I M A G E

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Serving the International Linear Algebra Community
Edited by S. J. Leon and R. C. Thompson

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Newly elected ILAS officers and board member
From left to right: Hans Schneider, Tsuyoshi Ando and James Weaver

ILAS NEWS

RESULTS OF THE 1991 ILAS ELECTIONS

Hans Schneider has been elected President of ILAS and **James Weaver** has been elected Treasurer. **Tsuyoshi Ando** and **David Carlson** were elected to serve on the Board of Directors. Each will serve a two year term beginning March 1, 1992.

Hans Schneider was born in Vienna, Austria, on January 24, 1927. He received the M.A., and Ph.D. degrees from the University of Edinburgh, Edinburgh, Scotland, in 1948 and 1952, respectively. His Ph.D. supervisor was A. C. Aitken. From 1952 to 1959 he was a Lecturer at the Queen's University of Belfast in Northern Ireland and since 1959 he has been a member of the Mathematics Department of the University of Wisconsin-Madison where he currently holds the position of James Joseph Sylvester Professor. From 1966 to 1968 he was Chair of the Department. He is the author of over 100 research papers and two undergraduate textbooks. Many of his publications are joint. His main field of specialization is matrix theory in its various forms. Fourteen students have obtained Ph.D.'s under his direction.

Hans has been Editor-in-Chief of *Linear Algebra and Its Applications* since 1972, jointly with R.A. Brualdi since 1979. He is an Editor of *Linear and Multilinear Algebra*. He was the first Chair of the SIAM Activity Group in Linear Algebra and is currently the first president of the International Linear Algebra Society.

James R. Weaver received his Ph.D. in 1969 at Michigan State University under Joseph E. Adney after having earned an MS and BS at Michigan State University and Kent State University, respectively. From 1969 he has been a faculty member at the University of West Florida where he has been a full professor since 1984.

He has been an active member of the AMS, ILAS, MAA and SIAM. In 1988-89 he served as President-Elect of the Florida Section of the MAA and in 1989-90 he was its President. He is a founder of the International Linear Algebra Society and was its first Treasurer. He served as President of the UWF Chapter of the United Faculty of Florida in 1988-89.

Jim's research interests include matrices that commute with a permutation matrix, matrix norms, and stochastic matrices.

Tsuyoshi Ando was born Feb. 1, 1932 in Sapporo, Japan. He received a B.S. (1953) and Ph.D. (1958) in Mathematics from Hokkaido University, Japan. He has taught at Hokkaido University since 1958 in the Division of Applied Mathematics, Research Institute of Applied Electricity. He has been a full professor since 1970 and has served as Director of the Institute since 1989.

Tsuyoshi is a member of ILAS, SIAM, SIAG/LA, AMS, and the Mathematical Society of Japan. His research interests are in the fields of operator and matrix inequalities and applications of matrix analysis to systems and networks.

Dave Carlson received an A.B. degree from San Diego College in 1957 and an M.S. (1959) and Ph.D. (1963) from the University of Wisconsin. His thesis advisor was Hans Schneider. He taught at the University of Wisconsin-Milwaukee, (1962–63) and at Oregon State University from 1963–84. He has been a full professor at San Diego State University since 1984 and served as Chair of the Mathematics Department 1984-89.

Dave Carlson served as Associate Editor of *Linear Algebra and Its Applications* during the period 1972–83 and since then he has continued to serve as an Advisory Editor. His research interests are in the fields of matrix theory (Lyapunov maps; eigenvalue, inertia, determinant, and invariant factor bounds; M-matrices and G-functions; Schur complements and generalized inverses; controllability; cones of matrices), multilinear algebra (induced multilinear maps), and the learning and teaching of mathematics (especially linear algebra and calculus).

Dave is a member of the AMS, MAA, SIAM and the National Council of Teachers of Mathematics. He served as Chair of the SIAM Activity Group on Linear Algebra 1989–91 and he is currently serving as Chair of the ILAS Education Committee and as a member of the MAA Committee for Calculus Reform and the First Two Years.

The following are the official election results as reported by the Chair of the Nominating Committee.

1991 ILAS ELECTION RESULTS

Report by Richard A. Brualdi

The 1991 ILAS Elections are now over. The results are:

President:
Hans Schneider: 87 votes
write-in 0

Treasurer:
James R. Weaver 87 votes
write-in 0

One seat on the Board of Directors

Tsuyoshi Ando	86 votes
write-in	0

Another seat on the Board of Directors

David Carlson	86 votes
write-in	1 vote for Ingram Olkin

As chair of the Nominating Committee and the person designated to count the ballots, I hereby declare that Hans Schneider has been elected President, James Weaver has been elected Treasurer, and T. Ando and David Carlson have been elected to the Board of Directors, each for a two year term beginning March 1, 1992. Congratulations to the winners!

ILAS *ATLAST* LINEAR ALGEBRA WORKSHOPS

Report by S. J. Leon

ATLAST is an NSF-ILAS Project to *A*ugment the *T*eaching of *L*inear *A*lgebra through the use of *S*oftware *T*ools. The project will offer ten faculty workshops on the use of software in teaching linear algebra. The workshops will last three days. They will be held at regional sites across the United States during the summers of 1992 and 1993. Each workshop will have the same format and content.

The *ATLAST* Project was conceived by the Education Committee of the International Linear Algebra Society (ILAS). Steven J. Leon of the ILAS Education Committee is serving as the *ATLAST* Project Director and the Assistant Director is Richard Faulkenberry. Both are in the Mathematics Department of the University of Massachusetts Dartmouth. The project is funded by a National Science Foundation Faculty Enhancement grant.

Workshop participants will learn about existing commercial linear algebra software packages and will be trained in the use of the MATLAB software package. Attendees will learn how to effectively incorporate computer exercises and laboratories into undergraduate linear algebra courses.

The *ATLAST* Project provides room and board for participants attending the workshops. Participants will learn to design computing exercises or projects at a level suitable for assigning to an undergraduate linear algebra class. These exercises will be class tested during the school year following the workshop and then submitted to the project director for inclusion in a data base. Participants will each receive a modest stipend for their submitted projects.

The data bases from each of the summer workshops will be edited and printed as manuals which will be distributed to the workshop attendees. The project director will select the best exercises from the manuals for inclusion in an *ATLAST* Project Book. This book will be published by one of the mathematics societies with the provision that its contents will be public domain. Participants' contributions will be acknowledged in both the data base and the Project Book.

Summer 1992 *ATLAST* Workshops

1. Workshop site: West Valley College, Saratoga, California
   Workshop dates: June 4–6, 1992
   Workshop Presenter: Dr. Jane Day, San Jose State University

2. Workshop site: Auburn University, Auburn Alabama
   Workshop dates: June 11–13
   Workshop Presenter: Dr. Kermit Sigmon, University of Florida

3. Workshop site: University of Wisconsin, Madison Wisconsin
   Workshop dates: June 18–20, 1992
   Workshop Presenter: Dr. Steven J. Leon, UMass Dartmouth

4. Workshop site: University of Wyoming, Laramie Wyoming
   Workshop dates: June 25–27, 1992
   Workshop Presenter: Dr. Eugene Herman, Grinnell College

5. Workshop site: University of Maryland, College Park, Maryland
   Workshop dates: July 22–25, 1992
   Workshop Presenter: Dr. David Hill, Temple University

All teachers of undergraduate linear algebra courses at colleges or universities in the USA are invited to apply for the ATLAST workshops. The deadline for applications is April 1, 1992, afterwhich applications will be accepted on a space available basis. For application forms and further information about the *ATLAST* Program contact:

Steven J. Leon
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ILAS NOMINATIONS FOR 1993

Report by Richard Brualdi, Chair, ILAS Nominating Committee

I am happy to report that the Nominating Committee of ILAS (Y.H. Au-Yeung, R. Brualdi, J. Dias da Silva, T. Laffey and S. Friedland) has successfully completed its selection of nominees for the ILAS elections scheduled for the summer of 1992 with term of office beginning March 1, 1993. Each of the nominees has agreed to be a candidate for office as designated below. The fact that such outstanding people are willing to stand for election in order to serve ILAS is a tribute to the success that the current officers have had in making ILAS into an important organization for linear algebraists all over the world. Congratulations!

