatrix of T whose graph is the kernel, K^c the principal one involving the nodes outside the kernel and r the spectral radius of matrices. Theorem 1. If $r(k) < r(K^c)$ and all row sums in T are less or equal than s, then $r(T) < s$. Theorem 2. The following are equivalent: (i) There exists a vector $x \gg 0$, such that $Tx = r(T)x$. (ii) $r(K^c) < r(K)$. The vector x is unique up to constants. Theorem 3. Suppose $s > r(T)$ and $(sI - T)x = y$. If $x_i > 0$ whenever $y_i < 0$, then $x \gg 0$. The results above, as well as some others, apply to inpu-output economic

analysis. Theorem 2 has been suggested in the remarks of "A Generalization of the Stein-Rosenberg Theorem" (Numer. Math. 34. 403-409 (1980)) by J.P. Milaszewicz. Theorem 3 is an extension of Theorem 6 in "Non-Negative Matrices: The Open Leontief Model" (Linear Algebra and Appl. 13, 175-201 (1979)) by G. Sierksma.

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Some New Efficient Algorithms Related to Cayley-Hamtilton Theorem

The evaluation of the roots of a polynomial $p(x)$ of degree n is performed by the power and shifted inverse power methods applied to the companion matrix. This is reduced to the evaluation of $x^K \bmod p(x)$ for large K so that all roots of $p(x)$ are computed to K correct digits very fast, involving $O(n \log n \log K)$ sequential arithmetic operations or $O(\log(nK))$ parallel steps, $n^3 + Kn$ processors, or $O(\log n \log K)$ steps, n processors, provided that the roots are not clustered. If they are clustered, running time increases $n/\log n$ times (in real case) and $n^2/\log n$ times (in general case). Some other similar algorithms evaluate a matrix polynomial $q(X)$ of degree K, X is an $n\times n$ matrix, in $O(K \log K + n^{2.5})$ sequential arithmetic operations or in $O(\log K + \log^2 n)$ parallel steps with $Kn + n^{3.5}$ processors. The number of processors can be reduced to $K + n^3$ if $q(X)$ is to be computed with arbitrary precision rather than exactly or if $O(\log n \log (Kn))$ steps are allowed to be involved.

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A Parallel Method for the Generalized Eigenvalue Problem

We present a parallel method to solve the generalized eigenvalue problem on a linear array of processors, each connected to their nearest neighbors and operating synchronously. We also include a wraparound connection from end to end. Our method is based on the well-known QZ algorithm of Moler and Stewart, which simulta-

neously reduces two nxn matrices to upper triangular form by orthogonal or unitary transformations. We show how this algorithm may be partitioned and distributed over n+1 processors, achieving a speed-up over the serial algorithm of O(n). We use the concept of windows to describe the action of each processor at each step. We show how to incorporate single shifts, and how to apply orthogonal plane rotations on either side of a matrix without the need to transpose the matrix itself.

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Design of and Experience with Frontal and Skyline Solvers for Vector and Parallel Processing of Finite Element Codes*

Frontal and skyline methods are efficient means for Gauss elimination of large systems of finite element equations. We discuss modifications to Hood's (1976) frontal algorithm for nonsymmetric systems which: (1) enhance vectorization on a Cray 1; (2) achieve high-level parallelism on an ELXSI 6400 via nested dissection of a computational domain (e.g., a 2-D test code runs on a four processor ELXSI with 55-95% utilization of each processor, even though frontwidth is at most 18). The parallel algorithm is readily extended to out-of-core solution and to as many processors as there are elements in the mesh. We also discuss vectorization of Hasbani & Engleman's (1979) nonsymmetric skyline solver. We compare performance of the two solvers on the Cray.

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On Homogeneous Algebras

A homogeneous algebra is a finite-dimensional algebra whose automorphism group acts transitively on the one-dimensional subspaces. R^3 with the usual vector cross product is the best known example. The talk will survey known results about homogeneous algebras, including the authors' classification of all such algebras of dimension less than or equal 4. The existence of a homogeneous algebra of dimension n can be studied by considering subspaces of n × n matrices all of whose members are projectively similar.

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Direct Parallel Algorithms for Exact Solution of Sparse Symmetric Linear Systems

A direct parallel algorithm for exact solution of a sparse $n \times n$ real symmetric (or Hermitian) linear system $Ax=b$ is presented. If the graph $G(A)=(V,E)$ (which has n vertices and an edge for each nonzero entry) is s(n)-separable, then the algorithm requires $O((\log n)(\log s(n))^2)$ time and $|E| + M(s(n))\sqrt{s(n)}$ processors. The algorithm computes a special factorization of A so that solving another linear system $Ax=b'$ with the same A requires only $O(\log n \log s(n))$ time and $|E| + (s(n))^2$ processors.

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A Program for the Parallel Computation of the Schur Decomposition of an Arbitrary Matrix.

We present a working program,which, given a square matrix A of order n, finds a unitary matrix U, such that U*AU is upper triangular to working accuracy. U is formed as a product of plane rotations. The choice of pivot planes for these rotations is an extension of the Brent-Luk schemata. Hence, the program will run on an (n/2)-square array of processors in O(n) time. We present motivation for the algorithm, as well as experimental results. However, no convergence proof is given.

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Prolegomena to Numerical Homological Algebra

Recent work by M. L. J. Hautus shows that the solvability of a regulator problem depends on the splitting of an exact sequence

$$0 \to Z \to H \to X \to 0,$$

where Z is the multivariable zero module of the system to be regulated, X is the pole module of an external disturbance generator, and H is defined by various connection matrices. This result is equivalent to some detailed results on matrix equations of the form A T - T B = C.

Standard homological algebra dictates that Ext (X,Z) is "generically" zero for the modules considered here. That is, classical results give no insight into sequences which are split in a "badly conditioned" or "non-robust" way. This preliminary report introduces numerical considerations into the study of module deformations and groups of module extensions.

