Third SIAM Conference on

LINEAR ALGEBRA

SIGNALS • SYSTEMS • CONTROL

AUGUST 16 - 19, 1993

UNIVERSITY OF WASHINGTON
SEATTLE

Plus a one-day Tutorial on
NUMERICAL METHODS IN CONTROL, SIGNAL AND IMAGE PROCESSING
August 15, 1993

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Society for Industrial and Applied Mathematics

CONFERENCE THEMES

Algebraic and Geometric Methods in Control
Computer Vision
Identification and Estimation
Large-Scale and Parallel Computations in Control and Signal Processing
Large-Scale Control Systems
Linear Algebra and Neural Networks
Linear Algebra and Wavelets
Mathematical Control and Systems Theory
Numerical Linear Algebra in Control
Optimal Control
Robust and H^∞ Control
Signal and Image Processing

FINAL PROGRAM

CONTENTS

ORGANIZING COMMITTEE

Biswa Nath Datta, Chair
Department of Mathematical Sciences
Northern Illinois University

Franklin T. Luk
Department of Computer Science
Rensselaer Polytechnic Institute

Daniel J. Pierce
Mathematics and Engineering Analysis
Boeing Computer Services

Robert J. Plemmons
Department of Mathematics and Computer Science
Wake Forest University

FUNDING

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

GET-TOGETHERS

SIAM Welcoming Reception
6:30 PM - 8:30 PM
Sunday, August 15, 1993
Walker Ames

Outdoor Salmon/Chicken Barbecue
Wednesday, August 18
6:00 PM
Battelle Conference Center

See page 16 for more information on SIAM Get-Togethers

PROGRAM OVERVIEW

Following are subject classifications for the sessions. The codes in parentheses designate session type and number. The session types are contributed presentation (CP), invited presentation (IP), minisymposia (MS), special topic lectures (SL), and special presentation (SP). For the poster presentations, please refer to page [illegible].

Classical Linear Systems: Control and Estimation
Computational Methods for Estimation of Distributed Parameters (MS26, page 17)
Control of Linear Systems (CP2, page 9)
Grassmannians, Projective Space and Linear Algebra (MS[illegible], page 20)
Multiple Input Spectral Estimation (MS14, page 10)
Stability and Identification (CP10, page 20)
State-Space Methods (MS30, page 18)

Complexity Issues
Complexity Issues in Linear Algebra (MS24, page 15)
Graphs, Computation, and Neural Network Design (SL12, page 17)

Core Linear Algebra
Algebraic Theory and Fast Algorithms for Toeplitz, Hankel, and Other Structures (SL1, page 8)
Matrix Completions and Applications (MS31, page 18)
Matrix Equations, Inertia, and Stability (MS[illegible], page 8)
Matrix Theory I and II (CP1, CP[illegible], pages 13, 22)
Topics in Matrix Theory (MS2, page 6)

Distributed Control Systems
Numerical Issues in Optimization-Based Design and Control (SL[illegible], page 21)

H-Infinity and Robust Control
H-Infinity Control from a Classical Circuit Viewpoint (IP1, page 6)
H-Infinity, Robust, and Adaptive Control (CP9, page 20)
Linear Matrix Inequalities in Systems and Control (SL14, page 17)
Numerical Computations of H-Infinity Controllers for Infinite Dimensional Systems (MS23, page 15)
Robust Stability and Control (SL4, page 12)
Sampled-Data Systems in Signal Processing and Control (IP6, page 16)

Industrial and Practical Life Applications of Control and Signal Processing
Automated System Identification and Control Using SVD (MS1, page 6)
Control Research at Boeing (MS12, page 10)
Global Climate Change and Systems Science: Modeling Methodology and Challenges (MS24, page 15)
Quality in Industrial Computation (SL17, page 21)
Signal Processing at Boeing (MS34, page 20)

Krylov Subspace Methods and Their Applications to Control Theory
Krylov Space Methods on State-Space Control Models (SL16, page 21)
Quadratic Eigenvalue Problems (IP2, page 6)
QMR Methods for Solving Large Linear Systems and Applications (SL12, page 17)
Rational Krylov Algorithms for Eigenvalues with Engineering Applications (SL7, page 12)

Large-Scale and Parallel Matrix Computations
Large-Scale and Parallel Matrix Computations and Their Applications — Parts 1 through 4 (MS9, MS20, MS28, MS36, Pages 9, 13, 18, 22)
Matrix Completions and Applications (MS31, page 18)
Parallel Computations and Numerical Linear Algebra (CP6, page 13)

Numerical and Symbolic Computations for Control and Signal Processing
Adaptive Methods (MS33, page 20)
Algorithms and Conditioning for Eigenvalue Assignment (SL2, page 8)
Computational Methods in Linear Least Squares (IP3, page 10)
Krylov Space Methods on State-Space Control Models (SL17, page 21)
Numerical Methods in Optimal Control (SL3, page 8)
Numerical Methods for Differential Algebraic Equations and Descriptor Systems (MS11, page 9)
Numerical Solution of Matrix Differential Equations with Structured Solutions (MS21, page 14)
Numerical and Symbolic Computations for [illegible] Control Problems — Parts 1 and 2 (MS27, MS35, pages 16, 20)
Numerical Techniques for Solving Optimal Control Problems (MS38, page 22)
Parallel Algorithms and Numerical Stability for Toeplitz Systems (IP4, page 10)
Parallel and Adaptive Algorithms for Beamforming and Direction Finding (MS6, page 7)
Retrospective on Condition Theory (SL11, page 17)
Signals, Seismics and Supers (IP7, page 20)
Surface Reconstruction with Uncertain Data (SL8, page 12)

Numerical Linear Algebra and Applications to Signal Processing
Analysis and Computational Methods for Dense Eigenvalue and Singular Value Problems — Parts 1 and 2 (MS7, MS10, pages 7, 9)
Computational Methods in Linear Least Squares (IP3, page 10)
Conditioning, Consistency, and Stability Issues in Signal Processing (SL5, page 13)
Eigenvalues and Singular Values: Generalizations and Accuracy Issues (MS32, page 20)
Iterative Methods for Toeplitz Systems (SL16, MS5, pages 21, 7)
Least Squares for Signal Processing (MS18, page 12)
Numerical Linear Algebra for Signal Processing and Control (MS19, page 12)
Numerical Linear Algebra I and II (CP[illegible], CP[illegible], pages [illegible])
Parallel Algorithms and Numerical Stability for Toeplitz Systems (IP4, page 10)
Parallel Computations and Numerical Linear Algebra (CP6, page 13)
Signals, Seismics and Supers (IP7, page 20)
Total Least Squares for Affinely Structured Matrices (SL14, page 17)

Operator Theory
Are Persistent Disturbances a Pain in the Hilbert Space? (SL4, page 8)

Optimal Control
Convex Optimization in Control Systems Analysis and Design — Parts 1 and 2 (MS1, MS9, pages 6, 8)
Numerical Methods in Optimal Control (SL3, page 8)
Numerical Techniques for Solving Optimal Control Problems (MS38, page 22)
Optimal Control (CP4, page 11)

Parallel Computations for Control and Signal Processing Problems
Parallel and Adaptive Algorithms for Beamforming and Direction Finding (MS6, page 7)
Parallel and Distributed Computation for Control Problems (MS29, page 18)
Parallel Signal Processing for Multiprocessor Systems (MS37, page 22)

Signal and Image Processing
Signals, Seismics and Supers (IP7, page 20)
Surface Reconstruction with Uncertain Data (SL8, page 12)
Theory and Practice of Estimator Design in Sensor Array Signal Processing (IP8, page 20)

Sensitivity Issues in Control and Signal Processing
Algorithms and Conditioning for Eigenvalue Assignment (SL2, page 8)
Conditioning, Consistency, and Stability Issues in Signal Processing (SL5, page 12)
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The Generalized and Quadratic Eigenvalue Problems and Applications to Control of Second-Order Systems
New Algorithms and Software for Eigen Problems Arising in Signal Processing and Control (MS25, page 16)
Quadratic Eigenvalue Problems (IP2, page 6)
Rational Krylov Algorithms for Eigenvalues with Engineering Applications (SL7, page 12)
Second Order Systems (MS16, page 11)

Wavelets
Cardinal Interpolation and Wavelets (SL10, page 17)
Linear Algebra and Neural Networks (IP5, page 15)
Topics in Wavelet Analysis (MS 39, page 22)
Wavelets and the Search for Good Filters (SP, page 14)

Numerical Methods in Control, Signal and Image Processing

August 15, 1993

Organizer: Biswa Nath Datta
Department of Mathematical Sciences, Northern Illinois University

Tutorial Description and Objectives

In the last few years many numerically reliable algorithms have been developed for important linear algebra problems arising in the design and analysis of control systems, and in signal and image processing. These methods do not seem to be widely known and the software based on these methods are not readily available to control theorists, applied mathematicians and practicing engineers. The researchers and engineers working in these important applications areas will be exposed to these numerically reliable algorithms and the associated software through this course.

Who Should Attend

Mathematicians; computer scientists; and control, systems, and signal and image processing engineers. Practicing engineers, graduate students and researchers looking for some future exciting areas of research are especially encouraged to attend.

Recommended Background

A first course in linear and numerical linear algebra and some basic knowledge in control and systems theory and/or signal and image processing. No rigorous knowledge of control theory and signal processing will be assumed.

Instructors

George Cybenko is a professor of electrical engineering and computer science at Dartmouth College. His research interests include numerical linear algebra and applications to signal processing and neural networks. He is the associate managing editor of *SIAM Journal on Matrix Analysis.*

Biswa Nath Datta is a professor of mathematical sciences at Northern Illinois University. His research interests include linear algebra and numerical linear algebra in control, including large scale and parallel computations in these areas. He serves on the editorial board of *SIAM Journal on Matrix Analysis and Applications* and *Journal of Mathematical Systems, Estimation and Control.* He is the chair of the SIAM conference associated with this course; and is the vice-chair of SIAM Activity Group on Linear Algebra.

Alan J. Laub is a professor of electrical engineering at University of California, Santa Barbara. His research interests are in computer aided control system design, linear and large-scale control and filter theory, parallel computations in control, etc. He is the past president and a distinguished member of the IEEE Control Systems Society. He has served or serves on the editorial board of five major journals. He is a fellow of IEEE Control System Society.

Robert J. Plemmons is the Z. Smith Reynolds Professor of Mathematics and Computer Science at Wake Forest University. His research interests include linear algebra, numerical linear algebra and their applications to signal and image processing. He serves on the editorial board of *SIAM Journal on Matrix Analysis and Applications, Linear Algebra and Its Applications,* and *SIAM Review.*

Paul Van Dooren is a professor of electrical engineering at the University of Illinois, Urbana-Champaign. His research interests include numerical linear algebra and applications to control and systems theory and signal processing. He serves on the editorial board of *SIAM Journal on Matrix Analysis and Applications, Linear Algebra and Its Applications,* and *Control Systems Letters.*

The course will be divided into two parts. Part I — Numerical Methods in Control and Systems Theory will be taught by Biswa Datta, Alan Laub, and Paul Van Dooren. Part II — Numerical Methods in Signal and Image Processing will be taught by George Cybenko and Robert Plemmons.

Part I will cover recently developed numerically viable methods for control systems design and analysis, including methods for large-scale and parallel computations. A brief architectural description of some of today's high performance computers and ideas, and actual results of implementation of existing algorithms on those computers will also be presented.

Part II will be devoted to the applications of recently developed matrix computations techniques to the solution of linear algebra problems arising in signal and image processing.

Special attention will be given to large-scale structured matrix computations such as techniques for block Toeplitz systems, FFT-based preconditioned iterative methods, etc., that have been successfully used in recent years to problems on restoration of images, etc.

PROGRAM

PART I	**Numerical Methods in Control and Systems Theory**
8:00 AM	**Introduction** Biswa N. Datta
8:15 AM	**Controllability, Observability, Luenberger Observer, Feedback Stabilization and Eigenvalue Assignment, Control of Second-Order Systems** Biswa N. Datta
9:30 AM	Coffee
10:00 AM	**Lyapunov, Sylvester and Riccati Equations** Alan J. Laub
11:15 AM	**Frequency Domain versus State Space (GCD Extraction, Minimal Realization, Spectral Factorization, Coprime Factorization, etc.)** Paul Van Dooren
12:30 PM	**Lunch**
Part II	**Numerical Methods in Signal and Image Processing**
2:00 PM	**Structured Matrix Computations in Signal Processing** Robert J. Plemmons
3:15 PM	Coffee
3:45 PM	**Numerical Linear Algebra in Signal Processing** George Cybenko
5:00 PM	Discussion
5:30 PM	Tutorial adjourns

The tutorial will be held in Kane Hall 110.

Coffee will be served in Kane Lobby.

Lunch will be served at By-George in Library building next to Kane Hall.

*SATURDAY, AUGUST 14

6:00 PM-8:00 PM
Registration for Tutorial opens
Kane Hall Lobby

*SUNDAY, AUGUST 15

8:00 AM-4:00 PM
Registration for Tutorial opens
Kane Hall Lobby

8:00 AM-5:30 PM
Tutorial
Kane 110

PART I — **Numerical Methods in Control and Systems Theory**

8:00 AM — **Introduction**
Biswa N. Datta

8:15 AM — **Controllability, Observability, Luenberger Observer, Feedback Stabilization and Eigenvalue Assignment, Control of Second-Order Systems**
Biswa N. Datta

9:30 AM — **Coffee**

10:00 AM — **Lyapunov, Sylvester and Riccati Equations**
Alan J. Laub

11:15 AM — **Frequency Domain versus State Space (GCD Extraction, Minimal Realization, Spectral Factorization, Coprime Factorization, etc.)**
Paul Van Dooren

12:30 PM — **Lunch**

Part II — **Numerical Methods in Signal and Image Processing**

2:00 PM — **Structured Matrix Computations in Signal Processing**
Robert J. Plemmons

3:15 PM — **Coffee**

3:45 PM — **Numerical Linear Algebra in Signal Processing**
George Cybenko

5:00 PM — **Discussion**

5:30 PM — **Tutorial adjourns**

6:30 PM-8:30 PM
Registration for Conference opens
Kane Hall Lobby

6:30 PM - 8:30 PM
Welcoming Reception
Kane Hall-Walker Ames Room

**Attendees are on their own for meals during both days. There are about eighty restaurants along University Way, NE.*

MONDAY MORNING, AUGUST 16

7:00 — **Breakfast**
McMahon Hall

7:00 — **Registration opens**
Kane Hall Lobby

7:45 — **Opening Remarks**
Biswa N. Datta
Kane Hall 130

8:00 — **IP1 H^∞ Control from a Classical Circuit Viewpoir**
Hidenori Kimura
Kane Hall 130

8:45 — **IP2 Quadratic Eigenvalue Problems**
Beresford N. Parlett
Kane Hall 130

9:30 — **Coffee / Kane Hall Lobby**

10:00 — **Concurrent Sessions**

MS1 — **Convex Optimization in Control Systems Analysi and Design--Part I: Applications**
Organizer: V. Balakrishnan
Savery 216

MS2 — **Topics in Matrix Theory**
Organizer: Moshe Goldberg
Kane Hall 110

MS3 — **Parallel Matrix Computations and Applications**
Organizer: Vicente Hernandez
Gowan Hall 201

MS4 — **Analysis and Computational Methods for Dense Eigenvalue and Singular Value Problems (Part 1 of 2)**
Organizer: Ilse C.F. Ipsen
Kane Hall 130

MS5 — **Grassmanians, Projective Space and Linear Algebra**
Organizer: Clyde F. Martin
Savery Hall 249

MS6 — **Parallel and Adaptive Algorithms for Beamforming and Direction Finding**
Organizer: Marc Moonen
Smith Hall 304

CP1 — **Numerical Linear Algebra I**
Thomas Hall 125

MONDAY AFTERNOON, AUGUST 16

12:00-1:30 — **Lunch**
McMahon Hall

1:30 — **Concurrent Sessions**

SL1 — **Algebraic Theory and Fast Algorithms for Toeplitz, Hankel and Other Structures**
Georg Heinig
Kane Hall 130

SL2 — **Algorithms and Conditioning for Eigenvalue Assignment**
Mark Arnold
Kane Hall 110

SL3 — **Numerical Methods in Optimal Control**
William W. Hager
Gowan Hall 201

SL4 — **Are Persistent Disturbances a Pain in the Hilbert Space?**
Mark J. Balas
Smith Hall 304

2:15 — **Coffee / Kane Hall Lobby**

2:45 — **Concurrent Sessions**

MS7 — **Convex Optimization in Control Systems Analysis and Design--Part II: Algorithms**
Organizer: V. Balakrishnan
Kane Hall 130

MS8 — **Matrix Equations, Inertia and Stability**
Organizer: David Carlson
Kane Hall 110

MS9 — **Large-Scale and Parallel Matrix Computations and Their Applications (Part 1 of 4)**
Organizer: Biswa N. Datta
Gowan Hall 201

MS10 — **Analysis and Computational Methods for Dense Eigenvalue and Singular Value Problems (Part 2 of 2)**
Organizer: Ilse C.F. Ipsen
Savery Hall 216

MS11 — **Numerical Methods for Differential Algebraic Equations and Descriptor Systems**
Organizer: Volker Mehrmann
Savery Hall 249

CP2 — **Control of Linear Systems**
Smith Hall 304

CP3 — **Signal Processing I**
Thomas Hall 125

5:30-7:30 — **Dinner**
McMahon Hall

TUESDAY MORNING, AUGUST 17

7:00-8:30 **Breakfast** *McMahon Hall*

7:30 **Registration opens**
Kane Hall Lobby

8:00 **IP3 Computational Methods in Linear Least Squares**
Ake Bjorck
Kane Hall 130

8:45 **IP4 Parallel Algorithms and Numerical Stability for Toeplitz Systems**
Richard P. Brent
Kane Hall

9:30 **Coffee /** Kane Hall Lobby

10:00 **Concurrent Sessions**

MS12 **Controls Research at Boeing**
Organizer: Richard D. Jones
Savery Hall 216

MS13 **MATLAB and Applications**
Organizer: Steven J. Leon
Kane Hall 110

MS14 **Multiple Taper Spectral Estimation**
Organizer: Kurt S. Riedel
Gowan Hall 201

MS15 **Iterative Methods for Toeplitz Systems**
Organizer: Robert J. Plemmons
Kane Hall 130

MS16 **Second Order Systems**
Organizer: Kresimir Veselic
Savery Hall 249

MS17 **Automated System Identification and Control Using SVD**
Organizer: Wallace E. Larimore
Smith Hall 304

CP4 **Optimal Control**
Thomas Hall 125

TUESDAY AFTERNOON, AUGUST 17

12:00-1:30 **Lunch** *McMahon Hall*

1:30 **Concurrent Sessions**

SL5 **Conditioning, Consistency, and Stability Issues in Signal Processing**
James R. Bunch
Kane Hall 130

SL6 **Robust Stability and Control**
S.P. Bhattacharyya
Kane Hall 110

SL7 **Rational Krylov Algorithms for Eigenvalues with Engineering Applications**
Axel Ruhe
Gowan Hall 201

SL8 **Surface Reconstruction with Uncertain Data**
Davi Geiger
Smith Hall 304

SL9 **Title to be announced**
Russell L. Daily
Savery Hall 249

2:15 **Coffee /** Kane Hall Lobby

3:00 **Concurrent Sessions**

MS18 **Least Squares for Signal Processing**
Organizer: James R. Bunch
Kane Hall 130

MS19 **Numerical Linear Algebra for Signal Processing and Control**
Organizer: Sven Hammarling
Kane Hall 110

MS20 **Large-Scale and Parallel Matrix Computations and Their Applications**
Organizer: Biswa N. Datta
Gowan Hall 201

MS21 **Numerical Solution of Matrix Differential Equations with Structured Solutions**
Organizers: Volker Mehrmann and Nancy K. Nichols
Savery Hall 216

CP5 **Matrix Theory**
Savery Hall 249

CP6 **Parallel Computations and Numerical Linear Algebra**
Smith Hall 304

Poster Session
Kane Hall Lobby

8:00-9:00
Special Presentation
Wavelets and the Search for Good Filters
Gilbert Strang
Kane Hall 130

WEDNESDAY MORNING, AUGUST 18

7:00-8:30 **Breakfast** *McMahon Hall*

7:30 **Registration opens**
Kane Hall Lobby

8:00 **IP5 Linear Algebra and Neural Networks**
M. Vidyasagar
Kane Hall 130

8:45 **IP6 Sampled-Data Systems in Signal Processing and Control**
Bruce Francis
Kane Hall 130

9:30 **Coffee /** Kane Hall Lobby

10:00 **Concurrent Sessions**

MS22 **Complexity Issues in Linear Algebra**
Organizer: Bruno V. Codenotti
Kane Hall 110

MS23 **Numerical Computation of H^∞ Controllers for Infinite Dimensional Systems**
Organizer: Hitay Ozbay
Kane Hall 130

MS24 **Global Climate Change and Systems Science: Modeling, Methodology and Challenges**
Organizer: N. Sreenath
Gowan Hall 201

MS25 **New Algorithms and Software for Eigenproblems Arising in Signal Processing and Control**
Organizer: Danny Sorensen
Savery Hall 249

MS26 **Computational Methods for Estimation of Distributed Parameters**
Organizer: Curt Vogel
Savery Hall 216

MS27 **Numerical and Symbolic Computations for Temporary Control Problems (Part 1 of 2)**
Organizer: Biswa N. Datta
Smith Hall 304

CP7 **Signal Processing II**
Thomas Hall 125

WEDNESDAY AFTERNOON, AUGUST 18

12:00-1:30 **Lunch** *McMahon Hall*

1:30 **Concurrent Sessions**

SL10 **Numerical Issues in Optimization Based Design and Control**
John A. Burns
Kane Hall 130

SL11 **Retrospective on Condition Theory**
Charles S. Kenney
Kane Hall 110

SL12 **QMR Methods for Solving Large Linear Systems and Applications**
Roland W. Freund
Gowan Hall 201

SL13 **Graphs, Computational, and Neural Network Design**
Nirmal Kumar Bose
Smith Hall 304

SL14 **Total Least Squares for Affinely Structured Matrices**
Bart L.R. De Moor
Savery Hall 249

2:15 **Coffee /** Kane Hall Lobby

3:00 **Concurrent Sessions**

MS28 **Large-Scale and Parallel Matrix Computations and Their Applications (Part 3 of 4)**
Organizer: Biswa N. Datta
Kane Hall 110

MS29 **Parallel and Distributed Computation for Control Problems**
Organizer: Floyd B. Hanson
Kane Hall 130

MS30 **State Space Methods**
Organizer: Leiba Rodman
Gowan Hall 201

MS31 **Matrix Completions and Applications**
Organizers: Charles R. Johnson and Pablo Tarazaga
Savery Hall 216

CP8 **Numerical Linear Algebra II**
Savery Hall 249

CP9 **H^∞ Robust, and Adaptive Control**
Smith Hall 304

5:45 **Buses Board for BBQ Dinner**

THURSDAY MORNING, AUGUST 19

7:00 AM-2:00 PM
By-George and Student Union Building open for Breakfast on cash basis. Attendees are on their own for meals today.

7:30 **Registration opens**
Kane Hall Lobby

7:50 **Concluding Remarks**
Robert J. Plemmons and John G. Lewis
Kane Hall 130

8:00 **IP7 Signals, Seismics and Supers**
George Cybenko
Kane Hall 130

8:45 **IP8 Theory and Practice of Estimator Design in Sensor Array Signal Processing**
Mos Kaveh
Kane Hall 130

9:30 **Coffee /** Kane Hall Lobby

10:00 **Concurrent Sessions**

MS32 **Eigenvalues and Singular Values: Generalizations and Accuracy Issues**
Organizer: Jesse Barlow
Gowan Hall 201

MS33 **Adaptive Methods**
Organizer: Sanzheng Qiao
Kane Hall 110

MS34 **Signal Processing at Boeing**
Organizer: J. Louis Tylee
Kane Hall 130

MS35 **Numerical and Symbolic Computations for Contemporary Control Problems (Part 2 of 2)**
Organizer: Biswa N. Datta
Savery Hall 216

CP10 **Stability and Identification**
Savery Hall 249

THURSDAY AFTERNOON, AUGUST 19

12:00 **Lunch**
Attendees are on their own for meals today. By-George and Student Union open for lunch until 2:00 PM, on cash-basis only.

1:30 **Concurrent Sessions**

SL15 **Linear Matrix Inequalities in Systems and Control**
Stephen Boyd
Kane Hall 130

SL16 **Iterative Methods for Toeplitz Systems**
Raymond H. Chan
Kane Hall 110

SL17 **Krylov Space Methods on State-Space Control Models**
Daniel L. Boley
Gowan Hall 201

SL18 **Quality in Industrial Computations**
Francoise Chatelin
Smith Hall 304

SL19 **Cardinal Interpolation and Wavelets**
Charles K. Chui
Savery Hall 249

2:15 **Coffee /** Kane Hall Lobby

3:00 **Concurrent Sessions**

MS36 **Large-Scale and Parallel Matrix Computations and Their Applications (Part 4 of 4)**
Organizer: Biswa N. Datta
Kane Hall 110

MS37 **Parallel Signal Processing for Multiprocessor Systems**
Organizer: Paul M. Chau
Kane Hall 130

MS38 **Numerical Techniques for Solving Optimal Control Problems**
Organizer: John T. Betts
Gowan Hall 201

MS39 **Topics in Wavelet Analysis**
Organizer: Stephen S. Yau
Savery Hall 216

CP11 **Matrix Theory II**
Savery Hall 249

5:30 **Conference adjourns**

CP = Contributed Presentations
IP = Invited Plenary Presentations
MS = Minisymposia
SL = Special Topic Lectures
SP = Special Presentations

7:00/McMahon Hall

Breakfast

7:30/Kane Hall Lobby

Registration opens

7:45/Kane Hall 130

Opening Remarks

Biswa N. Datta, Northern Illinois University

8:00/Kane Hall 130

IP1/Chair: Biswa N. Datta, Northern Illinois University

H^∞ Control from a Classical Circuit Viewpoint

The speaker will present a unifield framework of H^∞ control theory based on the *chain-scattering representation* of the plant. In this formulation the problem is reduced to the *J-lossless factorization* of the plant. J-lossless factorization is a fundamental notion of linear system theory including the inner-outer factorization and the spectral factorization as special cases. The speaker will discuss a new algorithm for J-lossless factorization based on *conjugation theory* which is a state-space representation of classical Nevanlinna-Pick and Carathéodory-Fejer interpolation theory. He will clarify some of the strong connections between the H^∞ synthesis method and the classical circuit synthesis.

Hidenori Kimura
Department of Mechanical Engineering for Computer Controlled Machinery
Osaka University, Japan

8:45/Kane Hall 130

IP2/Chair: John Lewis, Boeing Computer Services

Quadratic Eigenvalue Problems

The speaker will consider two approaches to solving quadratic eigenvalue problems: the careful reduction to a linear eigenvalue problem and staying with the original form. With the first approach, it is possible to use the Lanczos algorithm with an improper inner product. With the second, it is possible to use variations on inverse iteration. The speaker will discuss the merits of these methods, but at present there are no guarantees that they will work.

Beresford N. Parlett
Department of Mathematics
University of California, Berkeley

9:30/Kane Hall Lobby

Coffee

10:00 AM-12:00 PM

Concurrent Sessions

MS1/Savery Hall 216

Convex Optimization in Control Systems Analysis and Design—Part I: Applications

The minisymposium concerns the application of convex optimization techniques to problems arising in control systems analysis and design, with special focus on problems that can be posed as (finite-dimensional) optimization over linear matrix inequalities (LMIs). This approach, which is motivated by recent advances in convex optimization theory and increases in computational power, enables the solution of several important problems for which no analytical techniques are known to exist.

The speakers will describe how many problems in control may be posed as convex optimization problems and will pay some attention to numerical techniques and algorithms for solving these problems.

(See MS7, page 8, for Part II: Algorithms).

Organizer: Venkataramanan (Ragu) Balakrishnan
Stanford University

10:00 Multiobjective Controller Synthesis with H_∞ Design Specifications
Mario Rotea, Purdue University, West Lafayette

10:30 Parameter-Dependent Stabilization and Control of Parameter-Dependent Linear Systems: Applications for H-infinity like Gain Scheduling
Andrew Packard, Greg Becker, and Doug Philbrick, University of California, Berkeley; and Gary Balas, University of Minnesota, Minneapolis

11:00 An LMI-based Method for Frequency-dependent Scaling
Venkataramanan (Ragu) Balakrishnan, Stanford University

11:30 Linear Matrix Inequalities in Stochastic Control
Laurent El Ghaoui, Ecole Nationale Superierue de Techniques Avancees, France

12:00 Convex Analysis of Output Feedback Control Problems
Jose C. Geromel, LAC-DT/FEE - UNICAMP, Brazil

MS2/Kane Hall 110

Topics in Matrix Theory

The speakers in this minisymposium will discuss four different topics in modern matrix theory which may have applications in the area of signals, systems, and control. The topics (in the order presented) below are entirely independent, and the speakers expect to introduce them in a self-contained manner.

Organizer: Moshe Goldberg
Technion-Israel Institute of Technology

10:00 Eigenvalues of Graphs and Symmetric Integral Matrices
Robert Guralnick, University of Southern California

10:30 The Diagonals of Powers of Positived Matrices and Renewal Sequences
W.A.J. Luxemburg, California Institute of Technology

11:00 The Smith Canonical Form
Morris Newman, University of California, Santa Barbara

11:30 Multiplicativity, Quadrativity, and Stability of Matrix Seminorms
Moshe Goldberg, Organizer

MS3/Gowan Hall 201

Parallel Matrix Computations and Applications

Parallel computing has become one of the most important tools in numerical linear algebra, especially for large-scale or real-time problems such as those which arise in control systems, where it is necessary to compute eigenvalues or solutions of matrix equations. Nowadays, massively parallel computers with distributed memory algorithms seem a good approach to cope with these problems.

In this minisymposium, the speakers will outline how the symmetry of a matrix can be exploited in distributed eigenvalue computation, the study of parallel algorithms for the pole-assignment problem and the solution of linear matrix equations on parallel computers.

Organizer: Vicente Hernandez
Universidad Politecnica de Valencia, Spain

10:00 Parallel Algorithms for the Triangular Sylvester Equation
Mercedes Marques, Universidad Politecnica de Valencia, Spain; Robert A. van de Geijn, University of Texas, Austin; and Vicente Hernandez, Organizer

10:30 Systolic Algorithms for Linear Matrix Equations in Control Problems
Gloria Martinez, Universitat Jaume I, Spain; *Jose L. Hueso,* Universidad Politecnica de Valencia, Spain; and Vicente Hernandez, Organizer

11:00 On Jacobi Methods for the Standard and Generalized Symmetric Eigenvalue Problem on Multicomputers
Domingo Gimenez, Universidad de Murcia, Spain; *Antonio Vidal,* Universidad Politecnica de Valencia, Spain; and Vicente Hernandez, Organizer

11:30 Parallel Algorithms for the Pole Assignment Problem
Rafael Bru, Juana Cerdan and Ana M. Urbano, Universidad Politecnica de Valencia, Spain

10:00 AM-12:00 PM
Concurrent Sessions

MS4/Kane Hall 130
Analysis and Computational Methods for Dense Eigenvalue and Singular Value Problems (Part 1 of 2)

This minisymposium discusses new results for the numerical solution of dense eigenvalue and singular value problems. Such problems occur in signal processing, control theory, statistics and structural mechanics, among many others.

The speakers will focus on numerical accuracy of methods and convergence enhancement. To this end, both theoretical and more practical, implementation-specific results will be presented. The development of new methods is based on the use of orthogonal transformations, shift strategies for speeding up convergence, and algebraic perturbation theory for stopping and deflation criteria. Analysis of the methods is carried out by means of traditional round-off error analysis as well as through the use of isospectral flows.

Organizer: Ilse C.F. Ipsen
Yale University

10:00 The Use of QD and DQD Algorithms
Beresford N. Parlett, University of California, Berkeley

10:30 Relative Perturbation Results for Eigenvalue and Singular Value Problems
Stanley C. Eisenstat, Yale University, and *Ilse C.F. Ipsen,* Organizer

11:00 Downdating the Singular Value Decomposition
Stanley C. Eisentat and *Ming Gu,* Yale University

11:30 Finite Precision Analysis of Inverse Iteration
Shiv Chandrasekaran, Yale University, and Ilse C.F. Ipsen, Organizer

MS5/Savery Hall 249
Grassmanians, Projective Space and Linear Algebra

The purpose of this minisymposium is to provide an overview of the applications of Grassmanians and projective spaces in linear algebra and control theory. The applications include pole assignment problems in control theory, the analysis of eigenvalue methods in linear algebra, and the study of Riccati differential equations.

Organizer: Clyde F. Martin
Texas Tech University

10:00 The Role of Grassmanians in Control Theory
Robert Hermann, Brookline, MA and Clyde F. Martin, Organizer

10:30 Hermann-Martin Curves in Grassmanian
Xiaochang Wang, Texas Tech University

11:00 Riccati Equations, Grassmanians Manifolds and Polynomial Realizations
Clyde F. Martin, Organizer and Leonid Faybusovich, University of Notre Dame

11:30 Grassmanians, Generalized Grassmanians and the Pole Placement Map
Joachim Rosenthal and *M.S. Ravi,* University of Notre Dame

MS6/Smith Hall 304
Parallel and Adaptive Algorithms for Beamforming and Direction Finding

In recent years, beamforming and direction finding have been prime examples of applications where research has focussed on parallel and real-time linear algebra. The high computational load, together with the data rates of several hundreds of kHz in advanced telecommunications systems, motivates the development of highly parallel algorithms, which at the same time should exhibit good numerical properties. The speakers in this minisymposium will provide an overview of some of the topics that constitute this field.

Organizer: Marc Moonen
ESAT - Katholieke Universiteit Leuven, Belgium

10:00 Improved Givens Rotation Algorithms for MVDR Beamforming
J.G. McWhirter and *Ian K. Proudler,* Defence Research Agency, United Kingdom

10:30 Parallel Computing in Sensor Array Processing
Adam W. Bojanczyk and A.O. Steinhardt, Cornell University

11:00 A Systolic Jacobi Algorithm for Wideband Direction of Arrival Estimation
Ed F. Deprettere, Delft University of Technology, The Netherlands; Marc Moonen, Organizer; and F. Vanpoucke, ESAT - Katholieke Universiteit Leuven, Belgium

11:30 A Systolic Algorithm for Robust Adaptive Beamforming using an Adjustable Constraint
Marc Moonen, Organizer, and F. Vanpoucke, ESAT-Katholieke Universiteit Leuven, Belgium

CP1/Thomas Hall 125
Numerical Linear Algebra 1

Chair: Daniel J. Pierce, Boeing Computer Services

10:00 A New Algorithm for Finding Roots of a Polynomial
Robert H. Schappelle, McDonnell Douglas Technologies Inc, San Diego

10:15 Jacobi Methods for Accurate Eigenvalues and Singular Values
Roy Mathias, University of Minnesota, Minneapolis

10:30 A Hybrid Algorithm for Optimizing Eigenvalues of Symmetric Definite Pencils
Jean-Pierre A. Haeberly, Fordham University; and Michael L. Overton, Courant Institute of Mathematical Sciences, New York University

10:45 Analysis of Algorithms for Orthogonalizing Products of Unitary Matrices
Roy Mathias, University of Minnesota, Minneapolis

11:00 Reconfigurable Control Systems based on Partial Eigenstructure Assignments
Jin Jiang, University of Western Ontario, Canada

11:15 A Hybrid Method for Solving the Multiple-Input State Feedback Pole Assignment Problem
Mark E. Cawood and Christopher L. Cox, Clemson University

11:30 A MATLAB Toolbox for Control Analysis and Design of Descriptor Systems
Rolf Schupphaus and Peter C. Muller, University of Wuppertal, Germany

12:00/McMahon Hall

Lunch

1:30-2:15

Concurrent Sessions

SL1/Kane Hall 130

Chair: Leiba Rodman, College of William and Mary

Algebraic Theory and Fast Algorithms for Toeplitz, Hankel and Other Structures

Structured matrices, such as Toeplitz and Hankel matrices, appear very often in signal processing, control theory and related fields. For these matrices and their generalizations, there exists a huge literature considering the algebraic theory and fast algorithms of these matrices. Nevertheless there are still open problems. including problems concerning structure theory for the block case and the construction of stable algorithms even in the scalar case.

In the first part of the presentation, the speaker will present a sketch of the present state of theory and practice for Toeplitz and Hankel matrices. In the second part, he will discuss a new method for block Toeplitz matrix inversion which is based on a transformation into generalized Cauchy matrices and a pivoting technique.

Georg Heinig
Department of Mathematics
Universitat Leipzig, Germany

SL2/Kane Hall 110

Chair: Paul Van Dooren, University of Illinois, Urbana

Algorithms and Conditioning for Eigenvalue Assignment

The Eigenvalue Assignment Problem (EAP) has been very well studied in its 35+ years of existence. The last dozen years have produced some backward stable single-input methods and some "robust" multi-input methods. The EAP can be a useful tool in the design and analysis of control systems; it is a simple tool with relatively low computational cost, but requires the knowledge of the closed-loop eigenvalues.

The QR-based single-input methods of Miminis and Paige, Patel and Misra, and Petkov, Christov and Konstantinov are all special cases of a generic QR-based method. This generic method is closely related to a new RQ-based implementation of Datta's method. The speaker will describe this theory and discuss its implications for new parallel methods.

Mark Arnold
Ames Laboratory
Iowa State University

SL3/Gowan Hall 201

Chair: Floyd Hanson, University of Illinois, Chicago

Numerical Methods in Optimal Control

In this presentation the speaker will give an overview of numerical methods in optimal control. He will discuss both practical aspects of algorithms, as well as the recent progress on algorithm analysis. Variations of gradient, Newton, and multiplier methods will be examined.

William W. Hager
Department of Mathematics
University of Florida, Gainesville

SL4/Smith Hall 304

Chair: Stephen L. Campbell, North Carolina State University

Are Persistent Disturbances a Pain in the Hilbert Space?

In this presentation, the speaker will discuss with two problems in persistent disturbance accommodation for linear distributed parameter systems (DPS) posed on infinite-dimensional Hilbert spaces: disturbances (of known waveform but unknown amplitude) appearing at the DPS input and controller supressed in the state and disturbances appearing at the DPS output and new disturbance-free output produced by controller.