Vice-President (one to be elected):

Russell Merris, Hayward (USA)
Graciano de Oliveira, Coimbra (Portugal)

Secretary:

Daniel Hershkowitz, Haifa (Israel)

Board of Directors (two to be elected):

Harm Bart, Rotterdam (The Netherlands)
Rajendra Bhatia, New Delhi (India)
Steven Leon, North Dartmouth (USA)
Paul Van Dooren, Champaign-Urbana (USA).

According to the bylaws of ILAS, additional nominations for any of the offices above may be made by any three members of the Society with the prior approval of the nominee. Such nominations should be sent to Richard Brualdi by either regular or electronic mail before June 1, 1992.

NINTH ISSUE OF *IMAGE* PLANNED FOR JULY 1992

IMAGE is edited by S. J. Leon and R. C. Thompson. The Production Editor is Ann Cox. News items for the ninth issue should be sent no later than June 1, 1992 to:

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All news of interest to the Linear Algebra community is welcome including: news of conferences, journals and books, upcoming events, and activities of members. E-mail appears to be the fastest and most efficient way to submit news items.

Future issues of *IMAGE* will contain feature articles on linear algebra activities in other countries. These articles should be no more than three pages in length. If you're a member of ILAS then *IMAGE* is your publication. It needs your support. Please keep us informed about the linear algebra activities in your country.

ILAS-NET

The International Linear Algebra Society also maintains an electronic news service *ILAS-NET* edited by Danny Hershkowitz. If you want to submit news items or to have your name added to the *ILAS-NET* distribution list, send a message to Danny at:

MAR23AA@TECHNION.BITNET

ILAS MEETING ANNOUNCEMENTS

Twice a year the International Linear Algebra Society (ILAS) sends out dues notices. At that time ILAS can also send an announcement or a call for papers of an ILAS MEETING or an ILAS SPONSORED MEETING. The deadlines for submission of these announcements are June 20 and December 1 of each year. Information should be sent to:

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UPDATE ON LISBON MEETING OF THE ILAS

Report by J. A. Dias da Silva

The Second Meeting of the International Linear Algebra Society will be held at the University of Lisbon, Portugal, on August 3–7, 1992.

The following is a list of the 60 minute invited speakers.

Rajendra Bathia, India, **Israel Gohberg**, Israel, **Paul Halmos**, USA, **Russell Merris**, USA, **Axel Ruhe**, Sweden, **Vlatismil Ptak**, Czechoslovakia, **Marques De Sà**, Portugal, **Hans Schneider**, USA, **G. W. Stewart**, USA, **Robert C. Thompson**, USA, **Ion Zaballa**, Spain, **Shmuel Friedland**, USA

The following is a list of the 30 minute invited speakers.

T. Ando, Japan, **R. Bapat**, India, Natàlia Bebiano, Portugal, **Åke Björck**, Sweden, **Rafael Bru**, Spain, **Richard Brualdi**, USA, **Biswa N. Datta**, USA, **Ludwig Elsner**, Germany, **Dragomir Z. Djokovic**, Canada, **Jiang Erxiong**, People's Republic of China, **Miroslav Fiedler**, Czechoslovakia, **Juan Miguel Gracia**, Spain, **Vicente Hernandez**, Spain, **J. A. Holbrook**, USA, **Rien Kaashoek**, Netherlands, **Peter Lancaster**, Canada, **Chi-Kwong Li**, USA, **Raphael Loewy**, Israel, **Michael Neumann**, USA, **Frank Uhlig**, USA, **Michael Puystjens**, Belgium, **Uriel G. Rothblum**, USA, **Fernando C. Silva**, Portugal, **Bit-Shun Tam**, Taiwan, **Yik-Hoi Au-Yeung**, Hong Kong, **Ji-Guang Sun**, People's Republic of China

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FEATURE ARTICLE

LINEAR ALGEBRA IN SPAIN

by Juan M. Gracia and Vicente Hernández

The purpose of this note is to describe the evolution of research in Linear Algebra and Matrix Theory (and their Applications) in Spain over the last ten years. Since our information is limited, we shall only discuss: (1) research teams, and not isolated individuals, (2) those who publish their results in *Linear Algebra and Its Applications*, *Linear and Multilinear Algebra*, *SIAM Journal on Matrix Analysis and Applications*, *Integral Equations and Operator Theory*, and (3) those who have participated in the Meetings on Linear Algebra and Matrix Theory in Spain and Portugal during the years 1982, 1983, 1984, 1987 and 1989. We apologize to any one we may have forgotten or omitted.

First we would like to comment on the evoution of teaching Linear Algebra and Matrix Theory in Spanish universities. In 1965, J. J. Etayo, professor of Geometry at the University of Madrid, translated into Spanish the book *Introduction to Matrix Analysis* by R. Bellman. In 1966, *Theorie des Matrices* (2 vols.,) the French translation of the book by F. R. Gantmacher, was published. Both books caused a great impact, and a course was taught then at the University of Seville based on Bellman's study. At the same time, a course entitled *Linear Algebra* was introduced into the curricula of Physics and Engineering Schools, while some topics in Linear Programming and Nonnegative Matrices were taught in Economics courses. In contrast, Bourbaki's texts were used in Mathematics Schools and Linear Algebra was relegated to Geometry courses as an auxiliary tool. Probably the only exception, indicating the importance of Lienar Algebra outside Geometry, was Dou's book *Ecuaciones Diferenciales Ordinarias*, which used the Jordan canonical form for the solution of linear differential systems with constant coefficients. In the 1970s many people came to believe that the only possible activity in Linear Algebra was teaching. Two good textbooks, both titled *Algebra Lineal*, were written by F. Puerta and J. Rojo. Since matrices were only used as a tool in the solution of other problems, research limited exclusively to Matrix Theory seemed unthinkable. Thus, the authors of this synopsis, to follow their interest in this field, wrote doctoral dissertations in 1978 and 1979 straddling Linear Differential Equations, Matrix Theory and Control Theory. Others were moving in the same direction.

At the "Jornadas Matemáticas Hispano-Lusas" held in Spain in 1980, J. M. Gracia met J. Vitória, of Coimbra (Portugal). This meeting led to a productive collaboration between the Linear Algebra Group formed by Graciano de Oliveira at the University of Coimbra and those who were working in the field of Matrix Theory in Vitoria and Valencia. The Linear Algebra Group of the University of the Basque Country was founded in Vitoria in 1981. This group, made up of nine persons, has done work on inverse problems of matrices related to prescription of invariant factors and controllability indices. They also worked on generalized singular values, matrix polynomials, matrix equations, perturbation of matrices and matrix functions. In this group, I. Zaballa has been notable for his contribution to clarifying the relationship between control linear systems theory and the inverse problems of matrices developed by the Portuguese school. Another Linear Algebra Group started in 1984 at the Polytechnic University of Valencia, thanks to the work of V. Hernández and R. Bru. Made up of twenty persons, this group carries out research in linear and quadratic matrix equations in control theory, matrix polynomials, nonnegative matrices and linear systems, periodic linear systems, numerical linear algebra (sequential and parallel algorithms). In addition, some people are working in matrix differential equations, headed by L. Jodar.

At the beginning of the 1970s, Professor L. Vigil organized a group in Zaragoza concerned with the theory of orthogonal polynomials on algebraic curves. One of his students, F. Marcellán, presently a professor in Madrid, is collaborating with researchers in other Spanish and Portuguese universities. There is a group working with him on Bezoutians, Hankel, Toeplitz, Vandermonde and Pick matrices, and the theory of orthogonal matrix polynomials on the unit circle.

There is another group in Madrid, lead by Professor A. Pérez de Vargas, working in Biomathematics. This group is studying algebraic models related to biological processes: genetic algebras, zygotic algebras, idempotent elements. They have recenlty succeeded in establishing a model for the phenomenon of chromosomic rupture, affected both by mutation factors and crossing-over. Some people in Zaragoza are also working on the properties of nonassociative linear algebras in relation to genetic problems. This group, lead by S. González, is also studying Lie, Jordan and Berstein algebras.