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CONTRIBUTED PAPERS

Algorithms For Polynomial Matrix Operations

Among the polynomial matrix operations, the inverse and division are probably the most difficult ones. In this paper, we present some algorithms for finding the inverses of unimodular matrices and other invertable polynomial matrices as well as the division of polynomial matrices. The polynomial matrices are expanded by s-powers, and the algorithms are based on equating the coefficient matrices of same s-powers. The algorithms are easy to program and simpler than the previous ones. There is no substantial obticle to extend the algorithms into the case where more than one variables are involved.

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On the Computation of State Transition Matrices

The infinite series is often used to compute the state transition matrix of a linear system
$$\overset{\circ}{X} = AX + BU$$
The advantages are that it is not necessary to compute the eigenvalues of A, and is easy for programming. However, when the eigenvalues of A have large negative real parts, numerical errors caused by smearing occur for large t. Smearing is the loss of significant digits due to large intermediate sums in the computation of the sum of a series when computed in floating-point arithmetic. To avoid this situation, an alternate algorithm is proposed:

1. Compute $e^{(-A)t}$ using the infinite series.

2. Evaluate $e^{At} = (e^{-At})^{-1}$

The existence of e^{-At} is guaranteed since e^{At} is nonsingular for all t.

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Approximate Linear Realization from Finite Time-Series Data

A scheme for modelling finite sequences of multivariate time-series data in the form of linear, discrete-time systems is presented. The resulting state space model can, for example, be used for analyzing dynamic behavior or forecasting purposes. The approach combines the ideas of approximate balanced realization and a recently suggested realization algorithm for finite sequences of impulse responses, both developed in system theory. Special attention will be given to the problem of initial state determination. The presentation will conclude with an illustrative application of the scheme suggested.

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Using Symplectic Structure in Algorithms for Solving the Discrete Riccati Equation

Solutions of the discrete Riccati equation are associated with invariant subspaces of symplectic matrices and deflating subspaces of symplectic matrix pencils. Symplectic matrices have a rich variety of elementary symplectic factors. We describe some of these factors and suggest ways in which numerical algorithms can preserve and exploit them.

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The Sensitivity of the Stable, Non-negative Definite Lyapunov Equation

A priori and posteriori error bounds for the stable matrix Lyapunov equation

$$A^H + HA = -W$$

are derived, where A is an N x N stable matrix (i.e., the real part of all the eigenvalues of A are less than zero) and the pair (A, W) is controllable. These bounds are counterparts of the usual error bounds for the solutions of linear systems. As a consequence of these bounds, condition number values are proposed and three distinct qualitative estimates are identified that predict large condition numbers. Large condition numbers will occur when the ratio of a selected eigenvalue of A and A plus a perturbation is large or when W is positive definite and ill conditioned with respect to inversion or when the maximum eigenvalue of the Hermitian part of A is a large positive number. These bounds are less conservative than those currently available.

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Matrix-Free Methods for Stiff Systems of ODE's

When integrating stiff systems of ODE's by BDF methods, the resulting nonlinear algebraic system is usually solved by a modified-Newton method and a suitable linear system algorithm. Instead, Newton's method (unmodified) coupled with an iterative linear system method is substituted. The latter is a projection method called the Incomplete Orthogonalization Method, (IOM). A form of IOM, which requires no matrix storage whatever and with scaling included to enhance robustness, will be discussed in the

setting of Inexact Newton Methods. Tests on several stiff problems, with up to 16000 unknowns, show the method to be quite effective, and much more economical in both computational cost and storage than standard solution techniques.

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Linear Algebra in Phase Space Analysis of Ordinary Differential Equations

Phase space topology of a system of ordinary differential equations depends upon location and classification by local behavior of critical points, by solving the algebraic eigenproblem for the Jacobian of the system, evaluated at each critical point. A basis for the plane of real oscillation associated with a pair of complex conjugate eigenvalues, is the real and imaginary parts of the associated complex conjugate eigenvectors, taken as two real vectors. Two illustrative applications are from system dynamics (a business example from Forrester) and from sociocybernetics (system analysis of human relations), wherein classification depends upon higher order terms, analyzed by linear algebra, including a linear transformation to the above basis.

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Solution Of Linear Systems Of Equations Of Saddle Point Type By Domain Decomposition Techniques.

Systems of linear equations of saddle point type arise in different applications such as mixed formulation of self adjoint partial differential equations, Stokes equations, and structural analysis. An iterative mehtod of SOR type, that needs only a local calculation of the null space of the constraints is presented.

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Infinite Matrices and Some Applications

In this survey, we discuss applications of infinite matrix techniques to linear systems. In mathematical formulation of physical problems and their solutions, infinite matrices arise more naturally than finite matrices. For an infinite matrix A, the following cases are considered. Existence, uniqueness and boundedness of solutions are established for $Ax = b$ and $(dx/dt) = Ax$. Approximation by finite truncation is also obtained, complete with error bounds. Furthermore, we give intervals for eigenvalues of $Ax = \lambda x$ and of the differential system $-y'' + f(x)y = \lambda y$, $y(0) = y(\infty) = 0$. In the latter case and in $-y'' + f(x)y = g(x)$, $y(0) = y(\infty) = 0$, finite difference techniques are used. We illustrate our results by considering the Mathieu equation and the Schrödinger wave equation.

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MAXIMUM CHORDAL SUBGRAPHS OF GRID GRAPHS

Recently, Dearing, Shier, and Warner developed a polynomial-time algorithm for finding a maximal chordal subgraph of an arbitrary undirected graph. The complexity of finding a maximum chordal subgraph is an open problem in general. However, this paper will present bounds and algorithms for determining maximum chordal subgraphs of grid graphs associated with the discretization of PDE's on rectangular domains. The bounds and algorithms generalize to the graphs associated with higher order methods; e.g., the Rayleigh-Ritz-Galerkin method with tensor product B-splines.

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On the Use of Electrical Network Equations to Draw Graphs in the Plane

W.T. Tutte, "How to draw a graph", Proc. London Math. Soc. 13 (1963) implies that a convex, straight line embedding of a sufficiently connected planar graph is obtained by solving node voltage electrical network equations in 2 dimensions. Imagine a "spider web" whose threads are linear springs with zero unstressed length. Different embeddings result from different relative values of the positive spring constants. We find for all graphs and for n dimensions that when any one spring constant is changed, each vertex can only move parallel to that spring. A matrix tree theorem is then applied to give combinatorial conditions for the determination of the sign of each vertex's motion. We investigate the magnitudes of the changes and consider possible applications to heuristics for planar or non-planar graph layout problems.