The first problem is the "classical" disturbance accommodation problem for DPS. The second problem is new and has not been treated even for finite-dimensional systems.

The speaker will show how the second problem is related to finite-dimensional control of DPS without persistent disturbances and he will illustrate the discussion with some experimental results in control of mechanically flexible structures.

Mark J. Balas
Department of Aerospace Engineering Sciences
University of Colorado, Boulder

2:15/Kane Hall Lobby

Coffee

2:45-4:45

Concurrent Sessions

MS7/Kane Hall 130

Convex Optimization in Control Systems Analysis and Design—Part II: Algorithms

(See MS1, page 6, for Part I: Applications).

Organizer: Venkataramanan (Ragu) Balakrishnan
Stanford University

2:45 **Structure and Computational Complexity in Robustness Analysis**
John Doyle, California Institute of Technology

3:15 **Acceleration Strategies in Interior Point Methods for Semidefinite Programming**
Arkady Nemirovsky and *Yurii Nesterov*, Central Economical and Mathematical Institute, Russia

3:45 **A Primal-dual Interior-point Method for Optimization over Linear Matrix Inequalities**
Lieven Vandenberghe and Stephen Boyd, Stanford University

4:15 **A Second-Order Local Algorithm for a Class of Nondifferentiable Optimization Problems**
Michael K.H. Fan, and Batool Nekooie, Georgia Institute of Technology

MS8/Kane Hall 110

Matrix Equations, Inertia and Stability

Matrix equations, inertia and stability have been important in applications and in theory since the fundamental paper of Lyapunov in 1892. Papers by Ostrowski and Schneider, and by Taussky, in the early 1960's sparked increased interest in the field as did, a paper on robust stability by Kharitonov in the early 1980's. The speakers will present some recent work involving matrix equations eigenvalue location in various regions of the complex plane, and robust stability.

Organizer: David Carlson
San Diego State University
Chair: Biswa N. Datta, Northern Illinois University

2:45 **Inertia: Theory, Methods and Applications**
Biswa N. Datta, Chair

3:15 **Unit Disc Analogues of Some Kinds of Half-Plane Stability**
Bryan Cain, Iowa State University

3:45 **Applications of Linear Transformations to Matrix Equations**
Karabi Datta and Yoo Pyo Hong, Northern Illinois University

4:15 **Invariance of Matrix Inertia Under Parameter Variations**
Lee H. Keel, Tennessee State University

4:45 **An Inertia Theorem for the Lyapunov Equation**
Raphael Loewy, Technion-Israel Institute of Technology, Israel

2:45-4:45

Concurrent Sessions

MS9/Gowan Hall 201

Large-Scale and Parallel Matrix Computations and Their Applications (Part 1 of 4)

There have been some very fine developments in the area of large-scale and parallel matrix computations. For large-scale sequential matrix computations, the Krylov subspace methods such as Arnoldi-based GMRES, look-ahead Lanczos based QMR, nonsymmetric conjugate gradient, and special iterative methods, condition number estimators such as SPICE, and Lanczos-based eigenvalue methods, are some examples.

A remarkable development in the area of high-performance computing has been the development of matrix algorithms rich in BLAS-3 computations and the release of the associated software package, LAPACK. Attempts have been, and are being, made to incorporate these techniques for solution to large-scale control problems. However, these exciting recent developments in matrix computations seem to be relatively unknown to researchers and practicing engineers in control and systems theory.

The speakers in this four-part minisymposium will provide an overview of these developments and discuss their applications.

Organizer: Biswa N. Datta
Northern Illinois University

2:45 Parallel Implementation of the h-p version of the Finite Element Method on a Shared-memory Computer
Howard C. Elman, University of Maryland, College Park

3:15 Parallel Computation of Orthogonal Factors of Sparse Matrices
Szu-Min Lu, and *Jesse L. Barlow*, Pennsylvania State University

3:45 A Comparison of Techniques for Solving Ill-Conditioned Problems Arising from the Immersed Boundary Method
Loyce Adams and Zhiyun Yang, University of Washington

4:15 Convergence Result for the Block-symmetric Gauss-Seidel Iteration for the Non-symmetric Case: An Application to the Convection-Diffusion Equation
Randolph E. Bank, University of California, San Diego, and *M. Benbourenane*, Northern Illinois University

4:45 A Direct Algorithm for Computing Eigenspaces with Specified Eigenvalues of a Regular Matrix Pair (A, B) in Generalized Real Schur Form
Bô Kagström and Peter Poromaa, University of Umea, Sweden

MS10/Savery Hall 216

Analysis and Computational Methods for Dense Eigenvalue and Singular Value Problems (Part 2 of 2)

(See MS4, page 7, for summary)

Organizer: Ilse C.F. Ipsen
Yale University

2:45 Reordering Diagonal Blocks in Real Schur Form
Adam W. Bojanczyk, Cornell University, and Paul Van Dooren, University of Illinois, Urbana

3:15 The Computation of the Jordan Form via GQRD
Adam W. Bojanczyk, Cornell University, and *Paul Van Dooren*, University of Illinois, Urbana

3:45 How Can We Parallelize the Unsymmetric QR Algorithm?
David S. Watkins, Washington State University

4:15 Scaled Toda-Like Flows
Moody T. Chu, North Carolina State University

4:45 Isospectral Flows and Linear Programming
Jeffrey C. Lagarias, AT&T Bell Laboratories

MS11/Savery Hall 249

Numerical Methods for Differential Algebraic Equations and Descriptor Systems

Differential algebraic systems, descriptor systems or generalized state space systems play an important role in the modelling and analysis of problems in control, in particular in the treatment of mechanical multibody systems and electrical or gas networks. In this minisymposium, the speakers will present some recent developments in the numerical solution of such systems. The newest developments include numerical methods for differential algebraic equations and descriptor control problems as well as applications to real problems.

Organizer: Volker Mehrmann
Universität Bielefeld, Germany

2:45 Numerical Solution of Hamiltonian Eigenvalue Problems via Subspace Iteration Techniques
Peter Benner, Rheinisch-Westf Tech Hochschule Aachen, Germany

3:15 A New Class of Discretization Methods for Linear Differential-Algebraic Equations with Variable Coefficients
Peter Kunkel, Fachbereich Mathematik, Carl-von-Ossietzky-Universität Oldenburg, Germany, and *Volker Mehrmann*, Organizer

3:45 Numerical Integrators of General DAES Which Preserve Constraints
Stephen L. Campbell, North Carolina State University

4:15 Observer Design for Descriptor Systems with Applications to Gas Dynamical Systems
Simon Stringer, and Nancy K. Nichols, University of Reading, United Kingdom

4:45 Index Reduction for Linear Differential Algebraic Equations
Andreas Bugers, Universität Bielefeld, Germany, and Volker Mehrmann, Organizer

5:15 On the Discrete Generalized Lyapunov Equation
Vassilis L. Syrmos and Ravi Aripirala, University of Hawaii, Manoa

CP2/Smith Hall 304

Control of Linear Systems

Chair: Clyde Martin, Texas Tech University

2:45 A Parameterization of All Stabilizing Controllers by Polynomial Matrix Approach
Wataru Kase, Shizuoka Institute of Science and Technology, Japan; Katsutoshi Tamura, Sophia University, Japan; and Peter N. Nikiforuk, University of Saskatchewan, Canada

3:00 A New Look at the Mixed Sensitivity Minimization Problem for the Control System Design
Jiann-Shiou Yang, University of Minnesota, Duluth

3:15 A Design of Exact Model Matching Systems using Polynomial Basis
Wataru Kase, Shizuoka Institute of Science and Technology, Japan; *Y. Mutoh* and K. Tamura, Sophia University, Japan; and P.N. Nikiforuk, University of Saskatchewan, Canada

3:30 Controllability Analysis of Time Varying Linear Systems: Application of Computer Algebra Methods
Andras Edelmayer and Jozsef Bokor, Hungarian Academy of Sciences, Hungary; and Ferenc Szigeti, Eotvos Lorand University, Hungary

3:45 On the Generalized Interactor Matrix and the Model Matching Control for Linear Multivariable Non-Minimum Phase Systems
P.N. Nikiforuk, University of Saskatchewan and *Y. Mutoh*, Sophia University, Japan

4:00 Algebraic Computation of the Fundamental Solution of Linear Time Varying Systems
Andras Edelmayer and Jozsef Bokor, Hungarian Academy of Sciences, Hungary; and Ferenc Szigeti, Eotvos Lorand University, Hungary

4:15 Transfer Functions Approximation for Distributed Parameter Systems
A. Bernoussi and *A. El Jai*, University of Perpignan, France

4:30 Feedback Design Interval Linear Systems
Shuping Chen, Zhejiang University, People's Republic of China

CP3/Thomas Hall 125

Signal Processing 1

Chair: Franklin T. Luk, Rensselaer Polytechnic Institute

2:45 Numerical Performance of Two-Sided Linear Prediction
Jin-Jen Hsue and *Andrew E. Yagle*, University of Michigan, Ann Arbor

3:00 Iterative Methods for Restoration of 2-Dimensional Images
Daniela Calvetti, Stevens Institute of Technology

3:15 Constrained Image Reconstruction from Projections using the Wavelet Transform
Berkman Sahiner and *Andrew E. Yagle*, University of Michigan, Ann Arbor

3:30 On Signal Separation By Multi-resolution Analysis
Charlie H. Cooke, Old Dominion University

3:45 Multiresolution Algorithms for One-Dimensional Inverse Scattering Problems using the Wavelet Transform
Andrew E. Yagle, University of Michigan, Ann Arbor

4:00 Numerical Properties of Some Highly Concurrent Algorithms for Control and Signal Processing
Grigore Braileanu, Gonzaga University

4:15 EM-Type Algorithms for Maximizing Likelihoods in Transmission Tomography
Alvaro R. De Pierro, University of Pennsylvania

4:30 Surface Reconstruction Based on Texture Variation
Kyoung Mu Lee and *C.-C. Jay Kuo*, University of Southern California

4:45 Variance Bounds for Modal Analysis
L.T. McWhorter and *Louis L. Scharf*, University of Colorado, Boulder

5:00 Constructing Linear and Quadratic Forms from Projection Operators in ℓ^2
Mark S. Spurbeck and *Louis L. Scharf*, University of Colorado, Boulder

5:15 A Fast Algoritm for Computing Eigenspaces of Real Symmetric Toeplitz Matrices
Gregory S. Ammar and *Santosh K. Mohanty*, Northern Illinois University

5:30 PM-7:30 PM/McMahon Hall

Dinner

7:00-8:30/McMahon Hall
Breakfast

7:30/Kane Hall Lobby
Registration opens

8:00/Kane Hall 130
IP3/Chair: Gene H. Golub, Stanford University
Computational Methods in Linear Least Squares

The method of least squares and its variations is one of the most useful tools for processing scientific data. It plays a fundamental rule in many parameter estimation problems in signal processing. In this presentation, the speaker will first give a brief historic background of algorithms for linear least squares problems. He then will discuss some recent advances, emphasizing questions of efficiency and stability. In particular he will discuss the method of seminormal equations and show the importance of including one correction step, i.e. one step of iterative improvement. This method has applications, for example, to downdating least squares solutions and related factorizations. Some well-known algorithms, which are unstable, can be stablized using a similar technique.

Åke Bjørck
Department of Mathematics
Linkoping University, Sweden

8:45/Kane Hall 130
IP4/Chair: Franklin T. Luk, Rensselaer Polytechnic Institute
Parallel Algorithms and Numerical Stability for Toeplitz Systems

Toeplitz linear systems and Toeplitz least squares problems commonly arise in digital signal processing. The speaker will discuss algorithms for solving these problems and some of their generalizations, with an emphasis on algorithms that can be implemented efficiently on parallel machines and have good numerical properties. He will present results on the numerical stability of some parallel algorithms for LU and QR factorization of Toeplitz matrices.

Richard P. Brent
Research School of Physical Sciences and Engineering
Australian National University, Australia

9:30/Kane Hall Lobby
Coffee

10:00 AM-12:00 PM
Concurrent Sessions

MS12/Savery 216
Controls Research at Boeing

The Boeing Company is utilizing the latest developments in control system design and analysis. This minisymposium outlines several advances in control system design tools and techniques used at Boeing in development of commercial and military aircraft and missile systems. The speakers will outline control system analysis tools using H-infinity, LQ and unique root locus analysis, as well as, dynamic quadratic optimization. These techniques will be discribed and actual applications cited.

This minisymposium is an overview of new techniques applicable to real aerospace applications. It is intended for practitioners in control system design and analysis. These techniques will be presented in an aerospace perspective, however, they are applicable to many other fields.

Organizer: Richard D. Jones
Boeing Defence and Space Group, Seattle

10:00 Dynamic Optimization for Nonlinear Control
Richard D. Jones, Organizer

10:30 Modern Control Bank-To-Turn Autopilot for HAVE DASH II Missile
Michael A. Langehough, Boeing Defence and Space Group, Seattle

11:00 Applications of LQ and H-infinity Synthesis to Aircraft Control
Russell L. Daily, Boeing Defence and Space Group, Seattle

11:30 Boeing's Automatic Control System Workbench and the Linear Systems Toolbox
Gregory F. Robel, Boeing Commercial Airplane Group, Seattle

MS13/Kane Hall 110
MATLAB and Applications

The software package MATLAB has become an essential tool in engineering and applied mathematics. MATLAB was originally designed as a matrix laboratory to help students learn linear algebra and matrix theory. Since linear algebra education is so essential to all of the applied sciences, one of the speakers in this minisymposium will discuss the use of MATLAB in teaching linear algebra. Another speaker will preview new features and toolkits that are currently being developed for future releases of MATLAB. The remaining speakers will discuss applications of MATLAB to systems theory, signal processing, and digital filter design.

Organizer: Steven J. Leon
University of Massachusetts, Dartmouth

10:00 Applications of MATLAB to Signal Processing Algorithms and Digital Filter Design
C. S. Burrus, Rice University

10:30 Use of MATLAB in Linear System Theory
Pradeep Misra, Wright State University and *Vassilis Syrmos*, University of Hawaii

11:00 What's New with MATLAB
Cleve Moler, The MathWorks,Inc., Natick, MA

11:30 Educational Applications of MATLAB
Steven J. Leon, Organizer

MS14/Gowan Hall 201
Multiple Taper Spectral Estimation

Multiple taper analysis treats spectral analysis as an inverse problem for an integral equation of the first kind. The system can be solved by expanding the solution in a set of orthogonal spectral windows. Using the discrete prolate spheroidal wavefunctions, 2Nw highly localized bases functions can be obtained. The taper coefficients are a set of independent random variables, and spectral estimation is reduced to the standard statistical problem of variance estimation.

In the minisymposium, the speakers will compare multitaper spectral analysis with other nonparametric methods. They will discuss data adaptive schemes which adjust automatically to regions of large spectral range and describe examples from global warming, geophysics and plasma physics.

Organizer: Kurt S. Riedel
Courant Institute of Mathematical Sciences, New York University

10:00 Quadratic Spectral Estimators and Multitapering
Don Percival, University of Washington, Seattle, and Andrew Walden, Imperial College, United Kingdom

10:30 Quadratic-Inverse Spectrum Estimates
David J. Thomson, AT&T Bell Laboratories

11:00 Variance and Distribution of Multitaper Spectral Estimators for Rapidly Changing Spectra
Emma McCoy, Imperial College, United Kingdom; Don Percival, University of Washington, Seattle; and Andrew Walden, Imperial College, United Kingdom

11:30 Minimum Expected Loss Estimation for Evolutionary Spectra
Kurt S. Riedel, Organizer, Alexander Sidorenko, Courant Institute of Mathematical Sciences, and David J. Thomson, AT&T Bell Laboratories

10:00 AM-12:00 PM

Concurrent Sessions

MS15/Kane Hall 130

Iterative Methods for Toeplitz Systems

The purpose of this minisymposium is to survey the current use of iterative methods for solving Toeplitz and related systems. In 1986, Gilbert Strang addressed the question of whether iterative methods can compete with direct methods for solving symmetric positive definite Toeplitz systems of linear equations. The answer has turned out to be an unqualified yes. Strang proposed the use of circulant matrices to precondition conjugate gradient iterations for Toeplitz systems. The reason why this approach is competitive with direct methods is clear, circulant preconditioners for these Toeplitz problems allow the use of Fourier transforms throughout the computation, and these FFT—based iterations are not only numerically efficient, but also highly parallelizable. Numerous articles have extended the Strang idea to more general Toeplitz systems, and several types of circulant preconditioners have been suggested. For example, FFT—based preconditioners have been proposed for solving Toeplitz least squares problems, where applications include such important signal processing problems as image restoration or deblurring, active noise cancellation, seismic deconvolution, data compression, and high definition TV. The speakers in this minisymposium will describe current techniques and applications of iterative Toeplitz solvers.

Organizer: Robert J. Plemmons
Wake Forest University

10:00 Fast Iterative Methods for Least Squares Estimations
Raymond H. Chan and Michael K. Ng, Hong Kong University of Science and Technology, Hong Kong

10:30 Spectral Properties of Preconditioned Rational Toeplitz Matrices
Ta-Kang Ku, National Telecommunication Laboratories, Taiwan *C.-C. Jay Kuo*, University of Southern California

11:00 Fast Preconditioned Iterative Methods for Image Restoration
James G. Nagy, Southern Methodist University, and Robert J. Plemmons, Organizer

11:30 Building Preconditioners for Toeplitz and Related Systems
Robert J. Plemmons, Organizer

MS16/Savery Hall 249

Second Order Systems

We consider second order systems from the point of view of (optimal) control, stability, spectral and perturbation theory of the quadratic eigenvalue problem etc., including theory and algorithms.

Organizer: Kresimir Veselic
Feruniversitat Hagen, Germany

10:00 A Variational Principle for Real Eigenvalues of Quadratic Hermitian Problems
B. Najman, University of Zagreb, Yugoslavia

10:30 On the Stability of Rotating Systems
Kresimir Veselic, Organizer

11:00 Feedback Stabilization for Second Order Model
Biswa N. Datta and *Fernando Rincon*, Northern Illinois University

11:30 Active Vibration Absorbers for Flexible Structures: Design and Practical Implementional Questions
Trevor Williams, Jiafan Xu, University of Cincinnati, and Jer-Nan Juang, Space Craft Dynamics Branch-NASA Langley Research Center

MS17/Smith Hall 304

Automated System Identification and Control Using SVD

Some major advances in the identification of dynamical systems from observational data have occurred in the past decade based upon computation using the singular value decomposition (SVD). As a result, system identification has been automated for online identification and adaptive control of rather complex dynamical systems. In this minisymposium, the speakers will describe the SVD implementation of a canonical variate analysis (CVA) extended to the identification of linear stochastic systems and discuss implementation of CVA algorithms for parallel computing, applications to identification of forced vibrating structures and extensions to general nonlinear and chaotic system.

The purpose is to describe the developments in system identification using the SVD and the impact on the fields of empirical modeling, online adaptive control, and uncertainty modeling for robust control design. Also the computational and algorithmic and aspects will be discussed for serial and parallel computing. Current research on extensions to nonlinear system is described.

Organizer: Wallace E. Larimore
Adaptics, Inc., Reading, Massachusetts

10:00 Automated System Identification Using Canonical Variate Analysis
Wallace E. Larimore, Organizer

10:30 Parallel Algorithms for Canonical Variate Analysis
Franklin T. Luk, and David Vandevoorde, Rensselaer Polytechnic Institute

11:00 Analysis of Nonlinear Vibrating Systems Using Canonical Variates
Norman F. Hunter Jr., Los Alamos National Laboratory

11:30 Identification of Nonlinear Systems Using Canonical Function Analysis
John Baillieul, Boston University, and *Wallace E. Larimore*, Organizer

CP4/Thomas Hall 125

Optimal Control

Chair: William W. Hager, University of Florida, Gainesville

10:00 Time-Discretization of Hamiltonian Dynamical Systems
Yosi Shibberu, Rose-Hulman Institute of Technology

10:15 Minimum Horizon Strategy in Closed-loop Predictive Control
Bert Taube, Siemens Energy and Automation, Inc., Alpharetta, GA

10:30 Fast Recursive SQP Methods for the Direct Solution of Optimal Control Problems
Marc C. Steinbach, Universität Heidelberg, Germany

10:45 Relaxation of Optimal Control Problems Via Linear Programming
Daniel Hernandez-Hernandez, CINVESTAV-IPN, Mexico

11:00 On LQ Optimal Controller
Kuanyi Zhu, Nanyang Technological University, Singapore

11:15 Application of Boltyanskii's Optimality Principle for Investigation of One Linear Discrete Problem with Mixed Constraints
Sobolevskii Ioshua, Hebrew University of Jerusalem, Israel

11:30 On the Existence and Uniqueness for a Class of Optimal Control Problems
Gargi Chakraborty, University of Burdwan, West Bengal, India

11:45 The Final Net Demand Following Model of Time Varying Discret-Time Singular Dynamic Input-Output
Haiying Jing and *Guangbin Huang*, University of Technology, People's Republic of China; and Zhaoyu Yang, Liaoning Institute of Economic Management Cadre, People's Republic of China

12:00/McMahon Hall
Lunch

1:30-2:15
Concurrent Sessions

SL5/Kane Hall 130
Chair: John G. Lewis, Boeing Computer Services

Conditioning, Consistency, and Stability Issues in Signal Processing

Previous analyses for recursive least squares algorithms have drawn from stochastic and deterministic models, and analyses focus on a particular filter structure or algorithm. Recently, Regalia and Slock have utilized the concepts of backward stability to create a common framework for the stability analysis of many types of recursive filters. The speaker will discuss the connections between these works and traditional numerical analyses such as Wilkinson's.

James R. Bunch
Department of Mathematics
University of California, San Diego

SL6/Kane Hall 110
Chair: Charles Johnson, College of William and Mary

Robust Stability and Control

This presentation will focus on robust stability and control under parametric uncertainty. The speaker will discuss some of the major results obtained over the last ten years including the determination of robust stability under parametric perturbations, the exact calculation of the parametric stability margin, the robust stability of linear and multilinear interval systems via the generalization of Kharitonov's theorem, segment and vertex results, extremal segments and manifolds for interval systems and their role in control problems involving parametric as well as unstructured uncertainty. He will illustrate the results with examples and discuss future research directions.

S.P. Bhattacharyya
Department of Electrical Engineering
Texas A&M University

SL7/Gowan Hall 201
Chair: Daniel Boley, University of Minnesota, Minneapolis

Rational Krylov Algorithms for Eigenvalues with Engineering Applications

The speaker will describe new algorithm for the computation of eigenvalues of a nonsymmetric matrix pencil. The algorithm is a generalization of the shifted and inverted Lanczos (or Arnoldi) algorithm, in which several shifts are used in one run. It computes an orthogonal basis and a small Hessenberg pencil. The eigensolution of the Hessenberg pencil, gives Ritz approximations to the solution of the original pencil.

The speaker will discuss numerical tests on a matrix coming from an aircraft design application.

Axel Ruhe
Department of Computer Science
Chalmers University of Technology, Sweden

SL8/Smith Hall 304
Chair: Robert J. Plemmons, Wake Forest University

Surface Reconstruction with Uncertain Data

The problem of reconstructing surfaces is very important for computer vision, where we would like to recover for example depth from a stereo pair of images, depth from a shaded image and 3D motion from a sequence of images. The available surface data could come from different sources and with the associated degree of reliability of each source.

The speaker will discuss the problem of reconstructing surfaces from uncertain data within a Bayesian framework with the prior assumption of piecewise smooth surfaces. He will discuss deterministic algorithms derived from the probabilities distributions and applications to the reconstruction of images from very sparse data, the reconstruction of depth data from stereo pairs and to the study of the formation of illusory contours.

Davi Geiger
Siemens Corporate Research, Inc.
Princeton, New Jersey

SL9/Savery Hall 249
Chair: Daniel J. Pierce, Boeing Computer Services

Russell Lane Dailey
Boeing Defense and Space Group

2:15/Kane Hall Lobby
Coffee

3:00-5:00
Concurrent Sessions

MS18/Kane Hall 130

Least Squares for Signal Processing

Least squares techniques are common in signal processing because of inconsistent data. Recursive least squares and total least squares techniques are used for solving many signal processing problems. The speakers will present some recent research in these areas.

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

3:00 Subspace Angle and Accuracy of Linear Prediction Equations
Ricardo D. Fierro, and K. Yao, University of California, Los Angeles

3:30 The Effect of Interference on Recursive Least Squares Adaptive Equalization
Richard C. North, Naval Command, Control and Ocean Surveillance Center, San Diego

4:00 The Stability and Conditioning for the A Posteriori Recursive Least Squares Adaptive Filter
Richard C. LeBorne, University of California, San Diego and James R. Bunch, Organizer

MS19/Kane Hall 110

Numerical Linear Algebra for Signal Processing and Control

In this minisymposium, the speakers will discuss new developments in numerical linear algebra that are relevant to signal processing and control applications. The areas discussed include the problem of downdating for applications such as recursive least squares problems, a new matrix decomposition for computing an orthonormal basis for the noise subspace, a homotopy method to track the eigenvalues of symmetric tridiagonal matrices, and the solution of the periodic Lyapunov equation.

Organizer: Sven Hammarling
The Numerical Algorithms Group Ltd., United Kingdom

3:00 A New Matrix Decomposition for Signal Processing
Franklin T. Luk, Rensselaer Polytechnic Institute and Sanzheng Qiao, McMaster University, Canada

3:30 Accurate Downdating of the Rank-revealing URV Decomposition
Haesun Park, University of Minnesota, Minneapolis and Lars Elden, Linkoping University, Sweden

4:00 Another Homotopy Method to Solve the Symmetric Tridiagonal Eigenvalue Problem
Peter Arbenz and Michael H. Oettli, Institute fur Wissenschaftliches Rechnen, Eidgenossische Technische Hochschule, Switzerland

4:30 Solution of Periodic Lyapunov Equations via the Periodic Schur Form
J. Sreedhar and *Paul Van Dooren,* University of Illinois, Urbana-Champaign

3:00-5:00

Concurrent Sessions

MS20/Gowan Hall 201

Large-Scale and Parallel Matrix Computations and Their Applications (Part 2 of 4).

(See MS9, page 9, for summary)

Organizer: Biswa N. Datta
Northern Illinois University

3:00 Dynamic Condition Estimation and Rayleigh-Ritz Approximation
Ping Tak Peter Tang, Argonne National Laboratory

3:30 A Spectral Approach to Sparse Matrix Orderings
Alex Pothen, University of Waterloo, Canada

4:00 Stable Fast and Superfast Algorithms for Nonsymmetric Toeplitz Systems
Martin Gutknecht, ETH-Zentrum, Switzerland

4:30 Accurate Least Squares Solutions for Toeplitz Matrices
Haesun Park, University of Minnesota, Minneapolis, and Lars Elden, Linkoping University, Sweden

5:00 Synchronous and Asynchronous Parallel Two-Stage Block Iterative Methods for Linear Systems
Daniel B. Szyld, Temple University

5: 30 Title to be announced
Vince Fernando, University of California, Berkeley

MS21/Savery Hall 216

Numerical Solution of Matrix Differential Equations with Structured Solutions

Matrix differential equations, for which the solution has a particular algebraic structure occur in many different applications. Some major examples are: Hamiltonian problems, matrix Riccati differential equations, and systems that have a solution that is a sympletic or orthogonal matrix.

In this minisymposium, the speakers will present several new developments. A main topic will be the choice of proper discretization methods that guarantee that the algebraic structure is preserved during the numerical integration.

Organizers: Volker Mehrmann, Universität Bielefeld, Germany and Nancy K. Nichols, University of Reading, United Kingdom

3:00 Numerical Methods for the Computation of an Analytic Singular Value Decomposition of a Matrix Valued Function
Werner Rath, Rheinisch-Westf Tech Hochschule Aachen, Germany

3:30 Structure Preserving Interpolation for Smooth SVD-Paths
Dieter Putz, Rheinisch-Westf Tech Hochschule Aachen, Germany

4:00 Title to be announced
Simon Bell, University of Reading, United Kingdom

4:30 Numerical Solution of Differential Equations for the ASVD of a Matrix
Ken Wright, University of Newcastle-upon-Tyne, United Kingdom

CP5/Savery Hall 249

Matrix Theory

Chair: Karabi Datta, Northern Illinois University

3:00 On Some Matrix Completion Problems Arising in Metabolic Control Analysis
Asok K. Sen, Purdue University, Indianapolis

3:15 On Equalities in Symmetric Eigenvalue Inclusion Theorems
Noah H. Rhee, University of Missouri

3:30 On the Inertia of the Polytopes and Cones of Matrices
Wenchao Huang, University of Wisconsin, Madison

3:45 Gohberg-Semencul Formula Generalized to Krylov Matrices
David H. Wood, University of Delaware

4:00 Differential Properties of the Spectral Abscissa and the Spectral Radius for Analytic Matrix--Valued Mappings
James V. Burke, University of Washington, Seattle; and Michael L. Overton, Courant Institute of Mathematical Sciences, New york University

4:15 Embedding Line in the Plane Through Resultants
Jie-Tai Yu, University of Notre Dame

4:30 Properties of Some Rational Function Matrices
Kai Sheng Lu, Wuhan University of Water Transportation Engineering, People's Republic of China

4:45 Roundoff Errors and Graphs
Plamen Yalamov, Technical University, Bulgaria

CP6/Smith Hall 304

Parallel Computations and Numerical Linear Algebra

Chair: Lothar Reichel, Kent State University

3:00 A QR-Based Factorized Fixed-Interval Smoother
Yaakov Oshman, Technion-Israel Institute of Technology, Israel

3:15 Condition Estimation for Matrix Functions via the Schur Decomposition
Roy Mathias, University of Minnesota, Minneapolis

3:30 A Strassen-Type Matrix Inversion Algorithm
Susanne Molleskov Balle and Per Christian Hansen, Technical University of Denmark, Denmark

3:45 Parallel Orthogonal Triangularization on the Supernode Multicomputer
Antonio M. Vidal, Gregorio Quintana, and Jose M. Badia, Universidad Politecnica de Valencia, Spain

4:00 A Graph-theoretic Algorithm for the Decomposition of the Computation of Zeros of Large-Scale Control Systems
Ferdinand Svaricek, Universität Duisburg, Germany

4:15 Eigendendecomposition Based Partitioning of DSP Graphs for the Processor Assignment Problem in Multiprocessor Systems
Sati Banerjee and Paul M. Chau, University of California, San Diego

4:45 Block-Cyclic Dense Linear Algebra on the Connection Machine CM-5
Palle M. Pedersen, Thinking Machines Corporation

Kane Hall Lobby

Poster Session

Algebraic Approach to Projection Data Informativity
Ivan G. Kazantsev, Image Processing Laboratory, Russia

Nonstationary Signal Filtering by an ARX-Model
Zheng-Yuan Feng and Armin Schone, Universitat Bremen, Germany

Circular Pole Assignment for Descriptor Systems
Guojun Shi, East China Institute of Technology, People's Republic of China

An Application of Matrix Generalized Inverses to Optimal Control Problems of Linear Time-Invariant Discrete-Time Systems
Ala Al-Humadi, Embry-Riddle Aeronautical University

Eigenstructure Assignment by Proportional Plus Derivative Output Feedback in Singular Systems
Haiying Jing, Northeast University of Technology, People's Republic of China

Fast Intergal Manifold for the Singularly Perturbed Filtering Problem over Discrete-Continuous Observations
Natalia Navarova and Yuri V. Orlov-Institute of Control Sciences, Russia

Potentially Stable Tree Sign Patterns with Five Vertices
Kendall R. Bailey and Luz M. DeAlba, Drake University

A Closed Range Theorem for the Frobenius-Perron Operator and Its Applications to the Spectral Analysis
Jiu Ding, University of Southern Mississippi

On Some Formulas for Transfer Functions and Impulse Transfer Functions
Jerzy Tokarzewski, Military Technical Academy of Warsaw Institute of Mechanical Vehicles, Poland

Maximum Likelihood Estimation of Signal to Noise Ratio for High Sampling Rates
Amir Sarajedini, and Paul M. Chau, University of California, San Diego; and Robert Hecht-Nielsen, University of California, San Diego and HNC, Inc., San Diego

TLS-Based Iterative Prefiltering Technique for ARMA Modeling
M.P. Fargues, Naval Postgraduate School

Coded Input Neural Network
O. Olaniyan and C. Aissi, Howard University

Quadratic Stability Recovery via an Observer for Systems with both Structural and Unstructural Uncertainties
Tielong Shen and Katsutoshi Tamura, Sophia University, Japan

Advanced Method for Optimal Control
Victor Vladimirovich Vasiliev, Lenin All-Russian Electrotechnical Institute, Russia

An Inverse Problem in Laser Confocal Scanning Microscopy
Mary Oman and Curtis R. Vogel, Montana State University

A Band-Limited Signal Extrapolation by a Sequence of Points
Xiao Changbai, Nanjing University, People's Republic of China

5:30 PM-7:30 PM/McMahon Hall

Dinner

8:00-9:00/Kane Hall 130

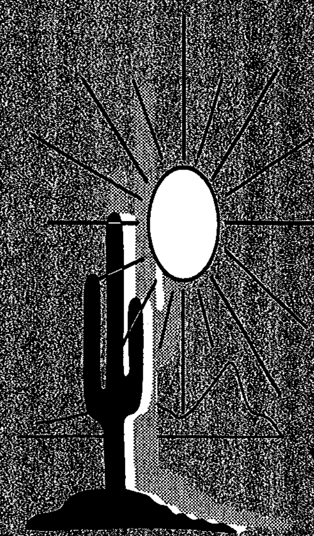
Special Presentation/Chair: Robert J. Plemmons, Wake Forest University

Wavelets and the Search for Good Filters

The search is not over! The speaker will mention important steps in the history of filters (the audience may know others) and then concentrate on quadrature mirror filters, now known as wavelets. They have useful properties but substantial restrictions. The original Haar wavelet provides an example of subband filters and multiresolution analysis. The Daubechies wavelets improve accuracy and smoothness but with longer support intervals (more taps and more coefficients in the dilation equation).

The speaker will describe new "short wavelets" that come from matrix dilation equations. They are constructed from two or more scaling functions. These Geronimo - Hardin wavelets are nonzero only on two intervals. They provide self-scaling orthogonal bases for a subspace containing all piecewise linear functions and its complement. The speaker will try to predict where some applications may arise.

Gilbert Strang
Department of Mathematics
Massachusetts Institute of Technology



7:00-8:30/McMahon Hall

Breakfast

7:30/Kane Hall Lobby

Registration opens

8:00/Kane Hall 130

IP5/Chair: Biswa N. Datta, Northern Illinois University

Linear Algebra and Neural Networks

Neural networks are a subject of intense research these days. A wide variety of methods are used to analyze such networks, ranging from differential geometry to statistical mechanics. In this presentation, the speaker will provide a panoramic view of some results which share the common feature that they are based on the application of linear algebra. These methods range from the elementary (symmetric multilinear algebra) to the relatively advanced (algebraic block coding).

M. Vidyasagar
Centre for Artificial Intelligence and Robotics
Bangalore, India

8:45/Kane Hall 130

IP6/Chair: Hidenori Kimura, Osaka University, Japan

Sampled-Data Systems in Signal Processing and Control

The signals of interest in control systems are usually continuous-time signals and the performance specifications are formulated in continuous time. But since digital technology offers many benefits, modern control systems usually employ digital technology for controllers and sometimes sensors. Such a control system involves both continuous-time and discrete-time signals, in a continuous-time framework. Similarly, in many communication systems the input and output signals are continuous-time, but the communication system hardware is digital.

Sampled-data systems operate in continuous time, but some continuous-time signals are sampled at certain time instants, yielding discrete-time signals. Sampled-data systems thus involve both continuous-time and discrete-time signals.

In this presentation, the speaker will survey recent extensions of analog design techniques—namely, H_2, H_∞, and L_1 optimization—to sampled-data systems and discuss applications such as optimal stability robustness of control systems and optimal discretization of analog filters.

Bruce A. Francis
Electrical and Computer Engineering Department
University of Toronto, Canada

9:30/Kane Hall Lobby

Coffee

10:00 AM-12:00 PM

Concurrent Sessions

MS22/Kane Hall 110

Complexity Issues in Linear Algebra

This minisymposium will focus on the (sequential and parallel) cost of solving and checking the most important problems in numerical linear algebra. Upper and lower bounds on the cost of performing linear algebra computations in different settings will be presented. The speakers in this session will give an overview of the state-of-the-art in the above areas and will discuss the main techniques used.

Organizer: Bruno V. Codenotti
IEI-CNR, Italy

10:00 Checking Linear Algebra Computations
Manuel Blum, University of California, Berkeley

10:30 Complexity of Approximate Solving of Large Linear Systems
Henryk Wozniakowski, Columbia University, and University of Warsaw, Poland and *Adam W. Bojanczyk,* Cornell University

11:00 Complexity of Parallel Matrix Computations
Victor Y. Pan, City University of New York, Lehman College

11:30 Self-Testing/Correcting Linear Algebra Computations
Ronitt Rubinfeld, Cornell University

MS23/Kane Hall 130

Numerical Computation of H^∞ Controllers for Infinite Dimensional Systems

This minisymposium will be focused on computational methods for H^∞ control of infinite dimensional plants. Such systems appear in many industrial applications involving time delays and spatially distributed parameter systems. Robustness and performance properties of a feedback control system can be determined using H^∞ techniques. Recently, it was shown that optimal H^∞ controllers for unstable distributed plants can be computed from finitely many linear equations. In the minisymposium, the speakers will discuss numerical construction of optimal controllers from these linear equations.

It has also been shown that for distributed plants optimal controllers are infinite dimensional and hence physical implementation can be a serious problem. Finite dimensional suboptimal controllers can be obtained by two methods: (1) approximating the plant and computing finite dimensional optimal controller corresponding to this system, (2) approximating the infinite dimensional optimal (or suboptimal) controller. The speakers will describe new convergence results for the first method and a new computational procedure for the second approach. Both of these methods rely on approximations of a certain infinite dimensional system, in the L^∞ norm.