In 1988 a Linear Algebra group was formed by F. Puerta and J. Ferrer in Barcelona. This group has been working on problems related to the construction of basis of a pair of matrices to obtain the Brunovsky canonical form by means of block similarities. They have also been working with deformation and bifurcation of pairs of matrices, extending results of Arnold. Another group, in Alicante, lead by C. Herrero is studying some aspects of Matrix Theory with applications in Economics, such as the Perron-Frobenius Theorem for set-valued functions and its relations with Games Theory, matrices with nonnegative inverse, weak-monotone matrices and the existence of positive generalized inverse.

Finally, we would like to mention the noteworthy work in Matrix Theory carried out by those whose principal interests are in other areas of Mathematics: J. E. Martínez-Legaz (Barcelona), M. A. Goberna and M. A. López (Alicante), M. Gasca (Zaragoza), J. Ochoa

(Madrid) and J. Sánchez-Dehesa (Granada). This was the first Spaniard to publish a paper in *Linear Algebra and Its Applications*.

This summary shows that interest in Spain in Linear Algebra and Matrix Theory, although slow to develop, is now promising. The importance of this field for young researchers is obviously much higher now than some years ago, and consequently many Ph.D. students are focussing their studies on this interesting area.

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NEWS ITEMS

LINEAR ALGEBRA CURRICULUM STUDY GROUP

Report by Dave Carlson

The Linear Algebra Curriculum Study Group is organizing a special session for the 1992 Joint Math Meetings in Baltimore. The session will be held Thursday, January 9 from 7:00 to 10:00 pm. One feature will be several presentations by users of linear algebra from other fields. Another will be the LACSG Proposed Syllabus for the First Course in Linear Algebra. The syllabus will be presented and its rationale and novel features highlighted. We would also like to have 10–15 minutes presentations by a few faculty who have used the syllabus already and can comment on its strengths and weaknesses in the classroom.

NATO Advanced Study Institute
Linear Algebra for Large Scale and Real-Time Applications
Leuven - Belgium, August 3-14 1992

Report by Gene Golub

Scope:

The Institute aims to bring together leading researchers involved in the design of large scale and real-time computations, and practitioners from industry and academia. It seeks to provide a forum to address and discuss the state of the art, as well as the needs for the future. The Institute will feature invited tutorial sessions as well as contributed papers, with ample time for informal workshops and discussion.

This meeting is a successor to a previous ASI, 'Numerical Linear Algebra, Digital Signal processing and Parallel Algorithms', Leuven, Belgium, August 1988.

Invited Lecturers:

P. Bjorstad, Universitetet i Bergen, Norway

S. Boyd, Stanford University, U.S.A.

G. Cybenko, Univ. of Illinois, Urbana-Champaign, U.S.A.

J. Demmel, University of California Berkeley, U.S.A

E. Deprettere, Technische Universiteit Delft, The Netherlands

P. Dewilde, Technische Universiteit Delft, The Netherlands

R. Freund, RIACS, U.S.A., and University of Wurzburg, Germany

M. Gentleman, National Research Council, Canada

S. Haykin, McMaster University, Canada

B. Kagstrom, University of Umea, Sweden

N. Kalouptsidis, University of Athens, Greece

F. Luk, RPI, U.S.A.

P. Toint, Universite de Namur, Belgium

M. Wright, AT & T, U.S.A.

C. Van Loan, Cornell University, U.S.A.

Venue

The Institute will be held at the Katholieke Universiteit Leuven, Leuven, Belgium. Leuven can be easily reached from Brussels International Airport. For the participants, dormitory rooms will be available on campus. All attendees are expected to stay for the full duration of the Institute.

Applications

Participation is by invitation only. Persons wishing to make an application to attend the Institute are invited to send five copies of a short vita to the address given below. In addition, five copies of a one page abstract are requested from those wishing to contribute a short paper. Application forms can be obtained by E-mail or regular mail at the address given below. The deadline for application is March 1st, though earlier applications are especially welcomed. Notification will be given by April 15th. Participants will be drawn from both NATO and non-NATO countries.

Organizing Committee

B. De Moor, Katholieke Universiteit Leuven, Belgium, director

G. H. Golub, Stanford University, U.S.A., co-director

A. Bunse-Gerstner, Universitat Bremen, Germany

S. Hammarling, Numerical Algorithms Group Ltd, Oxford, U.K.

J. Meinguet, Universite Catholique de Louvain, Belgium

J. Vandewalle, Katholieke Universiteit Leuven, Belgium

Correspondence Address

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E-mail: moonen@esat.kuleuven.ac.be

Workshop on Numerical Ranges and Numerical Radii

The College of William and Mary, August 10–15, 1992

Report by Chi-Kwong Li

The aim of the proposed workshop is to bring researchers on numerical ranges and numerical radii from different (research and geographic) areas together to exchange ideas on the subject. In particular, there are four primary objectives for the workshop.

(a) To study and further explore applications of various kinds of generalized numerical ranges and numerical radii in different branches of science.

(b) To discuss existing mathematical tools and techniques and try to generate new methods to handle problems on numerical ranges and numerical radii.

(c) To discuss possible research projects or computer projects on numerical ranges and numerical radii appropriate for the undergraduate or graduate level.

(d) To exchange research problems, ideas and experience on the subject.

While the main theme of the workshop is on numerical ranges and numerical radii, discussion will be focused on the relations and applications of the subject to several specific topics.

Day 1. Operator theory and C*-algebras

Day 2. Norms and Matrix inequalities

Day 3. Decomposable numerical ranges and Quantum physics

Day 4. Systems theory and Computer generation of numerical ranges

Day 5. Location of eigenvalues

Day 6. Other related subjects such as completion problems, linear preserver problems, etc.

For more information concerning the workshop please contact

Dr. Chi-Kwong Li
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The College of William and Mary
Williamsburg, VA 23187 USA
e-mail: ckli@cma.math.wm.edu
tel: (804) 221-2042

Support for this workshop comes from the The College of William and Mary. Support funds are being sought for workshop participants and more details will be known by the end of March, 1992.

Note: Persons from North America planning to attend the second ILAS meeting at Lisbon, August 3–7, 1992, may be able to include a stop at Williamsburg on their return tickets.

WORKSHOP ON MATRIX METHODS FOR STATISTICS

Report by George Styan

The Organizing Committee of Harold Henderson, Jeff Hunter, Bryan Manly, Simo Puntanen, Alastair Scott, and George Styan is pleased to invite you to attend an *International Workshop on Matrix Methods for Statistics* to be held on Friday-Saturday, 4–5 December 1992, at the University of Auckland, Auckland, New Zealand.

Co-sponsored by the International Linear Algebra Society, this Workshop is a satellite to, and almost immediately precedes, the International Biometric Conference-IBC92 (7-11 December 1992). We encourage you to attend our Workshop and then stay on for the IBC92 in Hamilton (90-minutes drive south of Auckland). There will be a Short Course on Dynamic Graphical Analysis given by R. Dennis Cook in Hamilton on Sunday, 6 December 1992. After the IBC92 there will be Genstat and Correlated Data Workshops, both scheduled to start on Monday, 14 December 1992, respectively in Rotorua (or Hamilton) and Queenstown.

The Mahalanobis Multivariate Statistics Meeting in Delhi (17-22 December 1992) will be preceded by a satellite meeting in Delhi (organized by Sujit Kumar Mitra) on generalized inverse and its application (11-16 December 1992). There are good airline connections from Auckland to Delhi via Singapore.

Several other workshops are scheduled to take place in Australia and New Zealand during the last two months of 1992. For information on these contact George Styan, e-mail: MT56@MUSICA.MCGILL.CA.

The purpose of our International Workshop on Matrix Methods for Statistics is to foster the interaction, in an informal setting, of researchers in the interface between matrix theory and statistics. We propose, therefore, that there be no parallel sessions, and that all, or almost all, the talks be of 20-minutes duration. That would make a total of (say) 20 talks, and so of 10 each day.

We have invited Garry Tee (Auckland) to talk about the work of Alexander Craig Aitken (1895-1967), and his plans to publish Aitken's Collected Papers. We would also hope that there would be time during the weekend to hold an organizational meeting for a possible 3rd Pacific Statistical Congress to be held in 1995 in Celebration of the 100th birthday of A. C. Aitken (the two earlier PSC's were held in Auckland, 1985, and Sydney, 1990).