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Spectra of the Extended de Bruijn-Goods Graphs

The de Bruijn-Goods graphs are extended. It is shown that the spectra of the extended de Bruijn-Goods graphs are all zeros except one which is index.

The above results are applied to the calculation of the numbers of the maximal circuits for the extended de Bruijn-Goods of order n.

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Where are the Cycles?

Directed graphs offer a very practical way to model complex situations. In some cases, it is most important that the digraph be acyclic. As the complexity of the model increases, it behooves a way to make sure that (i) there are no cycles, or that (ii) the vertices which are possibly involved in one cycle or more be identified.

The algorithm presented here satisfies the requirements posed by items (i) and (ii) above by making use of the fact that if a digraph is acyclic then it has at least one vertex of outdegree zero and at least a vertex of indegree zero [Harary F., Norman R., Cartwright D. "Structural Models: An Intro-duction to the Theory of Directed Graphs," J. Wiley, 1965, p. 64]. One of the advantages is that its efficiency is not data structure dependent.

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Nullities of Submatrices of Generalized Inverses

Let (α, α^c) and (β, β^c) be partitions of the lists $(1, \ldots, m)$ and $(1, \ldots, n)$, respectively. If m=n and $A \in \mathbb{C}^{n \times n}$ is invertible with inverse $A^{-1} \in \mathbb{C}^{n \times n}$, then it is known that the submatrices $A(\alpha, \beta)$ and $A^{-1}(\beta^c, \alpha^c)$ have equal row nullities and equal column nullities. [W. H. Gustafson, A note on matrix inversion, Linear Algebra Appl. 57: 71-73 (1984).] In this paper we consider $A \in \mathbb{C}^{m \times n}$ with Moore-Penrose inverse $A^\dagger \in \mathbb{C}^{n \times m}$ and provide relation-ships between the nullities of $A(\alpha, \beta)$ and $A^\dagger(\beta^c, \alpha^c)$.

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The Second Immanant and the Moment Sum of a Graph

Let G be a graph on n vertices affording a Laplacian matrix L(G). If d2 is the immanant corresponding to the partition $n = 2 + 1 + \ldots + 1$, then the coefficient of x in $d2(xI + L(G))$ is the "moment sum" of G.

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On the Null Space of a Subspace of Singular Matrices.

A classical result of Dieudonne is generalized. We prove: If W is a subspace of $m \times n$ $(m \le n)$ matrices of dimension $mn - n - k$, and W contains no matrix of rank m, and if $0 \le k \le n - 3$ or $mn - n - t \le k \le mn$ where t is the greatest integer less than or equal to $(n-1)/(m-1)$ then either i) there exists a nonzero m-vector $\underline{v}$ such that $\underline{v}^t A = \underline{0}$ for all $A \in W$ or ii) there exists a nonzero n-vector $\underline{u}$ such that $A\underline{u} = 0$ for all $A \in W$. For $r < m$, the case of all A in W having rank at most r is addressed.

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Null Vectors and Singularity of Acyclic Matrices

Let A be an n x n complex matrix which is com-binatorially symmetric. Let G be the nondirected graph with vertex set $V(G) = \langle n \rangle$ and edge set $E(G) = \{\{i,j\}: a_{ij} \neq 0 \text{ or } a_{ji} \neq 0\}$. We define the class of A-closed subsets of $V(G)$, and a special A-closed set $Q(A)$ (determined inductively using certain low-order principal minors of A).

Theorem 1. For every null-vector x of A, $Q(A) \subseteq \omega(x)$, where $\omega(x)$ is the set of indices of zero entries of x. Also, A is nonsingular iff $Q(A) = \langle n \rangle$.

Theorem 2. Let A be irreducible and acyclic, with all $a_{ii} = 0$. Then, for every A-closed set ω, there is a null-vector x of A with $\omega(x) = \omega$. Thus A is nonsingular iff $\langle n \rangle$ is the only A-closed set.

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A Polynomially Bounded Pivoting Algorithm for a Linear Complementarity Problem With a Quasi-Diagonally Dominant Matrix

In this talk, we describe a parametric principal pivoting algorithm for "solving" a linear complementarity problem defined by an n x n quasi-diagonally dominant matrix. The algorithm will in $O(n^4)$ time, either (i) conclude that the problem has no complementary solution, or (ii) computes a solution if it exists.

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Existance of Nonnegative Solutions for Leontief's Closed Dynamic Input-Output Model.

Conditions for the existance of a positive balanced growth solution for the discrete dynamic closed input-output (IO) model $(I-A+B)x(k)-Bx(k+1)=0$ are presented. Previous work in the area invariably assumed unrealistic restrictions on the matrices A or B. In our work these conditions are not imposed. The conditions studied depend on the graphs of the matrices rather than on the value of the coefficients. In particular, we prove that $U=(I-A)^{-1}B$ is irreducible if and only if the union of the graphs $G(A)$ and $G(B)$ is strongly connected.

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Path addition and marginal cost on user-optimized transportation networks.

On a user-optimized transportation network, the addition of a new Braess-type link or path may paradoxically raise the equilibrium travel cost C common to all K users sharing an Origin/Destination (O/D) pair. However, if the link costs are assumed to be linear functions of link flow, owing to matric and determinantal properties of the equilibrium relations, we can show that the marginal cost $2c/2k$ is a monotone non-increasing function of the number of O/D paths.

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Sensitivity of the Stationary Distribution Vector for an Ergodic Markov Chain

Stationary distribution vectors p^∞ for Markov chains with associated transition matrices T are important in the analysis of many models in the mathematical sciences, such as queuing networks, input-output economic models and compartmental tracer analysis models. The purpose of this talk is to provide insight into the sensitivity of p^∞ to perturbations in the transition probabilities of T and to understand some of the difficulties in computing an accurate p^∞. The group inverse of $I-T$ is shown to be of fundamental importance in understanding sensitivity or conditioning of p^∞. Ecological examples are given. A new stable algorithm for calculating the group inverse is described.