Organizer: Hitay Özbay
The Ohio State University, Columbus

10:00 Computational Algorithm for the Two-Block H^∞ Problem for Distributed Parameter Systems
Handung Tu, University of Minnesota, Minneapolis, and Kathryn Lenz, University of Minnesota, Duluth

10:30 Computation of H^∞ Controllers with Numerical Approximations
Kirsten A. Morris, University of Waterloo, Canada

11:00 Parametrization of Suboptimal H^∞ Controllers for Unstable Distributed Plants
Onur Toker, The Ohio State University, Columbus, and *Hitay Özbay,* Organizer

11:30 Approximating Frequency Response Data in MATLAB
M.P. Cai, G. Gu and *E. Bruce Lee,* University of Minnesota, Minneapolis

MS24/Gowan Hall 201

Global Climate Change and Systems Science: Modeling, Methodology and Challenges

Recent recognition around the world that anthropogenic activities, such as greenhouse gas emission, forest clearing, and CFC emission, are potentially capable of changing the climate of planet Earth has generated unprecedented interest in scientists, policy makers and the public alike. This minisymposium has been organized with the intent of bridging the gap between systems theory and global change with benefits flowing in both directions. The speakers will present an overview of the benefits of a "systems" approach, and discuss present day challenges, a systems interpretation of physical climate models, interpretation of predicted regional climate information to local weather, and, the use of multi-criteria decision theory for regional energy and hydrological planning.

Organizer: N. Sreenath
Case Western Reserve University

10:00 Systems Theory and Global Change Research
Mihajlo D. Mesarovic, Case Western Reserve University

10:30 An Integrated Conceptual Model of the Earth Climate System: Modeling Complexity and Challenges
N. Sreenath, Organizer

11:00 A Stochastic Approach for Assessing the Effect of Changes in Regional Circulation Patterns on Local Precipitation
Dennis P. Lettenmaier and James P. Hughes, University of Washington

11:30 Risk Analysis: An Application on Shoreline Management in the Great Lakes Under Climate Change Uncertainty
Philip Chao and Benjamin F. Hobbs, Case Western Reserve University

10:00 AM-12:00 PM

Concurrent Sessions

MS25/Savery Hall 249

New Algorithms and Software for Eigenproblems Arising in Signal Processing and Control

The computation of eigensystems and singular value decompositions is required for a number of applications in signal processing and control. Recently, new algorithms and software packages have been developed to provide increased capability to do these computations efficiently and stably. The purpose of this minisymposium is to provide awareness of the availability of these new techniques and software packages. Availability of software for the GSD, very large SVD, symmetric, non-symmetric and generalized eigenproblems will be presented.

Organizer: Danny C. Sorensen
Rice University

10:00 Generalized Singular Value Decomposition and its Applications in Linear System Identification
Zhaojun Bai, University of Kentucky

10:30 Massively-Parallel Implementations of Lanczos Algorithms for Computing the SVD of Large Sparse Matrices
Michael Berry, University of Tennessee, Knoxville, Susan Dumais and Andrew Ogielski, Bellcore

11:00 An Implicitly Restarted Lanczos Method based on Leja Points for Large Symmetric Eigenvalue Problems
Lothar Reichel, Kent State University

11:30 Implicitly Restarted Arnoldi Methods for Large Scale Eigenvalue Problems
Danny C. Sorensen, Organizer

MS26/Savery Hall 216

Computational Methods for Estimation of Distributed Parameters

In this minisymposium, the speakers will present several recent developments in computational mathematics which have significant applications in parameter estimation for distributed parameter systems. Among these developments are

- "Nonsmooth" Regularization methods. In particular, the Total Variation methods pioneered by Rudin and Osher. These methods allow the robust, efficient identification of nonsmooth parameter functions;
- Efficient iterative methods for large ill-conditioned systems which typically arise in parameter estimation for distributed parameter systems;
- Regularization parameter selection methods.

Organizer: Curt Vogel
Montana State University

10:00 Estimation of Multiphase Flow Functions in Porous Media
J. Gordon Wade and *A. Ted Watson,* Texas A&M University, College Station

10:30 Total Variation Based Image Processing with Nonlinear PDE
Stanley Osher, University of California, Los Angeles, and Cognitech, Inc., and *Leonid Rudin,* Cognitech, Inc., Santa Monica

11:00 Iterative Methods for Large Scale Variational Problems with Randomized GCV
Grace Wahba and *Jianjian Gong,* University of Wisconsin, Madison

11:30 Augmented Lagrangian Method with Second Order Update and Its Application to Parameter Estimation Problems
Kazufumi Ito, CRSC, North Carolina State University

MS27/Smith Hall 304

Numerical and Symbolic Computations for Contemporary Control Problems (Part 1 of 2)

The well-established sophisticated numerical linear algebra techniques and the associated software played a vital role in the development and implementation of numerically viable algorithms for classical control problems such as controllability and observability; eigenvalue assignment, frequency response, model reduction, the Lyapunov, Sylvester and Riccati equations, etc.

Attempts are now being made to incorporate some of the more recently developed techniques of numerical and symbolic computations and the associated software such as LAPACK to the development and implementation of algorithms for contemporary control problems, such as the H-infinity optimization problem, etc.

The speakers in this session will describe some of these recent attempts.

Organizer: Biswa Nath Datta
Northern Illinois University

10:00 Order Reduction of Aeroelastic Models through LK Transformation and Riccati Iteration
Len Anderson and *Gretta Ward,* Boeing Commercial Airplane Group

10:30 Recent Applications of Symbolic Computation in Control System Design
Daniel Ho, City Polytechnic of Hong Kong; James Lam, University of Mourne, Australia; S.K. Tin, Brown University; and C.Y. Han, University of Hong Kong

11:00 Computing Transfer Function Matrix and the H_∞ Norm for a Large and Sparse System Matrix
Samar Choudhary, Northern Illinois University and Biswa N. Datta, Organizer

CP7/Thomas Hall 125

Signal Processing II

Chair: Gregory S. Ammar, Northern Illinois University

10:00 Modelling and Identification of the Combustion Pressure Process in Internal Combustion Engines
Francis T. Connolly and *Andrew E. Yagle,* University of Michigan, Ann Arbor

10:15 Nonlinear Prediction Using Neural Networks
Laurence Goodby and Paul M. Chau, University of California, San Diego

10:30 Optimal State Estimation Using the Finite Element Method
H.E. Emara-Shabaik and *M.A. El-Gebeily,* King Fahd University of Petroleum and Minerals

10:45 Fast Algorithms for Close-to-Toeplitz-plus-Hankel System of Equations
Jin-Jen Hsue and *Andrew E. Yagle,* University of Michigan, Ann Arbor

11:00 A Circuit Theory of the Kalman Filter
David W. Carter, Draper Laboratory, Cambridge, MA

11:15 Reduced Order Covariance Extended Kalman Filter for Navigation
Frank A. SanFilippo, Northrop Corporation, Hawthorne, CA

11:30 Optimal State Estimation without the Requirement of a Priori Initial State Estimation-the MIMO System Case
Liu Danyang, Beijing Institute of Technology, People's Republic of China

11:45 Self-averaging of the Solutions of Linear Algebraic Equations With Random Coefficients
Vyacheslav L. Girko, Kiev University, Ukraine

GET-TOGETHERS

SIAM Welcoming Reception
6:30 PM - 8:30 PM
Sunday, August 15, 1993
Walker Ames
Assorted beverages and mini hors d'oeuvres

Outdoor Salmon/Chicken Barbecue
Wednesday, August 18
6:00 PM
Battelle Conference Center

Join colleagues in an evening of outdoor fun. Buses will be provided to and from the Battelle Conference Center. Battelle is located on 18 acres of park-like grounds with a pond, courtyards and walking paths in the heart of Seattle. Beer/wine and soda stations will be set up around the pond from 6:00 PM - 9:00 PM. At 6:45 PM a buffet will be available featuring barbecued salmon and chicken, green salad, potato salad, condiments, vegetables, corn bread, and for dessert, a build your own ice cream sundae bar. Outdoor games such as volleyball and croquet will be available. At 9:00 PM buses will board for the short trip back to the University.

Cost: $35.00 per person

12:00/McMahon Hall

Lunch

1:30-2:15

Concurrent Sessions

SL10/Kane Hall 130
Chair: Stephen Boyd, Stanford University

Numerical Issues in Optimization Based Design and Contol

In this presentation we first describe a optimal design problem that involves the construction of a geometric shape to minimize the difference between a given fluid flow field and the fluid flow over the shape. This problem falls into a class of infinite dimensional optimization problems known as shape optimization. We shall review several approaches to the solution of these problems and discuss some mathematical issues associated with the combination of optimization and simulation algorithms. A standard approach to such problems is to use a CFD code as a "black-box" function evaluator for some optimization code. In problems with flow discontinuities (shocks, etc.), this approach can produce some unexpected results. In particular, we show that it is possible for a high order scheme to introduce extraneous local minima that can cause the optimization algorithm to fail. Examples and the results from numerical experiments will be given to illustrate the ideas. Finally, we discuss a sensitivity equation method that provides an alternative approach to straight black-box methods.

John A. Burns
ICAM
Virginia Polytechnic Institute and State University

SL11/Kane Hall 110
Chair: James R. Bunch, University of California, San Diego

A Retrospective on Condition Theory

In 1966, John Rice presented a geometric view of the sensitivity of transformations between metric spaces in a paper entitled 'A Theory of Condition' in the SIAM Journal on Numerical Analysis. In many ways, this viewpoint provided a unifying framework for the diverse conditioning problems of linear systems, eigenproblems, finite precision arithmetic and other areas that had concerned numerical analysts since the beginning of the computer age at the end of World War II.

In this presentation, the speaker will briefly review the background leading up to Rice's paper and then take a detailed look at its influence on the succeeding development of the field, especially the dichotomy between local and global condition estimates. He will also review some recent trends, including probabilistic condition estimation, mixed and componentwise condition theory, and related issues such as backwards stability and the stabilizing effect of iterative refinement.

Charles S. Kenney
ECE Department
University of California, Santa Barbara

SL12/Gowan Hall 201
Chair: Cleve Moler, The MathWorks, Inc.

QMR Methods for Solving Large Linear Systems and Applications

In recent years, there has been extensive research activity in the area of Krylov subspace iterations for solving large non-Hermitian systems of linear equations. A number of new Krylov subspace methods were proposed, including quasi-minimal residual (QMR) algorithms whose iterates are characterized by a quasi-minimization of the residual norm. Unlike Krylov subspace schemes based on a true minimization of the residual norm, QMR methods have low work and storage requirements and thus can be used without restarts. On the other hand, the quasi-minimal residual property is strong enough to obtain for QMR algorithms essentially the same convergence results as for Krylov subspace schemes based on a true minimization property.

In this presentation, the speaker will describe the QMR approach and give an overview of the various QMR algorithms and their theory. He will discuss applications of the QMR approach to the solution of linear systems with special structures which arise in signal processing and systems and control theory. Examples of such systems include Toeplitz systems, systems with displacement structures, Lyapunov and Sylvester equations, and periodic systems with p-cyclic coefficient matrices.

Roland W. Freund
AT&T Bell Laboratories

SL13/Smith Hall 304
Chair: Clyde Martin, Texas Tech University

Graphs, Computational Geometry, and Neural Network Design

Graph theory is used for topological characterization of neural networks. Neural networks which are characterizable by the multilayer feedforward topology are trained for their connection weights as well as their structure by using Voronoi Diagrams, whose construction is facilitated by the recent advances in computational geometry. The speaker will illustrate important concepts in the graph theory/computational geometry based approach to the design of neural networks by numerous examples and discuss directions for future research.

Nirmal Kumar Bose
Department of Electrical Engineering
Pennsylvania State University

SL14/Savery Hall 249
Chair: Gene H. Golub, Stanford University

Total Least Squares for Affinely Structured Matrices

The Total Least Squares (STLS) problem, is a problem of approximating affinely structured matrices by rank deficient ones, while minimizing an L_2-error criterion. The optimality conditions lead to a nonlinear generalized singular value decomposition, which can be solved via an algorithm that is inspired by inverse iteration.

Structured rank deficient matrices arise in many applications in signal processing, system identification and control theory. The speaker will concentrate on the so-called L_2-optimal noisy realization problem, which is equivalent to approximating a given data sequence by the impulse response of a finite dimensional, time invariant linear system of a given order. This problem can be solved as a Structured Total Least Squares problem. "Classical" algorithms such as Steiglitz-McBride, Iterative Quadratic Maximum Likelihood and Cadzow's iteration do <u>not</u> converge to the optimal L_2 solution, as the speaker will issustrate with some simple counterexamples.

The speaker will discuss other applications as well, including an errors-in-variables variant of the Kalman filter, impulse response realization from noisy data, H_2 model reduction, H_2 system identification and calculating the largest stability radius of uncertain linear systems. He will present several numerical examples.

Bart De Moor
ESAT - Department of Electrical Engineering
Katholieke Universiteit Leuven, Belgium

Kane Hall Lobby

Coffee

3:00-5:00

Concurrent Sessions

MS28/Kane Hall 110

Large-Scale and Parallel Matrix Computations and Their Applications (Part 3 of 4).

(See MS9, page 9, for summary)

Organizer: Biswa N. Datta
Northern Illinois University

3:00 Massively Parallel Sparse Matrix Computations on Unstructured Meshes
Lori Freitag, *Mark Jones,* and Paul Plassmann, Argonne National Laboratory

3:30 Numerical Solution of the Einstein Field Equations
Paul Saylor, University of Illinois, Urbana

4:00 Computational Kernels for Iterative Methods
David R. Kincaid, University of Texas, Austin

4:30 Restarted Arnoldi Procedure and Eigenvalue Translation Technique for Solving Large Sparse Automatic Control Problems
Alex Yu. Yeremin, Russian Academy of Sciences, Russia and Elegant Mathematics Inc., USA

5:00 The Sigma-SOR Algorithm and the Optimal Strategy for the Utilization of the SOR Iterative Method
Zbigniew I. Woznicki, Institute of Atomic Energy, Poland

MS29/Kane Hall 130

Parallel and Distributed Computation for Control Problems

Parallel and distributed computation for control problems is a new emerging area in control theory and applications. This area is critically important for large scale applications, problems characterized by relatively large dimensionality considerations of *grand challenge* levels.

The current directions in this area mainly center around utilizing advances in hardware developments such as supercomputers or the next generation *ultracomputers* to handle the large scale aspects. Another direction is the development of new parallel (linear and nonlinear algebraic) algorithms that may have been as important as hardware developments for advances in handling large scale problems. Still another direction is the ability to represent the super amounts of output produced by the hardware and software advances through using graphical visualization techniques. However, one shortcoming is difficulty in demonstrating general conclusions, due to the computational nature of the area.

The speakers will describe parallel algorithms for control related applications using stochastic dynamic programming and Markov chain approximations, gradient projection methods and asynchronous methods. Implementations of these algorithms on many advances computers will be discussed, such as on the nCUBE2, Cray C-90, and Connection Machines CM-200 and CM-5.

Organizer: Floyd B. Hanson
University of Illinois, Chicago

3:00 Parallel Algorithms for Discrete-Time Differential and Clustered Dynamic Programming
Christine A. Shoemaker and L.-Z. Liao, Cornell University

3:30 Solving Optimal Control Problems on the C-90 and CM-5 Supercomputers
Gerard G. L. Meyer, James Carrig, The Johns Hopkins University, and *Louis J. Podrazik,* Institute for Defense Analysis Supercomputing Research Center

4:00 Markov Chain Approximations for the Heavy Traffic Trunk Line Problem
Dennis J. Jarvis and H.J. Kushner, Brown University

4:30 Asynchronous Parallel Fixed-Point Algorithms
John K. Antonio and Longsong Lin, Purdue University, West Lafayette

5:00 Multidimensional Visualization for Massively Parallel Processor Output
Floyd B. Hanson, C.J. Pratico, M.S. Vetter, and H.-H. Xu, University of Illinois, Chicago

MS30/Gowan Hall 201

State Space Methods

The state space method was introduced in the 1960's as a systematic tool for understanding linear dynamical systems. This method influenced profoundly modern engineering and spawned many important developments in engineering and mathematics (Kalman filtering, modeling and processing of random signals, H-infinity control). The state space approach often allows one to reduce problems concerning linear dynamical systems to linear algebra problems. Recently, the theory of rational matrix functions, especially various factorizations and interpolations for such functions, has been developed extensively using the state space method. In this minisymposium, the speakers will highlight several important recent developments in this and related areas.

Organizer: Leiba Rodman
College of William and Mary

3:00 State-Space Algorithms for Spectral Factorization Based on Tangential Nevanlinna-Pick Interpolation
Chin Chang and *Tryphon T. Georgiou,* University of Minnesota, Minneapolis

3:30 Bounding Condition Number of a Rational Matrix Function Over a Subset of C_∞
Marek Rakowski, Ohio State University, Columbus

4:00 Minimal Degree Coprime Factorization of Rational Matrix Functions
Madanpal Verma, McGill University, Canada, J.A. Ball, Virginia Polytechnic Institute and State University, J. Kim, Chonnam National University, Korea, and Leiba Rodman, Organizer

4:30 State Space Theory of Rational Matrix Functions with Symmetries
Leiba Rodman, Organizer

5:00 Stability and McMillan Degree for Rational Matrix Interpolants
J.A. Ball, Virginia Polytechnic Institute and State University and *Jeongook Kim,* Chonnam National University, Korea

5:30 On the Angle Operator of a Nondegenerate Subspace
E. Pekarev, Technological Institute of Food Industry, Ukraine

MS31/Savery Hall 216

Matrix Completions and Applications

A "partial matrix" is one in which some entries are specified, while others are free to be chosen from an agreed upon set. A "completion" is the conventional matrix resulting from a choice for the unspecified entries. A "matrix completion problem" asks whether there is a completion with some property of interest. For example, the "positive definite completion problem" asks whether there is a completion that is positive definite. Properties with a certain inheritance feature enjoy a great deal of structure. This minisymposium will deal with positive definite completions in the nonchordal case, invertible completions, formulae associated with completions and the relatively new topic of distance matrix completions. These matrix completion problems arise in a remarkable variety of applications, including systems and control theory.

Organizers: Charles R. Johnson, College of William and Mary, and Pablo Tarazaga, University of Puerto Rico

3:00 Distance Matrix Completion
Charles R. Johnson, Organizer

3:30 The Real Positive Definite Completion Problem for a Simple Cycle
Wayne Barrett, Brigham Young University, Charles R. Johnson, and Pablo Tarazaga, Organizers

4:00 Title to be announced
Michael Lundquist, Brigham Young University

4:30 Invertible Completions of Partial Operator Matrices; The Nonsymmetric Case
Mihaly Bakonyi, Georgia State University and Charles R. Johnson, Organizer

5:00 Completing a Matrix and Its Inverse
Hugo J. Woerdeman, The College of William and Mary

3:00-5:00

Concurrent Sessions

CP8/Savery Hall 249

Numerical Linear Algebra II

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

3:00 **Solving Linear Systems Involved in Constrained Optimization**
Yixun Shi, Bloomsburg University

3:15 **Fast Transform Based Preconditioners for Toeplitz Equations**
E. Boman, United Technologies Research Center and I. Koltracht, University of Connecticut

3:30 **Preconditioned Krylov Subspace Methods for Lyapunov Matrix Equations**
Marlis Hochbruck, Universität Wurzburg, Germany and *Gerhard Starke,* Universität Karlsruhe, Germany

3:45 **The Block Clustered Nonsymmetric Lanczos Algorithm**
Jose I. Aliaga and Vicente Hernandez, Universidad Politecnica de Valencia, Spain; and Daniel L. Boley, University of Minnesota, Minneapolis

4:00 **A Fast and Stable Matrix Sign Function Algorithm**
Cetin K. Koc and Bertan Bakkaloglu, Oregon State University; Leang S. Shieh, University of Houston

4:15 **The QZ Algorithm Applied to the Solution of Algebraic Riccati Equations for H^∞ Design**
Jenny L. Rawson, North Dakota State University

4:30 **URV ESPRIT for Tracking Time-Varying Signal**
Kuo Juey R. Lui, Dianne P. O'Leary, G. W. Stewart, and *Yuan-Jye J. Wu,* University of Maryland, College Park

4:45 **Systematic Design of Minimal Function Observers**
Chia-Chi Tsui, CUNY College of Staten Island

5:00 **A Skew-Hamiltonian Method for Solving Real Discrete-Time Algebraic Riccati Equation**
Hong-guo Xu, Fudan University, People's Republic of China

CP9/Smith Hall 304

H^∞ Robust, and Adaptive Control

Chair: S. P. Bhattacharyya, Texas A&M University

3:00 **A Control Algorithm for Reduced Order H_∞ Compensator Design**
Chin S. Hsu, Washington State University; Siva S. Banda and Hsi-Han Yeh, Flight Dynamics Directorate WPAFB, OH

3:15 **Risk Sensitive Production Planning of Stochastic Manufacturing Systems: A Singular Perturbation Approach**
Qing Zhang, University of Kentucky

3:30 **An Algorithm for the Use of Parametric Reduced-Order Models for a Robust Control**
Hossain Ahmadi, University of Tehran, Iran

3:45 **A Fast Algorithm for Set Membaership Identification via Parallelotopes**
L. Chisci, Universita di Pisa, Italy, *G. Zappa,* Universita di Firenze, Italy

4:00 **Indirect Adaptive Control of Nonlinear Systems**
Rachid Zouhal, Nour-Eddine Radhy and Abdellah El Moudni, Laboratoire d'Automatique et d'Informatique de Casablanca, Morocco

4:15 **Application of Two Adaptive Control Strategies to an Industrial Process**
Behzad Moshiri, University of Tehran, Iran

7:00 AM-2:00 PM
By-George and Student Union Building open for Breakfast on cash basis. Attendees are on their own for meals today.

7:30/Kane Hall Lobby
Registration opens

7:50/Kane Hall 130
Concluding Remarks
Robert J. Plemmons, Wake Forest University and John G. Lewis, Boeing Computer Services

8:00/Kane Hall 130
IP7/Chair: Biswa N. Datta, Northern Illinois University
Signals, Seismics and Supers
It is often difficult for linear algebra researchers to understand the true impact of their work on real signal processing problems. The variety of high performance machines presents another dimension to the difficulties. In this presentation, the speaker will describe work done by various groups in conjunction with ARCO aimed at presenting segments of real seismic processing codes. Those codes allow researchers to experiment with different algorithms and compare performance on different machines. The speaker will describe some case studies of different algorithms and different machines and discuss how similar work might be done in other areas of signal processing.

George Cybenko
Department of Mathematics
Dartmouth College

8:45/Kane Hall 130
IP8/Chair: Robert J. Plemmons, Wake Forest University
Theory and Practice of Estimator Design in Sensor Array Signal Processing
A sensor array system consists of a number of spatially distributed receiving elements such as dipoles or hydrophones connected to receivers and a processor. For example, the array may be narrowband or wideband and the processor may be for determining the directions of the sources of signals or for beamforming to reject interfering signals and enhance the quality of the desired signal in a communication system. Design of "high-resolution" estimators for direction-finding has been the subject of intense research in signal processing over the last decade. Requirements such as high estimator accuracy, computational efficiency and the need for real-time processing have provided a fertile ground for collaborations among researchers and practitioners from many disciplines, particularly those from the signal processing and numerical linear algebra communities.

In this presentation, the speaker will provide an overview of some recent results on direction-finding estimators for narrowband and wideband systems. He will discuss optimum and suboptimum estimators and pay particular attention to the class of signal-subspace estimators which have been the foci of much of recent research. He will present experimental results based on a laboratory array testbed, theoretical results and numerical simulations to demonstrate the potentials and limitations of a number of estimators. He will highlight some of the open issues.

Mos Kaveh
Department of Electrical Engineering
University of Minnesota, Minneapolis

9:30/Kane Hall Lobby
Coffee

10:00 AM-12:00 PM
Concurrent Sessions

MS32/Gowan Hall 201
Eigenvalues and Singular Values: Generalizations and Accuracy Issues
This minisymposium focuses on accuracy issues associated with eigenvalue and singular value problems. Within this topic, there is a wide scope. The speakers will concentrate on modifying eigenvalue and singular value decomposition and perturbation theory for the Hermitian eigenvalue problems.

Organizer: Jesse L. Barlow
The Pennsylvania State University, University Park

10:00 Efficient and Stable Algorithms for Modifying Singular Value Decompositions and Partial Singular Value Decompositions
Jesse L. Barlow, Organizer, Hongyuan Zha, and *Peter A. Yoon,* The Pennsylvania State University, University Park

10:30 Canonical Correlations of Matrix Pairs
Hongyuan Zha, The Pennsylvania State University, University Park

11:00 Accurate Symmetric Eigenreduction
Ivan Slapnicar, University of Split, Croatia, and Kresimir Veselic, Feruniversität, Hagen, Germany

11:30 A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenproblem
Carlos F. Borges and William B. Gragg, Naval Postgraduate School

MS33/Kane Hall 110
Adaptive Methods
The self-designing feature of the adaptive methods is particularly attractive in signal, system, and control applications. In a stationary environment, an adaptive method converges to the solution after successive iterations. In a non-stationary environment, an adaptive method is capable of tracking the variations of the input data. The speakers in this minisymposium will discuss the fast recursive least squares algorithms, the URV method for the noise space tracking, the incremental estimator for the smallest singular value, and eigenvalue problems.

Organizer: Sanzheng Qiao
McMaster University, Canada

10:00 Fast Adaptive Filtering Using the FFT
Michael K. Ng, Hong Kong University, Hong Kong and Robert J. Plemmons, Wake Forest University

10:30 Experiments with the Quaternion-Jacobi Method
Patricia J. Eberlein and Niloufer Mackey, State University of New York, Buffalo

11:00 An Incremental Estimator for the Smallest Singular Value of a Product of Matrices
C.T. Pan, Northern Illinois University, and *Sanzheng Qiao,* Organizer

11:30 On the Primitive Operations of the ULV Decomposition
Daniel Boley and Karen Sutherland, University of Minnesota, Minneapolis

MS34/Kane Hall 130
Signal Processing at Boeing
The speakers in this minisymposium will present a variety of signal processing applications in a large aerospace manufacturing firm. They will discuss actual applications of linear algebra to specific Boeing projects.

Organizer: J. Louis Tylee
Boeing Computer Services

10:00 Least Squares Processing of Fire Detector Sensor Data
J. Louis Tylee, Organizer

10:30 Matrix Algebra Application to Redundancy Management
James W. Burrows, Boeing Computer Services

11:00 Linear Algebra in Active Noise Control
Richard Burkhart, Boeing Computer Services

MS35/Savery Hall 216
Numerical and Symbolic Computations for Contemporary Control Problems (Part 2 of 2)
(See MS27, page 16, for summary)

Organizer: Biswa Nath Datta
Northern Illinois University

10:00 Efficient Calculation of H-infinity Norm and its Sensitivity to Parameter Variation
Daniel P. Giesy, Lockheed Engineering and Sciences Company

10:30 Computing Issues in Control Theory
Madan Verma, McGill University, Canada

11:00 A Global Minimum Search Algorithm for Estimating the Distance to Uncontrollability
Michael Neumann and Mei Gao, University of Connecticut, Storrs

11:30 The Set of 2-by-3 Matrix Pencils—Structure Transitions by the Nongeneric Cases Under Perturbations
Bô Kagström and Erik Elmroth, University of Umea, Sweden

CP10/Savery Hall 249
Stability and Identification
Chair: S.P. Bhattacharyya, Texas A&M University

10:00 Stability Analysis of Systems with Structured Time-Varying Uncertainties Using Structured Singular Value
Chwan-Lu Tseng and *I-Kong Fong,* National Taiwan University, Republic of China

10:15 A Current-law-based Approach to Derive Energy Functions for the Direct Method of Power System Stability Analysis
Young-Hyun Moon, University of Illinois, Urbana

10:30 Stability Analysis of Autonomous Linear Time-Delay Systems
Juing-Huei Su, *I-Kong Fong* and Chwan-Lu Tseng, National Taiwan University, Republic of China

10:45 Estimates of the Singular Perturbation Parameter for Stability, Controllability, and Observability of Linear Systems
S.M. Shahruz and A. K. Packard, Berkeley Engineering Research Institute

11:00 Characterization of Block Cascade Nonlinear Models Using Polyspectra
Kamal A.F. Moustafa and *Hosam E. Emara-Shabaik,* King Fahd University of Petroleum and Minerals, Saudi Arabia

12:00

Lunch

Attendees are on their own for meals today. By-George and Student Union are open for lunch until 2:00 PM, on a cash-basis only.

1:30-2:15

Concurrent Sessions

SL15/Kane Hall 130
Chair: Charles Johnson, College of William and Mary

Linear Matrix Inequalities in Systems and Control

A very wide variety of problems in systems and control theory can be cast or recast as convex problems involving linear matrix inequalities. For a few very special cases there are analytical solutions to these problems, but in general they can be solved numerically very efficiently. In many cases the inequalities have the form of simultaneous Lyapunov or algebraic Riccati inequalities; such problems can be solved in a time that is comparable to the time required to solve the same number of Lyapunov or Algebraic Riccati equations.

Some examples in which these problems arise include: multicriterion LQG, synthesis of linear state feedback for multiple or nonlinear plants ("multi-model control"), optimal transfer matrix realization, norm scaling, and synthesis of multipliers for Popov-like analysis of systems with unknown gains. The speaker will discuss aspects of his joint work with V. Balakrishnan, E. Feron, L. ElGhaoui, and L. Vandenberghe.

Stephen Boyd
Department of Electrical Engineering and Information Systems Laboratory
Stanford University

SL16/Kane Hall 110
Chair: Robert J. Plemmons, Wake Forest University

Iterative Methods for Toeplitz Systems

Toeplitz matrices are matrices with constant diagonals. In contrast to the $O(n^3)$ Gaussian elimination and $O(n \log^2)$ fast direct Toeplitz solvers, iterative method based on the preconditioned conjugate gradient method can solve n-by-n Toeplitz systems in $O(n \log n)$ operations. In this presentation, the speaker will provide an overview of recent results and developments on iterative solvers for Toeplitz systems and discuss their applications to numerical partial differential equations, integral equations, image processing and time-series analysis.

Raymond H. Chan
Department of Mathematics
Hong Kong University of Science and Technology, Hong Kong

SL17/Gowan Hall 201
Chair: Biswa N. Datta, Northern Illinois University

Krylov Space Methods on State-Space Control Models

The speaker will give an overview of various Lanczos/Krylov space methods and how they are being used for solving certain problems in Control Systems Theory based on state-space models. The matrix methods used are based on Krylov sequences and are closely related to modern iterative methods for standard matrix problems such as sets of linear equations and eigenvalue calculations. The speaker will describe how these methods can be applied to problems in Control Theory such as controllability, observability and model reduction. All the methods are based on the use of state-space models, which may be very sparse and of high dimensionality.

Daniel L. Boley
Department of Computer Science
University of Minnesota, Minneapolis

SL18/Smith Hall 304
Chair: Ake Bjorck, Linkoping University, Sweden

Quality in Industrial Computations

For a scientist or an engineer, it is of crucial importance to have confidence in the results of large computing codes and in the robustness of the models used. Indeed, the emergence of supercomputers allowed the intensive use of numerical simulation to replace physical experiments, even for problems at the frontiers of instability. However tools that provide information on the quality and validity of computer results are very rarely used in industry. The speaker will discuss how such tools can help solving industrial problems with the following characteristics: unstable models, pathological numerical behaviors, very large scale.

Francoise Chatelin
M&I Group
LCR-Thomson, France

SL19/Savery Hall 249
Chair: M. Vidyasagar, Centre for Artificial Intelligence and Robotics, India

Cardinal Interpolation and Wavelets

It is well known that the autocorrelation of an orthonormal scaling function is a fundamental function for cardinal interpolation. In this presentation, the speaker will describe a more general class of fundamental functions that are constructed in terms of any scaling function that locally reproduces all polynomials of degree n. Wavelets that generate complementary subspaces of the multiresolution analysis as a result of the projection operator can be constructed. This gives an analogous scheme of direct-sum decomposition and resconstruction as the usual L_2 setting. Although no orthogonality is achieved, the wavelet coefficients in each octave vanish whenever the data function is locally a polynomial of degree n. More precisely, the wavelet coefficients reveal the details of the data function in a similar way as wavelet decompositions in the L_2 setting.

Charles K. Chui
Center for Approximation Theory
Texas A&M University, College Station

2:15/Kane Hall Lobby

Coffee

3:00-5:00

Concurrent Sessions

MS36/Kane Hall 110

Large-Scale and Parallel Matrix Computations and Their Applications Part 4 of 4).

(See MS9, page 9, for summary)

Organizer: Biswa N. Datta
Northern Illinois University

3:00 Parallel Implementation of Dense Linear Algorithms
Robert A. van de Geijn, University of Texas, Austin

3:30 Design of a Parallel Nonsymmetric Eigenroutine Toolbox
Zhaojun Bai, University of Kentucky, and James W. Demmel, University of California, Berkeley

4:00 A Parallel Algorithm for Block Sylvester - Observer Matrix Equation and Its Implementations
Christian Bischof, Argonne National Laboratory, Biswa N. Datta, Organizer and *Avijit Purkayastha,* University of Puerto Rico, Mayaguez

4:30 Efficient Parallel Solution of Almost Block Diagonal Systems
Marcin Paprzycki, University of Texas Permian Basin, Odessa

5:00 Parallel Homotopy Algorithms for the Eigenvalue Problem and the Singular Value Problem
Zhonggang Zeng, Northern Illinois University

MS37/Kane Hall 130

Parallel Signal Processing for Multiprocessor Systems

The availability of recent high performance distributed computing and parallel processing machines is providing new opportunities for effective signal and image multiprocessing programming. Alternative parallel machine architectures motivate a rethinking of algorithm formulation and execution for optimum implementations. The efficient partitioning, mapping, and scheduling of computationally intensive algorithmic tasks to distributed computing nodes will be addressed in this minisymposium, as will techniques that produce calculation speedups by finding and exploiting concurrence. The speakers will discuss applications on computing platforms ranging from the new desktop parallel processing workstations (Sun SPARC 10) and specialized DSP parallel processors (AT&T DSP3) to the latest in vector supercomputers (CRAY Y-MP) and distributed MIMD machines (Intel Paragon).

Organizer: Paul M. Chau
University of California, San Diego

3:00 Decomposition of Signal Flow Graphs for Parallel Processing in Multiprocessor Systems
Paul M. Chau, Organizer

3:30 On Image Enhancement and Object Direction by 2D Adaptive Prediction Filtering Using Distributed Processing
James R. Zeidler, Naval Command, Control and Ocean Surveillance Center, San Diego; Tarun Soni and Walter H. Ku, University of California, San Diego

4:00 A Parallell Viterbi Decoder for Shared Memory Multiprocessor Architectures
Todd H. Chauvin and *Kar-Ming Cheung,* Jet Propulsion Laboratory

4:30 Wide-Area Gigabit Networks for Distributed Applications Across Heterogeneous Computing Environments
Carl D. Scarbnick, NSF San Diego Super Computer Center

MS38/Gowan Hall 201

Numerical Techniques for Solving Optimal Control Problems

This minisymposium will focus on practical numerical techniques for solving optimal control problems. The speakers will describe applications from aerospace, robotics, and chemical processes and discuss computational issues related to techniques appropriate for ordinary and partial differential equations. The multidisciplinary scope of both applications and methods will be emphasized in order to stimulate exchange of ideas.

Organizer: John T. Betts
Boeing Computer Services

3:00 Application of Sparse SQP Methods to Optimal Control Problems
John T. Betts, Organizer

3:30 Solving Dynamic Optimization Problems in Process Engineering
P. Tanartkit, J. Albuquerque and *Larry T. Biegler,* Carnegie Mellon University

4:00 Multiple Shooting SQP Methods for Parameterized Optimal Control Problems in ODE and DAE with Application to Robotics
H.Georg Bock, V.H. Schulz and M.C. Steinbach, Universitat Heidelberg, Germany

4:30 Numerical Methods for Parabolic Control Problems
Ekkehard W. Sachs, Universitat Trier, Germany

5:00 Branched Trajectory Optimization for Hypersonic Vehicles
Klaus H. Well, Institute of Flight Mechanics and Flight Control, Germany

MS39/Savery Hall 216

Topics in Wavelet Analysis

The theory and applications of wavelet analysis are attracting a great deal of attention from mathematicians, applied mathematicians, engineers, physicists, statisticians, and many other scientists in various fields.

In the recent years, many research centers have arose that are oriented to the wavelet analysis. The subject is developing rapidly and therefore there is obvious need for efficient exchange of ideas on it. This minisymposium is intended to serve this goal. The speakers will present an overview of recent results and research directions.