We regret that there is no money to support participants in our Workshop - furthermore, we plan to charge a US$20 registration fee. The preparation and printing of the program-cum-abstracts booklet will be done in, and financed by, the Dept. of Mathematics and Statistics, University of Auckland.

We would like to know your immediate, and hence initial, reaction to this invitation. Later on we would like to know who's coming, say by 30 June 1992, and if you're going to give a talk. We would then like to have the title and abstract by, say, 31 August 1992.

Please reply to this invitation to George Styan, e-mail: MT56@MUSICA.MCGILL.CA or FAX: 1-514-398-3899.

CALENDAR OF COMING CONFERENCES

January 13–17, 1992, IMA Workshop on Linear Algebra, Markov Chains, and Queuing Models, University of Minnesota

February 24 – March 1, 1992, IMA Workshop on Iterative Methods for for Sparse and Structured Problems, University of Minnesota

April 6–10, 1992, IMA Workshop on Linear Algebra for Signal Processing, University of Minnesota

April 9–16, 1992, Copper Mountain Conference on Iterative Methods
Information: cmcim92@copper.denver.colorado.edu

Summer 1992, *ATLAST* Workshops on the Use of Software in Teaching Linear Algebra
Information: S. J. Leon, e-mail: ATLAST@UMASSD.EDU

June 1–5, 1992, IMA Workshop on Linear Algebra for Control Theory, University of Minnesota

August 3–7, 1992, ILAS Conference, Lisbon University, Portugal
Information: See article in *IMAGE* #7

August 10–15, 1992, Workshop on Numerical Ranges and Numerical Radii, College of William and Mary
Information: Dr. Chi-Kwong Li, e-mail: ckli@cma.math.wm.edu

December 4–5, 1992, International Workshop on Matrix Methods for Statistics, University of Auckland, Auckland, New Zealand
Information: George Styan, e-mail: MT56@MUSICA.MCGILL.CA

March 17–20, 1993, ILAS Conference, University of West Florida, Pensacola, Florida
Information: See future issues of *IMAGE*

Summer 1993, *ATLAST* Workshops on the Use of Software in Teaching Linear Algebra
Information: S. J. Leon, e-mail: ATLAST@UMASSD.EDU

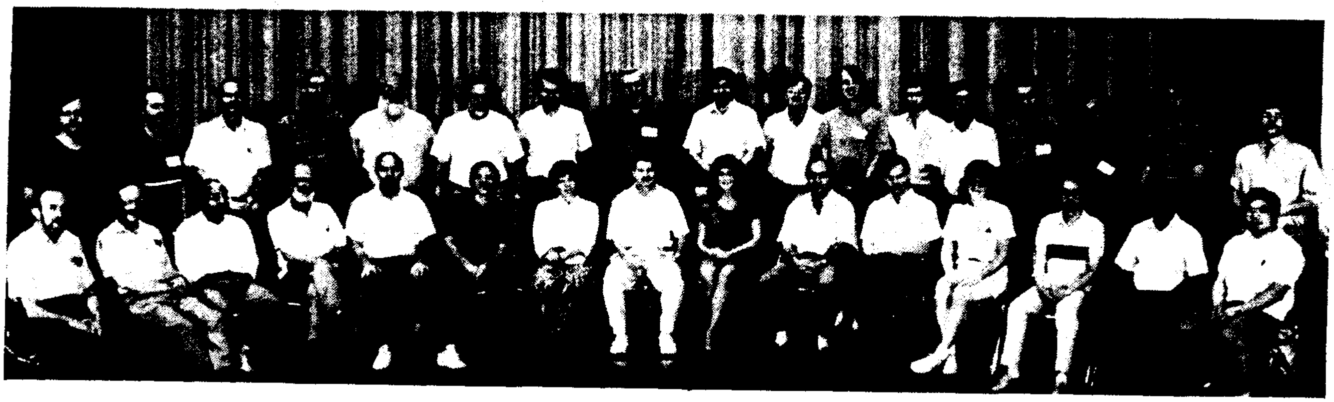
June 1993, Special Month in Linear Algebra, Technion-Israel Institute of Technology, Haifa; Eighth Haifa Matrix Theory Conference, Technion-Israel Institute of Technology, Haifa
Information: A. Berman, e-mail: MAR64AA@TECHNION.BITNET or D. Hershkowitz (MAR23AA@TECHNION.BITNET)

June 1993, 12th Householder Symposium on Numerical Linear Algebra, Lake Arrowhead, California
Information: Gene Golub, Computer Science Dept., Stanford University or Tony Chan, Mathematics Department, UCLA

August 1993, ILAS Conference, University of Essex, Colchester, England
Information: See future issues of *IMAGE*

December 13–17, 1993 International Cornelius Lanczos Centenary Conference, North Carolina State University, Raleigh, North Carolina
Information: R. J. Plemmons, North Carolina State University, Raleigh, NC 27695–8205

August 15–19, 1994, ILAS Conference, Erasmus University, Rotterdam
Information: See future issues of *IMAGE*



Atlanta Conference Group Picture. (Left to right) Seated: Irving Katz, Hans Schneider, Asok Sen, Paul Halmos, Frank Hall, Raphael Loewy, Katalin Bencsath, George Poole, Carolyn Eschenbach, Joan-Josep Climent, Michael Lundquist, Ann Cox, Nam-Kiu Tsing, Kit Kittappa, Wasin So. Standing: Michael Bakonyi, Leroy Beasley, Robert Hartwig, Jean Bevis, Robert Grone, William Anderson, Jr., Wayne Barrett, John Maybee, Charles Johnson, Ronald Smith, Marcus Pendergrass, Peter Ori, Tin-Yau Tam, Tamir Shalom, Ilya Spitkovsky, Peter Nylen, Thomas Lundy

NSF/CBMS Conference on Qualitative and Structured Matrix Theory

Report by Wayne Barrett

This conference was held from 19–24 August, 1991 at Georgia State University in Atlanta. The organizers for the conference were Jean Bevis, Carolyn Eschenbach, and Frank Hall, all of Georgia State. Funding was provided by the National Science Foundation Conference Board of Mathematical Sciences and by the Department of Mathematics and Computer Science, and the Division of Continuing Education of Georgia State University. The conference site was a short walk from one of the city's main attractions, Underground Atlanta, with a wide variety of shops, specialty stores, and eating establishments. On the first morning of the conference participants were startled by newspaper headlines announcing a coup in the Soviet Union and Gorbachev's ouster. Fortunately, things were back to normal by midweek. Those who stayed through Saturday enjoyed an outing and lunch at Stone Mountain Park.

The principal lecturer of the conference was **Charles R. Johnson** of the College of William and Mary who gave eight one-hour lectures on the subject of Qualitative and Structured Matrix Theory. The first lectures dealt with nonsingularity of sign pattern matrices. By Wednesday there was a considerable degree of intensity among several participants about a problem mentioned by Charlie on the first day: What sign patterns can an orthogonal matrix have? Paul Halmos, who came for the entire week, and who helped fuel the interest in this problem, also told us that he had now learned that matrix theory is not dead. Other topics discussed by Professor Johnson were qualitative rank, various notions of positivity, sign stability, the Perron complement and compressed directed graph, finding hidden structure, and matrix completion problems. We thank Charlie for taking on the overwhelming task to speak about such a quantity of material. His presentations were characteristically clear and informative and I think that everyone who came found the meeting worthwhile.

There were also four other hour talks during the conference:

Tamir Shalom, Columbia University, *Information Requirements for Inverting Toeplitz Matrices.*

Michael Lundquist, Brigham Young University, *Matrices whose Inverses have Chordal Structure*

Hans Schneider, University of Wisconsin-Madison, *Why did Frobenius hate graph theory (and was he right)?*

John Maybee, University of Colorado, *Constructing Sign Nonsingular Matrices*

The morning sessions consisted of the principal lectures with a mid-morning refreshment break. The five afternoon sessions consisted primarily of eleven 25-minute talks and two problem sessions with a mid- afternoon refreshment break. There were 40 participants who came from all parts of the United States, from Canada, Spain, and from Israel. The speakers' transparencies were photocopied and made available to the participants.