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K-part iterative solutions to Linear Systems

The solution of the linear system $(I-B)x=b$ is sought by considering iterative schemes of the form

$$y_m = B(\sum_{i=1}^{k} p_i y_{m-i}) + \sum_{i=1}^{k} q_i y_{m-i} + wb.$$

The convergence of y_m to x is shown to depend on $\sigma(B) \not\subseteq C-\Omega(S_1)$ where

$$\Omega(z)=(1-\sum_{i=1}^{k} q_i z^i) \Big/ (\sum_{i=1}^{k} p_i z^i).$$

The asymptotic rate of convergence is shown to be the log of the radius of the largest Disc, centered at the origin, which has no preimage points of $\Omega(z)$.

The material in this talk is contained in a paper which has been tentitively accepted by the SIAM Journal of Numeral Analysis.

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Semiiterative Methods for Nonsymmetric Linear Systems

Given a nonsingular linear system $Ax = b$, a splitting $A = M-N$ leads to the basic iteration (1) $x_m = Tx_{m-1}+c$ with $T:= M^{-1}N$ and $c := M^{-1}b$. Semiiterative methods (SIM's) with respect to (1) are investigated, under the assumption that the eigenvalues of T are contained in some rectangle Ω with $1 \notin \Omega$.
We construct a SIM which is asymtotically optimal with respect to Ω. Further, we consider four-step stationary iterative methods which are nearly optimal if the eigenvalues of T are known to lie within Ω. These results are applied to linear systems which result from the discretization of convection diffusion equations.

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from January 1985:

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Preconditioned Lanczos--A Robust Iterative Method

The Lanczos, or "bi-conjugate gradient" method, has a reputation as a very robust iterative linear system solver. TWODEPEP, which represents a unique tool for testing such robustness because of its ability to solve such a wide class of PDE's, has been outfitted with a preconditioned Lanczos method and a wide range of difficult PDE-related linear systems

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has been generated to test the new option.
Results show that not only is it fast for most
PDE applications, but it performs well on
highly nonsymmetric and/or indefinite problems.
An implementation scheme appropriate for vector
computers will also be presented.

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A Matrix Model of the Population Dynamics of the Pacific Salmon

This deterministic model describes the popula-
tion's growth rate and age distribution in terms
of a general transition matrix and its associated
eigenvalues and eigenvectors. The main result is
that matrices with this specific form always have
exactly four distinct eigenvalues (one positive,
one negative, and two complex) with the positive
eigenvalue dominant. (Its value determines the
maximum sustainable level of harvesting.) Follow-
ing this general discussion, approximate values of
the parameters are supplied for each of several
species of salmon. The eigenvalues and eigen-
vectors of the resulting matrices are then
computed numerically.

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Conditions for Asymptotically Exponential Solutions of Linear Difference Equations with Variable Coefficients

In the positive domain, conditions for
asymptotic exponential growth (AEG) of the
solutions $B(i)$ of a linear difference equation
with variable coefficients are explored. If $x(i)$
is the positive solution of the i-th charac-
teristic equation, then rapid convergence of $x(i)$
to x ensures AEG with growth rate $x-1$
(rapid convergence is the absolute convergence
of the series of remainders $\sum x(i)-x$).
Convergence of $x(i)$ to x is necessary. These
conditions are close and are based on a

recent result by the author on infinite
products of matrices (forthcoming in LAA).
These results have applications in population
dynamics as they yield weak conditions
on time dependent vital rates for AEG of the
sequence of births $B(i)$ at period i.

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Centrosymmetric Generalized Wright Model

The eigenvalues of the transition matrix P of the
generalized Wright model which allows for
mutation, migration and selection are given when
P is a centrosymmetric matrix. The speaker will
give an example and discuss the proofs.

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An Assessment of the Customary Linear Model for Tracer Kinetics in a Nonlinear Environment

In a simple nonlinear chemical kinetics model an
exact tracer kinetics model is set up in accor-
dance with the standard assumptions and then
compared with the customary linear approximation.
Certain qualitative differences are shown to
exist between the exact and the approximate
model. There will also be a report on ongoing
work concerning the question whether or not
these qualitative differences have practical
quantitative consequences.

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Generalized Deflated Block-Elimination

A stable algorithm is presented to solve a
nonsingular system of the form

$$\begin{vmatrix} A & B \\ C^T & D \end{vmatrix} \cdot \begin{vmatrix} x \\ y \end{vmatrix} = \begin{vmatrix} f \\ g \end{vmatrix}$$

where B and C are n by m matrices and the
n by n matrix A could be singular with at
most s small singular values. The algorithm
needs only a solver for A and the solution
to an m+s by m+s dense linear system.
It is, thus, well suited for problems
for which A has easily exploitable structures
and m+s is small with respect to n, such
as continuation methods, bifurcation problems
and constrained optimization.

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Curves on S^{n-1} That Lead to Eigenvalues or Their Means of a Matrix

This paper discusses a couple of dynamial system
on S^{n-1}, each defined in terms of a real square
matrix M. The solutions of the system are found
to always converge to points which provide es-
sential information about eigenvalues of that
matrix M. We show, in particular, how the
dynamics of a special flow is analogous to that
of the Rayleigh quotient iteration.

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Some Applications of Vandermonde Systems

Bjork and Pereya in 1970 developed an efficient
algorithm for solving Vandermonde systems.
Gustafson utilized this procedure to compute
weights for quadrature and interpolation. This
presentation will show the application of

Vandermonde systems to the approximations of arbitrary linear operators, the numerical inversion of the Laplace transform by a generalization of Bellman's method and the solution of a extremely ill-conditioned system of equations arising in the calculation of equilibrium constants.

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An Iterative Method for Computing the Square Root of the Inverse of a Matrix.

We present an iterative polynomial scheme based on an approximative Newton method. The scheme is used to compute $S^{-\frac{1}{2}}$, where S is a $n \times n$ positive definite matrix. The computation of $S^{-\frac{1}{2}}$ can be used to orthogonalize a system of vectors.

The convergence of the scheme is proved in the general case. In the special case, where the spectral radius of $(S-I)$ is less than 1, one can choose the initial matrix so that the scheme converges quadratically. The algorithm has a cost of $O(n^3)$ and is well suited for array-processors.