Organizer: Stephen S. Yau
University of Illinois, Chicago

3:00 Cardinal Interpolation and Wavelets
Charles K. Chui, Texas A & M University, College Station

3:30 A New Family of Wavelets with a Remarkable Sampling Properties
Gilbert G. Walter, University of Wisconsin, Milwaukee

4:00 Some New Results on Wavelet Transform
Stephen S. Yau, Organizer, T. Bielecki, E. Lin, and J. Chen, University of Illinois, Chicago

4:30 Rational Wavelets in System Identification and Model Reduction
Y.C. Pati, Stanford University and *P.S. Krishnaprasad,* University of Maryland, College Park

5:00 Numerical Stability of Biorthogonal Wavelets
Fritz Keinert, Iowa State University

CP11/Savery Hall 249

Matrix Theory II

Chair: Moshe Goldberg, Technion-Israel Institute of Technology, Israel

3:00 A Max-SNP-Hard Problem: Computing the Minimal PerturbationScaling to Achieve Instability in an Interval Matrix
Christopher L. DeMarco and *Gregory E. Coxson,* University of Wisconsin, Madison

3:15 The Asympototic Convergence Factor for a Rectangle under a Perturbation
Xiezhang Li, Georgia Southern University

3:30 Fast Convolution on the 2-Sphere: Theory and Practice
Dennis M. Healy, Jr., Daniel N. Rockmore and Sean S.B. Moore, Dartmouth College

3:45 Hierarchical Decompositions of Partitioned Matrices—Partition-respecting Similarity
Hisashi Ito, Hewlett-Packard Laboratories Japan, Japan; Satoru Iwata, University of Tokyo, Japan; and Kazuo Murota, Kyoto University, Japan

4:00 Hierarchical Decompositions of Partitioned Matrices—Partition-respecting Equivalency
Hisashi Ito, Hewlett-Packard Laboratories Japan, Japan; Satoru Iwata, University of Tokyo, Japan; and Kazuo Murota, Kyoto University, Japan

4:15 Some New Determinantal Identities Related to Chio's Theorem
Mark Kauderer, National Research Council-Rome Laboratory

4:30 Recent Developments of Nonnegative Splitting Theory
Zbigniew I. Woznicki, Institute of Atomic Energy, Poland

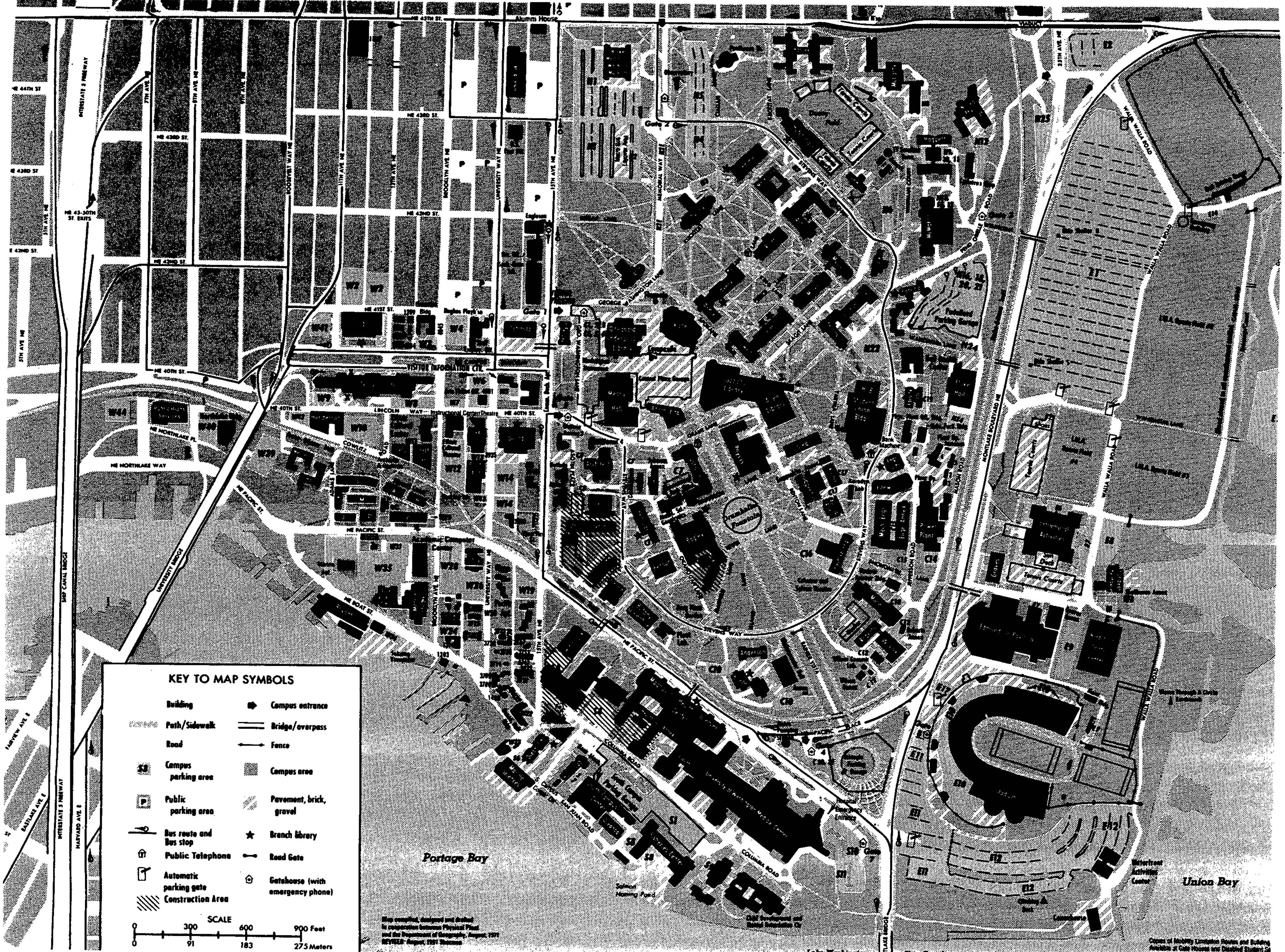
4:45 An Index Theorem for Monotone Matrix-valued Functions
Werner Kratz, University of Ulm, Germany

5:30 Conference Adjourns

SPEAKER INDEX

SPEAKER INDEX CONTINUED

CP = Contributed Presentation
IP = Invited Presentation
MS = Minisymposia
PS = Poster Session
SL = Special Lecture
SS = Special Session


KEY TO MAP SYMBOLS
Building
Path/Sidewalk
Road
Campus parking area
Public parking area
Bus route and Bus stop
Public Telephone
Automatic parking gate
Construction Area
Campus entrance
Bridge/overpass
Fence
Campus area
Pavement, brick, gravel
Branch library
Road Gate
Gatehouse (with emergency phone)
SCALE
0 300 600 900 Feet
0 91 183 275 Meters
Portage Bay
Union Bay
Lake Washington
Ship Canal
MONTLAKE BOULEVARD NE
WALLA WALLA ROAD
STEVENS WAY
NE PACIFIC ST.
NE 40TH ST.
NE 41ST ST.
NE 42ND ST.
NE 43RD ST.
NE 45TH ST.
NE BOAT ST.
NE NORTHLAKE WAY
NE NORTHLAKE PL.
UNIVERSITY WAY NE
BROOKLYN AVE NE
ROOSEVELT WAY NE
15TH AVE NE
INTERSTATE 5 FREEWAY
UNIVERSITY BRIDGE
SHIP CANAL BRIDGE
HARVARD AVE E
EASTLAKE AVE E
FAIRVIEW AVE E
COLUMBIA ROAD
SAN JUAN ROAD
MEMORIAL WAY
Gate 2
Gate 1
Alumni House
VISITOR INFORMATION CTR.
Waterfront Activities Center

MONDAY AM

MS 1

Multiobjective Controller Synthesis with $\mathcal{H}_\infty$ Design Specifications

Most control system design problems involve making tradeoffs among competing objectives, e.g. the size of the tracking errors vs. the size of the actuator signals, stability robustness vs performance, etc. In this paper we consider the synthesis problem that arises when the goal is to find a controller such that several $\mathcal{H}_\infty$ design specifications are jointly feasible. This problem can be interpreted and motivated in many different ways. For example, it may used to study tradeoffs between sensitivity and complementary sensitivity, or to minimize nominal $\mathcal{H}_\infty$ performance subject to a robust stability constraint, etc. First, a suitable upper bound for the worst case $\mathcal{H}_\infty$ performance measure, i.e. the largest $\mathcal{H}_\infty$ norm among the $\mathcal{H}_\infty$ norms of the closed loop transfer matrices of interest, is defined. Then, it is shown that the synthesis problem of finding a stabilizing controller that minimizes this upper bound may be reduced to a finite dimensional convex programming problem involving linear matrix inequalities.

Mario A. Rotea
School of Aeronautics and Astronautics
Purdue University, West Lafayette, IN

Parameter-Dependent Stabilization and Control of Parameter-Dependent Linear Systems: Applications for $\mathcal{H}_\infty$-like Gain Scheduling

The recent developments in state-space $\mathcal{H}_\infty$ theory are often expressed in terms of stabilizing solutions to a pair of Riccati equations satisfying a spectral radius coupling condition. Alternatively, it is possible to derive necessary and sufficient conditions in the form of 3 Affine Matrix Inequalities (AMI). The affine matrix inequalities represent convex constraints on the space of symmetric, positive definite matrices, and their feasability (or infeasability) determines the solvability (or unsolvability) of the sub-optimal $\mathcal{H}_\infty$ control problem. Here, we take the AMI approach, and solve two generalized $\mathcal{H}_\infty$ control problems. The problems involve a linear, time-varying plant, with time-varying parameter dependence. The assumption on the time-varying parameters are: the variations are known to lie in a known, convex set; the time variations are not known in advance (this rules out the use of existing LTV system theory); the time variations are known in real time, and can be used to affect the feedback law. The problems are reformulated as convex feasability problems, in the form of AMI's. The implications these problems have for gain-scheduling are obvious, since gain-scheduling conceptually involves a linear, parameter dependent plant. This approach allows us to treat gain-scheduled controllers as a single entity, with the gain-scheduling being effected entirely using linear fractional transformations on the time-varying parameters.

Andrew Packard
Greg Becker
Doug Philbrick
Mechanical Engineering, University of California, Berkeley, CA
Gary Balas
Aeronautical Engineering, University of Minnesota, Minneapolis, MN

An LMI-based Method for Frequency-dependent Scaling

For a linear system with unspecified parameters that lie between given upper and lower bounds, we present an algorithm for optimal frequency-dependent scaling of the system. This technique, which yields results that are less conservative than the conventional small-gain theorem, may be interpreted as adding extra dynamics to the original system and then searching for a quadratic Lyapunov function for the augmented system. We show that the search for the appropriate scaling function may be posed as a feasibility problem of a certain Linear Matrix Inequality.

V. (Ragu) Balakrishnan and Eric Feron
Stanford University
Stanford, CA 94305

Linear Matrix Inequalities in Stochastic Control

For linear systems affected by multiplicative white noise, we show that a number of analysis and state-feedback design problems can be recast as optimization problems over Linear Matrix Inequalities (LMIs). The problems we consider include computing a stochastic equivalent of a parametric stability margin and designing a constant state-feedback law to maximize this stability margin. We show that additional design constraints such as LQG-type constraints can be incorporated as additional LMIs. The implication therefore, is that these problems can be reliably solved using convex optimization techniques.

Laurent El Ghaoui
Ecole Nationale Superieure de Techniques Avancees
32, Bvd. Victor
75015 Paris, France

Convex Analysis of Output Feedback Control Problems

We address classical control problems, as for instance, optimal $\mathcal{H}_2$ and optimal $\mathcal{H}_\infty$ design problems, imposing static output feedback. It is shown that from a non-linear transformation, those problems can be converted into ones with appropriate geometrical properties, which enable to solve them by means of convex programming procedures. The importance of the presented approach stems from the fact that the global optimal solution, in almost all cases, is attained. Thanks to the geometrical properties, the method can be generalized to cope with uncertain systems in convex bounded domains, being one of the main advantages when compared with the methods available in the literature to date. We present the theoretical results together with illustrative examples.

J. C. Geromel
LAC-DT/FEE - UNICAMP
P.O. Box 6101
13.081-970 - Campinas - SP - BRAZIL

MS 2

Eigenvalues of Graphs and Symmetric Integral Matrices

We will discuss the problem of determining what polynomials can be the minimal polynomial of a symmetric integral matrix. We will discuss the solution of a problem of Alan Hoffman showing that every totally real algebraic integer is the eigenvalue of an integral symmetric matrix (this was first done by Dennis Estes). A consequence of this fact is that every totally real algebraic integer is the eigenvalue of the adjacency matrix of an undirected graph with no multiple edges or loops (and in fact of more specialized types of graphs).

Robert Guralnick
Department of Mathematics
University of Southern California
Los Angeles, CA 90089

The Diagonals of Powers of Positive Matrices and Renewal Sequences

A new inequality satisfied by the modulus of the resolvent of a positive matrix (in general, a positive linear operator) outside the spectral radius circle will be presented. One of the consequences of this inequality is a whole set of results concerning the sequences of the diagonal elements of the powers of such positive matrices. In addition to a new family of inequalities concerning the diagonal elements, we will show that the sequences generated by their powers are not only positive definite but also renewal sequences in the sense of the theory of regenerative processes.

W.A.J. Luxemburg
Department of Mathematics
California Institute of Technology
Pasadena, CA 91125

The Smith Canonical Form

Properties of the classical Smith Normal Form (SNF) and some generalizations of this concept are discussed. Applications to the graph isomorphism problem and to diophantine analysis are given. New conditions are derived which insure the multiplicativity of the SNF, and the problem of two-sided equivalence is introduced, where the multiplying matrices are taken from a subgroup of finite index of GL(n,ℝ). This leads naturally to the double coset problem for matrix groups. Finally, a new form of equivalence is introduced, whose invariants are easily computed, and which may be used to show that certain combinatorial designs are not permutation equivalent.

Morris Newman
Department of Mathematics
University of California
Santa Barbara, CA 93106

Multiplicativity, Quadrativity, and Stability of Matrix Seminorms

A constant $\mu > 0$ is called a *multiplicativity factor* (in short, an MF) for a seminorm S on an algebra $\mathcal{A}$, if $S(xy) \le \mu S(x)S(y)$ for all x, y in $\mathcal{A}$. Further, $\lambda > 0$ is a *quadrativity factor* (QF) for S if $S(x^2) \le \lambda S(x)^2$ for all x in $\mathcal{A}$. Finally, $\sigma > 0$ is a *stability factor* (SF) for S if $S(x^m) \le \sigma S(x)^m$ for all x in $\mathcal{A}$ and all positive integers m. In this talk we discuss existence of such factors for arbitrary seminorms (and norms) on matrix algebras. We show that while norms always have MFs and QFs, proper seminorms often do not. We also study the question whether QFs and MFs imply SFs.

Moshe Goldberg
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MS 3

Parallel Algorithms for the Triangular Sylvester Equation

In this paper we present several algorithms for solving the Triangular Sylvester Equation $AX + XB = C$ on MIMD computers with a ring topology, or a topology allowing a ring embedding.

The first approach assumes matrices A and C wrapped around the ring. It is based on the Parallel Triangular Solver by Li and Coleman. In a second approach, memory requirements are drastically reduced, while performance is maintained. A third approach distributed matrix B to further reduce memory requirements.

Results from experiments on the Intel iPSC/860 will be presented. On this architecture, we have obtained very good performance by coding the algorithms in terms of Level 3 BLAS (matrix-matrix operations). Finally, we compare our approaches to the implementation of the algorithm by Kågström and Poromaa.

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Systolic Algorithms for Linear Matrix Equations in Control Problems

Matrix Equations play an important role in Control Problems (state observer designs, functions of matrices, balanced realizations, etc.). We will discuss systolic algorithms for the solution of certain Linear Matrix Equations, such as the Triangular Generalized Sylvester and related equations (Sylvester, Stein, Commutant, etc.).
The sequential algorithms for solving these equations are mapped onto a bidimensional array in order to obtain the corresponding systolic algorithms.
Efficiency analysis suggests that we project the algorithm onto a linear array and apply block decomposition techniques. By using dense-to-banded transformations in linear arrays, we get the optimal efficiency.

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On Jacobi Methods for the Standard and Generalized Symmetric Eigenvalue Problem on Multicomputers

The Jacobi method for the standard and generalized eigenvalue problem presents a high degree of intrinsic parallelism. However, there are serious problems in reaching high performances when algorithms based on this method are implemented on Distributed Memory Multiprocessors, due to the difficulty of taking advantage of the symmetry without paying a large communication overhead.
We explore several matrix distributions in the multiprocessor system which allow us to exploit the symmetry of the matrix with moderate communication times, providing theoretically optimum algorithms.
Experiences on the Parsys SN 1040 and the Intel iPSC/2 multicomputers confirm the theoretical results.

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PARALLEL ALGORITHMS FOR THE POLE ASSIGNMENT PROBLEM

Given a linear control system $\dot{x}(t) = A(t)x(t)+B(t)u(t)$, we study some numerical algorithms for the pole assignment problem. This problem applies to the stabilization of the above control system. There are few parallel algorithms for that problem. We give some parallel algorithms whose computational effort is based on the solution of triangular linear systems. Further, in some cases these systems have small size. Moreover, the systems are independent and can be solved in parallel. We discuss their implementation on shared memory parallel computers and we illustrate the accuracy of them.

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MS 4

The use of qd and dqd Algorithms

The recent discovery that the qd algorithm (of Rutishauser) can be implemented, with shifts, in a more stable way than the standard version has made us look again at the various applications that Rutishauser envisaged for his algorithm. We will describe the changes and focus on two aspects: stability and shift strategy. It turns out that the auxiliary quantities needed in the differential qd algorithm contain valuable information about the distance to the nearest singular matrix.

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Relative Perturbation Results for Eigenvalue and Singular Value Problems

We present a technique for deriving relative perturbation results for singular values and vectors, as well as for eigenvalues and vectors.

We consider the class of perturbations δB where $B+\delta B$ is congruent to the original matrix B, i.e. $B+\delta B = D^T BD$ for some non-singular D. This includes relative perturbations that preserve the zero structure of the matrix, as well perturbations that amount to elimination of off-diagonal blocks.

The existing perturbation results for the relative error in singular values of bi-diagonal matrices can be derived from this class of perturbations. We present new perturbation bounds and extend the existing results to triangular matrices. Furthermore we bound the angles between true and computed singular/eigen vectors in terms of the matrix perturbation and a relative gap.

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Downdating the Singular Value Decomposition

We consider the problem of downdating the singular value decomposition. We separate this problem into three cases and show that two of them are well-conditioned and that the other can be ill-conditioned. We develop efficient and stable algorithms for each of these cases. Previous algorithms are all based on an unstable algorithm for solving the potentially ill-conditioned case.

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Finite Precision Analysis of Inverse Iteration

Given some set of computed eigenvalues of a real symmetric matrix, inverse iteration is the most efficient way of computing the corresponding set of eigenvectors. Wilkinson gave convincing arguments to show that the method computes "good" eigenvectors in finite precision for distinct eigenvalues. But clustered eigenvalues were not amenable to his arguments.

We demonstrate how to implement inverse iteration in finite precision such that it computes numerically orthogonal eigenvectors with small residual – irrespective of the eigenvalue distribution. We also obtain rigorous stopping and orthogonalisation criteria, which can be implemented by simple modifications to LAPACK routines.

In addition we reduce the "average-case" time complexity for symmetric tri-diagonal matrices of order n from $O(n^3)$ to $O(n^2)$.

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MS 5

The Role of Grassmanians in Control Theory

In this talk we review the role of Grassmanians in linear control theory, beginning with our work in the mid-1970s. We will show that these tools remain relevant in problems ranging from computerscience to the analysis of vision. We will give a short survey of current uses of Grassmanians in control theory today.

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Hermann-Martin Curves in Grassmannian

The space of all Hermann-Martin curves of degree q in Grass$(p, m+p)$ can be compactified into a projective variety $K^n_{p,m}$. The geometry of this variety is important in many aspects such as dynamic pole placement, tangential interpolation, etc. The formulas for the degrees of $K^q_{p,m}$ and subvarieties $Z(S, s, d)$ are derived using the technique of Schubert calculus. The deg $K^q_{p,m}$ is the number of complex dynamic compensators assigning a set of closed loop poles for any q-nondegenerate m-input, p-output system of McMillan degree $n = q(m+p-1) + mp$ and the deg $Z(S, s, d)$ can be used to find the numbers of solutions for bitangential interpolation problems.

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Riccati Equations, Grassmanians Manifolds and Polynomial Realizations

In this paper we reconsider again the role of power iterations in QR-like algorithms. This time the connection is studied via so-called Moser-Rutishauser map. We show that many QR-like algorithms are equivalent to power iterarations in the polynomial space. Relationships between QR-like algorithms and power iterations are established via realization theory of rational functions.

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Grassmanians, Generalized Grassmanians and the Pole Placement Map

The Grassmanian, Grass$(p, m+p)$, of p-dimensional planes in an $(m+p)$- dimensional vector space arises in the static pole placement problem, as the compactification of the space of all p-output, m-input transfer functions of McMillan degree zero. We give a brief survey of the applications of Schubert calculus to pole placement with static feedback. The first problem in the case of dynamic feedback is to construct a compact space corresponding to the Grassmanian. We describe the compactification of the space of all p-output, m-input transfer functions of McMillan degree at most q. This compactification uses the concept of homogeneous autoregressive systems. After relating this new space to the Grassmanian, we discuss intersection theory on this space of homogeneous autoregressive systems and its applications to pole placement with dynamic feedback.

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MS 6

Improved Givens Rotation Algorithms for MVDR Beamforming

The application of QR decomposition (QRD) to the problem of minimum variance distortionless response (MVDR) beamforming is now well established. The underlying technique, due to Schrieber, relies on the fact that the inverse Cholesky factor of the sampled data matrix can be updated using the same set of Givens rotations that update the Cholesky factor itself. The recent "inverse iterations" algorithm for recursive least squares optimisation also relies on this technique. Unfortunately, when an exponentially decaying data window is used the recursions for the update of the inverse Cholesky factor involve a division by the forget factor beta (1¿beta¿0). This division is clearly undesirable and can lead to a growth of numerical errors. In this paper it is shown how an alternative factorisation to that which is normally used for square-root-free Givens rotations can circumvent this problem. Two novel algorithms result from this approach; one of which corresponds to the recursive modified Gram-Schmidt algorithm recently derived by Sakai. Some numerical simulation results will be presented comparing the various algorithms.

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Parallel Computing in Sensor Array Processing

This talk discusses aspects of parallel computing for sensor arrays. There have been many parallel algorithms proposed for adaptive sensor array processing. Most of them require that the data flow among processing elements remains static. However it is not uncommon to be confronted with a situation where the data acquired varies in size. This violates the assumption of static distribution and static flow. We may then have to redistribute the data and change the algorithm. We discuss several such scenarios and the potential benefits coming from employing a variety of algorithms in response to data that varies in size over time.

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A Systolic Jacobi Algorithm for Wideband Direction of Arrival Estimation

In previous papers, we have presented adaptive and parallel VLSI matrix pencil algorithms for high resolution direction finding, where the signals that are impinging on the antenna arrays were assumed to be narrow band signals with known carrier frequency. In this paper, we extend the methods, algorithms and architectures to the case when the signals are wideband signals, which are expressed in terms of finite state transition systems, input with white noise signals. In the algorithm that is presented here, pole finding and direction finding are combined using a single subspace based algorithm which is structured in the form of a systolic Jacobi algorithm, much as in the narrow band direction finding problems.

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A Systolic Algorithm for Robust Adaptive Beamforming Using an Adjustable Constraint

In an adaptive beamformer the overall output power is minimized, subject to the constraint that the power of a signal of interest (SOI) is preserved. Here a priori knowledge of the steering vector of the SOI is needed. The steering vector is often estimated by means of a reference signal, which is extracted from the reconstructed signal. This approach leads to a recursive least-squares problem with an adjustable constraint. An algorithm is presented here which is based on a structure, known as the generalized sidelobe canceller, where now also the updating transformations for the adjustable constraint are incorporated. The algorithm is shown to lend itself well to parallel implementation, e.g., on systolic architectures.

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CP 1

A New Algorithm for Finding Roots of a Polynomial

A new algorithm for calculating complex polynomial roots is based on the total differential of the root. For first order corrections, the method is shown to be equivalent to a simultaneous Newtons method on all root estimates. Errors in intermediate root iterates are characterized by equivalent perturbations of the polynomial coefficients. The importance of this method is in its novelty and its extension to higher order algorithms. It has been used for root purification. The method is well suited to parallel implementation and to refinement of roots for small time-evolving changes in the polynomial coefficients.

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Jacobi Methods for Accurate Eigenvalues and Singular Values

Recently it was shown by Demmel and Veselic that Jacobi's method computes the eigenvalues of a dense positive definite to much higher relative accuracy than most other algorithms. We present various extensions and generalizations of their results. In particular we show how one can obtain the accuracy of Jacobi's method at a computational cost that is not much greater than the Hessenberg QR algorithm. We also show that one can define a Jacobi algorithm for which the relative error bound on the eigenvalues does not contain the growth factor in the bound due to Demmel and Veselic.

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A Hybrid Algorithm for Optimizing Eigenvalues of Symmetric Definite Pencils

We present an algorithm for the optimization of the maximum eigenvalue of a symmetric definite pencil depending affinely on a vector of parameters. The algorithm uses a hybrid approach, combining a scheme based on the method of centers, developed by Boyd and El Ghaoui, with a new quadratically convergent local scheme. A convenient expression for the generalized gradient of the maximum eigenvalue of the pencil is also given, expressed in terms of a dual matrix. The algorithm computes the dual matrix which establishes the optimality of the computed solution.

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Analysis of Algorithms for Orthogonalizing Products of Unitary Matrices

We consider the problem of computing $U_{k+1} = Q_k U_{k+1}$ (where U_0 is given) in finite precision (ϵ_M = machine precision) where U_0 and the Q_i are known to be unitary. This situation arises in various applications including signal processing. The problem is that $\hat{U}_k$, the computed product may not be unitary, so one applies an $O(n^2)$ orthogonalizing step after each multiplication to prevent $\hat{U}_k$ from drifting too far from the set of unitary matrices and to prevent $\hat{U}_k$ from drifting too far from U_k the true product. Our main results are

1. The cheapest of the algorithms considered is usually as good as any other method.
2. A new orthogonalization algorithm that *guarantees* that the distance of $\hat{U}_k$ ($k = 1, 2, \ldots$) to the set of unitary matrices is bounded by $n^{3.5}\epsilon_M$.

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Reconfigurable Control Systems based on Partial Eigenstructure Assignments

In large complex dynamic systems, it is not uncommon that large variations in system dynamic characteristics may occur due to sudden component failures or rapid changes in operating conditions. The nature of these large variations may be such that conventional or even adaptive controllers are no longer suitable. In fact, it often requires drastic changes in the associated control systems well as. A Reconfigurable Control System is defined as a control system that is capable of changing its parameters and/or structures automatically on-line in real-time to accommodate such large parameter variations. A design procedure for such control systems using *Eigenstructure Assignment* has been developed in [1]. However, if the variations occur only in a part of the system, it is more economical to reconfigure the controller for just that part of the system that has changed, rather than the entire system. This paper addresses the design issues for systems that subject to partial dynamic variations. The main tool used in the design is the *Partial Eigenstructure Assignment*. The controller design objectives are that the eigenvalues and the eigenvectors corresponding to the unchanged part of the system remain unchanged, but those related to the changed part are recovered to a maximum extent using state and/or output feedbacks.

[1] Jiang, J. '*Design of Reconfigurable Control Systems using Eigenstructure Assignments*,' Int. J. of Control, 1993 (in press).

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A Hybrid Method for Solving the Multiple-Input State Feedback Pole Assignment Problem

In this presentation, a hybrid method for multi-input pole assignment is introduced which combines the best features of the algorithms of Petkov, Christov, and Konstantinov and Kautsky, Nichols, and Van Dooren. The result is an algorithm which is robust in the sense of Kautsky et al., and numerically stable because orthogonal transformations are used in the manner of Petkov et al. Results from a Matlab implementation of the algorithm will be presented.

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A MATLAB Toolbox for Control Analysis and Design of Descriptor Systems

Current research in control theory deals with control systems modelled in descriptor form. The advantage of this system description is the physical meaning of the system variables and the direct possibility of connecting subsystems by algebraic constraints. For this system class analysis and design methods are required in order to bring them into application. Although a lot of work has been done in the last decade there is still a shortage of available methods for descriptor systems and particularly CAD-tools are missing. Therefore a MATLAB Toolbox for linear descriptor systems, with the emphasis on controlled mechanical systems, is presented. Additionally to basic and well-known control methods for descriptor systems new methods for pole assignment and linear-quadratic optimal control are considered. The presentation will show the main ideas of this control methods and will give insight into the scope of the Descriptor System Toolbox.

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MS 7

Structure and Computational Complexity in Robustness Analysis

This paper explores various types of performance and robustness analysis of uncertain systems, focusing particularly on the relationship between computational complexity and problem structure. Problem structure can be separated into the structure of the uncertainty and the known structure of the interconnection. In general, more highly structured uncertainty increases computational complexity while more highly structured interconnection can reduce it. Extreme examples of this are the general mixed μ problem, which is NP hard, versus the problems in Kharitonov's theorem and various small gain theorems, which typically have modest computational complexity.

An important feature distinguishing problems which are known to have modest computational complexity is that they can be reduced to finite dimensional convex optimization problems. This paper will map out which questions can be reduced to such problems versus which ones are NP hard, and speculate on the nature of some of the questions in between that remain unresolved. It will also discuss recent promising progress on developing practical algorithms for the NP hard problems.

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Acceleration Strategies in Interior Point Methods for Semidefinite Programming

The talk is devoted to acceleration of polynomial time path-following methods for optimization under Linear Matrix Inequality constraints. We present several acceleration schemes. It is demonstrated that in the general case of "unstructured" problem, same as in the cases of several sructured problems coming from Control Theory, these schemes reduce the order of dependence of the computational efforts on the size of the problem.

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A Primal-dual Interior-point Method for Optimization Over Linear Matrix Inequalities

We discuss an interior-point method for problems involving linear matrix inequalities. The method is based on the theory developed by Nesterov and Nemirovsky and generalizes Gonzaga and Todd's method for linear programming. The algorithm works in primal and dual spaces symmetrically.
The computational complexity of the method is determined by two components. A worst-case analysis shows that the *number of iterations* grows as the square root of the problem size. In practice it grows slower and can be assumed to be almost constant. The overall complexity is therefore dominated by the *amount of work per iteration* and the main cost there is the solution of a least-squares system. The conjugate-gradient algorithm can be used for this purpose and this results in important savings for two reasons. First we show that the polynomial bound on the number of iterations remains valid even if the conjugate-gradient algorithm is not run until completion. Secondly, the typical LMI's occurring in control theory are very structured, and this can easily be exploited in the conjugate-gradient algorithm. For instance, in an optimization problem constrained by L Lyapunov inequalities, each of size m, this leads to an overall *worst-case* complexity of $O(m^{5.5}L^{1.5})$ operations. The *average-case* complexity is slightly above $O(m^4L)$. This estimate can both theoretically and empirically be justified.

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A Second-Order Local Algorithm for a Class of Nondifferentiable Optimization Problems

We consider a class of nondifferentiable optimization problems where the objective and/or constraint functions are defined involving eigenvalues of a symmetric or Hermitian matrix. Examples are such as minimizing the largest eigenvalue or sums of the largest eigenvalues of a symmetric matrix subject to linear or affine matrix inequality constraints. This class of optimization problems arise frequently in control theory when requirements on singular values, eigenvalues, Lyaponov or Riccati equations are desired. In this talk, we first show that in a neighborhood of the solution, this class of optimization problems share a common structure, i.e., they can be recast as an optimization problem of the form

$$\min_{x\in\Re^m}\{f_1(x) : f_2(x) = 0\} \qquad (1)$$

where the functions $f_1(x)$ and $f_2(x)$ have certain special properties. Then, we propose an algorithm in solving (1). With some mild assumptions, it is shown that, if started close enough to the minimizer x^*, the proposed algorithm converges to x^* quadratically. Finally, we show that problem (1) also covers a class of *differentiable* optimization problems. In this case, it is shown that the proposed algorithm coincides with a variation of Newton's method.

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MS 8

Inertia: Theory, Methods, and Applications

A brief but comprehensive up-to-date review of matrix inertia on theory, methods, and applications will be presented. The survey will be far from being complete and exhaustuve, but essential information will be included. This will be the first attempt to present a complete survey on all aspects of inertia since an informative survey paper by Brian Cain appeared in Linear Algebra and Applications several years ago. We remark that the Cain's paper, however, did not include any discussions on computational aspects of inertia.

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Unit disc analogues of some kinds of half-plane stability

Among the many notions of stability for a linear operator L on a complex vector space some require that a certain half-plane contains the spectrum of L or the spectra of some operators associated with L, and others require that the open unit disc contains the spectrum or spectra. *Linear Algebra and its Applications* will soon publish a paper by Amit Bhaya and Eugenius Kaszkurewicz which defines and studies certain "disc based" notions of stability which are counterparts of the much studied "half-plane based" notions, diagonally stable and D-stable. Since the set of multipliers they use, $\mathbf{K} = \{K = \mathrm{Diag}(k_i) : \text{ each } |k_i| < 1\}$, is, in the finite dimensional case, compact and convex with finitely many extreme points, new notions of stability and problems quite unlike their half-plane prototypes emerge. We extend this work in several directions, e.g. to a counterpart for H-stability and into Hilbert space.

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Applications of Linear Transformations to Matrix Equations

In this paper we consider the well-known linear transformations

$$T_1(x) = (AXB - X) \quad \text{and} \quad T_2(x) = (AX - XB)$$

where $A \in M_n$ and $B \in M_m$. We show a new approach on the existence and uniqueness of the solution X of matrix equations $AXB - X = R$ and $AX - XB = R$.

Characterizing nonsingular solutions to the matrix equations has been the subject of several studies in the past. While partial results are known for Lyapunov and Sylvester equations, *no complete characterization for any matrix equation has been obtained yet.* As a consequence of our approach, we present in this paper a characterization of nonsingular solutions to the matrix equations.

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Invariance of Matrix Inertia under Parameter Variations

In this presentation, we consider the problem of determining the invariance of matrix inertia while the matrix entries are subject to variations. Two problems are treated: 1) To determine whether the inertia of matrix remains unchanged under a given range of perturbations and 2) To determine the maximum range of perturbations that preserves the inertia. A computational technique is given for solving these two problems. Some numerical examples are given for illustration.

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An Inertia Theorem for the Lyapunov Equation

Given any $A \in \mathbb{C}^{n,n}$, the inertia of A is the triple $\mathrm{In}(A) = (\pi(A), \nu(A), \delta(A))$ of the number of eigenvalues of A with positive, negative and zero real parts, respectively.
Suppose that H and K are nxn hermitian matrices such that K is positive semidefinite and $K = AH + HA^*$.
The controllability subspace C(A,K) associated with A and K is the subspace spanned by the columns of the $n \times n^2$ matrix $[K, AK, \dots, A^{n-1}K]$. Let $\ell = \dim C(A,K)$. Chen and Wimmer showed that if $\ell = n$ (that is, the pair (A,K) is controllable), then $\mathrm{In}(A) = \mathrm{In}(H)$. We generalize this result and show that $|\pi(A) - \pi(H)| \le n - \ell$ and $|\nu(A) - \nu(H)| \le n - \ell$, thus confirming a conjecture of Lerer and Rodman.

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MS 9

Parallel Implementation of the hp-version of the Finite Element Method on a Shared-Memory Computer

We study the costs incurred by an implementation of the *hp*-version of the finite element method for solving two-dimensional elliptic partial differential equations on a shared-memory parallel computer. For a collection of benchmark problems, we systematically examine the costs in CPU time of various individual subtasks performed by the finite element solver, including construction of local stiffness matrices, elimination of unknowns associated with element interiors, and global solution on element interfaces by a preconditioned conjugate gradient method. Our general observations are that the costs of the "naturally" parallel computations associated with local elements are significantly higher than any global computations, so that the latter do not represent a significant bottleneck to parallel efficiency. However, in order to avoid inefficiency caused by hierarchical computer memories, it is necessary to organize the local operations into blocks of computations. We show how to do this effectively using the Level 3 BLAS linear algebra kernels.

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Parallel Computation of Orthogonal Factors of Sparse Matrices

We study the solution of the least squares problem for a large and sparse overdetermined matrix A by QR factorization. We develop an efficient method for computing Q^Tb where is the orthogonal factor.

In this paper, we determine the number of multiplications required to compute Q^Tb use the multifrontal Householder QR factorization by Lewis, Pierce and Wah[Technical report ECA-TR-127, Boeing computer services(1989)]. Instead of storing the Q matrix itself, we store all the nonzero parts of the Householder transformation matrices Q_i's of all the multifrontal matrices F_i's of A. It is clearly that $Qb = Q_k Q_{k-1} \cdots Q_1 b$. We also use Schreiber and Van Loan's Storage-Efficient-WY Representation [SIAM J. Sci. Stat. Computing, 10(1989),pp. 55-57] for each Q_i to introduce BLAS-2 operations. A theoretical operation count for the K by K unbordered grid model problem is included which shows the proposed method requires $O(N_R)$ multiplications ($O(K^2 \log K)$ for the K by K grid model problems) to compute Q^Tb, where N_R represents the number of nonzeros of the Cholesky factor of A. Some numerical results for the grid model problems as well as Harwell- Boeing problems on both sequential machines and iPSC distributed memory machines are provided.

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A Comparison of Techniques for Solving Ill-Conditioned Problems Arising from the Immersed Boundary Method

The immersed boundary method is a technique invented by Charles Peskin for solving incompressible fluid dynamics problems with complicated boundaries immersed in the flow. The technique employs a fixed underlying cartesian grid and a separate, possibly moving, grid f or the boundary. An implicit solution strategy for quantities on the cartesian grid and on the boundary leads to a coefficient matrix of the form $\begin{pmatrix} A & S \\ R & 0 \end{pmatrix}$ where A represents the Stokes equations, R restricts cartesian grid values to the boundary and S spreads the boundary values to the cartesian grid. As a result the Schur complement matrix $R^T A^{-1} S$ can be very poorly conditioned or even singular. We describe several regularization strategies for solving these problems and compare their performance on different machine architectures.

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Convergence Result for the Block-symmetric Gauss-Seidel Iteration for the Non-symmetric case: An Application to the Convection-Diffusion Equation

The standard hierarchical basis multigrid method is applied to the convection-diffusion equation. The discretization using an upwind finite element discretization scheme leads to a highly non-symmetric linear system of equations. The system is solved using the block-symmetric Gauss-Seide l iteration. Our goal is to gain insight into the behavior of the convergence rate of the meth od as a function of the mesh size, the size of the convective term and the stren gth of the upwinding, which is governed by a user controlled parameter. This is a bit unusual in comparison with most theoretical studies in this area, where the intent is usually to demonstrate the mesh independence of various quant ities. Some numerical results will be presented.

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A Direct Algorithm for Computing Eigenspaces with Specified Eigenvalues of a Regular Matrix Pair (A,B)

Please refer to a revised abstract on page A44.

This paper presents a new I ^- ... on a DIRECT method for reorde... ...chur form by solving ... ...ons. One paper appeared recentl) ... ...cale and Real-Time Applications (editirs i ... Moor).

Bo Kagstr... and Peter Poromaa
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MS 10

Reordering Diagonal Blocks in Real Schur Form

The problem of reordering the eigenvalues of a matrix in real Schur form arises in the computation of the invariant subspaces corresponding to the various groups of eigenvalues of the matrix. A basic step in such reordering is to swap two neighboring 1×1 or 2×2 diagonal blocks by an orthogonal transformation. Swapping two 1×1 blocks or swapping 1×1 and 2×2 blocks are well understood. Swapping two 2×2 blocks poses some numerical difficulties. Recently, Bai and Demmel have proposed an algorithm for swapping two 2×2 blocks which is for all practical purposes backward stable. In this talk we describe an alternative approach for swapping two 2×2 blocks which is based on an eigenvector calculation. The method guarantees that there will be only small rounding errors in the (2,1) block of the transformed 4×4 matrix. A generalization to a regular 4×4 pencil will also be discussed.

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The Computation of the Jordan Form via GQRD

De Moor and Van Dooren have recently proposed a generalization of the QR decomposition to any number of matrices of compatible dimensions where individual matrices are triangularized. Such a generalized QR decomposition can be used to reveal the Jordan structure of a matrix. The talk will describe this method together with results of preliminary numerical tests.