Hans mentioned the following quote from the last paragraph of Fobenius' last mathematical paper at the beginning of his talk:

Die Theorie der Graphen, mittels deren Hr. König den obigen Satz abgeleitet hat, ist nach meiner Ansicht ein wenig geignetes Hilfsmittel für die Entwicklung der Determinantentheorie.

That is to say:

In my opinion the theory of graphs, by means of which Mr. König has stated the above theorem, is a tool little suited for the development of the theory of determinants.

Fortunately, as was clear to everyone who attended the conference, this is one belief of Frobenius which did not prevail.

We thank the organizers again for their efforts in hosting a very successful conference.

ICIAM 91 WASHINGTON D.C.

Report by S. J. Leon

Thousands of mathematicians from all over the world gathered in Washington, D.C., July 8–12, 1991 for the second International Congress of Industrial and Applied Mathematics (ICIAM) hosted by SIAM. It was fortunate the the congress was held in an air conditioned hotel as Washington DC lived up to its reputation for steaming summer weather.

Inside, while the temperature was cool, the mathematical activity was hot and furious. There was so much going on at once, that I found it impossible to go to all of the talks I wanted to attend. Even the plenary sessions were in parallel.

Highlights of the conference include, the awarding of the first Wilkinson prize for numerical software to Linda Petzold for her DASSL package, a code for the solution of initial value problems of index zero or one, and the presentation of a special ICIAM award for outstanding contributions to the International Applied Mathematics Community to Gene Golub of Stanford University. The Wilkinson prize was established in honor of the late James Wilkinson and the award was presented by his widow Heather Wilkinson.

The conference was remarkably well organized considering its size. The international makeup of the conference enabled attendees to keep abreast of the latest worldwide research in their fields. In short ICIAM 91 was a exceptionally rewarding event. We look forward to the next ICIAM which is scheduled for Berlin, Germany in 1995.

FIRST INTERNATIONAL CONFERENCE ON ABS METHODS

2–6 SEPT., 1991, Luoyang, China

Report by Emilio Spedicato, University of Bergamo

ABS methods (the name derives from the initials of J. Abaffy, C. Broyden and E. Spedicato, who first contributed to their development) were introduced at the beginning of the eighties to give a unified representation of most algorithms for linear and nonlinear systems and are now being applied to optimization problems. More than a hundred papers have been published in this area, the state of the subject at mid 1989 being presented in the monograph of J. Abaffy and E. Spedicato: *ABS projection algorithms: mathematical techniques for linear and nonlinear equations*, Ellis Horwood. On the occasion of the presentation of the Chinese translation of the above monograph, a conference was organized by E. Spedicato and N. Deng (one of the Chinese translators, the other being Z. Meifang, both of Beijing Polytechnical University) on ABS methods in the city of Luoyang. The choice of a Chinese location reflected to some extent the presence of a rather large group of Chinese mathematicians working in this field. The conference was attended by about fifty participants, mainly from China but also from Italy (Bertocchi, Gaviano, Spedicato), Hungary (Abaffy), Soviet Union (Eremin, Kolotilina). Chinese participants came from Beijing, Dalian, Nanjing, Shanghai, Luoyang, Chengdu, Chonquing, Quingdao, Qufu, Zhenzhou, Quinhuangdao, Jilin, indicating a surprising high number of researchers active in ABS methods.

About thirty communications were presented, dealing with nonlinear systems, nonlinear optimization, parallel formulations and applications to large problems in oil industry. A selected number of presented papers will be published in a special issue of the Journal Optimization Methods and Software, published by Gordon and Breach. It is likely that another short workshop on ABS methods will be organized in St. Petersbourg next June, in occasion of the publication of the Russian edition of the above mentioned monograph.

FOURTH SIAG/LA LINEAR ALGEBRA CONFERENCE

Report by S. J. Leon

The fourth trienniel SIAG/LA conference on Applied Linear Algebra was held at the University of Minnesota September 11–14, 1991. The conference was scheduled to coincide with the beginning of a special year on Linear Algebra at the university's Institute for Mathematics and Its Applications. There were a wide variety of talks covering all areas of research in Linear Algebra. Indeed, this conference provided an excellent opportunity to catch up on the current state of the art in Linear Algebra.

Under the heading of Core Linear Algebra there were two invited presentations, nine minisymposia, and two sessions of contributed papers. The invited presentations were given by Irving Kaplansky who spoke on *Basis Free Methods of Linear Algebra* and Miroslav Fiedler who spoke on *Some Combinatorial Aspects of Matrix.*

Under the heading of Numerical and Computational Linear Algebra there was one invited presentation, eight minisymposia, and eleven sessions of contributed papers. The invited presentation was given by Charlie Van Loan on *The Design and Analysis of Block Matrix Algorithms.*

Under the heading of Matrix Functions, Systems and Control there was one invited presentation, three minisymposia, and two sessions of contributed papers. The invited presentation was given by Athanasios C. Antoulas who spoke on *Rational Matrix Functions with Applications to Systems Theory: Interpolation Problems.*

Other areas in which there were invited speakers and minisymposia include: Perturbation Theory, Matrix Theory in Statistics, Signal Processing, Methods for Sparse Systems, Mathematical Programming, and Numerical Methods for Markov Chains. Additionally there were two minisymposia on Teaching Issues and Pedagogy.

There were nine invited presentations altogether. In addition to the four already mentioned, there were invited talks by

G. W. Stewart, *Numerical Methods for Markov Chains*

Friedrich Pukelsheim *Matrix Theory for the Design of Experiments*

Margaret H. Wright, *Linear Algebra Issues in Interior Methods*

Alan S. Willsky, *Multiscale Stochastic Models and Multiscale Statistical Signal Processing*

Åke Björck, *Numerical Stability of Direct Methods for Sparse Augmented Systems*

One of the highlights of the conference was the awarding of the SIAG/LA Prize to James Demmel and William Kahan for their paper "Accurate Singular Values of Bidiagonal Matrices", *SIAM J. Sci. Comp.*, 1990. There was a banquet on Friday the 13th after which we were lucky enough to be treated to an entertaining talk by Alan J. Hoffman, IBM Thomas J.Watson Research Center, about his early days at the National Bureau of Standards.

This was a most worthwhile conference. The organizing committee, (chaired by Richard Brualdi), should be commended for a job well done!

JOURNAL NEWS

LINEAR ALGEBRA AND ITS APPLICATIONS (LAA)

Special Issues in Progress

Title:	Proceedings of Auburn 1990 Conference
Special Editors:	Frank Uhlig, David Carlson
Full Announcement:	See *IMAGE* #3
Publication:	To appear as Volumes 162-163, February 1992.

Title:	Proc. of the Sixth Haifa Conference on Matrix Theory
Special Editors:	A. Berman, M. Goldberg, D. Hershkowitz
Submission deadline:	October 1, 1990

Title:	Proc. of the International Workshop on Linear Models, Experimental Designs, and Related Matrix Theory
Special Editors:	J. K. Baksalary and G. Styan
Submission Deadline:	October 31, 1990

Title:	Proc. of the Second NIU Conference on Linear Algebra, Numerical Linear Algebra and Applications
Special Editors:	Biswa Datta, Robert Plemmons and Roger Horn
Submission Deadline:	August 31, 1991

Title:	Numerical Linear Algebra in Control, Signals and Systems
Special Editors:	Gregory Ammar, Volker Mehrmann, Nancy K. Nichols, and Paul Van Dooren
Submission Deadline:	July 31, 1992

Title:	Proceedings of the Workshop on Computational Linear Algebra in Algebraic and Related Problems
Special Editors:	R. M. Guralnick and G. O. Michler
Submission Deadline:	October 30, 1992

Title:	Proc. of the Second Conference of the ILAS, Lisbon
Special Editors:	J. A. Dias Da Silva, Chi-Kwong Li, and Graciano de Oliveira
Submission Deadline:	October 30, 1992

Title:	Special Issue Honoring Ingram Olkin
Special Editors:	Friedrich Pukelsheim, George P. H. Styan, Henry Wolkowicz, and Ion Zaballa
Submission Deadline:	August 31, 1992

Title:	Special Issue Honoring Marvin Marcus
Special Editors:	Bryan E. Cain, Moshe Goldberg, Robert Grone, Nicholas J. Higham
Submission Deadline:	December 31, 1992

Title:	Third Special Issue on Linear Systems and Control
Special Editors:	A. C. Antoulas, P. A. Fuhrmann, M. L. J. Hautus and Y. Yamamoto
Submission Deadline:	November 30, 1992

BOOK REVIEWS

Matrices: Methods and Applications, by Stephen Barnett, Clarendon Press, Oxford, 1990, xiii + 450 pp., ISBN 0-19-859680-4

Review by Adi Ben-Israel, Rutgers University

This book is intended for students, and users, of matrix methods. It is very well written, in an informal style that has become the author's trademark. Students will love this book: It provides an easy access to matrix theory, its main facts and ideas, illustrated with many concrete examples. Users will appreciate this book for its encyclopedic coverage and eclectic applications.