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Efficient Parallel Matrix Inversion

We present parallel algorithms for $n \times n$ matrix inversion that are numerically stable and asymptotically efficient (unlike the previously known algorithms). In particular, a quadratically convergent iterative method gives the inverse (within the accuracy $2^{-n^c}, c>0$) of a rational matrix with condition $< n^{O(1)}$ in $O(\log n)^2$ time using $M(n)$ processors, $M(n) = n^h$, h is the exponent of matrix multiplication, $\underline{n} < 2.5$. This is the optimum processor bound and a $\sqrt{n}$ improvement of known processor bounds for polylog time matrix inversion. It is the first known polylog time algorithm for matrix inversion that is numerically stable.

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John Reif, Laboratory of Computer Science, Mass. Inst. of Technology, Cambridge, MA 02139 and Aiken Computation Laboratory, Division of Applied Sciences, Harvard University, Cambridge, MA 02138

Wide Quotient Trees for Finite Element Problems

SPARSPAK contains an algorithm due to George and Liu that solves sparse symmetric positive definite systems by using a quotient tree partitioning of the matrix. It uses breadth-first search to find quotient trees that tend to be tall and narrow. We suggest a method based on nested dissection that finds short, wide quotient trees. On large 2-dimensional finite element grids, these trees induce a finer partition than breadth-first quotient trees. In theory this is more efficient for sufficiently large problems; we present experiments to estimate what "sufficiently large" means.

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Numerical Algorithms for Determining an Invariant Subspace of a Matrix

Numerical algorithms are developed for finding an invariant subspace of a matrix corresponding to an eigenvalue or cluster of eigenvalues. This approach requires that one already has available several eigenvectors and generalized eigenvectors whose span lies close to the desired subspace.

These vectors are used to select a subset of coordinate vectors thereby establishing a partition of the matrix. This partition is used to generate a geometrically convergent sum of matrices whose range coincides with the invariant subspace. Error bounds establishing the accuracy of the approximation of the subspace are also found. Examples are given.

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Parallel Block Jacobi Algorithms

Recently F. T. Luk and R. P. Brent have introduced algorithms for solving symmetric eigenvalue problems with systolic arrays (Cornell CS reports TR83-562 and TR84-625). In this paper we define and analyze several block Jacobi algorithms which use systolic arrays to solve diagonal subproblems. This allows the solution of problems which are too large for the systolic array. Parallelism is obtained by solving several subproblems simultaneously. With a mild constraint on the termination criteria of the systolic arrays, it is shown that cyclic algorithms always converge. Without the constraint some pivoting is needed to guarantee convergence. A kind of partial pivoting is shown to be sufficient.

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CONTRIBUTED PAPERS

The Conjugate Gradient Method with Element by Element Preconditioners:Preliminary Report

This study deals with techniques for solving large symmetric positive definite linear systems which arise in the finite element analysis of problems in structural and solid mechanics. The conjugate gradient method is used with preconditioners constructed elementwise. Specifically the preconditioner is constructed from factors of the individual scaled element arrays. The factors are either of the form LDL^T or QR. They can be combined to form an approximation to a factorization of the global array. The whole process can be carried out without ever actually constructing the global array. An important feature of these methods is that much of the array processing can be done in parallel.

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Analysis of Convergence of Nonlinear, Nonstationary Functional Iterations

Here convergence properties of a nonlinear, nonstationary Gauss-Seidel type functional given by $x^{k+1} = G_k(x^{k+1}, x^k)$, $(x^k = $ the kth iteration are considered, where $G_k: D_{k+1} \times D_k \to D_{k+1}$

Local linearization principle has been used together with some properties of a sequence of square matrices $\{A_k\}$ $k = 1,2,\ldots$ which satisfy $\lim_{k\to\infty} A_k A_{k-1} \cdots A_1 = 0$. Such matrices called D-matrices, showed the mode of convergence.

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Functions of Perturbed Matrices

The perturbation series

$$f(A + tB) = f(A) + tH_1 + t^2H_2 + \cdots$$

is explicitly computed for $n \times n$ matrices A,B and functions f which are analytic on $\sigma(A)$. The H-matrices turn out to be "relative iterates" of the perturbing matrix B, in a natural sense. The results which will be presented are reformulations and extensions of portions of the author's paper Chain algebras, Discrete Mathematics 37 (1981), 229-244. Various applications will be indicated.

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Derivatives of D_1AD_2 Matrices

We consider two approaches to derivatives of D1AD2 matrices with respect to entries of A as well as row and column sums. This might be interesting since (1) an implicit function approach requires an inverse of a singular matrix; (2) Differentiating a result due to Sinkhorn (1967) shows that D1AD2 matrices are not differentiable w.r.t. row and column sums unless the definition of D1AD2 matrices is modified slightly. Also (2) motivates computing the derivatives as the limit of the derivatives of the iterative scaling procedure which may be used to compute D1AD2 matrices. Jacobian matrices of D1AD2 derivatives evaluated at A* = D1AD2 are idempotent.
While these derivatives have been studied before, apparently the points raised here have been overlooked previously. [eg., Bacharach, 1970.]

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Rationalization of Fractions:

I will consider two areas: 1) ordinary fractions over the integers & 2) rational functions of n-th degree polynomials. The basic principle is that when dividing the smaller of the numerator/denominator of a fraction into the larger, the remainder contains as a common factor the greatest common factor of the numerator/denominator. Repeated application yields this factor. Applications include matrix calculations using fractions without accumulating large numerators/denominators. Also, multiple factors of polynomials can be removed by considering the quotient p /p'.

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Fast Division of Polynomials via Triangular Toeplitz Matrix Inversion

How many arithmetic operations (ops), (parallel) steps and processors (prs) are needed for division with remainder of 2 complex polynomials? The known Sieveking-Kung algorithm relies on computing the power series reciprocal and uses $n \log n$ ops, $\log^2 n$ steps, n prs or in Reif's modification $\log n$ steps, n^2 prs (all estimates within constant factors); $\log n \log \log n$ steps suffice for the solution over arbitrary field of constants. We attain all the above estimates via the inversion of triangular Toeplitz matrices. Furthermore the problem can be solved with arbitrary precision in $\log n$ steps, n prs in this way.