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How Can We Parallelize the Unsymmetric QR Algorithm?

The QR algorithm continues to be the workhorse for solving dense, unsymmetric eigenvalue problems, but attempts to parallelize it have met with failure. The parallelism in a single QR step is fine grained, hence difficult to exploit. Multishift QR codes have failed because of forward instability. Pipelined codes suffer from degradation of the convergence rate. We will discuss these problems and show how modified shifting strategies may lead to successful parallel algorithms.

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Scaled Toda-Like Flows

A new framework for constructing isospectral flows in $R^{n \times n}$ is considered. The structure allows arbitrary and independent scaling for each off-diagonal element in the underlying matrix and, hence, is more general than many already proposed in the literature. Convergence proofs are thus unified and simplified. It is shown that the time-1 mapping of the scaled Toda-like flow still enjoys a QR-like iteration. Examples are given to demonstrate how different scalings lead to different well known flows. Numerical experiments illustrate the effect of scaling on speeding up the convergence.

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Isospectral Flows and Linear Programming

There is an analogy between the isospectral flow underlying the QR-algorithm for finding eigenvalues of real symmetric matrices (the Toda flow), and flows occurring in interior point methods in linear programming. This analogy is exact: there is a flow, the active set flow, on real symmetric matrices, which solves the linear programming problem. It was discovered by Stoer, Sonnevend and Zhao. Various properties of the active set flow will be discussed.

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MS 11

Numerical Solution of Hamiltonian Eigenvalue Problems via Subspace Iteration Techniques

This talk is concerned with the numerical solution of Hamiltonian eigenvalue problems. Solving this problem is the basis for the numerical solution of algebraic Riccati equation and linear quadratic optimal control problems.

We present an efficient structure preserving algorithm for the computation of invariant subspaces of Hamiltonian matrices. This algorithm is based on the multishift technique proposed by G. Ammar and V. Mehrmann. Numerical properties of this algorithm and the application to the solution of algebraic Riccati equations combined with defect correction will be outlined.

Peter Benner
RWTH Aachen

A New Class of Discretization Methods For Linear Differential-Algebraic Equations with Variable Coefficients

We discuss new discretization methods for linear differential-algebraic equations with variable coefficients. We introduce numerical methods to compute the local invariants of such differential-algebraic equations that were introduced by the authors in a previous paper. Using these quantitities we are able to determine numerically global invariances like the strangeness index, which generalizes the differentiation index for differential-algebraic equations that in particular include undetermined solution components. Based on these methods we then obtain regularization schemes, which allow us to employ general solution methods. The new methods are tested on a number of numerical examples.

Peter Kunkel
Carl-von-Ossietzky-Universität Oldenburg

Volker Mehrmann
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Numerical Integrators of General DAEs which Preserve Constraints

Higher index DAEs frequently occur in mechanics and control problems. Mechanics problem are often index three if actuator dynamics are ingnored and of even higher index if actuator dynamics are included in the simulation. Recently numerical methods have been developed for general nonstructured higher index DAEs. However, these methods can exhibit drift off the solution manifold which is often undesirable during simulations. In this talk we shall discuss progress in the development of numerical methods for general DAEs which avoid drift.

Stephen L. Campbell
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Observer Design for Descriptor Systems with Applications to Gas Dynamical Systems

Reliable numerical procedures for the design of dynamic observers for linear descriptor systems are discussed. The methods are based on pole placement and singular value assignment and lead to robust designs that are insensitive (in a certain sense) to perturbations to the system. The techniques are applied to the problem of estimating unmeasured demand flows in a gas transmission network with sparse telemetry. The network is modelled by an implicit discrete linear system with pressure measurements only at pipe junctions. Direct and dynamic observers are developed and compared. The effects on the estimated states of model errors and of biased and unbiased (white) noise in the measured data are investigated.

Simon Stringer
University of Reading

Nancy Nichols
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Index Reduction for Linear Differential Algebraic Equations

We discuss the solution of linear differential-algebraic equations with constant coefficients of the form

$$E\dot{x}(t) = Ax(t) + f(t)$$

and give a new stable algorithm for solving initial value problems in these systems.
The algorithm is based on a sequence of singular value decompositions and reduces the index of the system iteratively until only an algebraic equation or an ordinary differential equation is to solve. Our algorithm determines not solvable or not uniquely solvable systems and includes tests for the consistency of given initial values.

Andreas Bügers
Universität Bielefeld
Volker Mehrmann Universität Bielefeld

On the Discrete Generalized Lyapunov Equation

In this paper we study the discrete generalized Lyapunov equation for implicit systems defined by $Ex_{k+1} = Ax_k$. The results from standard Lyapunov theory are extended to generalized systems. We show how the anticipation phenomenon and the asymptotic stability of the system can be studied in terms of the solutions to the discrete generalized Lyapunov equation given by $A^TPA - E^TPE + E^TQE = 0$. In particular, necessary and sufficient conditions for a discrete implicit system to be asymptotically stable and anticipation free are obtained. We further study under which conditions these solutions are unique. A computationally efficient scheme for the solution of the generalized discrete Lyapunov equation is proposed based on orthogonal transformations and solution of a triangular system of equations. We present numerical examples to illustrate the accuracy of the results developed in the paper.

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CP 2

A Parameterization of All Stabilizing Controllers by Polynomial Matrix Approach

A parameterization of all stabilizing controllers for a given system is important in linear system theory. In many literatures, the free parameters have been given by proper stable rational function matrices. With the rational function parameterization, it is difficult to assign the degree of controller and the closed pole locations. In this paper, a simple calculation method to obtain the left annihilating matrix of a given polynomial matrix is presented. Using the calculation, we give a parameterization of stabilizing controllers in terms of polynomial matrices, which makes the assignment of the degree and the pole locations possible.

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A New Look at the Mixed Sensitivity Minimization Problem for the Control System Design

We deal with the problem of designing, for a linear time-invariant plant $G(s)$, a controller $F(s)$ which stabilizes $G(s)$ and, at the same time, to minimizes the criterion min $||W_1S||_2^2 + \lambda\ ||W_2T||_2^2$, where the system sensitivity matrix $S(s)$ and complementary sensitivity matrix $T(s)$ are defined, respectively, as $S(s) = [I + G(s)F(s)]^{-1}$, $T(s) = I - S(s)$ and $W_1(s), W_2(s)$ are frequency dependent user-defined weighting matrices. We suggest using the robust estimation techniques in regularized image restoration to solve the minimization problem. With a standard Youla parameterization, the problem is converted into min $||T_1 - T_2QB||_2^2 + \lambda\ ||T_3 - T_4QB||_2^2$, where $T_i(s)$ $(i = 1, 2, 3, 4)$, $B(s)$ are matrices related to $W_1(s), W_2(s)$, and $G(s)$ and $Q(s)$ is the matrix variable we are looking for, i.e., a tradeoff between two model matching problems in the L^2 space. The model matching problem is further reduced to a standard image restoration problem in the l^q space with q determined by the dimensions of $T_i(s)$ and the discrete Fourier Transform (DFT) points taken, i.e., min $||x_1-D_1\alpha||_2^2+\lambda\,||x_2-D_2\alpha||_2^2$, where x_1, x_2, and α are vectors associated with the DFT of T_1, T_3, and Q in lexicograpgical orders by column and the block diagonal matrices D_1, D_2 are properly constructed associated with the DFT of T_2 and T_4. The standard robust regularization technique in then applied to find the optimum α. The optimal controller is then determined from $Q(s)$ via the inverse DFT conversion from α.

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A Design of Exact Model Matching Systems using Polynomial Basis

Exact Model Matching (EMM) is not only a useful design method for linear control systems, but also important one for the elementary structure of an adaptive control systems. It is reported that EMM system is designed by deriving an interactor matrix of the plant, and then solving the design equation. In this presentation, we give a new procedure for the EMM design based on an idea of polynomial basis. By this method, we can obtain the interactor and feedback compensators at the same time. We also show a parametrization of the EMM compensators.

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Controllability Analysis of Time Varying Linear Systems: Application of Computer Algebra Methods

Along the lines of our recent results this paper focuses on the algebraic computation of the reachability subspace of time varying linear systems. Properties and application of Lie algebra structures to this problem is discussed. The problem includes computation of the basis of matrix Lie algebra and the problem of its solvability. The construction of the basis of the reachability subspace of linear dynamic systems as well as the basic form of the fundamental solution in presence of time varying system perturbations is presented. The computational methods are implemented in the framework of a computer algebra system.

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On the Generalized Interactor Matrix and the Model Matching Control for Linear Multivariable Non-Minimum Phase Systems

An interactor matrix plays an important role in the polynomial algebraic design method for the model matching control of linear multivariable systems. However, since the interactor matrix corresponds to only zeros at infinity of the system, the plant is assumed to be a minimum phase system. In this presentation, we generalize the definition of the interactor matrix so that it corresponds to not only zeros at infinity but also prespecified finite zeros of a given transfer matrix. It is shown that, if we replace the interactor matrix by this generalized interactor matrix, the polynomial algebraic method can be applied to design of the model matching control for a multivariable non-minimum phase plant without any modifications.

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Algebraic Computation of the Fundamental Solution of Linear Time Varying Systems

On the well founded mathematical basis of Lie algebra, in this paper we present a computational framework for determining the fundamental solution of time dependent linear systems using symbolical computer algebra operations. The idea can play invaluable role in a broad class of applications aimed at the computer based exploration of time varying phenomena in dynamical processes. The proposed method apply directly to algebraic computation of controllability and observability of time varying linear systems and provides an error free computational alternative to the contemporary standard approaches in system theory.

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Transfer Functions Approximation for Distributed Parameter Systems

In this paper we consider a one-dimensional linear distributed system excited by a pointwise boundary control. The study in the frequency domain of such system necessitates the knowledge and the approximation of the transfer function $G(s)$ which is strictly proper.

The purpose of this paper is to give an original explicit approach for the approximation of $G(s)$ based on Pade techniques for $|s| \leq n$ and a residual term for $|s| > n$.
For nuclear systems, K. Glover, J. Lam, J.R. Partington and R.F Curtain *[Journal approximation theory and SIAM journal control and optimization, July 1988...]* have studied the transfer function approximation problem. In this paper we give approximation results in the case of a non nuclear system. Moreover these results can be easily extended to more general systems.

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A New Concept for Observabilty

The concept of observability for any linear or nonlinear systems is extended in this paper. The result shows for any given system described by input and state variables, we can always find a scalar output which is linear in state variables such that the system is observable. Meanwhile the criterion for choosing the coefficients of the scalar output is given. All results obtained are based on the Wu-Ritt's variety decomposition theorem in differential algebraic geometry.

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Feedback Design Interval linear Systems

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Abstract. Let $\mathbf{A} = \{p(s;a);\ \underline{a}_i < a_i < \bar{a}_i\}$; $\mathbf{B} = \{q(s;b);\ \underline{b}_i < b_i < \bar{b}_i\}$ and let $\mathbf{G} = \{ q(s;b) \ / \ p(s;a);\ p \in \mathbf{A},\ q \in \mathbf{B}\}$, where $a=(a_i) \in \mathbf{R}^{n+1}, b=(b_i) \in \mathbf{R}^{m+1}, p(s;a) = a_0 s^n + \cdots + a_n,\ q(s;b) = b_0 s^m + \cdots + b_m$. Denote $\mathbf{H}_n$ = { *Hurwitz polynomials of degree n* } and {*SPR*} = { *strictly positive real functions* }. *The study of a family* $\mathbf{A}$ *of polynomials and/or a family* $\mathbf{G}$ *of rational fractions is of primary importance in the control theory for linear systems. Kharitonov has shown that* $\mathbf{A}$ $\mathbf{H}_n$ *iff four specified corner polynomials of* $\mathbf{A}$ *are in* $\mathbf{H}_n$. *H. Chapellat and M. Dahleh have shown respectively that* $\mathbf{G}$ {*SPR*} *iff sixteen specified corner transfer functions are in* {*SPR*}. *We improved this result with an independent proof showing that the number "sixteen" can be reduced to "eight". A numerical example is also given. Then we study the problems of feedback design for the family* $\mathbf{A}$ *and/or the family* $\mathbf{G}$, *for which few results are available in the literature.*

Keywords: Linear system, Interval Plant, Positive Real Function, Feedback Stabilization

CP 3

Numerical Performance of Two-Sided Linear Prediction

Linear prediction in time series analysis is usually one-sided (OSP): present value is estimated as a weighted linear combination of past values. In two-sided linear prediction (TSP), present value is estimated as a symmetrically-weighted linear combination of past and future values. We prove the following: (1) variance of TSP residuals is less than that of OSP residuals, by a known factor for finite-order AR processes. This is useful for interpolation to replace known outliers; (2) TSP-based spectral estimates minimize a frequency-domain error criterion different from OSP, one which emphasizes spectral valleys rather than peaks; but (3) TSP is equivalent to extended Prony's method, which makes it very useful for narrowband spectral estimation.

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Iterative Methods for Restauration of 2-Dimensional Images

The calculation of Wiener filters, which minimize the mean square error in restauration of noisy images, for 2-dimensional images requires the solution of very large linear systems of equations. If we assume that the image is separable, the filter computation yields a Sylvester's equation $AX - XB = C$, where $A \in \mathbf{R}^{n \times n}$, $B \in \mathbf{R}^{m \times m}$, and $C \in \mathbf{R}^{n \times m}$ are given matrices, and $X \in \mathbf{R}^{n \times m}$ is the solution matrix to be determined. The ADI iterative method is an attractive method for the solution of Sylvester's equation when the matrices A and B are large, sparse and some information about the spectra $\lambda(A)$ and $\lambda(B)$ is available. The ADI method proceeds by strictly alternating between the solution of the two equations

$$\begin{aligned} (A - \delta_k I)X_{k+1} &= X_k(B - \delta_k I) + C, \\ X_{k+2}(B - \tau_k I) &= (A - \tau_k I)X_{k+1} - C, \end{aligned}$$

for $k = 0, 1, 2, \ldots$. Here X_0 is a given initial approximate solution, and the δ_k and τ_k are real or complex parameters chosen so that the computed approximate solutions X_k converge rapidly to the solution of the Sylvester equation as k increases. In this talk we consider the case where the transmitted image is wide-sense stationary, separable first order Markovian, and we discuss how the ADI method method can give faster convergence than when strict alternation is required. The talk presents joint work with Norm Levenberg and Lothar Reichel.

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Constrained Image Reconstruction from Projections using the Wavelet Transform

We derive a fast image-domain filter which solves the following constrained inverse Radon transform problem: Given constraints on certain wavelet coefficients of the image, compute from its projections the image which either: (1) requires the smallest perturbation of the projection data to satisfy these constraints; or (2) is the constrained linear least-squares image estimate. The wavelet transform can be used for spatially-varying filtering of an image, suppressing noise locally in smooth regions; we also discuss detection of such regions in a noisy image; this leads to the wavelet coefficient constraints. Numerical results show improvement over filtered images, since the constraints improve the reconstruction in non-constrained areas as well.

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On Signal Separation By Multi-resolution Analysis

The problem of separating a base signal from sampled data corrupted by an unwanted high frequency signal is considered. When the sampling rate is such that the high frequency signal is undersampled, the resulting aliased signal in some cases can be approximately removed. Examples are given where removal is accomplished by projecting the composite signal on a supspace of a multi-resolution analysis and viewing a coarser resolution.

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Multiresolution Algorithms for One-Dimensional Inverse Scattering Problems using the Wavelet Transform

The wavelet transform (WT) is applied to the inverse scattering problem of reconstructing the reflectivity (r) of a two-component wave system from its impulse reflection response (R). Three new multiresolution algorithms are obtained. First, a WT in time yields independent wave systems with wavespeeds determined by the dilation factor. Second, WTs in time and space yield coupled wave systems with wavespeeds determined by the two dilation factors. Finally, WTs in time and space are applied to the Krein integral equation, resulting in a block-slanted-Toeplitz linear system of equations, to which the coupled wave system is related. The latter two results relate WT(r) to WT(R).

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Numerical Properties of Some Highly Concurrent Algorithms for Control and Signal Processing

Based on the Lanczos-Clenshaw method for solving linear ODEs through Chebyshev series expansion, a new transformation, A: $L^2 \to l^2$, is used to generate highly concurrent algorithms for digital signal processing and control applications. According to this method, a signal y(t) is associated with the vector y = A y(t), and its derivative with Dy, where D is an upper triangular matrix; accordingly, linear systems are represented by matrix operators. The speaker will focus on the numerical properties of three algorithms: the fast A-transform, a model reduction method for closed-loop control systems, and a new digital filter design technique; unlike existent results, the filters thus designed will be exact replicas of the analog prototypes and, at the same time, will generate interpolated output values concurrently with the current output.

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EM-Type Algorithms for Maximizing Likelihoods in Transmission Tomography

Transmission Tomography (TT) is the quantitative determination of the X-ray attenuation coefficients inside an object. In some situations (reduced radiation, severe attenuation) a maximum likelihood approach using the EM (expectation maximization) algorithm produces better results than classical convolution methods. In this work we present a novel interpretation of some previously proposed EM methods in TT that makes easier understanding of their convergence properties and allows the introduction of several improvements as well as new, and possibly better, algorithms.

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Surface Reconstruction Based on Texture Variation

Texture information depicted on a 3-D surface is distorted by the projection onto the 2-D image plane, and the distortion depends on the relative position between the camera and a local surface patch and its orientation. To recover the shape of a surface from projected texture information is known as the shape from texture (SFT) problem. Most existing SFT algorithms extract the surface orientations of planer objects.

In this research, we propose a new SFT algorithm which recovers surface heights of curved objects directly. We approximate a curved surface with a union of triangular surface patches, and relate the local densities of textural primitives in the image domain to nodal height variables of the approximated curved surface.

This procedure leads to a nonlinear system of equations which are then solved via a successive linearization scheme.

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Variance Bounds for Modal Analysis

Our purpose is to derive error bounds for modal analysis. We ask these error bounds to predict the threshold signal-to-noise ratio (SNR) where performance degrades catastrophically. Traditionally, Cramer-Rao bounds have been used to describe performance above threshold, but no satisfactory way of computing threshold SNR has existed. We use Barankin and Battacharrya bounds extended to multiple and Hilbert space parameter sets to bound performance and predict the threshold SNR. We apply the technique to problems in time series analysis and array processing.

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Constructing Linear and Quadratic Forms from Projection Operators in ℓ^2

Our purpose is to construct linear and quadratic forms from projection operators in ℓ^2. These forms arise in the solution of detection, estimation, and time series analysis in ℓ^2. Our technique is to build perfect reconstruction filter pairs of the variety found in wavelet filter banks and then to iteratively replicate these filter banks to provide a multiscale decomposition of ℓ^2 using pseudoinverses and oblique projections. We show that estimators and detectors may be factored into a concatenation of projectors and pseudoinverses and apply this decomposition to the solution of filtering problems.

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A Fast Algorithm for Computing Eigenspaces of Real Symmetric Toeplitz Matrices

We present a numerical method for the eigenspace decomposition of real symmetric Toeplitz matrices. The method reduces the problem into a number of stable matrix-vector and matrix-matrix multiplications. For a matrix of order n, our method involves $O(n^2\log_2^2 n)$ flops with $O(n^2\log_2 n)$ data movement, whereas traditional methods to compute the eigenspace of real symmetric matrices involve $O(n^3)$ flops with $O(n^3)$ data movement. Our method has two major computational parts. The first part is completely dominated by the use of FFTs and the second part is rich in level 2 and level 3 BLAS. So, it is inherently efficient for high performance vector and parallel processors. In case of clustered eigenvalues, the flop counts in our method has overhead depending on the number of clustered eigenvalues, but still less than $O(n^3)$. Clustering does not affect the order of data movement.

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MS 12

Dynamic Optimization for Nonlinear Control

This paper explores the use of dynamic optimiztion as a method to accom odate control actuator nonlinearities. Two aerospace examples are presented including control o f a missile during fin actuator saturation and development of an adaptive pulse modulator for control of a space vehicle with reaction jets.

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Modern Control Bank-To-Turn Autopilot for the HAVE DASH II Missile

This paper addresses the application of a modern control, bank-to-turn autopilot to the HAVE DASH II air-to-air missile. The application of control techniques to an asymmetric airframe with highly nonlinear aerodynamic characteristics is discussed. Design analysis, simulation and flight test results are presented.

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Session #SL 9

Speaker: Russell L. Daily

Abstract has not reached the SIAM office at press time.

Boeing's Automatic Control System Workbench and the Linear System Toolbox

This talk will give an overview of Boeing's Automatic Control System Wo rkbench, which is a graphically driven environment which provides access to, and integration among, a variety of software tools useful for the analysis, design, a nd simulatino of automatic control systems. The talk will also describe some of our tools for linear systems analysis and design, including a unique root locus f unction, and some which exploit the real Schur decomposition.

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MS 13

Applications of MATLAB to Signal Processing Algorithms and Digital Filter Design

This paper will show how the flop count and timing ability of Matlab can be used to develop and analyze various signal processing algorithms such as the FFT. Exercises that can be used in teaching DSP will be developed. Examples of using Matlab in the approximation problem in designing digital filters will be given. In particular, the Remez exchange algorithm and Iterative Reweighted Least Squares will be described for one and two dimensional filter design.

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Use of MATLAB in Linear System Theory

As the understanding of linear multivariable systems advances, progressively more complicated problems are being addressed. Traditional methods for system analysis and design are adequate for small order problems. However, as the size of the problem grows it becomes exceedingly important to use reliable (numerical) techniques for their analysis and design. MATLAB provides the researchers a platform with a very quick turn around time, where they do not have to concern themselves with the numerical aspects of developing the code. Instead, they can focus their attention on verification of their theoretical ideas. In this presentation, we review the impact of MATLAB in the advancement of linear system theory and present an overview of several frequently used concepts and their MATLAB implementation.

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Session MS 13

Speaker: Cleve Moler

Abstract has not reached the SIAM office at press time.

Educational Applications of MATLAB

MATLAB was originally designed as a matrix laboratory for teaching linear algebra and matrix theory. Using this powerful tool it is possible to greatly enhance linear algebra courses and to give students a new perspective of the subject. The talk will focus on how to effectively incorporate the MATLAB software into undergraduate linear algebra courses. It will describe how to create meaningful computer exercises and provide a number of interesting examples. We will also discuss recent efforts to reform linear algebra education.

One such effort is the ATLAST Project. ATLAST is an acronym for Augmenting the Teaching of Linear Algebra through the use of Software Tools. The project is a collaborative effort of ten universities and over three hundred instructors from across the USA. The project is designed to encourage and facilitate the use of software in linear algebra courses. ATLAST participants are collaborating to produce a public domain database of computer exercises for instructors to use in teaching linear algebra.

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MS 14

Quadratic Spectral Estimators and Multitapering

Multitaper spectral estimation was originally introduced by Thomson (1982) as a solution to the spectral estimation problem based upon a stochastic integral equation. Subsequently Bronez (1985) showed that, for the special case of complex-valued stationary processes, the multitaper approach arises naturally from a study of the bias and variance properties of the class of quadratic spectral estimators. His approach relies heavily on well-known results in linear algebra concerning the decomposition of positive semi-definite matrices. In this introductory talk, we will discuss the relationship between quadratic spectral estimators and multitapering for real-valued stationary processes using a linear algebra approach closely paralleling that of Bronez's.

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Quadratic-Inverse Spectrum Estimates

Multiple-window spectrum estimation methods (Proc.IEEE .B 70, pp 1055-96, 1982) derive from a frequency-localized least-squares solution of the first-kind Fredholm equation connecting the Fourier transform of a short sample of a stationary process with the Cramer spectral representation of the process. Quadratic-inverse spectrum estimates (Phil. Trans. R. Soc. Lond. A ..B 332, pp 539-97, 1990.) extend this theory to give optimum estimates of the second moments by decomposing the covariance matrix of the multiple-window eigencoefficients into a components-of-variance like series of known basis matrices with scalar coefficients. In this talk, I describe some relations of quadratic-inverse theory to and Karhunen-Loeve expansions, to maximum-likelihood estimates, and to covariance extension models.

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Variance and Distribution of Multitaper Spectral Estimators for Rapidly Changing Spectra

Multitaper spectral estimation has proven very powerful as a spectral analysis method wherever the spectrum of interest is detailed and/or varies rapidly with a large dynamic range. In his original paper D.J. Thomson gave a simple approximation for the variance of a multitaper spectral estimate which is generally adequate when the spectrum is slowly varying over the taper bandwidth. We show that near zero or Nyquist frequency this approximation is poor even for white noise, and derive the exact expression of the variance in the general case of a stationary real-valued time series. This expression is illustrated on an autoregressive time series, and a fractionally differenced white noise process, and a convenient computational approach outlined. For the fractionally differenced white noise, quantile-quantile plots were calculated to show the departure from chi-squared behaviour of the multitaper spectrum estimates at different frequencies.

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Minimum Expected Loss Estimation for Evolutionary Spectra

We examine three common spectral estimators: the smoothed tapered periodogram, Welch's method of overlapping subsegments, and multiple taper spectral estimates. We compare the expected loss, bias^2 + variance, of the three methods. Our results depend on the local spectral variation, S"(f)/S(f), and on the Rayleigh resolution. The more peaked the local spectrum is relative to the Rayleigh resolution, the larger multitaper's advantage is relative to the standard methods. We also compare the methods using real data from T.F.T.R. plasma fluctuations, testing convergence as the data interval increases.

We give a new adaptive weighting for the multitaper estimate which is based on the local expected error. In contrast, Thomson's adaptive weighting is based on the broadband bias.

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MS 15

Fast Iterative Methods For Least Squares Estimations

Least squares estimations have been used extensively in many applications, e.g. system identification and signal prediction. When the stochastic process is stationary, the least squares estimators can be found by solving a Toeplitz or near-Toeplitz matrix system depending on the knowledge of the data statistics. In this paper, we employ the preconditioned conjugate gradient method with circulant preconditioners to solve such systems. Our proposed circulant preconditioners are derived from the spectral property of the given stationary process. In the case where the spectral density function $s(\theta)$ of the process is known, we prove that if $s(\theta)$ is a positive continuous function, then the spectrum of the preconditioned system will be clustered around 1 and the method converges superlinearly. However, if the statistics of the process is unknown, then we prove that with probability 1, the spectrum of the preconditioned system is still clustered around 1 provided that large data samples are taken. For finite impulse response (FIR) system identification problems, our numerical results show that an n-th order least squares estimators can usually be obtained in $O(n \log n)$ operations when $O(n)$ data samples are used.

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Spectral Properties of Preconditioned Rational Toeplitz Matrices

Since signals are often modeled as the outputs of a linear system characterized by a rational system function driven by white noise, it often requires to solve a Toeplitz or Toeplitz-plus-Hankel system of equations with a rational generating function in signal estimation, analysis and processing. Various preconditioners have recently been proposed so that an $N \times N$ Toeplitz or Toeplitz-plus-Hankel system $A_N \mathbf{x} = \mathbf{b}$ can be solved effectively by the preconditioned conjugate gradient (PCG) method. In this research, we propose a systematic approach to generate a class of preconditioners P_N for Toeplitz or Toeplitz-plus-Hankel matrix A_N. Then, we characterize the spectral properties of $P_N^{-1} A_N$ when the corresponding Toeplitz or Hankel matrix is generated by a rational function. We classify the eigenvalues of the preconditioned matrix into two classes, i.e. the outliers and the clustered eigenvalues. We prove that the number of outliers depends on the order of the rational generating function, and the clustering radius ϵ is proportional to the magnitude of the last element in the generating sequence used to construct these preconditioners. Consequently, the number of iteration for the PCG method to converge depends primarily on the order of the rational generating function.

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Fast Preconditioned Iterative Methods for Image Restoration

After discretization, a spatially invariant image restoration problem can be formulated as a discrete ill-posed problem $g = Hf + \eta$, where the matrix H is a block Toeplitz matrix. Due to the ill-posed nature of the image restoration problem, the computed solution is very sensitive to noise, η. Regularization is used to alleviate this sensitivity, and the resulting system is solved by the preconditioned conjugate gradient method using 2-D FFT-based preconditioners introduced by Chan, Nagy and Plemmons and by Hanke, Nagy and Plemmons. It is shown that these preconditioning schemes incorporate either of two different regularization procedures; namely Tikhonov regularization and iterative regularization with the conjugate gradient algorithm. Numerical results are reported illustrating good convergence properties of these FFT-based preconditioners.

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Building Preconditioners for Toeplitz and Related Systems

The purpose of this is to survey the current methods and criteria for constructing circulant-type preconditioners for conjugate gradient iterative methods in solving Toeplitz and related systems. The use of circulant preconditioners for these Toeplitz problems allows the application of Fourier transforms throughout the computations, and these FFT--based iterations are not only numerically efficient, but also highly parallelizable. Applications include such several important signal and image processing problems.

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MS 16

Feedback Stabilization of a Second-Order System: A Nonmodal Approach

A novel approach for feedback stabilization of a second-order model is proposed. Specifically, two nonmodal algorithms are described and it is shown mathematically that under some mild assumptions on the damping matrix, the feedback matrix obtained by each algorithm indeed stabilizes a closed-loop system.

The first algorithm requires the solution of a symmetric positive definite linear system and the inversion of a small matrix. A remarkable feature of this algorithm is that it does not require knowledge of stiffness and damping for implementation, which makes it very feasible for practical application. The second algorithm requires the solution of a small linear least-squares problem, and an estimate of the stability index, which can be obtained just by computing the extremal eigenvalues of the data matrices which are symmetric for almost all practical applications.

These minimal computational requirements make the proposed algorithms suitable for practical implementations, even for large and sparse systems, using the state-of-the-art techniques of matrix computations. This is in sharp contrast with the traditional modal approach ordinarily used by practicing engineers, which requires the solution of a quadratic eigenvalue problem or, equivalently, the solution of a $2n \times 2n$ generalized eigenvalue problem and, therefore, may not be practical for very large and sparse problems.

Besides the proposed algorithms, the paper also contains some mathematical results on the bounds of the eigenvalues of a second-order pencil, which may be useful for investigating stability of second-order systems, and are of independent interest.

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Active Vibration Absorbers for Flexible Space Structures: Design and Practical Implementational Questions

The dynamics of flexible space structures (FSS) are not usually well known before launch. This makes it important to develop controllers for such systems that can never be destabilized by perturbations in the structural model. Such considerations motivate the important class of *active vibration absorbers* (AVAs) [1][2], in which the control system mimics a fictitious (or virtual) flexible structure attached to the physical structure to be controlled. These control systems, based on the use of collocated actuators and rate sensors, guarantee closed-loop stability regardless of any uncertainties present in the structural model. The controller design problem then becomes that of choosing the natural frequencies, damping ratios and mode shapes of this virtual structure. Such compensators are ideally suited to a high-authority/low-authority control scheme; they provide the stabilizing low-authority inner loop, so allowing a higher-performance feedback technique with no guaranteed stability, for instance a linear quadratic regulator (LQR), to be applied safely. The first question studied in this paper is that of developing methods for designing virtual passive controllers when the primary control objective is to achieve vibration absorption at various specified disturbance frequencies. The second question to be studied are the effects of practical implementational constraints on the behavior of AVA controllers. Finally, these results will be illustrated by application to several examples.

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MS 17

Automated System Identification Using Canonical Variate Analysis

The singular value decomposition (SVD) has received much recent attention for system identification. Such methods have the potential for stable and noniterative computation whereas most system identification methods are iterative and prone to ill- conditioning. Current SVD methods can produce poor results in the presence of noise or feedback in the system. The canonical variate analysis method gives an optimal weighted SVD depending on the particular noise characteristics. The use of the Akaike Information Criteria (AIC) for optimal selection of the model state order results in a completely automated procedure for system identification. The procedure has been incorporated in real-time adaptive control of complex multi-input multi-output systems. Extensive results have been obtained for complex high order simulations as well as wind tunnel test of aircraft wing flutter.

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Parallel Algorithms for Canonical Variate Analysis

In this talk we first show how a canonical variate analysis can be reduced to the computation of the SVD of a product of three matrices. We next describe an efficient algorithm that does not require explicit matrix inversions and explicit matrix products. Finally, we show how our algorithm is amenable to computation on parallel machines.

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Analysis of Nonlinear Vibrating Systems Using Canonical Variates

The identification and analysis of vibrating structures is fundamental to the practice of science and engineering. We describe a time series approach to the analysis of nonlinear vibrating structures using a local form of canonical variate analysis. This is an alternative to the very limited information obtained from a linear analysis, and typically requires a reasonably sized dataset to construct the model. We summarize the technique, emphasizing its relationship to current dynamical systems research and to canonical variate analysis. Following the theoretical development, applications to a variety of driven (random noise excited) nonlinear oscillators are presented.

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Identification of Nonlinear Systems Using Canonical Function Analysis

Accurate empirical modeling of nonlinear dynamical systems requires an adequate state space embedding. For deterministic nonlinear systems, Takens theorem guarantees an optimal embedding that is finite dimensional and linear. When noise is present, there is usually no finite dimensional embedding, and efficient solution of the problem fundamentally involves approximate embedding that requires nonlinear functions of the past observations. The approach of canonical function analysis determines an optimal selection of the state for a given state dimension. The theory of canonical functions for nonlinear systems is discussed in a Hilbert space setting that is required for the nonlinear case. Computational algorithms are discussed for determining the canonical states and nonlinear state dynamics. The method is demonstrated on simulated data from a stochastic version of the Lorenz chaotic attractor.

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CP 4

Time-Discretization of Hamiltonian Dynamical Systems

Hamiltonian systems are used in a wide variety of applications ranging in scope from quantum mechanics to optimal control theory. Computational methods which preserve their special structure are, therefore, of considerable interest. In general, conventional numerical methods, such as the midpoint or trapezoidal scheme commonly used to integrate dynamical systems, do not conserve the Hamiltonian function of autonomous Hamiltonian systems. New difference equations for Hamiltonian systems are derived from a discrete variational principle. The equations completely determine piecewise-linear, continuous trajectories which exactly conserve the Hamiltonian function at the midpoints of each linear segment and exactly conserve, at the vertices, all conserved quadratic functions. The equations are equivariant with respect to a collection of symplectic, piecewise-linear, continuous coordinate transformations. For autonomous, positive-definite, linear Hamiltonian systems, the discrete equations have solutions identical to solutions obtained by the midpoint and trapezoidal schemes.

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Minimum horizon strategy in closed-loop predictive control

Open - and closed-loop predictive schemes are well known in process control. Main representatives are LQG and GPC, respectively. A special case can be obtained by employing a receding horizon strategy. The result: LQG=GPC. The advantages: 1.no a priori assumptions about the compensator structure,2.LQ-optimal analytic control projection,3.well understandable tunings + 4.good numerical behavior. The disadvantage:The interplay between the maximum output horizon and the control weighting can destabilize stable plants. The idea here is as follows: 1.a priori assumption of a 2 dof compensator structure,2.variable finite minimum output and control horizon,3.infinite maximum output and control horizon + 4.dynamic control weighting. The improvement: The interplay between the upper limit of the minimum output horizon and the control weighting does not destabilize any stable plant. Scope of presentation:1.robustness w.r.t. not well known plant order,2.numerical behavior of new predictive design.

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Fast Recursive SQP Methods for the Direct Solution of Optimal Control Problems

Direct Boundary Value Problem Methods, which use parameterized control functions and treat the discretized BVP as an equality-constraint in a large, nonlinear, constrained optimization problem, have proven very successful in solving nonlinear optimal control problems. In realistic applications thousands of variables can appear in the optimization problem. Its solution by dense SQP or trust region methods is therefore very slow. The talk addresses some problems of an efficient algorithm: high-rank structure-preserving updates to the block-diagonal hessian, a recursive block-sparse QP solver, parallelization on several levels. The numerical properties of the algorithm are demonstrated by applications from aerospace engineering and robotics.

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Relaxation of Optimal Control Problems via Linear Programming

We are concerned with the relaxation of infinite horizon, deterministic control problems by means of infinite-dimensional linear programs. The idea is to introduce a linear program (P) and its dual (P*). Under appropriate conditions we show that (P) is solvable and that (P) is V is the valued function. Moreover, there is no duality gap, i.e. sup(P*) = min(P).

We also present a discrete-time approximation scheme to obtain the optimal value min(P) = V.

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On LQ optimal controller

This paper presents an alternative to a LQ optimal control based on an input-output descriptiontion of the system. The resulting control law computes the control gain matrix recuirsively through the solution of the standard Riccati equation. But the state variables of the system which would be required to know in LQ optimal control, can be directly approached from the control and output variables of the system without measurement of the states or applying estimate techniques. In fact, this approch can be also viewed as another control algorithm for long-range predictive control.

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Application of Boltyanskii's Optimality Principle for Investigation of One Linear Discrete Problem with Mixed Constraints

Consider the problem

(1) $x(t) = x(t-1) + Au(t),\ t=\overline{1,N}$

(2) $x(0) = x^0 > 0$

(3) $Bu(t) \leq x(t-1),\ t = \overline{1,N}$

(4) $u(t) \geq 0$

Find the control u(t) and the trajectory x(t) satisfying the conditions (1)-(4) and maximizing the scalar product (c,x(t)). Here $c>0$ is a vector with non-negative coordinates and A,B are (m x n) matrices with non-negative elements.

Peculiarity and difficulty of problem under consideration are in mixed constraints containing control and trajectory.

Principle optimality by V.G. Boltyanskii is used for investigation of the problem. It is based on method of tents.

In the case of decomposable inequalities (3) the solving algorithm is given. Numerical example is given and it shows alternative opportunities of this algorithm.

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On the existence and Uniqueness for a Class of Optimal Control Problems

Problem area is an area of applied mathematics in which methods of functional analysis are used. Generalization of Porter's idea about minimum norm problem (W.A. Porter, Modern Foundation of Systems Engineering, Macmillan, New York, 1966) in locally convex linear topological spaces is not only important in theoretical sense, but also it has the advantage for application to distributive parameter systems. Moreover, in most of the practical problems, constraints on the control variable are not necessarily confined to amplitude constraint. They may be energy, power and area also. The concept of openness, continuity in locally convex linear topological spaces, Tychonov's theorem, Krein-Milman theorem and properties of adjoint or conjugate transformation are used to obtain the optimal control. From this idea one can seek control variable in any optimal control problem in any space in which a unit ball can be considered as a constraint set.