The dust jacket describes the book as follows:

> Techniques of matrix theory find wide application throughout engineering and the physical, life, and social sciences. Consequently, matrix methods comprise an important component in any 'tool kit' of applied mathematics. This wide-ranging textbook provides a clearly written and up-to-date account of these methods suitable for both undergraduates and more advanced students.
>
> The author's aim has been to provide a down-to-earth approach with results illustrated with many examples drawn from the areas of application. The range of topics covered is large: from basic matrix algebra to advanced concepts such as generalized inverses and Hadamard matrices, and applications to error-correcting codes, control theory, and linear programming.
>
> Practicalities are borne ever in mind and throughout numerous exercises (with answers) will make the book ideal for students. Research workers too will benefit from the accessible accounts of advanced matrix techniques which they use.

This description, while doing part of my job as reviewer, is an understatement: The wealth of modern, advanced material, which Barnett managed to pack in this small volume, is impressive. Much of this material is given in hundreds of exercises (in each section) and problems (following each section), which make this an excellent choice for a text, or supplement, for a first course in matrix theory and methods.

The book contents are:

Ch. 1. **How matrices arise** (10 pp.): Selected examples.

Ch. 2. **Basic algebra of matrices** (26 pp.): The basic operations, including Kronecker and Hadamard products, and derivatives of matrices.

Ch. 3. **Unique solution of linear equations** (16 pp.): Gaussian elimination, LU and illustration of ill-conditioning.

Ch. 4. **Determinant and inverse** (33 pp.): A recursive definition of the determinant, its properties and evaluation. The Inverse. Cramer's rule.

Ch. 5. **Rank, non-unique solution of equations, and applications** (41 pp.): Elementary operations and equivalent matrices. The normal (reduced triangular) form. The general solution of linear equations. Least squares. Linear dependence. Application to error-correcting codes.

Ch. 6. **Eigenvalues and eigenvectors** (48 pp.): Definition, applications and properties. Similarity. Linear differential and difference equations. Calculation of eigenvalues and eigenvectors. Iterative solution of linear equations.

Ch. 7. **Quadratic and hermitian forms** (23 pp.): Lagrange's reduction. Sylvester's law of inertia. Definiteness tests. Applications to optimization and stability.

Ch. 8. **Canonical forms** (28 pp.): Jordan, Schur, Hessenberg. Singular value and polar decomposition.

Ch. 9. **Matrix functions** (22 pp.): Definition, convergence and properties. Sylvester's formula. Application to linear differential and difference equations. Matrix sign function.

Ch. 10. **Generalized inverses** (32 pp.): The Moore-Penrose, Drazin and other inverses. Applications to linear equations, control systems, linear programming and statistics.

Ch. 11. **Polynomials, stability, and matrix equations** (42 pp.): Companion and resultant matrices. Divisors. Location of roots. Liapunov and Ricatti equations and their solutions.

Ch. 12. **Polynomials and rational matrices** (20 pp.): Properties, elementary operations and Smith normal form. Prime and rational matrices.

Ch. 13. **Patterned matrices** (43 pp.): Banded, circulant, Toepliz and Hankel matrices, and many others; a veritable who-is-who in matrix theory.

Ch. 14. **Miscellaneous topics** (36 pp.): Matrix equations. Non-negative and M-matrices. Norms and condition.

Bibliography (76 books). **Answers to exercises and problems. Index.**

The promised topics (matrix theory, methods & applications) are covered very well. The treatment of numerical and computational issues is adequate for students and most practitioners (who should consult advanced texts on numerical analysis if they get serious, computationally.) A professor who adopts this book for a linear algebra course would have to provide the usual material on vector spaces, and linear transformations, not included in this otherwise excellent text.

Interpolation of Rational Matrix Functions, by J. A. Ball, I. Gohberg and L. Rodman, Birkhauser Verlag, 1990

Review by André Ran

This book deals with far reaching generalizations of interpolation problems of Lagrange and Nevanlinna-Pick type to rational matrix valued functions. Motivation for studying these generalizations comes from systems and control theory, in particular from the recent developments in H_∞-control theory. Applications to this part of control theory are treated in the last part of the book.

To get the flavor of the book, let us consider some of the problems which are treated in the book in their simplest non-trivial form. Let $z_1, ..., z_p$ be distinct points in the open unit disc, and let $x_1, ..., x_p$ be non-zero vectors in C^m, while $y_1, ..., y_p$ are arbitrary vectors in C^n. We are looking for an $n \times m$ rational matrix function $F(z)$ such that

(i) F is analytic in the open unit disc,

(ii) $F(z_i)x_i = y_i$ for $i = 1, ..., p$.

This is a simple form of what is called in the book the Lagrange-Sylvester interpolation problem. Clearly, for the scalar case this problem has a trivial solution. The second problem we consider is the following: the given data are as above. Now on top of (i), (ii) we require $F(z)$ to satisfy (iii) $\| F(z) \| \leq 1$ for z in the unit disc. For the scalar case this is the well-known Nevanlinna-Pick interpolation problem, the solution of which already is quite non-trivial. A necessary and sufficient conditions for this problem to be solvable is the positivity of the so-called Pick matrix. The set of solutions for the tangential Nevanlinna-Pick problem outlined above can be parametrized as follows: introduce a matrix

$$J = \begin{pmatrix} I_n & 0 \\ 0 & -I_m \end{pmatrix}$$

Then there is a $(n+m) \times (n+m)$ rational matrix function

$$\Theta(z) = \begin{pmatrix} \theta_{11}(z) & \theta_{12}(z) \\ \theta_{21}(z) & \theta_{22}(z) \end{pmatrix}$$

which is a so-called J-inner matrix function, such that all solutions are given by

$$F(z) = (\theta_{11}(z)G(z) + \theta_{12}(z))(\theta_{21}(z)G(z) + \theta_{22}(z))^{-1}$$

where $G(z)$ is analytic in the open unit disc and has contractive values: $\| G(z) \| \leq 1$ for $| z | \leq 1$. So we see here two aspects to the solution of the Nevanlinna-Pick problem: a necessary and sufficient condition for a solution to exists, and a parametrization of all solutions. These two aspects appear also when the interpolation data are vastly more complex, and this is one of the main lines through the book under review.

The book consists of 6 parts. The first two parts deal with homogeneous interpolation problems for rational matrix valued functions, and can be viewed also as a thorough study of the pole and zero structure of such functions. The third part describes the pole and zero structure of a rational matrix valued function in terms of a certain subspace of rational vector valued functions, the so-called null-pole subspace of the function. So far the interpolation problems treated have been of the homogeneous type without metric constraints, i.e. problems of the type (i), (ii) above with $y_i = 0$. In the fourth part the full nonhomogeneous problem is considered, and an application to the partial realization problem is given. The fifth part treats the Nevanlinna-Pick, Nehari and Caratheodory-Toeplitz interpolation problems. Here the metric constraint (iii) comes into play for the first time. In the last part applications are given to three important problems in the area of control theory, namely: sensitivity minimization, model reduction and robust stabilization. In the study of all these problems it is frequently necessary to solve matrix equations of Sylvester, Lyapunov or Stein type. There is an appendix on these equations.