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Pertubation theory for a group of eigenvalues

We present a generalization of Kato's pertubation theory which treats simultaneously a group of several eigenvalues. Numerical applications are given.

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NONLINEAR EIGENVALUE APPROXIMATION

Let $F(\lambda)$ denote a n×n matrix valued, holomorphic function of λ in some open subset U of the complex plane. It is well-known that $I-F(\lambda)$ is nonsingular in U except possibly for a countable set of points with no limit point in U. Let ζ denote such a point. The problem is to approximate ζ. We examine the generalized eigenvalue problem (GEVP) $L(\zeta) + (z-\zeta)L'(\zeta)$ where $L(\lambda) = I - F(\lambda)$. Now given $\lambda \in U$, define $\mathcal{S}(\lambda)$ to be the element of the spectrum of this GEVP which is closest to λ. If ζ is a nondefective eigenvalue of the GEVP, then fixed point iteration on $\mathcal{S}$ will converge quadratically to $\zeta = \mathcal{S}(\zeta)$ if started sufficiently close to ζ.

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Unitary Completions and Noncanonical LU Factorization

Any matrix F has a noncanonical LU factorization F=LMU where L and U are block lower and block upper triangular matrices respectively and M is a unique block subpermutation matrix in canonical form. We also specify when unitary completions of a partially defined matrix with prescribed block lower triangular entries exist. When this is the case we obtain a linear fractional map parametrization of all such completions. Moreover, we can specify exactly which middle factors M arise in the noncanonical LU factorization F=LMU for such completions. The results follow by classifying subspaces of matrices which are modules over the algebra of upper triangular matrices. This work is joint with Israel Gohberg.

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A Numerical Comparison of Methods for Computing the Inertia of a General Matrix

A comparison is given of several numerical methods for computing the inertia of an unreduced Hessenberg matrix. These direct methods are based upon finding a Hermitian solution to a particular Lyapunov matrix equation and then computing the inertia of this solution. The methods have been developed by David Carlson, B. N. Datta, and Karabi Datta. In these direct methods the solution of the Lyapunov matrix equation is not computed explicitly and this is what makes these methods viable alternatives to using the QR methods for solving the inertia problem. The comparison is made on the basis of numerical efficiency, storage requirements and accuracy. The results indicate that the inertia of a matrix can be computed effectively by direct methods for matrices of moderate size.

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Lyapunov Approximation of Reachable Sets for Controlled Linear Systems.

We calculate an approximation to the reachable set of a class of linear control systems. The method involves the construction of a Lyapunov-like function, and ultimately requires the numerical solution of a simple optimisation problem. Advantages of the method are that it is applicable to n dimensional systems, and does not require caculation of orbits or a choice of boundary conditions. Further, the system need not be completely controllable for the method to be applicable. However, while the method ensures that the reachable set lies within a specified set, a closeness-of-fit criterion is not available.

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CANADA

PLATZMAN'S PROBLEM REVISITED

A decade ago George Platzman, an oceanographer, created a global tidal model that required computing the interior eigenvalues of a large sparse symmetric matrix. Platzman's problem stimulated much interest among numerical linear algebraists, especially among Lanczos aficionados, but the eigensystem proved to be very difficult to compute.

The intervening decade has seen several significant advances in the understanding and application of the Lanczos algorithm. Platzman's problem has remained a formidable

challenge for these advances. We will review how the advances of the past ten years affect the apparent difficulty of this problem. In particular we illustrate how the idea of shifting and inverting the spectrum performs on Platzman's matrices, and how Platzman's problem finally yields to a block shift and invert Lanczos code.

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Inexact One-Step Method

The classical one-step stationary iteration for a nonlinear equation is of the form $x^{k+1} = G \, x^k$, $k=0,1,\dots$. In the case of G linear, G is usually chosen to be the product of triangular matrices (for example, the SOR method), or a product of tridiagonal matrices (for example, the ADI method). We consider a generalization of these methods: $x^{k+1} = G \, x^k + r^k$, $k=0,1,\dots$. In the case of G linear, x^{k+1} can be computed iteratively, for instance, by a preconditioned conjugate gradient method. We extend some of the classical theories regarding the convergence rate of the one-step methods to this new class of methods; we present upper bounds for the norm of r^k to guarantee convergence.

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Generalized Inverses of Matrices Over Rings

We survey the known results on generalized inverses of matrices over integral domains and investigate the related problems for matrices over some rings which are not integral domains.

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A Probalistic Approach in Approximating the Stationary Distribution of a Nearly Completely Decomposable Markov Chain

All existing approximations for the stationary distribution of a nearly completely decomposable Markov chain are based on solving systems which are pertubations of the exact system. We develop here an original approximation which is based on probabilistic arguments. A series expansion of the accured error is given as well.

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Monotonicity of Permanents in Ω_n

Let Ω_n be the convex polytope of all $n \times n$ doubly stochastic matrices. Let J_n be the $n \times n$ matrix all of whose entries are $\frac{1}{n}$. For $A \in \Omega_n$ let $p_k(A)$ denote the sum of the permanents of all $k \times k$ submatrices of A. It has been conjectured by Dokovic and others that the matrix function $p_k(X)$ is monotone decreasing on the segment from A to J_n where A is any matrix in Ω_n. Given any two permutation matrices P_1 and P_2, let F be the face of Ω_n of smallest dimension which contains P_1 and P_2. Then Dokovic's conjecture is true if we restrict A to lie in F.

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Transitive Closure and Related Semiring Properties Via Eliminants

Closed semirings are algebraic structures that provide a unified approach to a number of seemingly unrelated problems of computer science and operations research. For example, semirings can be used to describe the algebra related to regular expressions, graph-theoretical path problems, and linear equations. We present a new axiomatic formulation of closed semirings. We introduce the concept of eliminant, which simplifies the treatment of closed semirings considerably, and yields very simple proofs of otherwise difficult theorems. We use eliminants to define matrix closure, formulate closure algorithms, and prove their correctness.