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The Final Net Demand Following Model of Time Varying Discrete-time Singular Dynamic Input-Output

The dynamic input-output model has recently received much attention of many economics and mathematicians since 1960, especially the optimization of the model. Many achievements have been obtained in the field. However the most results obtained in the past are discussed regarding this model as a normal system. Now we have known that it is a singular system practically. So in the paper, we discuss the optimal problem of this model as a singular system, obtain a circulate formula for the final net demand following model. Because the solution of singular discrete time-varying systems has not been obtained now, we give an algorithm of solving approximating solution which is optimal solution with meaning of this paper by using generalized inverse of matrix. A practical example verifies that the method of this paper is feasible.

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MS 18

Subspace Angle and Accuracy of Linear Prediction Equations

We consider the problem of resolving closely spaced sinusoids in a noisy environment using the least squares (LS) or total least squares (TLS) techniques for solving the linear prediction (LP) equations. It has been frequently observed in computer simulations that increasing the number of equations or augmenting the matrix in the TLS sense may improve the frequency estimates significantly. The accuracy of the frequency estimates is inherently related to the accuracy of the computed polynomial coefficients. We will focus on the accuracy of the polynomial coefficients in a noisy environment using the LS and TLS techniques. The analysis depends mainly on the result that the accuracy in the polynomial coefficients depend directly on a subspace angle. We examine how the noise, increasing the number of equations, or augmenting the system may reduce the sensitivity of the noise subspace, and thus provide improved estimation of the polynomial coefficients.

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The Effect of Interference on Recursive Least Squares Adaptive Equalization

Adaptive equalization is a technique used in communication receivers to compensate for channel-induced distortions. This presentation analyzes the effects of interference (narrowband, broadband, and correlated) on the operation of RLS adaptive equalization algorithms. It is shown that both the linear and decision-feedback RLS adaptive equalizers have a build-in capability to reject narrowband interference due to the embedded predictive filter in these equalizer structures. The predictive filter forms a narrowband notch centered at the interferer frequency. The notch bandwidth of the LMS and RLS equalizers is shown to be related to periodic non-Wiener terms in the weight misadjustment noise. Spatial processing is suggested as a method of enhancing the tolerance of adaptive equalizers to broadband interference.

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The Stability and Conditioning for the A Posteriori Recursive Least Squares Adaptive Filter

The concept of backward stability, borrowed from the field of numerical analysis, has recently proved to be a useful analytical tool for engineers studying the numerical behavior of *fast algorithms* such as the *fast* RLSL filter. A filter is said to be backward stable if the computed state is the exact realization for a slightly perturbed set of input data. The adaptive nature of the RLSL filter allows it to contract or expand to the rank of the underlying covariance matrix. The means with which this is controlled impacts filter performance. Conditions will be given that guarantee that errors propagating from stage to stage and in time will remain small.

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Unitary Hessenberg Methods for the Retrieval of Harmonics Problem

We consider a fundamental problem in signal processing: Signals ..., s_{-1}, s_0, s_1, s_2, ..., are approximated by a sinusoidal sum:

$$s_k \approx \sum_{j=1}^{n} \omega_j \cos(\theta_j k), k = 0, 1, 2, \ldots,$$

for some integer n, some frequencies $\theta_j, j = 1, \ldots, n$ and amplitudes $\omega_j, j = 1, \ldots, n$. This problem is known as the "retrieval of harmonics" problem in signal processing and as a nonlinear least squares problem in numerical computation. This paper gives a survey concerning how this nonlinear problem is treated in linear ways. There are basically two methods for solving this problem analogous to those for the linear least squares problem: the lattice method and the Toeplitz approximation method. Both methods lead to an eigenvalue problem for unitary Hessenberg matrices.

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MS 19

A New Matrix Decomposition for Signal Processing

A recurring matrix problem in signal processing concerns generalized eigenvalues:

$$A^H Ax = \lambda B^H Bx,$$

where the matrix B has full column rank. Often, the generalized eigenvalues, call them d_j^2's, satisfy this property:

$$d_1^2 \geq d_2^2 \geq \cdots \geq d_{p-k}^2 >> d_{p-k+1}^2 \approx \cdots \approx d_p^2 .$$

The k-dimensional subspace spanned by the eigenvectors corresponding to the k smallest generalized eigenvalues is called the noise subspace. We are interested in computing an orthonormal basis for this subspace. To solve the problem, we have developed a new matrix decomposition of A and B called the ULLVD. The principal advantage of the ULLVD is that it can be updated efficiently when new rows are added to A or B.

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Sanzheng Qiao
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Accurate Downdating of the Rank-revealing URV Decomposition

We introduce an accurate algorithm for downdating a row in the rank-revealing URV decomposition, which was recently introduced by Stewart. By downdating the full rank part and the noise part in two separate steps, the new algorithm can produce accurate results even for ill-conditioned problems. Such problems occur, for example, when the rank of the matrix is decreased as a consequence of downdating. Other possible generalizations of existing QR decomposition downdating algorithms for the rank-revealing URV downdating are discussed. Numerical test results comparing the performance of these new URV decomposition downdating algorithms in the sliding window method are presented.

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Another Homotopy Method to Solve the Symmetric Tridiagonal Eigenvalue Problem

When computing the spectral decomposition of an irreducible symmetric tridiagonal matrix T by a homotopy method one defines a family of eigenvalue problems

$$T(t)\mathbf{x}(t) = \lambda(t)\mathbf{x}(t), \qquad 0 \leq t \leq 1,$$

such that $T(0)$ is a matrix with known or easily computed eigenvalues and eigenvectors and $T(1) = T$. The idea is then to track the eigenvalue curves $\lambda_k(t)$ and the corresponding eigenvectors as t is running from 0 to 1.
We define $T(0)$ to be a tridiagonal matrix with one pair of zero off-diagonal elements such that $T(1) - T(0)$ has rank one. This implies that the eigenvector curves increase or decrease monotonically. The eigenpairs $(\lambda_k(t), \mathbf{x}_k(t))$ are tracked (in parallel) by Rayleigh quotient iterations.

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Solution of Periodic Lyapunov Equations via the Periodic Schur Form

In this talk we present a new algorithm for computing the steady state solution of periodic Lyapunov equations

$$P_{i+1} = A_i P_i A_i^T - B_i B_i^T, \text{ where } A_i = A_{i+K},\ B_i = B_{i+K}$$

The method makes use of the periodic Schur form of the matrix sequence A_i, $i = 1, \ldots, K$ and then uses similar backsubstitution techniques to the Bartels and Stewart or Hammarling methods for the standard Lyapunov equation. The method also extends to the implicit Lyapunov equation

$$E_i P_{i+1} E_i^T = A_i P_i A_i^T - B_i B_i^T, \quad \text{where } A_i = A_{i+K},\ B_i = B_{i+K},\ E_i = E_{i+K}$$

by using the periodic Schur form of the sequence A_i, E_i, $i = 1, \ldots, K$.

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MS 20

Dynamic Condition Estimation and Rayleigh-Ritz Approximation

We show that the well-known Rayleigh-Ritz approximation method is applicable in dynamic condition estimation. In fact, it can be used as a common framework from which many recently proposed dynamic condition estimators can be viewed and understood. This framework leads to natural generalizations of some existing dynamic condition estimators as well as more convenient alternatives. Numerical examples are also provided to illustrate these claims.

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A Spectral Approach to Sparse Matrix Orderings

The efficient factorization of a sparse matrix requires the computation of an ordering for the numerical factorization step. In the context of parallel computation, a good ordering leads to fast computation of the numerical factorization by maintaining load balance, reducing communication costs, and preserving sparsity in the factors. We describe *spectral nested dissection*, an ordering scheme that employs spectral information from the Laplacian matrix associated with the original matrix. Our experimental results on practical problems show that this spectral method effectively reduces factorization time in a parallel environment. Theoretically, we describe relationships between the separator size and eigenvalues of the Laplacian, and analyse spectral partitions for some classes of problems. We also analyse a spectral algorithm for the envelope reduction problem in sparse matrices, a problem of interest in the engineering disciplines.

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Stable Fast and Superfast Algorithms for Nonsymmetric Toeplitz Systems

It has been known for a long time (Levinson, 1947; Durbin, 1959; Trench, 1964; Bareiss, 1969; and others) that an $N \times N$ Toeplitz system can be solved fast, in $O(N^2)$ operations. More recently, superfast $O(N \log^2 N)$ algorithms were found (Musicus, 1984; de Hoog, 1987; Ammar and Gragg, 1986-88). However, these algorithms require a strongly regular matrix; i.e., one whose leading principal minors are all nonzero. In the last ten years, a number of authors have overcome this limitation by devising algorithms that can cope with exactly singular principal minors but are still unstable when near-singular ones occur. We have developed several Levinson and Schur type algorithms that can cope with arbitrary non-Hermitian Toeplitz matrices in a stable way, and which are still fast or even superfast as long as the number of successive near-singular leading principal minors remains limited.

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Accurate Least Squares Solutions for Toeplitz Matrices

We consider the QR decomposition method for an $m \times n$ Toeplitz matrix by Bojanczyk, Brent, and de Hoog (BBH). This method requires $O(mn)$ flops and the R factor is computed recursively by solving a sequence of updating and downdating problems. We modify the BBH algorithm and remove half of the downdating by using orthogonal transformations. Furthermore, we monitor the conditioning of the downdating problems, and use the method of corrected semi-normal equations (CSNE) to obtain higher accuracy for ill-conditioned downdating problems. Numerical experiments show that the new algorithm improves the accuracy significantly while the computational complexity stays essentially in $O(mn)$.

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Synchronous and Asynchronous Parallel Two-stage Block Iterative Methods for Linear Systems

Two-stage Block Iterative methods for the parallel solution of linear systems of the form $Ax = b$ are discussed. These are block iterative methods in which the linear system corresponding to a diagonal block at each (outer) iteration is solved in turn by an (inner) iterative method. The number of inner iterations may vary from block to block and from one outer iteration to another. In the asynchronous method, each processor (corresponding to a different block) does not wait for new information from all other processors, with the potential of accelerating overall convergence. Under general conditions, convergence is shown for the algorithms. Numerical experiments are also presented.

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MS 21

Numerical Methods for the Computation of An Analytic Singular Value Decomposition of a Matrix Valued Function

An analytic singular value decomposition (ASVD) of a path of matrices $E(t)$ is an analytic path of factorisations $E(t) = X(t)S(t)Y(t)^T$ where $X(t)$ and $Y(t)$ are orthogonal and $S(t)$ is diagonal. The diagonal entries of $S(t)$ are allowed to be either positiv or negativ and to appear in any order. For an analytic path matrix $E(t)$ exists an ASVD, but this ASVD is not unique. We describe the freedom of choice in constructing an ASVD and present different approaches to resolve this freedom to get new numerical methods for the computation of unique ASVD's.

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Structure Preserving Interpolation for Smooth SVD-Paths

We consider a new approach to approximate Svd-pathes of matrices A(t). These approximations interpolate discrete Svds $A(t_i) = U_i S_i V_i^T$ in such a manner, that the factors $\tilde{U}, \tilde{S}, \tilde{V}$ of the interpolating pathes are automatically orthogonal resp. diagonal. The idea is to represent the orthogonal factors U_i, V_i as rotations. Further I show a theorem about convergence and the order of approximation. Finally, numerical results for the special cases of cubic splines and Hermite splines are presented.

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MS 21

Speaker: Simon Bell

Abstract has not reached the SIAM office at press time.

Numerical Solution of Differential Equations for the ASVD of a Matrix

Given a matrix smoothly dependent on some parameter t the possibility of the existence a a similarly smooth singular value decomposition has been considered in [1]. There the concept of an analytic singular value decomposition (ASVD) is introduced. In [2] differential equations for such a decomposition were derived. Some preliminary results on their numerical solution presented in [2]and [3].

This paper considers the solution of these differential equations using piecewise Gaussian collocation or equivalently Gaussian implicit Runge-Kutta formulae. These methods give rise to the solution of a set of non-linear equations at each step. In [3] it is noted that full Newton Linearization is very expensive and simple iteration is unreliable near equal modulus singular values. Here a number of alternative approaches to this problem are considered.

Some consideration is also given to the construction of step-adjustiong methods based on theses formulae, and the possibility of obtaining spurious solutions.

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CP 5

On Some Matrix Completion Problems Arising in Metabolic Control Analysis

An objective of Metabolic Control Theory is to calculate the control coefficients of the enzymes in a metabolic pathway by inverting a matrix of elasticity coefficients. However, since some of the elasticity coefficients are often difficult and even impossible to measure experimentally, a pragmatic approach for studying the control properties is to measure some of the elasticity coefficients and some of the control coefficients, and calculate the remaining elasticity coefficients and control coefficients using Metabolic Control Theory. I will discuss the underlying mathematical problem which consists of completing the elasticity matrix E and the control matrix E^{-1} when each of these matrices is only partially known.

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On Equalities in Symmetric Eigenvalue Inclusion Theorems

In this paper we study about the cases of equalities in several symmetric eigenvalue inclusion theorems including the Weyl's inequalities and the Cauchy's Interlace theorem and more. It turns out that in all cases equalities can be characterized in terms of suitable conditions on eigenvectors. Our results find applications on the refinements in symmetric eigenvalue inclusion theorems in the case of unreduced tridiagonal matrices. Our results give a unified viewpoint of such refinements.

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On the Inertia of the Polytopes and Cones of Matrices

Suppose P is a polytope and C is a cone in the nxn-dimension Euclidean space of all the nxn real matrices. Here, P and C are formed by nxn real matrices. A matrix A is said to have the inertia (r,l,t) if A has r eigenvalues on the open right complex plane, l eigenvalues on the open left complex plane and t eigenvalues on the imaginary axis. In this paper, we have proved that all the matrices in a polytope P have the same inertia (r,l,t) if and only if there exists an integer k such that all the matrices in every k-dimension faces of P have the inertia (r,l,t). If C is a relative closed, pointed polyhedral cone of nxn matrices, then all the matrices in C have the same inertia (r,l,t) if and only if there exists an integer k such that all the matrices in every k-dimension faces of C have the inertia (r,l,t). Also, some inertia inequalities and some inertia stabilities are discussed in this paper.

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Gohberg-Semencul Formula Generalized to Krylov Matrices

Krylov matrices with structured generators include many of the usual structured matrices as special cases: circulant, Toeplitz, Hankel, Vandermonde, Cauchy, Leslie-Toeplitz, r-Toeplitz, and Bezoutian, to name a few. We give a new formula for the inverse of a Krylov matrix. In the case of a Toeplitz matrix, our formula specializes to the Gohberg-Semencul formula for the inverse of a Toeplitz matrix.

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Differential Properties of the Spectral Abscissa and the Spectral Radius for Analytic Matrix–Valued Mappings

We define and study a directional derivative for two functions of the spectrum of an analytic matrix-valued function. These are the maximum real part of the spectrum (the spectral abscissa) and the maximum modulus of the spectrum (the spectral radius). Results are first obtained for the roots of polynomials with analytic coefficients by way of Puiseux-Newton series. In this regard, the primary analytic tool is the Puiseux-Newton diagram. These results are then translated into the context of matrices. Precise results are obtained when the eigenvalues that achieve the maximum value for the function under consideration are all either semisimple or nonderogatory. In the general case a lower bound for the directional derivative is given which, in particular, describes those directions in which the directional derivative attains an infinite value.

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Variational Analysis of an Extended Eigenvalue Problem

For a symmetric matrix $B \in R^{n \times n}$ and a vector $a \in R^n$, the maximal extended eigenvalue

$$\lambda(a) := \max\{\lambda : \exists x \in R^n \text{ s.t. } (B - \lambda I)x = a, \ x^t x = 1\},$$

is known to arise in optimality conditions for the mathematical programming problem $P(a)$ given by

$$\max\{x^t Bx - 2a^t x : x^t x = 1\},$$

as well as in extended Rayleigh-Ritz type results pertaining to the one parameter family of nonsymmetric border perturbations of B given by

$$A(t; a) := \begin{pmatrix} B & a \\ -a^t & t \end{pmatrix}.$$

Nonsmooth analysis is employed in order to describe the function $\lambda(\cdot)$, with special emphasis on its sensitivity near the origin. Further connections with $P(a)$ are drawn.

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Leverrier's Algorithm for Orthogonal Polynomial Bases

Determination of the characteristic polynomial $a(\lambda) = \det(\lambda I-A)$ and the matrix $B(\lambda) = \mathrm{adj}(\lambda I-A)$ for a given square matrix A has many applications in linear control theory. The well-known algorithm attributed to Leverrier and others allows simultaneous computation of $a(\lambda)$ and $B(\lambda)$. A new extension is presented whereby $a(\lambda)$ and $B(\lambda)$ can be derived relative to any basis of orthogonal polynomials which satisfy a standard three-term recurrence relation. Closed form expressions are given for the cases of Chebyshev, Hermite, Legendre and Laguerre polynomials. Some additional properties of the algorithm peculiar to the Chebyshev case are also obtained.

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Embedding Line in the Plane Through Resultants

By means of classical Sylvester resultants and minimal polynomials, we prove

Theorem 1. Let K be a field and let $u(t), v(t) \in K[t]$, where $\mathrm{char}(K)$ is not a divisor of $\mathrm{gcp}(\deg(u(t)), \deg(v(t))$. Then
(1) $K(t) = K(u(t), v(t))$ if and only if $\mathrm{Res}_t(\frac{u(t)-u(s)}{t-s}, \frac{v(t)-v(s)}{t-s}) \neq 0$.
(2) $K[t] = K[u(t), v(t)]$ if and only if $\mathrm{Res}_t(\frac{u(t)-u(s)}{t-s}, \frac{v(t)-v(s)}{t-s}) \in K^*$.
(3) Let $\mathrm{Res}_t(\frac{u(t)-u(s)}{t-s}, \frac{v(t)-v(s)}{t-s}) = c\prod_{i=1}^m (s - s_i)^{n_i}$.
Then $(u(s_i), v(s_i)), i = 1, \ldots, m$ are all singularities (with multiplicities n_i) of the curve $x = u(t), y = v(t)$.

By using Theorem 1, we obtain a very simple proof of the following fundamental theorem.

Theorem 2. (Embedding line in the plane)
Let K be a field and let $u(t), v(t) \in K[t]$ such that $K[t] = K[u(t), v(t)]$, where $\mathrm{char}(K)$ is not a divisor of $\mathrm{gcp}(\deg(u(t)), \deg(v(t))$. Then there exist $f(t, s), g(t, s) \in K[t, s]$ such that $K[t, s] = K[f, g]$ and $f(t, 0) = u(t), g(t, 0) = v(t)$.

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Properties of Some Rational Function Matrices

A matrix is called a rational function matrix (RFM) if each entry in the matrix is a rational function in independently variable parameters. Very little is known about the properties of RFMs. Thus studying the reducibility,separability,etc.,of some RFMs is of mathematical significance. Also,it is of phsical significance since such the RFMs can describe many physical systems such as RLC networks very accurately. So,the results obtained can be directly applied to engineering.

The speaker will describe new results to reducibility and separability of some RFMs and their applications.

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Roundoff Errors and Graphs

Roundoff error analysis is one of the most important things in the design of numerical algorithms. There are two principle ways to estimate the error propagation, i.e. backward and forward analysis. The backward analysis developed by J.H. Wilkinson is only an idea, and doesn't show us how the equivalent perturbations are defined. In this talk a constructive method for doing backward analysis is described briefly. Using this method a class of algorithms is given for which the relative equivalent perturbations don't depend on data. Some examples are represented.

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CP 6

A QR-Based Factorized Fixed-Interval Smoother

The paper addresses the problem of optimal fixed-interval state smoothing in linear dynamic systems. Fixed-interval smoothing is an important area in state estimation, which has many off-line applications. The existing fixed-interval smoothers include the classic, non-factorized Rauch-Tung-Striebel and Bryson-Frazier algorithms, and the factorized algorithms recently introduced by

Bierman [Automatica, Vol. 19, No. 5, 1983, pp. 503-511], Watanabe [Automatica, Vol. 22, No. 4, 1986, pp. 465-475] and McReynolds [IEEE Trans. AC, Vol. 35, No. 10, 1990, pp. 1181-1183]. The proposed algorithm combines an existing forward recursive V-Lambda square root filter [Oshman, J. Guidance, Control and Dynamics, Vol. 12, No. 5, 1989, pp. 681-690] and a new backward recursive QR-based smoothing scheme. The new algorithm avoids hazardous covariance matrix subtraction and features excellent numerical stability characteristics.

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The Condition Number Estimation for RLS in Signal Processing

In this paper, we discuss a method to monitor the condition number for recursive least square problems in signal processing. We compare our method with other methods for estimating the condition number in rank one updates and show that our method performs favourably in comparison.

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Condition Estimation for Matrix Functions via the Schur Decomposition

In control theory and other settings one needs to compute function of s matrix. We show how to cheaply estimate the Frechét derivative and the condition number for a general class of matrix functions (the class includes the matrix sign function and functions that can be expressed as power series) via the Schur decomposition. In the case of the matrix sign function we also give a method to compute the Frechét derivative exactly. We also show that often this general method based on the Schur decomposition when applied the matrix sign function and the matrix exponential enables one to compute the function and estimate its condition number more cheaply than the various special techniques that exploit special properties of these two functions.

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A Strassen-Type Matrix Inversion Algorithm

We describe a recursive matrix inversion algorithm similar in spirit to Strassen's matrix multiplication algorithm. When full recursion is used, the complexity of the algorithm is $O(n^{\log_2 7})$. More important on SIMD parallel computers, however, is the algorithm's homogeneity and its high level of data-parallelism. The algorithm is potentially unstable for general matrices, but we show how a simple stabilization technique, combined with a few steps of iterative refinement, makes the algorithm a competitor to existing algorithms for solution of systems of linear equations of SIMD computers. Timing results on a Connection Machine CM-200 are also presented.

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Parallel Orthogonal Triangularization on the Supernode Multicomputer

Matrix orthogonal triangularization is one of the most common and useful operations in Numerical Linear Algebra. In recent years several authors have designed parallel algorithms to perform this operation on shared and distributed memory multiprocessors. The basic goal of our work is the implementation and evaluation, on a Supernode multicomputer, of several parallel algorithms for triangularizing a matrix by using Householder Reflections and Givens Rotations. The work includes comparisons between the two above mentioned transformations and the utilization of two parallel languages: OCCAM-2 and Parallel C. A complete study of the experimental performances of all the algorithms are presented.

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A Graph-theoretic Algorithm for the Decomposition of the Computation of Zeros of Large-Scale Control Systems

The zeros of multivariable control systems are important in many aspects of control theory. The problem of reliable computation of these zeros is still open for large-scale systems. We present a new graph-theoretic algorithm which proofs whether the computation of zeros can be decomposed in several smaller parallelizable problems. If this question can be answered with yes the algorithm yields the corresponding decomposition. The algorithm will be illustrated by a 19-order model of a technical plant with 3 in- and outputs. For this model the algorithm gives the result that the computation of zeros can be split into 2 eigenvalue and 3 zero problems with a maximum order of 5. After the decomposition these 5 problems can be solved parallel which requires only 5 per cent of the computing time of the original problem. Furthermore, the number of the exact digits of the results can be increased up to 7. It is remarkable that for this model the eigenvalue problem is not decomposable.

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Eigendecomposition Based Partitioning of DSP Graphs for the Processor Assignment Problem in Multiprocessor Systems

The problem being addressed is partitioning DSP graphs *optimally* with the objective of assigning different partitions to different processors, thereby enhancing an overall problem-specific performance criteria. In the processor assignment problem, partitioning is important in order to attain load balancing and minimization of inter-processor communication costs. When several processors cooperate to solve computationally intensive tasks, the above two factors are critical considerations. Among several approaches commonly used for the partitioning problem are the Kernighan & Lin algorithm, its modification proposed by Fiduc-

cia & Mattheyses and the Ratio Cut partitioning approach. All these algorithms are graph theoretical approaches. Pothen, Simon & Liou have suggested a partitioning approach based on eigen decomposition of the associated graph matrix. The computations in this approach comprise of matrix-vector operations and are easily parallelizable for large problems. We modify this approach using not merely the cardinality of nodes in the partitioned subset, but the operation complexity of a DSP task as the partitioning metric. This in turn influences the load balancing criterion as tasks of nearly equal computational complexity are assigned to the different processors. We describe our formulation and implementation of the problem and show the partitioning results for some representative DSP graphs.

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Block-Cyclic Dense Linear Algebra on the Connection Machine CM-5

LU factorization, QR factorization, and tridiagonalization are all dense linear algebra elimination based routines. Efficient implementation of these on distributed memory architectures is important for many applications.

A method for using block-cyclic elimination order was presented by Lichtenstein and Johnsson [Tech. Rep. TMC-215, Thinking Machines Corp., 1992]. This method is adjusted for the Connection Machine CM-5 and improved by decreasing the number of excess computations while blocking the communication to exploit an increase communication bandwidth.

The improved method and results from an implementation are presented. One result is 45+ GFlops peak performance for Gaussian elimination with partial pivoting.

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POSTER

Algebraic Approach to Projection Data Informativity

Algebraic reconstruction techniques are widely used in computerized tomography. They provide a powerful means of image reconstruction from irregular projection data. Quality of the image reconstructed depends on projection matrix structure and right-hand side projection data informativity. Features of this dependence are subject of the work. It is shown, that there exists an uncertainty relation between information content of projections and reconstruction problem well-poseness. Algebraic approach to finding of Radon transform informative domains is suggested. Applications of the uncertainty level knowledge to image reconstruction from few projections are considered.

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Nonstationary Signal Filtering by an ARX-Model

This paper presents a new method for filtering two kinds of typical nonstationary signals in industrial processes, ramp and step signals with noises. Using a linear transformation and the least squares method two interesting properties of a special ARX model are derived. They describe relations between estimated parameter values of such ARX models at different operating points. On this basis a filtering algorithm is developed. In comparison with normal filtering methods this algorithm is less sensitive to noises and the filtering precision is, to a certain degree, independent of model orders and the data window width.

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Circular Pole Assignment for Descriptor Systems

The problem of circular pole assignment for continuous-time descriptor systems is considered. The goal of the problem is to assign the maximum number of finite eigenvalues in a prespecified circle and guarantee the closed-loop regularity. A simple, effective "generalized Riccati equation approach"is developed to solve the addressed problem. It is shown that a desired state feedback control law is determined by using the "negative" definite solution of a "standard discrete Riccati equation" which can be computed directly. The proposed technique is well suited for the requirements of robustness against large parameter variations, sensor failures, and gain reduction etc..

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An Application of Matrix Generalized Inverses to Optimal Control Problems of Linear Time-Invariant Discrete-Time Systems.

Consider the time system $Ex(k+1) = Ax(k) + Bu(k)$ where E is a singular square matrix. It is assumed that the system is either a priori regular or it is regularizable by a feedback law of the form $u(k) = Ky(k) + V(k)$. The problem is this: Find and input sequence which will drive $x(k)$ from a given $x(0)$ to a desired "final vector" $x(N)$ in a given number of steps N while minimizing the cost.

$$\sum_{k=1}^{N-1} [x(k) - x(N)]^T Q [x(k) - x(N)] + \sum_{k=0}^{N-1} u(k)^T R u$$

The novelty of this paper's approach is the use of singular-value decomposition and of weighted generalized inverses.

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Eigenstructure Assignment by Proportional Plus Derivative Output Feedback in Singular Systems

Some results on the eigenstucture assignment by state feedback in singular systems have been made recently. Because the state vectors can't be measured directly, the eigenstructure assignment by output feedback seems to be more important than that by state feedback. So we investigate this problem by proportional plus derivative output feedback in this paper, obtain an explicit expression of the closed loop eigenvectors on the closed loop eigenvalues and a set of parameters. This method can not only provide a complete parametrization of closed loop eigenvectors, but also make the closed loop eigenvalues participating in corresponding optimal problem together with the closed loop eigenvectors. The results of this paper establish the basis for further designing Robust controller in singular systems.

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Fast Integral Manifold for the Singularly Perturbed Filtering Problem over Discrete-Continuous Observations

The present work continues the investigation started in [1]. Using the defined transformation, as in case of continuous observations, the initial problem is decoupled into the "slow" and "fast" subproblems.

We construct the Kalman-Bucy filter for "fast" subproblem, show that the solution H of the "fast" filtering system can be found as asymptotic expansion with respect to small parameter and also, we obtain the exact expression for H and its estimation. The above result, in principle, enables us to obtain the solution of the initial filtering problem with any degree of accuracy.

[1] Navarova N.Ye., Orlov Yu.V. Decomposition of the Singularly Perturbed Filtering Problem with Discrete-Continuous Observations//Proceedings of the International Conference on Systems Sciences, Wroclaw, Poland, p.102-103, 1992.

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Potentially Stable Tree Sign Patterns with Five Vertices

The problem of characterizing potentially stable sign-pattern matrices remains unsolved. This presentation is about potential stability of sign pattern matrices whose undirected graphs are trees (tsp's). Potentially stable tree sign patterns have been enumerated, up to size four, by C. R. Johnson and T. A. Summers. Our goal is to enumerate and characterize those tsp's with five vertices. Our main tool will be a computer program capable of generating all possible tsp's and corresponding matrix representations.

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A Closed Range Theorem for the Frobenius-Perron Operator and and Its Application to the Spectral Analysis

We use the functional analysis technique and the probability theory to obtain some general results for the Frobenius-Perron operator $P_S : L^1(X) \rightarrow L^1(X)$ and the Koopman operator $U_S : L^\infty(X) \rightarrow L^\infty(X)$ associated with a nonsingular transformation S in a σ-finite measure space X. As an application of thses results, we give necessary and sufficient conditions for P_S and U_S to be isometric, respectively, and the complete spectral analysis in this case is presented, which is important in the convergence rate analysis of the current numerical methods for computing absolutely continuous invariant measures.

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On Some Formulas for Transfer Junctions and Impulse Transfer Functions

For the zeros of sampled-data systems little knowledge is available at present. For example the transfer function of a controllable and observable continuous-time system and the impulse transfer function of its discrete-time counterpart may have different numbers of zeros. In order to find some useful approach to the question several formulas for transfer functions have been derived. For a strictly causal continuous-time SISO system which does not have poles at the origin the transfer function may be expressed as g(o) det(SE-A)/det(SI-A) (if g(s) does not vanish at the origin) where E is an idempotent matrix defined by the inverse of A and b,c. A relevant formula is obtained for the discrete counterpart of the system. Then, relations between coefficients of the numerators are examined and some conclusions concerning zeros are obtained.

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Maximum Likelihood Estimation of Signal to Noise Ratio for High Sampling Rates

Conventional techniques for maximum likelihood estimation of signal to noise ratio employ a single sample of the matched filter per symbol period. For Binary Phase Shift Keying, our approach involves convolving the incoming signal with a set of orthogonal functions and sampling each convolution many times over a symbol period to produce a vector of samples from each convolution (or matched filter). However, consecutive samples from each convolution are correlated. We combine the samples from the different convolutions to produce a new vector of samples that are mutually uncorrelated. A probability distribution is then calculated from these samples conditioned on signal energy and noise. The probability distribution is used to generate maximum likelihood estimates of energy and noise. These functions are transcendental, and hence, are solved using either iterative techniques or alternatively a neural network approximator to give an estimate for energy and noise. The resulting values are subsequently used to estimate the signal to noise ratio.

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TLS-Based Iterative Prefiltering Technique for ARMA Modeling

Modeling time-series with linear pole-zero AutoRegressive-Moving Average (ARMA) models has numerous applications in signal processing. This problem is in gene ral non-linear and most ARMA modeling techniques are iterative in nature. The Iterative Prefiltering (IP) method has the advantage of computing a nonminimum phase representation. The original IP minimization procedure is an ill-conditi oned problem which has classically been solved using a Least Squares approach.

This work shows that improvements in the modeling performances may be obtained by using a Total Least Squares approach in the IP method when modeling noisy signals.

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CODED INPUT NEURAL NETWORK

The capability of linear classifiers, in particular single layer Neural Networks, is improved by increasing the input signal space. The maximum input signal space dimension to implement a given nonlinear mapping is studied. A new technique to reduce the number of redundancy is also proposed. Several examples including computer simulation results are presented for illustration.

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Quadraric Stability Recorvery via an Observer for Systems with both Structural and Unstructural Uncertainties

The quadratic stabilization approach seems to be effective to robust stabilization problem for linear systems with structural uncertainty. However, quadratic stabilization problem for systems with unstructural uncertainty which is described in frequency domain has not been fully discussed.
In this paper, we will show that the quadratic stabilization problem for linear system with both uncertainties, time-varying parameter perturbation and frequency domain uncertainty, can reduced to H_∞ standard problem with a scaling parameter. And we propose a asymptotic recovery method via on observer to recover the quadratic stability of the system, if there exists a state feedback gain matrix such that the system is quadratic stable for bounded time-varying parameter perturbation and frequency domain uncertainty and the state is unmeasurable. An design example is given.

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Advanced Method for Optimal Control

Disclosure is made of a self-optimizing control system for an object with a unimodal quality function. The system which was early under review are disadvantageous in theirs limited accuracy. It is an object of the present work to improve the accuracy and response of optimal control systems.

There is known optimal control systems comprising a search signal generators to ensure maximum output of such energy sources as solar batteries, MHD generator, etc. However, the control signal in the system under review are disadvantageous in its limited accuracy of control due to the presence of noise, and its relatively low response due to the presence of the averaging filter intended for noise suppression, which, quite naturally, operates with a certain time lag.

The system is patented in USA No. 4179730.

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An Inverse Problem in Laser Confocal Scanning Microscopy

We will consider two dimensional convolution equations

$$Ku = \int k(\mathbf{x} - \mathbf{y})\, u(\mathbf{y})\, d\mathbf{y} = g$$

which arise in confocal scanning microscopy. The kernel k characterizes various blurring effects such as diffraction. These problems are highly ill-conditioned, extremely large, and the desired solution u is often not smooth. We will examine several numerical techniques which effectively deal with these difficulties.

Mary Oman
Curtis R. Vogel
Department of Mathematical Sciences
Montana State University

A Band-Limited Signal Extrapolation by a Sequence of Points

In this paper, an extrapolation scheme is given to extrapolate a bind-limited signal f(t) ($t \in R$) by the given values of f(t) on a sequence of points x $x_n \in [-T,T]$ with T > 0 and $\{x_n\}^\infty$ has limiting points.

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MS 22

Checking Linear Algebra Computations

Under reasonable assumptions, a program that successfully passes t random tests can be expected to fail on the next test with probability approximately $1/t$, so it's mean time to failure is approximately t runs. The dilemma for testing is to ensure that a program will work properly for much longer than it has been tested. "Result checking" is a method for ensuring that a program that successfully passes t tests will have a mean time to failure of approximately t^2 runs. Definitions, theorems, and examples will be presented in the context of linear algebra.

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COMPLEXITY OF APPROXIMATE SOLVING OF LARGE LINEAR SYSTEMS

We survey recent complexity results for solving large linear systems and for approximate computing of extreme eigenvalues of large symmetric matrices. In particular, we discuss optimality properties of Krylov information and the Lanczos algorithm with random starting vectors.

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Adam W. Bojanczyk
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Complexity of Parallel Matrix Computations

We review the parallel complexity of fundamental computations with general, sparse and special matrices, including computations with matrices of Toeplitz, Hankel, Vandermonde and generalized Hilber types and their correlation to computations with general matrices. We cover some general techniques of parallel computations and their applications to improving matrix computations.

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Self Testing/Correcting Linear Algebra Computations

Suppose someone gives us an extremely fast program P that we can call as a black box to compute a function f. Should we trust that P works correctly? A *self-testing/correcting pair* for f allows us to: (1) estimate the probability that $P(x) \neq f(x)$ when x is randomly chosen; (2) on *any* input x, compute $f(x)$ correctly as long as P is not too faulty on average. Furthermore, both (1) and (2) take time only slightly more than the original running time of P.

We present general techniques for constructing simple to program self-testing/correcting pairs that apply to a variety of functions, including matrix multiplication, matrix inversion, matrix determinant, matrix rank, integer multiplication, and integer division.

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MS 23

Computational Algorithm for the Two-Block H^∞-Problem for Distributed Parameter Systems

Solving H^∞-control problems for unstable systems with an infinite number of states is a topic of current research. This talk presents a computational algorithm based on operator theoretic methods for solving H^∞ control problems for unstable, linear, time invariant, distributed systems. Examples are presented that illustrate a MATLAB implementation of the algorithm.

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Computation of H^∞ Controllers with Numerical Approximations

The most basic H^∞ control problem is weighted sensitivity minimization. The assumption that a sequence of approximations converge to the infinite-dimensional plant in the graph topology does not imply convergence of the optimal sensitivity, or of the corresponding controllers, even when all plants are stable. The mixed sensitivity problem arises when sensitivity is being reduced in conjunction with a robustness constraint. If the original plant is stable, uniform convergence of the transfer functions implies that the optimal mixed sensitivities converge. Many, but not all, common approximation schemes satisfy this convergence condition. Furthermore, in this case it is possible to construct a sequence of finite-dimensional controllers which stabilize the original plant for large enough model order, and a level of performance arbitrarily close to the optimal performance can be achieved by a finite-dimensional controller. For a unstable plant, the four-block problem must be used. In this paper convergence proofs will be presented, along with numerical results.

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CANADA

Parametrization of Suboptimal H^∞ Controllers for Unstable Distributed Plants

We consider two block suboptimal H^∞ control problem for unstable infinite dimensional plants. We obtain a new characterization for all suboptimal controllers using Adamjan-Arov-Krein theory and recent results of Özbay Smith and Tannenbaum. We show that in this parametrization one has to compute two spectral factorizations from the weighting functions, and one rational function (whose order is fixed and depends on the order of wights) from certain interpolation conditions. We present computer programs (written in C, and in MATLAB commands) for numerical evaluation of these rational functions. Examples from delay systems and flexible beam applications are given.

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Approximating Frequency Response Data in MATLAB

A recently developed MATLAB based software package for fitting a transfer function model to frequency response data will be described. Finding a close fit to frequency response data is often the first step in designing a feedback control system. Once an adequate mathematical model is known various techniques of analysis and design can be used to realize a feedback control system to meet performance specifications.

Given reasonably accurate magnitude and phase information over the normal operating frequency range (signature on $j\Re$) the data is then interpolated onto the unit circle and then expanded into a Fourier series in terms of the usual basis using FFT based calculations. Using singular value decomposition techniques it is then possible to access the importance of various couplings and do a model reduction to extract the essence of the data in transfer function form. The software is convenient to use and computationally well behaved. Experience with the software including its use in transfer fitting to gain and phase constraints as well as its use in finding adequate finite dimensional controllers for certain infinite dimensional linear system will be reported.