The book gives a good impression of how a particular part of linear algebra, namely the theory of rational matrix valued functions, is applied to relatively new problems in control theory. The material presented is quite suitable for presentation in a one-semester course for graduate students in the field of systems and control theory. However, the selection of the material to be presented should be done with care. The best way to do this, and indeed the best way to read the book (in my opinion at least), is to start at the end, in the applications part. Then back-track through the book to see what is necessary to know in order to arrive at your favorite application. However, the un-initiated in the field would be advised to read part one first, before embarking on the line I have just described.

There is one minor thing I do not like about the book: the proofreading could have been done better. Not only are there quite a number of typos, some of them are really annoying. (For instance, in the definition of a J-inner function a * for the adjoint is missing, and it is pretty hard to figure out whether that should be on the right or on the left.) However, that doesn't diminish very much the pleasure of reading 600 pages of well-presented, good mathematics. I can heartily recommend the book to anyone who is interested in the applications of linear algebra to problems in control theory.

The Total Least Squares Problem: Computational Aspects and Analysis by Sabine Van Huffel and Joos Vandewalle, SIAM, Philadelphia, 1991, xiii + 300 pp.

Review by Zhaojun Bai, University of Kentucky

The book under review is the first monograph entirely devoted to the total least squares (TLS) problems, a research area in which the authors have made significant contributions. In this work, they provide a comprehensive and up-to-date treatment of rigorous mathematical analysis, computational methods and applications of the TLS problems.

The TLS method represents a technique that can be applied to solving a linear system of equations $AX \approx B$, usually overdetermined, where both the data matrix A and the right hand side B are subject to errors, due to inherently inaccurate data measurement and sensing. The technique has been independently developed in various scientific disciplines. It also bears different names; for example, it is known as the "errors-in-variables" regression in statistical literature or eigenvector method in system identification applications. For the numerical analysis community, to the best of this reviewer's knowledge, it was first introduced by Golub and Van Loan in 1980 [1]. With the advent of matrix computations, and the availability of modern computer technology, the numerical treatment of the TLS problems has reached a very sophisticated level during the last decade.

To begin with, the authors start in Chapter 1 with an introductory overview on the formulation of the TLS problems, and their various applications, and set up notations for the rest of book. Chapter 2 surveys the main principles of the basic TLS problem and shows the key role of the singular value decomposition in the computation and analysis of the TLS problems. Extensions of the basic TLS problem are investigated in Chapter 3, where the issue of nongeneric solutions of the TLS problems is discussed in detail. Chapters 4 and 5 show how to improve the efficiency of the TLS computations in a *direct* way by modifying the singular value decomposition computations appropriately, and in a *iterative* way if a priori information about the TLS solution is available.

The properties of the TLS methods are fully analyzed in the following four chapters. Chapter 6 proves interesting algebraic connections between the TLS and LS problems, Chapter 7 compares the sensitivity of the TLS problems with that of the LS problems in the presence of errors in all data. Chapter 8 presents the statistical properties of the TLS solutions based on the knowledge of the distribution of the errors in the data and evaluates their practical relevance. Chapter 9 outlines algebraic connections, interrelations, and differences between the classical linear regression estimators and (non)generic TLS estimation in the presence of multicollinearities.

Finally, in concluding Chapter 10, the authors survey some recent extensions of the classical TLS problems currently under investigation, make suggestions for further research.

A total of 220 references are collected in the book. Some FORTRAN 77 code for the TLS algorithms in this book can be obtained via netlib, a system for the distribution of mathematical software through electronic mail.

A basic knowledge of numerical linear algebra, matrix computations, and some terminology of elementary statistics is required of the reader; however, some background material is included to make the book reasonably self-contained. It must be admitted, however, that the text is not easily digestible by a practitioner. When regarding the practical use of the TLS methods, more related references should be consulted.

TLS problems are still an exceedingly active research topic. Many problems still need further investigation. More literature will appear in diverse journals and conferences in the future. The reviewer would like to quote Professor Gene Golub's foreword for the book to conclude this review: *"We owe the authors a debt of gratitude for their complete and careful discussion of a tool that can be of great value in many situations."*

Reference

[1] G. H. Golub and C. F. Van Loan, "An analysis of the total least squares problem", *SIAM J. Numer. Anal.*, 17(1980), pp.883-893.

Combinatorial Matrix Theory by Richard A. Brualdi and Herbert J. Ryser, Cambridge University Press, 1991

Review by Wayne Barrett, Brigham Young University

As explained by Richard Brualdi in his preface, he proposed the idea of writing a joint book on combinatorial matrix theory to Herb Ryser on March 20, 1984. Although some preliminary material was prepared, Herb's untimely death on July 12, 1985 prevented them from working intensively on the book together as planned. Fortunately, both for the matrix theory community and for mathematics at large, Richard Brualdi has completed the project alone.

The inside of the jacket gives the description, "This is the first book length exposition of basic results of combinatorial matrix theory, that is the use of combinatorics and graph theory in matrix theory and the study of intrinsic properties of matrices viewed as arrays of numbers rather than as algebraic objects." Although graph theory has now played a prominent role in matrix theory for many years, this is the first book to systematically exploit this relationship in a wide range of topics. It is a pioneering book which both unifies and makes accessible a substantial body of recent research in matrix theory for both students and workers in the field.

In the 1990–91 academic year I had the opportunity to teach a graduate course in matrix theory at Brigham Young University from the manuscript version of the book. Because I consider Richard Brualdi to be in the top group of matrix theorists internationally, both as an expositor as well as a researcher, I approached the course with a good deal of enthusiasm, and I am happy to report that overall the book lived up to my expectations. For the most part, it is extremely well written, and the mathematics is very attractive. I had four students each term some of whom really became excited about the subject. Part of the attraction is that the author has accomplished the difficult task of writing a book whose material is accessible to students yet leads right up to current research. Three of my students had taken a one semester course out of Horn and Johnson's "Matrix Analysis," which was adequate preparation, and one took such a course concurrently, which was also sufficient. I want to add that the clarity and accessibility of the book do not mean it is easy; there is much to challenge the reader. Except for a 2–3 week digression to discuss the Perron-Frobenius theory of nonnegative matrices, we stayed with the book in our course and we still had to omit many topics.

The first chapter on incidence matrices introduces the concept of term rank via $(0,1)$-matrices. and proves a fundamental minimax characterization and the marriage theorem. The power of matrix theoretic ideas already stands out when contrasted with a set-theoretic proof of the marriage theorem from an undergraduate combinatorics text. The chapter also develops some important algebraic properties of $(0,1)$-matrices and gives applications.

Chapter 2 develops basic properties of undirected graphs such as the adjacency matrix, oriented incidence matrix, and the Laplacian matrix.

Chapter 3 introduces directed graphs and provides a thorough grounding in the fundamental concepts of irreducible matrices, strongly connected graphs, primitive matrices and exponents. Proofs are given for the Frobenius normal form, and Wielandt's bound for the exponent of a primitive $(0,1)$-matrix, and a variety of other topics are explored, e.g., eigenvalue inclusion regions.

Chapters 4–8 discuss bipartite graphs, regular graphs, network flows with applications to existence theorems for nonnegative integral matrices, the permanent and latin squares.

Chapter 9, the longest chapter in the book, introduces a remarkable set of ideas. It begins by developing the expansion of the determinant in terms of directed cycles. This is applied in subsequent sections to prove a theorem of Frobenius relating irreducible matrices and irreducible polynomials, MacMahon's Master Theorem, the theorem of Cayley that the determinant of a skew-symmetric matrix is the square of its pfaffian, Tutte's theorem characterizing graphs with a perfect matching, and three polynomial identities: the Cayley-Hamilton theorem, the fundamental trace identity of $M_n(R)$, and the standard polynomial identity of $M_n(R)$ or the Amitsur-Levitzki theorem. The fact that all of these theorems can be given graph-theoretic proofs is impressive, and their inclusion is one of the great features of the book.

The sections and chapters are unusually independent. For example, if you open the book to page 31 you can read and understand the proof of Theorem 2.3.3 with nothing more than the definition of totally unimodular which is given at the top of the page. This proof also illustrates the elegance and economy of thought that is typical throughout the book; enough details, but not too many. Also, I had a student who did not take the first semester of the course, yet was able to take the second semester and earn an A. This was a capable, hard-working student, but not a brilliant one.