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Linear Algebra in Robust Multivariable Control Theory: The Structured Singular Value

In a control theory context, robustness means the maintenance of desirable performance characteristics despite large model uncertainty. An important issue in analyzing robustness is that system uncertainty typically has known structure. The need for a precise mathematical tool to analyze systems with structured uncertainty led to a new matrix functional called the Structured Singular Value (SSV). The SSV is a generalization of both eigenvalues and singular values, each of which applies for problems with special structure. The SSV and related topics were recently the focus of a workshop attended by over 100 researchers in control theory[*]. This paper will report on the

status of the SSV including computational issues and applications.

*J. Doyle, Lecture Notes, 1984 ONR/Honeywell Workshop on Advances in Multivariable Control, Oct. 8-10, 1984, Minneapolis, MN.

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The Role Of The Schur Product In The Eigenstructure Approach To Parameter Estimation

The Schur or the element to element product of matrices has not been extensively studied and is rarely used in estimation theory. In this paper we describe an application of the Schur product in the modeling of covariance matrices related to parameter estimation via eigenstructure methods. For example, in the direction of arrival (DOA) estimation problem with spatial decorrelation of wavefronts, the resulting array covariance matrix can be shown to be the Schur product of the spatial coherence matrix (a property of the medium) and the array covariance assuming perfect spatial coherence. This observation, in conjunction with some interesting though easily proved properties of the Schur product, has suggested ways to solve the DOA problem via an eigen decomposition of the covariance.

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On the generators of a contollability matrix

A matrix $C = (b_1, \ldots, b_n)$ in R_{nn} is called a controllability matrix if rank $C = k$ whenever for some k the columns $b_1, \ldots, b_k$ are linearly independent while $b_1, \ldots, b_k, b_{k+1}$ are dependent. Given such a C, we determine all A in R_{nn} such that $C = (b_1, Ab_1, \ldots, A^{n-1}b_1)$. Moreover we find all possible ranks for such A and study the sparsity structure available for all such A of a given rank.

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The Generalized Householder Transformation

Many algorithms for solving eigenvalue, least squares and nonlinear programming problems require the determination of an orthogonal matrix Q such that for a given matrix C, Q transforms C into an upper triangular matrix, QC. Usually Q is a product of Householder transformations. Each transformation is a rank 1 correction of the identity matrix designed to annihilate elements in one vector.

Several years ago, Bronlund and Johnsen proposed a generalization of the Householder transformation that is a rank k correction of the identity matrix designed to annihilate elements in k vectors simultaneously. In this talk, their generalized Householder transformation will be discussed in the context of sparse problems.

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Squeezing the Most out of Eigenvalue Solvers on High-Performance Computers

This talk describes modifications to many of the standard algorithms used in computing eigenvalues and eigenvectors of matrices. These modifications, which decrease the number of vector memory references, can dramatically increase the per-formance of the underlying software on high performance computers without resorting to assembler language, without significantly influencing the floating point operation count, and without effecting the roundoff error properties of the algorithms. The techniques are applied to a wide variety of algorithms and are beneficial in various architectural settings.

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Projectionally Exposed Cones in Convex Programming

Relative to the Convex Programming Problem, Jon Borwein and Henry Wolkowicz introduced the concept of projectionally exposed cones. A cone is projectionally exposed if for each face there exists a projection which projects the entire cone onto the given face. When the associated constraint function of a convex programming problem takes values in a projectionally exposed cone, then certain multipliers may be chosen from a smaller set. Under this motivation the authors begin characterizing both polyhedral and nonpolyhedral cones which are projectionally exposed or orthogonally projectionally exposed.

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Cholesky Factorization of Structured Matrices

Cholesky factorization of Hermitian positive-definite matrices is required in applications involving least-squares criteria, such as inverse scattering, linear estimation (and, in particular, Kalman filtering), and second-order modeling of stochastic processes. The recent derivation of efficient algorithms for Cholesky factorization of Toeplitz and Hankel matrices spurred a growing interest in characterizing classes of matrices whose factorization can be accomplished in less than the $O(N^3)$ operations required to factor nonstructured matrices of size $N \times N$.

We show that the pursuit of "fast-Cholesky" algorithms leads in a natural way to the notion of matrices with a *displacement structure*, whose factorization requires $O(\beta N^2)$ operations, where β is a structural index independent of N ($\beta = 1$ for Toeplitz matrices).

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An Inequality for the Second Immanant

Let x be the degree $n-1$ character of S_n corresponding to the partition $(2,1,\ldots,1)$, and let d_2 be the corresponding immanant defined on n-by-n complex matrices. Then

$$\text{per}(A) \geq (n-1)^{-1} d_2(A)$$

for all positive semidefinite A, where $\text{per}(A)$ is the permanent of A.

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SOME GENERALIZATIONS OF THE SINGULAR VALUE CONCEPT

The singular values of a complex matrix can be characterized in several ways. Each of these characterizations, when suitably generalized, leads to the definition of a new chain of numbers associated with a matrix, containing the singular values as a particular case. This communication surveys some properties of these various types of generalized singular values.

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Hypergraphs of k-Dimensional Matrices

Let $A = (A_{i_1 i_2 \cdots i_k})$ be a nonzero $n_1 \times n_2 \times \ldots \times n_k$ matrix. The hypergraph of A is the hypergraph $H(A)$ with vertices the hyperplanes $x_s^r = \{(i_1, i_2, \ldots, i_k) : i_r = s; i_t = 1, 2, \cdots, n_t; t = 1, 2, \cdots, k\}$ and edges the sets $\{x_{i_1}^1, x_{i_2}^2, \ldots, x_{i_k}^k\}$ for which $A_{i_1 i_2 \ldots i_k} \neq 0$. If A is an ordinary (2-dimensional) matrix then $H(A)$ is the bipartite graph usually associated with A. In general, if $X_r = \{x_s^r : 1 \leq s \leq n_r\}$, $r = 1, 2, \ldots, k$, then $H(A)$ is a simple uniform hypergraph of rank k with $|E \cap X_r| = 1$ for each edge E of $H(A)$. A number of properties of $H(A)$ are presented.