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MS 24

Systems Theory and Global Chance Research

Global change research is predicated on the view of the globe as a system. Yet in actual research, such as modeling of global change phenomena, this view is not taken explicitly into account. Bridging the gap between systems theory and global change research will yield benefits to both sides: the results from systems research could be applied in addressing the global change problems and, conversely, new problems could be formulated for systems theory research. Global coordination of national greenhouse gases emission reduction policies will be presented as a case study.

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An Integrated Conceptual Model of the Earth Climate System: Modeling Complexity and Challenges

A formal interpretation of the global climate change system is attempted from a Systems Science perspective. This is done with the hope that the crossfertilization between "systems science" on one hand and the important "global issues" on the other, will lead to a better understanding of, and perhaps solution to many outstanding problems on the global side, while simultaneously advancing theoretical and methodological approaches on the systems side. In this first step, we propose a systems model of the global climate change system in terms of inputs, outputs, states and transfer functions when possible. A short list of important and open systems problems in climate change area is presented.

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A Stochastic Approach for Assessing the Effect of Changes in Regional Circulation Patterns on Local Precipitation

A stochastic model is described that allows transfer of information from General Circulation Models to precipitation gage locations using a weather state classification scheme. The weather states, which are based on present and previous day's sea-level pressure, are related stochastically to gage daily precipitation and temperature. Weather states are defined to give maximal separation of test station precipitation distributions using the CART (Classification and Regression Trees) procedure. Precipitation amounts are resampled from historical observations, conditional on the weather state and the previous day's rain state. Daily temperature maxima and minima are simulated by conditioning on the present and previous day's rain state, with the residual modeled as an AR(1) process. The model parameters are estimated using nine years (1965-73) of concurrent National Meteorological Center (NMC) gridded observations and four precipitation stations in the Columbia River Basin. The model is illustrated using both historical NMC gridded observations of sea level pressure and lower atmosphere temperature, as well as the same variables from the GFDL General Circulation Model for present climate and CO_2 doubling. A 40-year sequence of simulated precipitation and temperature is used to estimate seasonal streamflows and flood frequency distributions under present and doubled CO_2 climates.

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Risk Analysis: An Application on Shoreline Management to the Great Lakes Under Climate Change Uncertainty

Coastlines on the Great Lakes naturally erode and are subject to flooding events. The rate that the shore erodes is a function of water levels, wave action, coastal geomorphology (onshore and offshore), and level of man-made shore protection. Inevitably development along the shoreline is subject to property damages. Property owners pursue various methods to alleviate damages. Structural shoreline protection methods include seawalls, jetties, breakwaters, as well as, flood-proofing buildings and elevating buildings. Non-structural methods are essentially land-use controls, either regulatory or incentive-based. Better understanding of shore processes and economics of shoreline damages have led managers to try to encourage owners to employ non-structural methods over structural methods. Even so, structural shore protection is still a viable option where other land-use controls are not applicable, for example, a highly developed urban area.

Climate change could potentially decrease the expected benefits of structural methods, because of lower mean lake levels. However, a reduction of ice cover due to higher temperatures under climate change could expose shores to wave attack of severe winter storms, thereby increasing the benefits of structural methods. This study seeks to apply risk analysis to assess whether decisions concerning structural shore protection that are made now are affected by the uncertainty of climate change. I propose decision trees combined with multi-criteria decision analysis to identify the uncertainties which most affect decisions.

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MS 25

Generalized Singular Value Decomposition and its Applications in Linear System Identification

We have recently devised an algorithm for computing the generalized singular value decomposition (GSVD) of a pair (A,B) of matrices, The algorithm provides the first stable and convergent solution we know of, it is based on a generalized of Kogbetliantz's algorithm, originally by Paige. The software has been made available in LAPACK. In this talk, we will discuss the basic features of the GSVD and its computation, and demonstrate its application in the bootstrapped total least squares estimator in linear system identification. Part of this work is joint with J. Demmel at UC Berkeley, and R. Pintelon at Vrije Universiteit Brussel.

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Massively--Parallel Implementations of Lanczos Algorithms for Computing the SVD of Large Sparse Matrices

We consider parallel implementations of single--vector Lanczos algorithms from SVDPACKC, a numerical software library (ANSI-C) for computing the singular value decomposition of large sparse matrices. The programs described here solve the equivalent 2-cyclic or A'A eigensystems to compute a predetermined number of the largest singular values and corresponding singular vectors of an unstructured sparse matrix A. The specific issues considered here include (1) a discussion of numerical software design that facilitates systematic code porting to parallel machines, (2) the choice of data distribution among the processing elements for parallel machines configured as a 2-D mesh, and (3) an analysis of relative contributions of computations and data communication in an architecture consisting of a sequential host and an attached parallel computer. Performance results on a 4,096-processor Maspar MP-2 with a DECstation 5000-200 host are reported for the computation of the SVD of sparse term-document matrices arising from an information retrieval application.

The largest sparse term-document matrix considered thus far has 700,000 rows and 100,000 columns with over 81 million nonzeros.

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An Implicitly Restarted Lanczos Method Based on Leja Points for Large Symmetric Eigenvalue Problems

The Lanczos process is a well known technique for approximating a few eigenvalues and corresponding eigenvectors of a symmetric n by n matrix. However, loss of orthogonality of the computed Ritz vectors can reduce the accuracy of computed approximate eigenvalues. This problem is addressed by fixing the number of steps in the Lanczos process at a prescribed value k and then treating the residual vector as a function of the initial Lanczos vector. The starting vector is then updated through an iterative scheme based on the use of Leja points for an interval containing undesired eigenvalues. This iterative scheme is designed to force convergence of the residual vector to zero.
The resulting algorithm is capable of computing a few of the largest or smallest eigenvalues. No auxiliary storage is required. Numerically accurate eigenvectors are available on request. The talk presents joint work with D. Calvetti and D.C. Sorensen.

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Implicitly Restarted Arnoldi Methods for Large Scale Eigenvalue Problems

We shall discuss the development of mathematical software for large scale eigenvalue problems based upon a new variant of the Arnoldi process. This variant employs an implicit restarting scheme that may be viewed as a truncation of the standard implicitly shifted QR-iteration for dense problems. Numerical difficulties and storage problems normally associated with Arnoldi and Lanczos processes are avoided. The algorithm is capable of computing a few (k) eigenvalues with user specified features such as largest real part or largest magnitude using n*2k + O(k^2) storage. No auxiliary storage is required. A set of Schur basis vectors for the k-dimensional eigen-space is computed which is numerically orthogonal to working precision. Numerically accurate eigenvectors are available on request.
The software ARPACK that is based upon an implementation of this algorithm has been designed to be efficient on a variety of high performance computers. Parallelism within the scheme is obtained primarily through the matrix-vector operations that comprise the majority of the work in the algorithm. The software is capable of solving large scale symmetric, nonsymmetric, and generalized eigenproblems from significant application areas. We shall be present computational experience and several comparative tests on high performance computers. The development of the ARPACK software is joint work with Phuong Vu of Cray Research.

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MS 26

Estimation of Multiphase Flow Functions in Porous Media

The state equations for immiscible fluid flow in porous media are coupled nonlinear PDE's. Rock properties may vary spatially or with the state variables. Several of these properties cannot be measured directly but must be inferred from measurements of state variables. We present work dealing with simultaneous estimation of relative permeability and capillary pressure functions in laboratory core samples. This estimation is based on "in situ" pressure and saturation data obtained by nuclear magnetic resonance imaging and X-ray tomography during multiphase flowing experiments. These data are used in an output least-squares method, with a numerical simulator which is three dimensional so that gravity effects and spatial variations in rock properties can be represented.

A. Ted Watson
Texas A&M University, College Station, TX
J. Gordon Wade
Texas A&M University, College Station, TX

Total Variation Based Image Processing with Nonlinear PDE

Ill-posed image processing tasks, such as image restoration and super-resolution, can be successfully solved using a computational framework of nonlinear PDE's. We formulated the following constrained optimization problem:

Minimize Total Variation$F(u(x,y))$

Subject to constraints

Constraints are derived from image degradation parameters, e.g. blurring processes, moments of the noise, etc. A solution can found via solving a corresponding time-dependent Euler-Lagrange equation with either approximate Lagrange multipliers or with the penalty method, both of which convert a constrained optimization problem into an unconstrained optimization problem. The PDE obtained by minimizing a TV functional is a modified equation of the motion of level sets with mean curvature velocity scaled by $1/|Grad(u)|$. The advantage of the TV based approach is that nonsmooth solutions are allowed, unlike traditional image processing algorithms.

Lenny Rudin
Stanley Osher
Cognitech, Inc.
Santa Monica, CA

Iterative Methods for Large Scale Variational Problems with Randomized GCV

In statistics, meteorology and oceanography, an important variational problem is to find the minimizer f_λ of the functional

$$\|y-g\|^2+\lambda J(f),$$

where y is an $n\times 1$ observation vector, $g=[(Kf)(t_1),\cdots,(Kf)(t_n)]'$, $(Kf)(t_1),\cdots,(Kf)(t_n)$ are n data functionals, $J(f)$ is the penalty functional, and generalized cross validation(gcv) or unbiassed risk(ubr) is to be used to choose the smoothing parameter λ. As the number of observations becomes very large, currently used matrix decomposition methods for solving the above problem become difficult if the problem is unstructured, due primarily to very large memory requirements. We propose an iterative method which combines the effectiveness of the L-BFGS method and that of randomized gcv to solve the above problem when the penalty functional is taken to be quadratic. Following Wahba, in Engle and Groetsch, Inverse and Ill-Posed Problems, Academic Press(1987), who discusses early stopping in iterative methods as a form of regularization, we propose and demonstrate the use of randomized gcv and randomized ubr to jointly determine λ and the stopping rule in the iterative calculations. This approach may allow the use of gcv and ubr risk in extremely large problems.

Jianjian Gong
University of Wisconsin-Madison
Grace Wahba
University of Wisconsin-Madison

Augmented Lagrangian Method with 2nd Order Update and Its Application to Parameter Estimation Problems

In this paper we discuss the second order update for the augmented Lagrangian method. Convergence properties of the method are established for infinite dimensional constrained minimizations. The method is successfully applied to parameter estimation problems in elliptic PDEs. Some of our numerical findings are presented.

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MS 27

Computational Upgrades in Model Reduction Techniques

This year Boeing Computer Services has an investment project to explore the improvement of computational techniques in some of their standard model reduction tools. This talk will present ... s, or initial findings, of incorporating new techniq... methodologies so as to modernize these tools ... of this abstract the work had yet to b... that there are many new techniques ... that exploit blocking as well as algo... can be employed to improve the perfo... ge of applicability of the softwares. The resu... may also suggest or validate the incorporation of sim... in other such softwares.

Canceled. Replaced by Gretta Ward, Boeing Commercial Airplane Group. See abstract on page A44.

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Recent Applications of Symbolic Computation in Control System Design

Recent years have seen a growing interest in the application of Symbolic Computation to Computer Aided Control System Design(CACSD). At present numerical type of CACSD packages are well developed, however these packages cannot produce analytic type of solution. For example, to formulate a control design problem, a set of inputs and outputs have to be chosen from a given feedback configuration, and the input-output relationship derived. Such algebra calculations could become very involved if the system has many interconnected subsystems. Hence the symbolic calculations will be used to help the formulation at the initial stage, and thus form an integral part of the design process. Our objective in this paper is to illustrate the power of Symbolic Computation in this last regard by describing the latest development in this area.

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C.Y. Han
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Computing Transfer Function Matrix and the H_∞ Norm for a Large and Sparse System Matrix

The problems of computing the transfer function matrix and the associated H_∞ norm are important computational problems in contemporary Control Theory. While there exist numerically viable algorithms for these problems in the small and dense cases , the algorithms for large and sparse problems do not seem to exist. In this talk we will discuss theoretical and computational issues involved in developing algorithms for these problems when the system matrix is very large and especially structured as that arising in the design of large space structures. An algorithm that makes use of the computational techniques such as the GMRES , QMR etc. and packages like LAPACK, is currently being developed. This algorithm along with results of implementations will be presented.

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CP 7

Modelling and Identification of the Combustion Pressure Process in Internal Combustion Engines

We present a new model relating cylinder combustion pressure to crankshaft angular velocity. Using crankshaft angle as independent variable results in a linear differential equation. Using a discrete Gaussian random process modulating a raised-cosine template function to parametrize combustion pressure variability results in a discrete-time difference equation. Finally, the inverse problem of identifying combustion pressure from noisy measurements of angular velocity is solved using a Kalman-filter-based stochastic deconvolution algorithm. Detailed experimental results from an actual automobile engine validate the proposed model and identification algorithm.

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Nonlinear Prediction Using Neural Networks

Adaptive neural networks (ANNs) have typically been applied to such back-end signal processing tasks as detection. Recently, it has been shown that neural networks may be used to advantage in such front-end signal processing tasks as filtering and prediction when the signals involved come from nonlinear systems or where Gaussian noise cannot be assumed. For example, Xue, Hu, and Tomkins have shown that neural-network-based whitening filters have superior performance over conventional linear adaptive techniques in electrocardiogram detection. In this work, we examine neural-network-based predictors and compare these with other adaptive prediction techniques. It is shown that for speech signals, ANN-based predictors can offer as much as a 76% reduction in prediction error over simple linear techniques, such as the LMS algorithm.

Laurence Goodby
University of California, San Diego, CA
Paul M. Chau
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Optimal State Estimation Using The Finite Element Method

Optimal state estimators for nonlinear stochastic systems are known to be of infinite dimension. To overcome this difficulty, extensions of linear techniques are commonly used. However, such techniques result only in suboptimal state estimators.

In this paper, optimal state estimators are numerically obtained. Therefore, the problem of infinite dimensionality is avoided. The scope of this work can be summerized as follows. The Fokker-Plank-Kolmogorov equation is solved using the finite element method, then the state estimates are generated, and finally a numerical example is given to illustrate the approach.

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Fast Algorithms for Close-to-Toeplitz-plus-Hankel Systems of Equations

We extend the low-displacement rank definition of close-to-Toeplitz (CT) matrices to close-to-Toeplitz-plus-Hankel (CTPH) matrices, and develop new fast algorithms for solving CTPH systems of equations. A matrix is defined as CTPH if it is the sum of a CT matrix and a second CT matrix post-multiplied by an exchange matrix; an equivalent definition in terms of UV-rank is also given. This definition is motivated by the application of the new algorithms to two sided linear prediction, which differs from one-sided linear prediction in that both past and future time series values are used to estimate the present value.

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A Circuit Theory of the Kalman Filter

Use of Kalman filters is widespread in science and engineering, but typical derivations of the Kalman filter are tedious and dense and the estimation equations themselves appear difficult to remember. We give a short and graphic derivation of the discrete Kalman filter by considering simple measurement circuits. The information filter formulation is also quickly derived by this approach. Covariance matrices arise in the circuit analog as resistance matrices, and measurement noise is the intrinsic thermal noise of the corresponding resistive network. The estimation equations have a simple formulation which makes use of the generalized parallel combination operator $A \| B = (A^+ + B^+)^+$.

David W. Carter
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Reduced Order Covariance Extended Kalman Filter for Navigation

Modern navigation systems require high order Kalman Filters for optimal state estimation; however, reduced order filters are typically employed to minimize the computational burden associated with the filter error covariance equations. The proposed approach maintains the original filter order, while reducing the order of the error covariance by the orthonormal projection of the filter error state vector onto a low order manifold. This approach is especially applicable to systems with naturally partitioned state vectors, e.g., position and velocity three-vector partitions in navigation systems.

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Optimal State Estimation without the Requirement of a Priori Initial State Estimation -- the MIMO System Case

The result given by the Kalman filter is the BLUE (best linear unbiased estimate) if the unbiased a priori estimate of the initial state and the variance are available. The same state estimation problem is reconsidered for MIMO systems with the requirement of a priori estimation of initial state removed. The algorithm presented in this paper gives the BLUE of system states without the requirement of any a priori knowledge about the initial state. The concept of reconstructibility of stochastic systems is established and the necessary and sufficient condition for complete reconstructibility is given.

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Selfaveraging of the Solutions of Linear Algebraic Equations with Random Coefficients

In this report the author had found the new estimates for the solutions of Linear Algebraic Equations of large dimension. In some sense these estimates are better than the known estimates. The selfaveraging for the solutions of Linear Algebraic Equations means that the vector-solution converges to the solution of some nonrandom Linear Algebraic Equations. This rather important result helps us to find the consistent estimates of solution of Linear Algebraic equations, which apply in the control of manipulator motion [2, p. 518], in the Kolmogorov-Wiener filter [2, p. 593], in the theory of estimation of parameter of some systems [2, p. 481] and so on.

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MS 28

Orderings for Parallel Conjugate Gradient Iterations

J.M. Ortega's presentation has been cancelled. He has been replaced by Mark Jones, Argonne National Lab. See M. Jones' abstract on page A44.

When the symmetric positive definite $Ax = b$ is ... by the conjugate gradient iteration with incomplete Cho... OR preconditioning, a potential bottleneck on paral... solution of the triangular systems to carry out ... efficiency of these triangular solves ca... by a reordering. In particular ... gs reduce the triangular solves t... ltiplications, which can be done ... ely, reorderings may seriously ... ergence of the preconditioned conjugate ... at there is a trade-off between efficiency per ... number of iterations. Some orderings, for example, the ... ordering, maintain the rate of convergence and have sufficient ... allelism to be effective on vector computers, such as a CRAY. However, we will show that the diagonal ordering is not effective on machines such as the Intel iPSC/860. We also give experimental and theoretical results for some other multicolor and domain decomposition orderings.

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Numerical Solution of the Einstein Field Equations

Large scale computing problems are common in the solution of partial differential equations and lead to the use of parallel computers with algorithms that employ iterative methods and preconditionings. The solution of the Einstein field equations is an example of a set of partial differential equations for which there is the added complication of satisfying a constraint such as the Hamiltonian. The topic of the talk will be the application of iterative methods to this example in such a way as to satisfy constraints. This is a report on a research project to which S. Lee, L. Petzold, E. Seidel and S. Ashby, have contributed.

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Computational Kernels for Iterative Methods

Recent work here and elsewhere has focused on the establishment of a set of computational kernels for solving sparse linear systems by iterative methods. Many iterative algorithms can be decomposed into a relatively small set of basic computational operations. Since these are the most computationally intensive parts of the code, it is possible to develop efficient and portable implementations of iterative algorithms by writing them in terms of these basic building blocks. Such computational kernels are particularly advantageous for developing software for use on various high performance computers. The development of parallelizable computational kernels is particularly complicated. Several different researchers have begun to write and test software for computational kernels. Their approaches will be compared and contrasted.

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Restarted Arnoldi Procedure and Eigenvalue Translation Technique for Solving Large Sparse Automatic Control Problems

The talk considers the problem of constructing efficient and numerically stable algorithms for solving eigenvalue assignment problems with large sparse matrices. Existing algorithms for solving this problem are not suitable for large sparse matrices since they require either computation of the exact eigenspaces of the matrix associated with eigenvalues to be assigned or the reduction of the entire matrix to the Hessenberg form which fully destroys the sparsity structure. Moreover, the larger is the size of the problem to be solved the more unstable are the existing algorithms.

The suggested algorithms is based on eigenvalue translations by consecutive low rank transformation of the original matrix which deal with only approximations to the eigenspaces corresponding to the eigenvalues to be assigned computed at several restarted Arnoldi cycles. It enables us to preserve automatically the sparsity structure of the original matrix since in this case the original eigenvalue assignment problem is reduced to a sequence of eigenvalue assignment problems of much smaller sizes exploiting only a procedure for multiplying a matrix by a vector. In order to maintain the numerical stability we construct similarity transformations of the transformed matrix after every Arnoldi cycle. This transformation preserves the spectrum assigned but minimizes the largest singular value of the transformed matrix and can be computed without destroying the sparsity structure.

The full theoretical justification of the algorithm considered is presented and results of numerical experiments with sparse matrices of sizes about several tens of thousands are reported.

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The Sigma-SOR Algorithm and the Optimal Strategy for the Utilization of the SOR Iterative Method

The paper presents with a numerical illustration the method for obtaining a priori estimate of the optimum relaxation factor in the SOR iterative method. The computational strategy of this method uses the so called Sigma-SOR Algorithm based on the theoretical result proven in the paper. The proposed method is especially efficient in solving problems with slowly convergent iteration process and in this case it is strongly competitive to adaptive procedures used for determining dynamically the optimum relaxation factor during the course of the SOR solution.

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MS 29

Parallel Algorithms for Discrete Time Differential and Clustered Dynamic Programming

A very efficient serial algorithm for deterministic nonlinear optimal control problems is Differential Dynamic Programming (DDP). We developed a new algorithm for parallelizing DDP within time steps that is efficient for problems with a large state dimension and a relatively small number of processors. Results will be presented for 1000 state variables. For a large number of processors, we have developed a second algorithm called Clustered Dynamic Programming, which enables parallel processing across time steps. We will present results indicating a speed-up of 31 on 32 processors by comparison to serial DDP for a nonlinear problem with over 10,000 time periods.

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Solving Optimal Control Problems on the C-90 and CM-5 Supercomputers

In this paper we present the results of solving various control constrained optimal control problems on two recently available supercomputers: the Cray Y-MP C-90 and the Connection Machine-5. In particular, we consider control problems with the usual hard bound constraints as well as other constraint sets defined by a Cartesian product of balls and unit simplexes. We investigate solving these problems using a parametrized gradient projection approach that allows direct comparison with well-known existing methods. The difference in the architectures considerd leads to distinctly different implementations of the algorithm primitives; details of the issues involved and the corresponding performance achieved will be presented.

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Markov Chain Approximations for the Heavy Traffic Trunk Line Problem

The routing problem in large trunk line type networks creates large systems and approximation methods must be used. Using heavy traffic limit theorems, this paper develop a numerical method for numerically solving the optimal ergodic cost problem for three or more dimensional (links) systems via the Markov chain approximation method on shared memory vector multiprocessors. A multigrid solution technique is used to solve the system which utilizes vector data structures which remove dimension dependence. Mapping techniques are introduced to reduce the need for conditional testing, especially at boundaries. The general approach used can be applied to other difficult telecommunication decision problems.

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Asynchronous Parallel Fixed-Point Algorithms

A methodology is presented for tuning parallel linear fixed-point algorithms by balancing the time each processor spends computing with the amount of idle time spent waiting for new information

from other processors.
An important parameter in the formulation, called the degree of synchronization, is used to characterize the fraction of time each processor waits on new information before beginning computation with available information.
An analytical model is developed for estimating the overall convergence time as a function of of the degree of synchronization, the granularity of the parallel machine, the number of processors allocated, the dimension of the problem, and the degree of coupling among the iterative equations. For the case where all parameters except the degree of synchronization are given, a mathematical formula for determining the degree of synchronization that yields the smallest overall convergence time is provided. Experimental studies on the nCUBE 2 supercomputer indicate the validity of the analytical model in predicting convergence times.

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Multidimensional Visualization for Massively Parallel Processor Output

The parallel processing of large scale applications usually leads to large scale output. This paper addresses the problem of management and visualization of large scale multi-state, multi-control problem output. An implementation of a "world within a world" vision concept permits visualization of a 3D solution surface in an inner world, which can be changed along with a corresponding change of the parameters of nested 3D outer worlds. This implementation allows the control manager to visualize multidimensional resources along with parameter sensitivity of independent variables, the optimal value and optimal control vector, with respect to the state vector and a multitude of model parameters. This visualization tool is applicable for visualizing many other multidimensional results. However, the method is illustrated for management of a renewable resource in an uncertain environment application.

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MS 30

State-Space Algorithms for Spectral Factorization Based on Tangential Nevanlinna-Pick Interpolation

We address the problem of spectral factorization of matrix-valued functions. We present an approach which utilizes the tangential Nevanlinna-Pick algorithm and draw connections with the methodology of sequential Kalman filtering. We derive state-space formulae for the implementation of the algorithm and discuss their relation to the Riccati difference equation and to existing fast filtering algorithms.

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Bounding Condition Number of a Rational Matrix Function over a Subset of C_∞

A well-known result of Glover provides an upper bound for the norm of a strictly proper stable rational matrix function over the right half plane. Some applications involve a related problem of estimating the maximum value of the condition number of an arbitrary rational matrix function G in a compact set $\sigma \subset C_\infty$ containing no poles nor zeros of G, where a condition number of a matrix denotes the ratio of its largest to its smallest positive singular value. We give an adaptive procedure for solving this problem. Our approach is based on Hankel singular values and recent results on realization and generalized inversion of rational matrix functions.

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Minimal Degree Coprime Factorization of Rational Matrix Functions

We consider the problem of constructing a right coprime factorization $P = ND^{-1}$ of a given rational matrix function P given in realization from $P(S) = 1 + C(s - A)^{-1}B$ such that the sum of the McMillan degrees of N and D is as small as possible. For the scalar case the problem can be solved simply by sorting out zeros and poles of P. The execution of the same idea in the matrix case requires the more sophisticated notions of zero and pole structure for rational matrix functions as a given in the recent book of Ball- Gohberg-Rodman (BGR). We give an explicit linear algebra procedure for arriving at the minimal possible sum degrees of N and D. The technique is based on relating state space realizations of the factors N and D to the corestrictions of a null-pole triple for G. This leads to a constructive procedure for obtaining state space realizations of N and D.

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STATE SPACE THEORY OF RATIONAL MATRIX FUNCTIONS WITH SYMMETRIES

We study classes of rational matrix functions W(z) with complex coefficients which enjoy certain symmetry properties. More exactly, W(z) is fixed by a degree preserving automorphism (or, more generally, a degree preserving automorphism composed with inner automorphism) of the multiplicative group of regular rational matrix functions. Various problems concerning minimal realizations, factorizations and interpolation of symmetric rational matrix functions are discussed. Such functions play important role in the modern control systems theory, notably H-infinity control. The presentation is based on joint work with D.Alpay, J.A.Ball, and I.Gohberg.

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Stability and McMillan Degree for Rational Matrix Interpolants

Given a set of interpolation conditions for a rational matrix function one can ask to find an interpolant which (1) meets a stability constraint or (2) has the minimal possible McMillan degree among all interpolants with no stability side constraint. A connection between the problems (1) and (2) is derived. Specifically, it is shown that a minimal degree solution of a given set of interpolation conditions together with an associated mirror-image set of interpolation conditions is automatically stable whenever it is unique. Also, it is proved that if a minimal degree solution for the above problem is not unique, then not all minimal degree solutions are stable. But, in the later case, there exists at least one minimal degree solution which is also stable.

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Session MS 30

Speaker: E. Pekarev

Abstract has not reached the SIAM office at press time.

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Session MS 31

Speaker: Michael Lundquist

Abstract has not reached the SIAM office at press time.

MS 31

Distance Matrix Completions

When is a partial Euclidean distance matrix completable to a Euclidean distance matrix? We discuss recent results on this problem(including the chordal case), its relationship to the positive definite completion problem, and its motivations from "molecular mapping".

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The Real Positive Definite Completion Problem for a Simple Cycle

Given a real symmetric matrix some of whose entries are unknown, an important problem in the analysis and design of large systems in science and engineering is determining an assignment of these entries that yields a positive definite matrix with specified properties. The question of whether or not a positive definite completion exists is completely understood in the case that the undirected graph corresponding to the specified entries of the matrix is chordal. Given a matrix with known entries along the diagonal, superdiagonal, subdiagonal and in the corners (the case in which the undirected graph is a cycle) we present necessary and sufficient conditions for existence of a positive definite completion in terms of n angles associated with the prescribed data. We also provide a geometrical description of the set of all completions.

Invertible Completions of Partial Operator Matrices; The Nonsymmetric Case

We consider nonsymmetric partial operator matrices R whose directed graph belongs to a certain class and for which certain key, fully specified principal submatrices are invertible. Under these circumstances, we prove the existence of a unique invertible completion F of R such that $(F^{-1})_{ij}$ is block zero whenever R_{ij} is unspecified. In this way, the existing results of Johnson and Lunsdquist are generalized to the nonsymmetric case.

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Completing a Matrix and Its Inverse

Let A and B be partially prescribed matrices. We look for completions C and D of A and B, respectively, such that C is the inverse of D.
This problem appears, among others, in statistics when a joint probability density is sought of which some marginals are known. In that case C and D are in addition required to be positive definite.
We shall consider several specific cases. There are connections with minimal rank completion problems, matrix equations of various types (e.g. Riccati equations), and also maximum entropy problems. Techniques from these different connections are used.
This presentation is part of the minisymposium "Matrix Completion and Applications" organized by P. Tarazaga.

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CP 8

solving linear systems involved in constrained optimization

Many interior methods for large scale convex programming solve an (n+m) by (n+m) linear system in each iteration. The last m equations require exact solutions to maintain the feasibility. Current implementations reduce it into an m by m system. The solution must be exact (very costly and sometimes impractical) because otherwise the error would be entirely passed onto the last m equations of the original system. Thus infeasible strategies are sometimes used. We propose an inexpensive iterative method which guarantees exact solutions to the last m equations. The convergence is proved. The method also applies to more general situations.

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Fast Transform Based Preconditioners for Toeplitz Equations

A new precondtioner for $n \times n$ symmetric, positive definite Toeplitz systems is presented. This preconditioner is an element of the n-dimensional vector space of matrices which are diagonalized by the Discrete Sine transform. Conditions are given for which the preconditioner is positive definite and for which the preconditioned system has asymptotically clustered eigenvalues. The diagonal form of the preconditioner can be calculated in $O(n\log(n))$ operations if $n = 2^k$. Thus only n additional parameters need be stored. Moreover the preconditioning step of the Preconditioned Conjugate Gradient algorithm can be performed in $(O(n\log(n))$ operations. The results of numerical experimentation with this preconditioner are presented. Our preconditioner is comparable to, and in some cases superior to the well known circulant preconditioners. Additional preconditioners based on other fast orthogonal transforms are also considered.

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Preconditioned Krylov Subspace Methods for Lyapunov Matrix Equations

We study the iterative solution of Lyapunov matrix equations

$$AX + XA^T = -D^T D$$

by preconditioned Krylov subspace methods. These solution techniques are of interest for problems leading to large and sparse matrices A as those arising from certain applications in large space structure control theory. For these problems, the matrix A arises from a finite element or finite difference discretization of an elliptic boundary value problem and is therefore large and sparse. We show how CG-type methods can be applied to this type of equation utilizing the special structure when computing matrix-vector and inner products. As our numerical results show, it is essential to combine this approach with preconditioning. Several preconditioners for such problems will be presented and analyzed. Finally we present numerical examples where the different preconditioners are compared.

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The Block Clustered Nonsymmetric Lanczos Algorithm

The Lanczos Method can be used to solve certain problems in Control Systems Theory, such as controllability, observability or model reduction. Specifically, when the state-space model of the System is very large sparse, the pattern must be preserved.

Several algorithms have been proposed to solve these problems for SISO Systems, based on the Clustered Nonsymmetric Lanczos Algorithm. This one takes care of the breakdowns which may appear in the nonsymmetric Lanczos process. We propose one block version of this algorithm, which will be used to solve those problems in MIMO Systems.

Also, we will present a design of the algorithm for a massively parallel architecture such as the CM5.

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A Fast and Stable Matrix Sign Function Algorithm

Matrix sign function has several applications in system theory and matrix analysis, including solution of algebraic Riccati and matrix Lyapunov equations, system decomposition, model reduction, and separation of eigenpairs. Best known methods include Newton-Raphson type algorithms and rational iterations for computing the matrix sign function. Newton-Raphson type algorithms start with the inversion of the initial matrix, thus, convergence might be slow for ill-conditioned matrices. Rational approximations involve taking higher powers of a given matrix for each step of the iteration, which might introduce numerical errors. We propose an iterative algorithm which computes main diagonal Padé approximants for varying order of convergence rates. The algorithm is multiplication-rich and globally convergent, and computes the sign of a complex matrix by using the continued fraction expansion of the principal-square-root function.

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The QZ Algorithm Applied to the Solution of Algebraic Riccati Equations for H_∞ Design

A new method is presented for the solution of the algebraic Riccati equations which occur in H_∞ design. This method avoids numerical instabilities introduced by matrix inversion, reducing conservatism when the Riccati equations are used to design robust controllers. As in Potter's and Laub's procedures, a basis must be found for the stable eigenspace of the Hamiltonian matrix associated with the Riccati equation. This can be done via the generalized Schur decomposition of a matrix pencil, so that $A'P + PA - PBR^{-1}B'P + Q = 0$ can be solved without matrix inversion (P. Van Dooren, "A Generalized Eigenvalue Approach for Solving Riccati Equations," *SIAM J. Sci. Stat. Comput.*, vol. 2, no.2, pp. 121-135). In this presentation, a similar method is given for solving $A'P + PA + P(R_1 - BR_2^{-1}B')P + Q = 0$ using the QZ factorization. It is demonstrated in an example of low-order H_∞ controller design.

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URV ESPRIT for Tracking Time-Varying Signal

ESPRIT is an algorithm for determining the directions of arrival(DOA) of a set of narrowband signals impinging on an array of sensors with translational invariance. One main limitation of ESPRIT in practical applications is the high computational burden to estimate parameters and subspace by using either eigendecomposition or singular value decomposition. In this study we investigate the use of the rank revealing URV decomposition to develop a new implementation of ESPRIT. From our simulation, we find that the URV based algorithm is effective for time-varying DOA estimate using either rectangular or exponential windowing methods and is more efficient than the SVD based algorithm.

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SYSTEMATIC DESIGN OF MINIMAL FUNCTION OBSERVERS

A function observer $\{F,[L:TB],[N:M]\}$ generates state feedback $Kx(t)$ directly for the open loop system $\{A \in R^{n\times n}, B, C \in R^{m\times n}\}$, with $\lambda(F)$ arbitrarily given. Two equations

$$TA - FT = LC \quad (1)$$

and

$$K = [N:M][T':C']' \quad (2)$$

must be satisfied in the design. To have a minimal function observer order, which can be much lower than the lowest state observer order n-m and which equals the number of rows of T needed for (2) to be solvable, the freedom of solution T of (1) must be fully used in solving (2). To do it systematically, the freedom of T **must** be fully independent of the parameters of (1). This requirement is uniquely and fully satisfied not too long ago, and only then the minimal function observer design has been simplified to the solving of a set of linear equations (2) **exclusively and therefore systematically.** This basic development deserves being further mentioned and highlighted here.

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A Skew-Hamiltonian Method for Solving Real Discrete-Time Algebraic Riccati Equation

Real discrete-time algebraic Riccati Equation raises from optimal control systems. Several algorithms are designed for this problem with computing an invariant subspace of the associate symplectic matrix, but they don't use the special structure.

We developed a structural-preserving algorithm based on our new theoretical results. A skew-Hamiltonian matrix under some restrictions can be found then the first n columns of the sum of this matrix and the original symplectic one forms the associate invariant subspace and the solution can be got. The algorithm sufficiently use the special matrix structures.

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CP 9

A Control Algorithm for Reduced Order H_∞ Compensator Design

The controller design for the standard H_∞ problem requires solving two Riccati equations and the resulting compensators have the same dimension as the order of the generalized plant. The controller complexity limits the practical applications of H_∞ control theory. In this paper, we present a numerical algorithm that gives proper compensators of order equal to the order of the plant minus the number of the measured output. The current methods of designing strictly proper reduced order compensators call upon homotopic continuation or gradient-based numerical search to solve tightly coupled Riccati equations. Our algorithm, which is derived from the well known bounded real lemma, only requires solving two decoupled Riccati equations and a homogeneous Sylvester equation. The concise derivation of our algorithm and its application for designing a manual flight control system for the lateral axis of the single engine VISTA F-16 supersonic test vehicle will be included in our presentation.

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Risk Sensitive Production Planning of Stochastic Manufacturing Systems: A Singular Perturbation Approach

This paper is concerned with robust production planning of stochastic manufacturing systems in which the rates of machine breakdown and repair are much larger than the rate of fluctuation in demand.

It is shown that the risk sensitive production planning problem can be approximated by an H infinity control problem in which the stochastic machine availability process is replaced by its mean availability. Near optimal production plans are constructed from near optimal controls of the H infinity control problem. Finally, these results are extended to problems with state constraints.

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An Algorithm for the Use of Parametric Reduced-Order Models for a Robust Control

This paper deals with the analysis of parametric reduced-order models as applied for a robust process control purpose. While order reduction schemes for control of large-scale systems have been studied in the past,however, it is desirable to utilize the particular structure of the plant dynamics to construct a class of reduced-order models which are maximally robust to parameter variations for the nominal range of such perturbations. In this paper, for a linear time-invariant system and for an initially nonrobust parametric reduced-order model constructed from the Routh array, a constraint optimizaton algorithm is proposed in which an initially constructed model from the Routh orthogonal functions,is modified to result in a reduced order model which exhibits least state and output trajectory sensitivity for parameter variations under the specified nominal conditions and preserves stability requirements. For this purpose Lyapunov stability requirements are utilized. Performance of the derived model for a robust output control in a linear time-invariant system is subsequently studied.

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A fast algorithm for set membership identification via parallelotopes

Recent years have witnessed a renewed interest in system identification in order to provide hard bounds on the system uncertainty. This is required by advanced robust and adaptive control schemes. Recursive identification techniques usually exploit ellipsoidic regions [1] for outbounding, in a recursive optimal way, the feasible parameter set. Recently parallelotopic regions have been suggested [2]. In this paper, a novel algorithm is presented which updates in an optimal way a parallelotopic bound, exploiting only $O(n^2)$ operations, n being the dimension of the parameter vector. Moreover, due to the exclusive use of orthogonal transformations, it possesses good numerical properties. Thanks to this algorithm, the computational load of the parallelotopic approach becomes comparable with the ellipsoidic approach, while convergence turns out to be faster, as confirmed by simulation experiments.

[1] Fogel, E. and F. Huang (1982). On the value of information in system identification - bounded noise case. *Automatica*, **26**, 229-238.

[2] Vicino, A. and G. Zappa (1992). Sequential approximation of uncertainty sets via parallelotopes, to appear in IFAC World Congress, Sydney.

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Indirect Adaptive Control of Nonlinear Systems

A simple suboptimal control law is derived from a new criterion which provides an efficient way to control a multivariable Hammerstein's model whose linear part is not necessarily with a minimum phase. By knowledge of the interconnections nature between the inputs and the outputs of system, the basic version of the adaptive control relating to this special class of nonlinear systems is improved. The improvement appears clearly in solving the nonlinear equation by Newton-Raphson's numerical algorithm. A self-tuning algorithm is given which is an efficient way for the control of this class of non-linear systems.