There is also an ample supply of exercises throughout the book which makes it practical to use as a text. There are no answers, but there is often a reference to a recent paper! A warning in assigning problems: in most cases there are no clues to determine how difficult the problems in any given section might be. Sometimes exercise 1 is the most difficult! One student, who was not a quick thinker in class, very much enjoyed solving the homework problems although it took her considerable time and effort. Richard Brualdi has done a real service in supplying such a good set in a first edition. We wished that there were more problems of medium difficulty, but I found it difficult to create good problems. One also does not have the luxury of being able to consult other books.

The book sometimes errs on the side of brevity. I could usually help frustrated students fill in the gaps, but several proofs were too terse for me. For example, there is too much hidden in the statement containing equation (9.9) in the proof of Theorem 9.2.7. I found a key lemma in the original paper by Schneider. I also don't think it is possible to fathom Swan's proof of the Amitsur-Levitzki theorem without seeing plenty of pictures. Here, again, I found Swan's original papers very helpful. There are a number of places throughout the book where additional amplification or a picture or two would help.

A great asset of the book is its lists of references at the end of each section. See, for example the lists at the end of sections 3.5 and 5.2. This makes it a valuable source for examining the research being done on a specific subject. Furthermore, there is a Master reference list at the end of the book which is 18 pages long. The fact that the material in the text and problems is so well-documented alleviated considerably the problems I mentioned with brevity.

I think Richard Brualdi's book will be the standard reference on combinatorial matrix theory for some time to come. Coming to matrix theory from another field, I really appreciate having a book from which students can acquire the tools needed to pursue research in combinatorial aspects of matrix theory. I had to learn them through my own researh over a period of several years. It was also a pleasure to learn the proofs of some of the well-known facts in the field which I had never gotten around to looking up (e.g., Wielandt's theorem). Brualdi's book nicely complements the material found in the two books of Horn and Johnson. Taken together they give a broad picture of modern activity in matrix theory and illustrate its vitality. Happily, Richard already has plans for a second volume entitled "Combinatorial Matrix Classes."

From the preface we learn that Herb Ryser envisioned, "Ideally, such a book would contain lots of information but not be cluttered with detail. Above all it should reveal the great power and beauty of matrix theory in combinatorial settings....I do believe we could come up with a really exciting and elegant book that could have a great deal of impact." Richard Brualdi has succeeded in turning this hope into a reality.

Parallel Algorithms for Matrix Computations by K. A. Gallivan et al., SIAM, 1990

Review by Amit Bhaya, Federal University of Rio de Janeiro

This book consists of two papers and a 2016-item bibliography that describe and reference a broad selection of important parallel algorithms for matrix computations, over a time period ranging from the early surveys of the seventies by Miranker, Heller and Sameh to late 1988. Efficient parallel algorithms are fundamental for a large number of scientific and engineering problems and the last two decades have witnessed an explosion of research in this area, driven by an ever increasing variety of vector and parallel machines with several different types of architecture.

The first paper, entitled "Parallel Algorithms for Dense Linear Algebra Computation" by Gallivan, Plemmons and Sameh is a survey reprinted from the March 1990 issue of *SIAM Review*. It starts with a brief discussion of currently available parallel and vector machines as well as the CEDAR research prototype machine and analyses the way in which architecture influences algorithm design. This is followed by a discussion of the decomposition of algorithms into computational primitives (the three levels of the Basic Linear Algebra Subroutines (BLAS)). The analysis of a decomposition is carried out in terms of a decoupling of the ratio of the data-loading overhead to the raw computational speed of the algorithm into a 'cache-miss' ratio and a 'cost' ratio. It should be pointed out the bulk of this analysis and all computational results presented are for the Alliant FX/8 (a shared memory machine with eight register-based vector processors), although some results and relevant references for the distributed-memory case are cited. This, in fact, is a trend that continues throughout the rest of the paper: distributed-memory architectures are given very little detailed attention. Triangular system solvers are discussed next with emphasis on row and column oriented schemes based on BLAS primitives in the shared-memory case and on the fan-out and fan-in communications primitives in the distributed-memory case, as well as on some new alternative schemes. Five versions of shared-memory LU factorizations based on different partitions of the matrix and different sets of computational primitives are discussed next, followed by a brief discussion of distributed-memory and hybrid algorithms.

The remaining twenty pages of this seventy-five page paper are devoted to: least squares problems (10 pages) with discussions of block Householder, block Gram Schmidt and pipelined Givens methods; eigenvalue problems (6 pages) with rapid discussions of block schemes for the QR algorithm, Jacobi and Jacobi-like algorithms; singular value problems (half a page); parallel rapid elliptic solvers (4 pages), touching on the classical matrix decomposition and block cyclic reduction schemes for separable elliptic P.D.E.'s on regular domains.

The second paper entitled "Parallel Algorithms for Sparse Linear Systems" by Heath, Ng and Peyton is also reprinted from the *SIAM Review* (September 1991). It is a brisk survey of recent progress in the development of parallel algorithms for direct methods for solving sparse symmetric positive definite linear systems by Cholesky factorization. The four phases ordering, symbolic factorization, numeric factorization and triangular solution – are all discussed, although, as the authors point out, "unfortunately, there is relatively little to say about parallel algorithms for forward and backward triangular solutions" and that "parallel algorithms for ordering [and] symbolic factorization [are] ... lacking in efficiency". Thus the bulk of the paper is devoted to the design and implementation of parallel numerical factorization algorithms, in an effort to exploit the greater inherent parallelism of sparse matrix computations (as opposed to the dense counterpart), which is underutilized today, as the authors emphasize.

The paper begins with a brief but clear survey of sequential methods for the four phases. This is followed by a conceptual discussion of orderings for parallel factorization including the important question of an appropriate metric (other than fill-in) for them.

The separate question of computing an ordering in parallel is still a very difficult open problem, so the emphasis is on the examination of heuristics which generate low- fill orderings that are suitable for parallel sparse factorization. Tree restructuring, nested dissection and graph partitioning heuristics are the techniques discussed.

The simplicity of dynamic allocation of tasks for sparse column-Cholesky on a shared-memory MIMD machines is contrasted with the situation in distributed-memory machines for which a static allocation is usually preferred. The popular sparse column-Cholesky algorithm is chosen to exemplify parallel sparse Cholesky algorithms (for the shared-memory case), while fan-out and fan-in methods are discussed for the distributed-memory case. The paper concludes with a description and survey of parallel multifrontal methods.

The third item in the book is "A Bibliography on Parallel and Vector Numerical Algorithms" compiled by Ortega, Voigt and Romine which also contains some references on machine architecture, programming languages and related topics. The bibliography is very detailed and misses little that is important in the period ranging from the publication of the first papers on the subject (early seventies) to late 1988. Having said that, I should point out that a quick comparison with the list of references of the previous two papers indicates that there is not that much intersection between the three sets and the Bibliography is certainly not a superset. One interesting and useful feature of this compilation is (I quote): "Certain conference proceedings and anthologies that have been published in book form we list under the name of the editor (or editors) and then list individual articles with a pointer back to the whole volume".

One minor although inevitable problem is that a large number of references are to technical reports that are often quite hard to get hold of and have appeared in journal form after the publication of this book. One hopes that conscientious authors are collaborating with the compilers of the electronic version of this list (romine@msr.epm.ornl.gov or rgv@icase.edu) to update Technical Report references to journal references, whenever appropriate.

In summary, I agree with the statement made in the preface that the book will serve as a valuable (adjective mine) reference guide on parallel and vector matrix computations on high-performance computers. On the other hand, most graduate students (the other potential users mentioned in the preface) will probably need gentler introductions of the kind available in the recent excellent texts by Ortega [1] and Dongarra et al. [2], both of which treat iterative methods as well, which are not covered in this book.

References

[1] J. M. Ortega, *Introduction to Parallel and Vector Solution of Linear Systems*, Plenum Press, New York, 1988.

[2] J. J. Dongarra, I. S. Duff, D. C. Sorensen and H. A. van der Vorst, *Solving Linear Systems on Vector and Shared Memory Computers*, SIAM, Philadelphia, 1991.

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