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A Probabilistic Algorithm for Graph Isomorphism

In this paper we derive a probabilistic algorithm for checking the graph isomorphism problem which is based only on solutions of linear equations and is extremely easy to apply. Surprisingly, this algorithm shows that for graphs with bounded eigenvalue multiplicity the isomorphism test is of order $O(n^6)$ independently of the multiplicity bound! Compare that with Babai, Grigoryev and Mount [1982]. In fact this result holds for directed multigraphs with bounded eigenvalue multiplicity. Our algorithm would remain polynomial for graphs of unbounded valency with the logarithm growth.

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Some Comments about Semimonotone and Copositive Matrices

For a square matrix $M \in \mathbb{R}^{n \times n}$ and column vector $q \in \mathbb{R}^n$, the linear complementarity problem (q, M) is the following: find nonnegative column vectors w, z such that $w - Mz = q$ and $w^T z = 0$. The paper focuses on the relationship of M being semimonotone (copositive) and having at least one solution to (q, M) for each column vector q to the property of $(0, M)$ having a unique solution.

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Some Comments on Substochastic Matrices

This paper will investigate the problem of solving certain sets of equations within the semigroup of all $n \times n$ substochastic matrices. These results will lead us to certain applications such as describing the maximal subgroups of the semigroup of all $n \times n$ substochastic matrices and finding generalized inverses of a substochastic matrix.

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Fees	On Site	$125	$150	$15

Monday, April 29 Wednesday, May 1
Pool Party $10   Banquet $10
Open Bar, Hors d'oeuvres

Special Note:
There will be no prorated fees. There will be no refunds after the conference
starts.

Telephone Messages
The telephone number at the Mission Valley Inn is 1-919-828-3173. They will
either connect you to the SIAM desk or forward a message.

UPCOMING SIAM CONFERENCES

June 24–26, 1985
SIAM 1985 National Meeting
Pittsburgh Hyatt at Chatham Center
Pittsburgh, Pennsylvania

October 28–30, 1985
SIAM Fall Meeting
Arizona State University
Tempe, Arizona

July 15–19, 1985
**SIAM Conference on Geometric
Modeling and Robotics**
Hilton Hotel
Albany, New York

November 18–21, 1985
**SIAM Conference on Parallel
Processing**
Omni Hotel
Norfolk, Virginia

SIAM Meetings & Conferences

June 24-26, 1985
SIAM 1985 National Meeting
Pittsburgh Hyatt, Pittsburgh, PA
  Modern Topics in Applied Mathematics. Included will be robotics, variational problems, nonlinear partial differential equations, and computational fluid dynamics. *Program chairman:* George Fix, Carnegie-Mellon University, Pittsburgh.

June 24-28, 1985
SIMS 1985 Research Application Conference (RAC-85): Modern Statistical Methods in Chronic Disease Epidemiology
Alta Lodge Conference Center, Alta, Utah
  Topics will include: relative risk regression methods (the cohort study, the case-control study, and regression diagnostics), carcinogenesis models and methods in low dose extrapolation, and genetic epidemiology. There will be invited papers; applications from observers will be welcome. *Co-chairmen:* Ross L. Prentice and Suresh H. Moolgavkar, University of Washington, Seattle.

July 15-19, 1985
SIAM Conference on Geometric Modeling and Robotics
Albany, NY
  An international conference to bring together those concerned with the implementation of robots and geometric design techniques with theoreticians. Talks and workshops will focus on surface modeling, solid modeling, robotics and database structures for geometric modeling. *Organizing committee:* Carl de Boor, David Ferguson, John Hopcroft, Harry McLaughlin, Leon Seitelman, and Michael Wozny.

October 28-30, 1985
SIAM 1985 Fall Meeting
Arizona State University, Tempe
  Topics will include VLSI and applied mathematics, numerical solution of bifurcation problems, modern trends in numerical fluid dynamics, functional differential equations and their applications. *Program chairmen:* Daniel Jankowski and A. Feldstein, Arizona State University.
  Abstract deadline: May 31, 1985

November 18-21, 1985
Second SIAM Conference on Parallel Processing for Scientific Computing
Omni Hotel, Norfolk, VA
  The first day of the conference will be a full-day tutorial on parallel processing. It will focus on the influence of computer architecture and give a review of parallel numerical algorithms. The main conference program will address experience with operational parallel machines and developments in numerical algorithms. *Program chairman:* R.G. Voigt, ICASE-NASA Langley Research Center.
  Abstract deadline: June 7, 1985

May 14-16, 1986
Third SIAM Conference on Discrete Mathematics
Clemson University, Clemson, SC
  A conference to encourage interaction between the developers and users of discrete mathematics. Topics will include: discrete optimization; graph theory; discrete mathematics in biological, computational, engineering, medical, physical, and social sciences; crytography; operations research; algebraic network reliability; domination numbers; and partially ordered sets. *Program co-chairmen:* Richard D. Ringeisen (Clemson University) and Fred S. Roberts (Rutgers University).
  Abstract deadline: December 9, 1985

July 21-25, 1986
SIAM 1986 National Meeting
Boston Park Plaza Hotel, Boston, MA
  Topics include: parallel computation; multi-grid methods; compressible flow calculations; surface approximation and computer-aided design; bubbly fluids or fluidized beds; geophysical modeling; computer tomography; crystal growth in materials; porous media; and iterated mappings and chaos. *Program chairman:* Robert O'Malley, Rennselaer Polytechnic Institute.

PAPERS AND POSTERS

Contributed papers and poster presentations at the SIAM national and fall meetings may treat any aspect of applied mathe-matics, although contributions consistent with the themes of the plenary symposia are especially desired. At SIAM conferences, papers and poster presentations must be related to conference topics.

MINISYMPOSIA

Proposals for minisymposia are invited for the national and fall meetings. Minisymposia that focus on a topic consistent with the themes of the plenary symposia are especially desired. Organizers of minisymposia must be SIAM members.

STANDARD FORM

Abstracts of contributed papers and poster presentations, as well as proposals for minisymposia, must be submitted on standard SIAM forms. These may be obtained by contacting SIAM Conference Coordinator, Suite 1400, Architects Building, 117 South 17th Street, Philadelphia, PA 19103, (215) 564-2929.