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Application of Two Adaptive Control Strategies to an Industrial Process

This paper presents the results of simulation tests to evaluate the application of the two multivariable adaptive control algorithms to a simulated model of a distillation column due to Goodwin et.al and Cook. The Goodwin et.al method was not capable of rejecting the disturbances due to the nonlinearity of the plant, so the method was modified by using a differencing operator to the plant and model outputs. The Cook method was also modified. It was shown that an appropriate choice of the regression (data) vector makes it possible to reduce the number of parameters in the regulator structure. As a result, a simpler controller structure can be applied. In addition, the use of a suitable dead-zone in the adaptive-law avoids wind-up in the estimator. In both methods, the set-point tracking performance, the load disturbance rejection, the parameter convergence and the interaction problem were investigated. As simulation results demonstrate the modified Cook method possesses some robustness against unmodelled dynamics and bounded disturbances compared with the results obtained by the modified version of Goodwin et.al method

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MS 32

Efficient and Stable Algorithms for modifying Singular Value Decompositions and Partial Singular Value Decompositions

We consider the problem of updating and downdating the two-sided unitary decomposition $A = U \begin{pmatrix} B \\ 0 \end{pmatrix} V^H$ where $U \in \mathbf{C}^{n\times n}$, $V \in \mathbf{C}^{n\times n}$ are unitary, and B has one of the forms

$$B = \Sigma = diag(\sigma_1, \sigma_2, \ldots, \sigma_n) \quad \begin{matrix} \sigma_1 \geq \ldots \geq \sigma_n \\ \| (\sigma_{k+1}, \ldots, \sigma_n) \| \leq \epsilon \end{matrix} \qquad (0.1)$$

$$B = \underset{k \quad n-k}{\begin{pmatrix} B_1 & 0 \\ 0 & B_2 \end{pmatrix}} \begin{matrix} k \\ n-k \end{matrix} \quad \begin{matrix} B_1 \text{ upper bidiagonal} \\ \| B_2 \|_F \leq \epsilon,\ B_2 \text{ diagonal} \end{matrix} \qquad (0.2)$$

Here k is the computed rank of A and ϵ is proportional to the tolerence used to determine the rank. We require B_1 to have at least one zero superdiagonal entry. The form (0.1) is the singular value decomposition(SVD) and the form (0.2) is a special case of the partial SVD. Let $z \in \mathbf{C}^n$. We propose algorithms to find bidiagonal matrices $\bar{B}_U$,$\bar{B}_D$ such that $B_U^H B_U = B^H B + zz^H$ and $B_D^H B_D = B^H B - zz^H$. Moreover, $\bar{B}_U$ and $\bar{B}_D$ have the property that

$$\bar{B} = \underset{l \quad n-l}{\begin{pmatrix} \bar{B}_1 & \phi_l e_1 e_l^T \\ 0 & \bar{B}_2 \end{pmatrix}} \begin{matrix} l \\ n-l \end{matrix} \quad \left\| \begin{pmatrix} \phi_l e_1 e_l^T \\ \bar{B}_2 \end{pmatrix} \right\|_F \leq \epsilon$$

where $l = k+1$ for $\bar{B}_U$ and $l = k$ for $\bar{B}_D$. Thus the new bidiagonal form properly represents the separation between the signal and noise subspaces. Moveover, the SVD of the modified matrix can be obtained more accurately. We give an appropriate perturbation theory and numberical examples.

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Canonical Correlations of Matrix Pairs

This talk is concerned with the analysis of the canonical correlations of matrix pairs and their numerical computation. We first develop a decomposition theorem for matrix pairs having the same number of rows which explicitly exhibits their canonical correlations.
We then derive perturbation bounds of the canonical correlations for normwise as well as componentwise perturbations. We demonstrate that it is generally not true that small relative perturbations in the matrix pair result in small relative perturbations in its canonical correlations and we single out a class of so-called normally-scaled matrix pairs for which good relative perturbation bounds exist. We propose several numerical algorithms for computing the canonical correlations of general matrix pairs, emphasis is placed on the case of large sparse or structured matrix pairs. We demonstrate the efficiency of the algorithms using matrix pairs arising from analyzing the past and future of time series.
We also briefly discuss several extensions of canonical correlations of matrix pairs.

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Accurate Symmetric Eigenreduction

A "well-behaved" matrix is the matrix for which small relative changes in its elements cause small relative changes in its eigenvalues. We characterize real symmetric well-behaved matrices and give an algorithm which computes their eigenvalues accurately in the above sense. The algorithm consists of the decomposition $H = GJG^T$, where H is real symmetric, $|J|$ is the identity, and G has full column rank, followed by the one-sided Jacobi-type iteration on the pair G, J. Both, theoretical and numerical results reveal the fact that this algorithm is never much worse and can be much better than the standard Jacobi or the QR algorithm. However, appropriate permutation of the starting matrix can considerably improve the accuracy of the latter two algorithms; an observation for which we do not have complete theoretical explanation, as yet. Since the Jacobi part contributes in general much less to the final error than the decomposition, it is desirable that the matrix H be already given by its factors.

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A Parallel Divide and Conquer Algorithm for the Generalized Real Symmetric Definite Tridiagonal Eigenvalue Problem

We develop a parallel divide and conquer algorithm, by *extension*, for the generalized real symmetric definite tridiagonal eigenproblem. The algorithm employs techniques first proposed by Gu and Eisenstat to prevent loss of orthogonality for the *modification* algorithm. We examine numerical stability and adapt the insightful error analysis of Gu and Eisenstat to the arrow case. The algorithm incorporates an elegant zero finder with global monotone cubic convergence that has performed well in numerical experiments. A complete set of tested matlab routines implementing the algorithm is available on request from the authors.

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MS 33

Fast Adaptive Filtering using the FFT

Adaptive finite impuluse response (FIR) filters are used extensively in many practical applications, e.g. system identification, equalization of telephone channels and noise cancellation. The main concerns in the design of adaptive filtering algorithms are their convergence performance and their computational requirements. The concerns are especially important when the filters are used for real-time applications or the sizes of the filters are very large. In this paper, some new adaptive filtering algorithms are introduced. We employ the Fast Fourier Transforms (FFTs) as our main tool to give rapid convergence rates and to reduce the computational requirements. Comparisons of the FFT-based approach with the standard recursive least squares (RLS) updating and downdating methods, and with fast RLS methods are reported. Other methods considered include a frequency domain FFT-based frequency domain version of the quasi-Newton least mean squares (LMS) adaptive filtering algorithm by Marshall and Jenkens, along with a hybrid LMS-RLS scheme that is also based on FFT computations. Numerical experiments are given to illustrate the performances of our proposed algorithms. Preliminary results indicate that these iterative methods can compete with direct methods in an adaptive signal processing environment.

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Experiments with the Quaternion-Jacobi Method

We briefly describe the Quaternion-Jacobi algorithm (QJ) for the diagonalization of symmetric matrices. This algorithm is based on a 4x4 orthogonal similarity transformation which creates a 2x2 block of four zeros off the diagonal, instead of the solitary zero created by a Jacobi rotation. We point out that using a single 4x4 similarity transformation instead of diagonalizing a 4x4 matrix using Jacobi rotations is 3.6 - 4 times faster, even though a 3x3 SVD is required by the former.
We have written programs for QJ which reflect the inherent parallelism of Jacobi-type methods, and we compare the performance of QJ with parallel Jacobi implementations. The QJ method appears to consistently require 1-2 fewer sweeps than the Jacobi algorithms, while retaining the characteristic accuracy of Jacobi methods.
We compare our experimental results with theoretical estimates, and discuss some new aspects of this interesting new algorithm.

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An Incremental Estimator for the Smallest Singular Value of a Product of Matrices

An accurate estimate of the smaller singular value and its associated singular vectors is essential for the 2-norm condition number estimator and the URV decomposition. In this paper, we present an estimator for the smallest singular value of a product matrices and explore its applications.

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On the Primitive Operations of the ULV Decomposition.

We explore several different applications of the approximate SVD which is updated by rank one corrections. The updating procedure is based on Stewart's ULV decomposition and Luk & Qiao's extensions to the GSVD. We explore how the computation may be organized so that it can be applied directly to two different applications: subspace tracking in signal processing, and total least squares in linear algebra.
To date, the only admissible criterion for separating the "noise" subspace has been based solely on the magnitude of the singular values.
But often this criterion is not sufficient, hence there is a need for a more flexible organization of the algorithms, discussed in this talk.

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MS 34

Least Squares Processing of Fire Detector Sensor Data

Existing resistance-type jet engine fire detection systems are unreliable and costly to maintain. Newly proposed fire detection sensors (which offer lower cost and higher reliability) use multi-valued readings to determine existence of fires and other anomalous conditions. These multi-valued readings require some signal processing to make a determination of the "health" of an engine. A least-squares approach to decomposing the multi-valued sensor readings into component parts is described. If the component part associated with a fire is present with some significance, a fire can be declared.

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Matrix Algebra Application to Redundancy Management

To reduce cost and improve reliability, the avionics on Boeing's new airplane, the 777, will stress fault tolerance. Sensor redundancy management in the strapdown inertial navigator involves a significant application of matrix linear algebra. This relationship has not been brought out clearly before, and most previous skewed redundant inertial navigators have employed ad hoc, intuitive methods. Starting with the sensor configuration matrix, the computation of the partly coefficient matrix and the algebra involved in sensor reconfiguration after failure detection and isolation will be described.

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Linear Algebra in Active Noise Control

Real time linear algebra is a key to meeting the computationally intensive requirements of broad band active noise control in enclosed spaces. Such control cancels nuisance noise with a system of speakers or actuators to generate anti-noise, using control microphones for feedback adaptivity and source microphones for feedforward control. Linear algebra is also important in associated simulations. Methods used include Kalman filters, GMRES, convolutions, and covariance matrix factorizations, sometimes in unfamiliar roles. Converting between traditional frequency domain and newer time domain methods has been challenging.

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MS35

Efficient Calculation of H_∞ Norm and its Sensitivity to Parameter Variation

We present an algorithm and describe software for the calculation of the H_∞ norm of the transfer function of a time-invariant linear system and of the sensitivity of that norm to parameter variation. We seek efficiency in the H_∞ norm calculation in the case that the number of system states is much larger than the numbers of inputs and outputs. We improve on previous work in extracting information from each computation of a Boyd-Balakrishnan-Kabamba Hamiltonian matrix and its eigenvalues. Terminal convergence is achieved using higher order information extracted from computing the transfer function matrix and its SVD. Sensitivity to parameter variation comes from an analytic formula. Except for the user's calculation of the sensitivity of the system matrices to parameter variation, the sensitivity computation adds very little calculation to the H_∞ norm computation.

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Computing Issues in Control Theory

Control design specifications, often expressed in the frequency domain, lead to factorizations of rational matrices. These include coprime, spectral, J-inner outer factorization, etc. Based on realization and minimal factorization theory state space methods for computing these factorizations can be developed. However, relationship with state space factorization methods, potentially useful for developing efficient algorithms, remains to be explored. This talk will focus on some relevant issues in this direction.

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A Global Minimum Search Algorithm for Estimating the Distance to Uncontrollability

Let $A \in \mathbb{R}^{n,n}$ and $B \in \mathbb{R}^{n,m}$. We suggest a new search algorithm for estimating the distance $\mu(A,B)$ of a controllable pair (A,B) to the set of uncontrollable pairs by estimating the global minimum of the function $\sigma_{\min}([A-\lambda I, B])$, $\lambda \in \mathbb{C}$, where $\sigma_{\min}(\cdot)$ denotes the smallest singular value of a matrix. Using simple properties of this function due to Ralph Byers one first observes that, provided $rank(B) < n$, the minimization problem can be transformed to a minimization problem in the bounded region $\{(x,z) \| x| \le \|A\|_2, |z| \le \|A\|_2\}$ in the two dimensional real plane. The algorithm then progressively partitions this region into simplexes and by determining whether their vertices (x_j, z_j) satisfy that $z_j > \min_{y \in \mathbb{R}} \sigma_{\min}([A-(x_j+iy)I, B])$, it computes after a finite number of steps upper and lower bounds for $\mu(A,B)$. The difference between the two is small if $\mu(A,B)$ is small, while the lower bound is large if $\mu(A,B)$ is large thus ensuring safe decisions. An error analysis together with numerical examples and an operation count are all presented. Only simple modifications of the search region are necessary to extend the applicabilty of the algorithm to the case when $rank(B) \le n$.

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The Family of 2-by-3 Matrix Pencils - Structure Transitions of the Nongeneric Case ... ...turbations

This talk discuss ... relation, behaviour under ...

Please refer to page A44 for a new, revised abstract.

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CP 10

Stability Analysis of Systems with Structured Time-Varying Uncertainties Using Structured Singular Value

For uncertain continuous-time system $\dot{x}(t) = [A_0 + \sum_{i=1}^{m} k_i(t)A_i + \sum_{i,j=1}^{m} k_i(t)k_j(t)A_{ij}]x(t)$ and discrete-time system $x(t+1) = [A_0 + \sum_{i=1}^{m} k_i(t)A_i]x(t)$ it is well known that the Lyapunov stability theory can be used to determine the robust stability region in the space of parameters k_i's, provided A_0 is a stable matrix. We show in this paper the key step in using the Lyapunov stability theory, i.e., determining the positive definiteness of a matrix perturbed by the uncertainty parameters, can be transformed into the analysis of the structured singular value of a larger matrix. We also show that the method of Tesi and Vicino (*IEEE Trans. Auto. Contr.* Vol. AC-35, pp. 186-191) for testing the nonsingularity of a matrix can be used for our formulation. Note that Tesi and Vicino use the test to analyze the robust stability of systems with time-invariant nonlinearly-coupled structured uncertainties. Though the test of Tesi and Vicino gives a closed-form solution to the problem with $m = 1, 2$, as m increases a rather complicated signomial algorithm is needed to solve the problem. Here we use the standard μ-analysis tool to apply our method to several example systems and show that by using this method, less conservative results are often obtained.

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A Current-Law-Based Approach to Derive Energy Functions for the Direct Method of Power System Stability Analysis

Many papers have been presented to develop energy functions for detaile d power system models with considerable progress. However, no general approach is found yet to deal with various detailed generator models.

This paper presents useful theorems to represent the generator energy by a curren t-voltage integration. A complex phasor integral is obtained by integrating bus c urrent equations with respect to bus voltages. The real part of this integral is proven to be a structure-preserving energy function reflecting the resistance, sa liency and flux-decaying effects of detailed generator model exactly, and the ima ginary part a new interesting energy function.

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Stability Analysis of Autonomous Linear Time-Delay Systems

The stability of linear time-delay system $\dot{x}(t) = Ax(t) + Bx(t-\tau)$ is studied, where $\tau \geq 0$ is the delay time. We present a necessary and sufficient condition for checking whether the system is asymptotically stable independent of τ. This condition requires only computations of the eigenvalues of two matrices. When the system is asymptotically stable for $\tau = 0$, but not independent of τ, an algorithm is proposed for determining how large τ can be to keep the asymptotic stability. The algorithm consists of two parts. The first part finds in the complex plane the region where unstable roots of the characteristic equation can appear. The result is in general less conservative than that given by Mori and Kokame (*IEEE Trans. Auto. Contr.*, Vol. AC-34, pp. 460-462). Based on the result and the idea that roots of the characteristic equation depend continuously on τ, the second part gives a condition on τ such that the roots of the characteristic equation can not cross the $j\omega$ axis of the complex plane.

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Estimates of the Singular Perturbation Parameter for Stability, Controllability, and Observability of Linear Systems

It is well known that the dynamics of singularly perturbed systems can be approximated by the dynamics of the corresponding reduced-order and the boundary layer subsystems for sufficiently small values of the singular perturbation parameter. In this paper, estimates of the singular perturbation parameter are obtained, so that if the singular perturbation parameter is less than these estimates, then the stability, controllability, and observability of linear singularly perturbed systems can be deduced from those of the corresponding reduced-order and the boundary layer subsystems.

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Characterization of Block Cascade Nonlinear Models Using Polyspectra

When dealing with dynamic system identification, the system structure is usually assumed known apriori. This is an essential step before carrying out order and parameter estimation of physical systems. It is known that the structure of a wide class of nonlinear systems can be represented by cascades of linear and nonlinear block, i.e. combinations of what is called Wiener and Hammerstein models. Such representation provides a convenience way of computing the nonlinear system kernels.

In this paper, the structure of block cascade models is characterized using polyspectra which is known to be computationally efficient. We will consider various combinations of block cascade models, formulate the pol the polyspectra of their output processes, and then develop a criteria that can be used to determine the structure of the model.

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MS 36

Parallel Implementation of Dense Linear Algorithms

In this talk, we examine general techniques for implementing matrix algorithm on massively parallel processing systems. These techniques allow high utilization of individual nodes, reduce communication requirements, and enhance portability and scalability of the codes. In particular, we will concentrate on advances made in an effort to port key algorithms from LAPACK to such architectures. Data collected on state-of-the-art parallel systems will be included.

Joint work with Jim Demmel (UC-Berkeley), Jack Dongarra (Univ. of TN-Knoxville and ORNL), and David Walker (ORNL)

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Design of a Parallel Nonsymmetric Eigenroutine Toolbox

The nonsymmetric eigenproblem is one of the hardest linear algebra problems to solve effectively on massively parallel machines.
Rather than trying to design a "black box" eigenroutine in the spirit of EISPACK or LAPACK, we propose building a toolbox for this problem. The tools are meant to be used in different combinations on different problems and architectures. In this talk, we describe these tools which include basic block matrix computations, the matrix sign function, 2-dimensional bisection, and spectral divide and conquer using the matrix sign function to find selected eigenvalues. We also outline how we deal with ill-conditioning and potential instability. Numerical examples are included.

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A Parallel Algorithm for Block Sylvester-Observer Matrix Equation and Its Implementations

In this paper, we study the aspects of developement and implementations of parallel algorithms for the Sylvester-observer matrix equation: $XA + BX = GC$, arising in the construction of Luenberger observer in Control Theory. Though there exist several viable numerical serial algorithms for the problem, no parallel algorithm has been proposed so far.

A new highly parallel algorithm is proposed and implemented on some of the high performance shared-memory and distributed computers of today's choice, such as the CRAY Y-MP, the Siemens S600/0, the Intel ipsc/860, etc. Our experimental results on these machines confirm the efficiency of the algorithm and show that the algorithm is well-suited for achieving high speed on these architectures. The algorithm and its implementations make use of the state-of-the-art techniques for matrix computations and the recently released associated software package LAPACK.

The algorithm is compared with the best-known sequential method, the Hessenberg-Schur method for the Sylvester equation problem, by squeezing out as much parallelism as possible from the latter. The study shows the parallel-superiority of the proposed algorithm over the Hessenberg-Schur method.

The research reported in the paper is expected to benefit both the applied mathematics and the control engineering communities.

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Biswa Nath Datta
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Avijit Purkayastha
University of Puerto Rico at Mayaguez

Efficient Parallel Solution of Almost Block Diagonal Systems

A variety of computational problems leads naturally to the solution of almost block diagonal (ABD) systems. One of such problems is the solution of a two-point boundary value problem (for ordinary differential equations). We will present the recent developments in the area of parallel solution of such systems. Two general approaches toward the parallelization of ABD systems will be discussed: one based on tearing and one on BLAS based parallelization. The results of experiments, with codes representing both approaches, performed on the Sequent and on the Cray Y-MP will be examined.

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Parallel Homotopy Algorithms for the Eigenvalue Problem and the Singular Value Problem

Parallel computations of matrix eigenproblems is a challenge in numerical linear algebra, especially for nonsymmetric eigenproblems. In recent years, the homotopy continuation method has been developed to solve these problems on advanced architectures. The theory, implementation and progress of several versions of the homotopy continuation algorithm for eigenproblems and singular value problems will be presented.

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MS 37

Decomposition of Signal Flow Graphs for Parallel Processing in Multiprocessor Systems

With the advent of the latest generation of fast microprocessors, specialized DSP accelerators, massively parallel processors and distributed computing systems, these highly parallel machine architectures dictate the need for efficient decomposition of computationally intensive algorithm signal flow graphs to expedite multiprocessor execution. Computational speedups occur by algorithm formulation to maximally exploit intrinsic concurrence, by optimal partitioning and mapping of graph tasks to node processing, by parallelizing and pipelining operations, and by load balancing with minimization of inter-processor communication costs. Representative signal flow graphs isomorphic to common signal processing applications will be analyzed and illustrative results will be presented. Comparative performance metrics based upon the above techniques and applied to the example graphs will be discussed.

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On Image Enhancement and Object Detection by 2D Adaptive Prediction Filtering using Distributed Processing

Digital image processing is a computationally intensive field and has long been a driving force in the development of parallel architectures. Adaptive filtering using two dimensional causal and non-causal filter windows has recently been used to perform various tasks such as image enhancement and clutter suppression. Computational requirements of typical real-time image processing applications are described in this paper. These requirements are an order of magnitude more than the computational speed of current state-of-the-art processing elements. In this paper a parallel architecture for adaptive prediction filters based on an array of processing elements which permits the utilization of such algorithms to applications requiring a high throughput is presented. The use of distributed processing systems to trade-off number of processing elements with speed requirements of the individual processors is described.

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A Parallel Viterbi Decoder for Shared Memory Multiprocessor Architectures

The efficient implementation of the Viterbi Algorithm for a shared memory multiprocessing environment is examined. In particular, a simple method of partitioning the state metrics across N processors is suggested for architectures in which all processors are penalized equally for communication with any other processor. The suggested partitioning is shown to result in a concise, efficient update procedure for the state metrics requiring little communication between processors other than periodic barrier synchronization and exchange of pointers to starting regions on which to operate. If the state metrics are integer valued, the implementation does not require periodic renormalization of the metrics. For the particular application of the Viterbi algorithm to telemetry decoding with a large number of states (2^{13}) and a small number of processors, the suggested state partitioning and update procedure is analyzed for performance and scalability. Specific timing results for one, two, and four processors are offered.

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Wide-Area Gigabit Networks for Distributed Applications Across Heterogeneous Computing Environments

The CASA gigabit testbed project – a collaborative effort among the San Diego Super Computer Center, the California Institute of Technology, the Jet Propulsion Laboratory, and Los Alamos National Laboratory will be discussed. This NSF-DARPA project, awarded to the Corporation for National Research Initiatives (CNRI), is concerned with developing wide-area gigabit networks to distribute grand challenge applications across heterogeneous computing environments. The machines that comprise this network include both vector supercomputers and distributed memory MIMD machines.

The distributed application we discuss is a coupled atmospheric-oceanographic model. Traditionally, these codes have run on a single CRAY platform, with the atmospheric code integrated for a fixed time period and then the oceanographic code integrated for the same time period. The two models are coupled by trading information at the air-sea interface. To demonstrate the effectiveness of the wide-area network involved in the CASA project, the atmospheric code will run on a CRAY Y-MP at JPL and the oceanographic code will run on the Delta machine at Caltech. In particular, we present implementation techniques that produce large speedups by allowing the models to run concurrently.

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MS 38

The Application of Sparse SQP Methods to Optimal Control Problems

Discretization of optimal control problems using collocation or direct transcription methods leads to the solution of a large sparse nonlinear program. This talk will address issues that arise when applying a sparse sequential quadratic programming (SQP) algorithm based on the Schur-complement. Particular attention will be given to techniques for maintaining a positive definite projected Hessian matrix, when direct solution of the Kuhn-Tucker (KT) system is required.

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Solving Dynamic Optimization Problems in Process Engineering

Process engineering provides a wealth of applications for dynamic optimization problems. To address these, our approach stems from a discretization of the differential-algebraic system through collocation on finite elements. Here we include path constraints to allow for profile saturation as well as singular arcs. Consequently, handling of higher index systems is necessary for these systems. In addition, the placement of the finite elements is controlled as part of the optimization problem formulation through additional inequality constraints.

Solution of this problem formulation is considered through two decomposition approaches. In the first, we consider a reduced Hessian SQP approach where the state variables are eliminated through linearization of the state equations and control variables are adjusted in the QP step. This approach is motivated by the structure of process engineering problems where the dimension of the state variables is much higher than that of the control. The second approach relies on a Riccati-like decomposition for the DAE system and is particularly useful for addressing EVM problems in parameter estimation. Several examples will be presented that illustrate these approaches.

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Multiple Shooting SQP Methods for Parameterized Optimal Control Problems in ODE and DAE with Application to Robotics

Multiple shooting and collocation methods make a powerful tool for the numerical solution of parameterized optimal control problems. They lead to large scale nonlinear programming problems typically ranging from hundreds to thousands of variables but also showing considerable structure, which has to be be exploited e.g. in gradient and Hessian generation and the qudratic programming work involved in SQP methods. Some features of a multiple shooting algorithm exploiting properties of the differential equations and the QP problems are discussed, and applications in optimal control of industrial and space based robots are given.

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Numerical Methods for Parabolic Control Problems

In this talk various problems are considered which arise in the control of partial differential equations. Among those addressed are heat conduction processes governed by nonlinear diffusion equations. We review some of the concepts for a numerical solution from an optimization point of view. In particular, we discuss variants of SQP methods for the numerical solution of the resulting optimization problems.

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Branched Trajectory Optimization for Hypersonic Vehicles

Numerical solutions of multi-phase, branched optimal control problems are considered. A phase is defined as a subinterval in which the differential equations are continuous, a branched trajectory optimization is a problem in which two or more vehicles must be optimized simultaneously. A direct multiple shooting approach is described briefly which transcribes the optimal control problem into a nonlinear programming problem (NLP). The NLP is solved using standard Sequential Quadratic Programming algorithms. The method is applied to determine optimal ascent- and reentry trajectories of a two-stage-to-orbit (TSTO) vehicle, that is a simultaneous trajectory optimization of both stages. The method is embedded into an advanced user interface which allows a user to edit most of the necessary input in a simple way. This utility is described briefly.

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MS 39

Cardinal Interpolation and Wavelets

It is wellknown that the autocorrelation of an orthonormal scaling function is a fundamental function for cardinal interpolation. This research considers a more general class of fundamental functions that are constructed in terms of any scaling functin that locally reproduces all polynomials of degree n. Wavelets that generate complementary subspaces of the multiresolution analysis as a result of the projection operator are constructed. This gives an analogous scheme of direct- sum decomposition and resconstruction as the usual L^2 setting. Although no orthogonality is achieved, the wavelet coefficients in each octave vanish whenever the data function is locally a polynomial of degree n. More precisely, the wavelet coefficients reveal the details of the data function in a similar way as wavelet decompositions in the L^2 setting.

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Session MS 39

Speaker: Gilbert Walter

Abstract has not reached the SIAM office at press time.

Some New Results on Wavelet Transform

Some fundamental and useful properties of Wavelet transforms will be presented. A unified approach for both discret and continuous time-frequency localization is introduced. We will show uniqueness theorem and inversion formula for the newly introduced wavelet transform-wavelet Stieltjes transform.

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Rational Wavelets in System Identification and Model Reduction

The need for rational approximation of transfer functions arises in the contexts of both system identification and model reduction. In these problems the objective is to construct low-order rational approximations of transfer functions using available data which may take the form of observed input-output behavior (in system identification) or nonrational/high-order transfer function models (in model reduction). We present a framework for rational approximation of transfer functions using a class of rational wavelet decompositions of the Hardy space H^2. A key feature of this class of decompositions is that they provide a natural vehicle for the simultaneous 'weighting' of a rational transfer function model in both the time and frequency domains. Such weighting is often used in system identification to incorporate various forms of *a priori* knowledge into the model. However previous methods are restricted to weighting in only one of the two domains. In model reduction, simultaneous time and frequency domain weighting may be exploited in generating parsimonious rational wavelet representations of high-order or nonrational transfer functions. The viewpoint and methods developed in this work provide a unifying framework for a broad class of techniques which include the classical Laguerre models and the Kautz models. We illustrate these ideas by examples and present a fast algorithm for the computation of rational wavelet approximations.

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Numerical Stability of Biorthogonal Wavelets

Biorthogonal wavelets have advantages over orthogonal wavelets in some applications, but they are not as stable numerically. Decomposition and/or reconstruction through several levels may lead to unacceptable roundoff errors. In this talk, we will give some estimates for the condition numbers associated with biorthogonal wavelet calculations, and show that in many cases the errors are quite small.

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CP 11

A Max-SNP-Hard Problem: Computing the Minimal Perturbation Scaling To Achieve Instability In an Interval Matrix.

An interval matrix can be represented in terms of a "center" matrix and a nonnegative error matrix specifying maximum elementwise perturbations from the center matrix. One approach to testing robust stability (regularity) of an interval matrix with stable (nonsingular) center matrix is to compute the minimum scaling of this error matrix for which instability (singularity) is achieved and then to compare this result to 1. In this paper it is shown that approximating this minimum scaling is MAX-SNP-hard. This implies that in the general case, unless P=NP, this entity cannot be approximated with a ratio arbitrarily close to unity in polynomial time.

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The Asymptotic Convergence Factor for a Rectangle under a Perturbation

Let Ω be a rectangle symmetric with respect to the axes and exclude 1. The asymptotic convergence factor (ACF) for Ω is used to measure the rate of convergence for the asymptotically optimal semiiterative methods for solving a linear system $\mathbf{x} = T\mathbf{x} + \mathbf{c}$, where the spectrum of T is a subset of Ω.

The sensitivity of the ACF for Ω to a perturbation of its boundry is investigated with the application of Hardamard's variation formula. Three formulae for the sensitivity are derived.

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Fast Convolution on the 2-Sphere: Theory and Practice

Let S^2 denote the usual 2-sphere. Any $f \in L^2(S^2)$ can be expanded in terms of the spherical harmonics. Call f **bandlimited** with bandlimit N if its expansion uses only the first N harmonics. We present an $O(N \log^2 N)$ algorithm for exact convolution of two bandlimited functions of bandlimit N, extending earlier work of one of us which gave an $O(N^{3/2})$ algorithm. Implementation of the algorithm shows that even at small problem sizes it is faster than naive implementation. Numerical stability is discussed and experimental results are presented. This algorithm has potential applications in computer vision and weather modelling.

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Hieararchical Decompositions of Partitioned Matrices (I)—Partition-respecting Similarity

The block-triangularization of a square matrix under similarity transformations preserving a prescribed partition is addressed. Partitioned square matrix, of which the row (column) set is divided into a certain number of groups, arises from a mathematical formulation of discrete stochastic or engineering systems. For such a system the block-triangular form represents the decomposition into subsystems or the hierarchical structure. A module is defined from a partitioned square matrix, and the uniqueness of the block-triangular form is deduced from the Jordan-Hölder theorem. The results cover block-triangularization methods such as the strongly-connected-component decomposition of directed graphs and the Jordan normal form.

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Kyoto University, Kyoto, Japan

Hieararchical Decompositions of Partitioned Matrices (II)—Partition-respecting Equivalency

The block-triangularization of a (not necessarily square) matrix under equivalence transformations conformal with a given partition is addressed. Partitioned matrix, of which the row-set and the column-set are divided into certain numbers of groups, arises from a mathematical formulation of discrete physical or engineering systems. The block-triangularizability is proved to be equivalent to the existence of an associated module, and the uniqueness of the block-triangular form follows from the Jordan-Hölder theorem. The results cover block-triangularization methods such as the Dulmage-Mendelsohn decomposition of bipartite graphs, the combinatorial canonical form of layered mixed matrices and the rank normal form.

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Some New Determinantal Identities Related to Chio's Theorem

By expanding a certain symplectic matrix representing a partial Fourier transform (which is a Fourier transform which only transforms some but not all dimensions of the space) in two different ways a new determinantal identity is derived. This identity is related to similar identities of Sylvester, Chio, and others but is apparently new. A one dimensional consequence of this identity is

where a is an nxn nonsingular matrix. A partially new notation is introduced for conveniently specifying when a matrix has certain rows or columns zero.

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Recent Developments of Nonnegative Splitting Theory

The paper "Nonnegative Splitting Theory" (1992, the manuscript submitted to Editor) provides many comparison theorems as useful tools for the convergence analysis of iterative methods used for solving the linear equation systems with monotone matrices A representing a broad class of physical and engineering problems. This theory based on the Perron-Frobenius theory of nonnegative matrices is a generalization of the regular splitting results originated by Varga in 1960 and improved later by the author. The nonnegative splitting theory results allow to make the comparison of spectral radii of iteration matrices in particular iterative methods represented by (weak) nonnegative splittings of A.

If M is a nonsingular matrix with M > 0, then the decomposition A = M - N is defined as

i) *a regular splitting of A if N $>$ 0,*

ii) *a nonnegative splitting of A if M N $>$ 0 and NM $>$ 0,*

iii) *a weak nonnegative splitting of A if either M N $>$ 0 or NM $>$ 0.*

In the present paper the series of new comparison theorems for the above splittings of A, with A $>$ 0 (or A $>$ 0), have been proven under natural and compound conditions. The relation of nonnegative splitting theory results with those obtained by other authors is discussed as well.

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An Index Theorem for Monotone Matrix-valued Functions

In this talk we shall discuss the following index theorem, which is closely related to oscillation theorems on linear, self-adjoint differential systems as e.g. results by M. Morse. Let be given $m \times m$-matrices R_1, R_2, X, U, which satisfy

$$R_1 R_2^T = R_2 R_1^T, \quad X^T U = U^T X, \quad \text{rank}(R_1, R_2) = \text{rank}(X^T, U^T) = m .$$

Moreover, assume that $X(t)$, $U(t)$ are $m \times m$-matrix-valued functions on some interval $\mathcal{J} = [-\varepsilon, \varepsilon]$, $\varepsilon > 0$, such that

$$X^T(t)U(t) = U^T(t)X(t) \quad \text{on } \mathcal{J}, \quad X(t) \to X \quad \text{and} \quad U(t) \to U \quad \text{as } t \to 0,$$

$X(t)$ is invertible for $t \in \mathcal{J}\backslash\{0\}$, and such that $U(t)X^{-1}(t)$ is decreasing on $\mathcal{J}\backslash\{0\}$, and denote

$$M(t) = R_1 R_2^T + R_2 U(t) X^{-1}(t) R_2^T, \quad \Lambda(t) = R_1 X(t) + R_2 U(t), \quad \Lambda = R_1 X + R_2 U .$$

Then, ind $M(0+)$, ind $M(0-)$ and def $\Lambda(0+)$ exist with

$$\text{ind}\, M(0+) - \text{ind}\, M(0-) = \text{def}\, \Lambda - \text{def}\, \Lambda(0+) - \text{def}\, X ,$$

where ind denotes the index (i.e. the number of negative eigenvalues) and where def denotes the defect (i.e. the dimension of the kernel) of a matrix. The basic tool for the proof of this result consists of a theorem on the rank of a certain product of matrices, and this **rank theorem** must be considered as the key result.

Werner Kratz
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MS9 (continued)

A Direct Algorithm for Computing Eigenspaces with Specified Eigenvalues of a Regular Matrix Pair (A, B) in Generalized Real Schur Form

A direct orthogonal equivalence transformation method for reordering the eigenvalues along the diagonal in the generalized real Schur form of a regular matrix pair (A, B) is presented. Each swap of two adjacent eigenvalues (real, or complex conjugate pairs) involves solving a generalized Sylvester equation and the construction of two orthogonal transformation matrices from certain eigenspaces associated with the corresponding diagonal blocks. An error analysis of the direct reordering method is presented. Results from numerical experiments on well-conditioned as well as ill-conditioned problems illustrate the stability and the accuracy of the method. A direct reordering algorithm with controlled backward error is described. Finally, LAPACK-style software for computing eigenspaces with specified eigenvalues of a regular matrix pair (A, B) is presented.

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MS27 (continued)

Order Reduction of Aeroelastic Models through LK Transformation and Riccati Iteration

This talk presents the application of the LK transformation taken from singular perturbations to the order reduction of the aeroelastic models of flight vehicles. Order reduction methodology is described that has been found to accurately reduce the order of large time-domain aeroelastic models for the design of aircraft active flight control systems. The LK transformation. and Riccati iteration when needed, can greatly reduce the model order, yet accurately represent the vehicle time-domain and frequency-domain characteristics up to a specified bandwidth. Numerical examples are provided.

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MS28 continued)

Massively Parallel Sparse Matrix Computations on Unstructured Meshes

We describe algorithms and software for sparse matrix computations on massively parallel computers such as the Intel DELTA. We have developed parallel algorithms and software for mesh refinement, mesh partitioning, and the solution of sparse, unstructured linear systems. We briefly describe a parallel mesh refinement algorithm where parallelism is accomplished through the computation of independent sets. A parallel geometric mesh partitioning scheme is then given that computes provably good partitions that are useful for parallel sparse iterative methods. Finally we demonstrate the performance of these algorithms in combination with parallel sparse linear system solver based on the conjugate gradient method preconditioned by incomplete factorization. We present results for this combination of algorithms for a large-scale scientific application on the Intel DELTA.

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MS35 (continued)

The Set of 2-by-3 Matrix Pencils – Structure Transitions of the Nongeneric Cases under Perturbations

The set (or family) of 2-by-3 matrix pencils $A - \lambda B$ comprises 18 structurally different singular cases. With structurally different we mean that all cases have different Kronecker structures (canonical forms). The *generic* case corresponds to A and B both having full row ranks. By dropping the row ranks of A and/or B and imposing different sizes of their "common nullspace(s)" we are able to generate all 17 *non-generic* cases starting from the generic pencil. By making A and B more rank deficient and increasing their "common nullspace(s)" we generate nongeneric pencils with higher co-dimension. Explicit expressions for these case–transforming "perturbations" are discussed. Since computing the Kronecker structure of a singular pencil is a potentially ill–posed problem, it is interesting to see how the nongeneric cases behave under perturbations. We add random perturbations of different sizes to all A and B, corresponding to the 17 non–generic cases, and compute their generalized Schur forms assuming a fixed relative accuracy of the input data. We then study the structure transitions of each nongeneric case as a function of the size of the perturbations added. For large enough perturbations all non-generic pencils turn generic. Some nongeneric cases transit between several nongeneric structures before turning generic. These transitions always go from higher to lower co-dimensions, indicating that there is a natural "nesting" (hierarchy) between the non-generic structures. The applications we have in mind include computing the "closest" nongeneric pencil to a generic $A - \lambda B$. For example, estimating the distance to the closest uncontrollable system.

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