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Manchester Centre for Computational Mathematics
Numerical Analysis Reports

DEPARTMENTS OF MATHEMATICS

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Contents

This Annual Report serves to publicize the work that has taken place in the Manchester Centre for Computational Mathematics during 2001. *Along with other MCCM technical reports, information about the M.Sc. in Applied Numerical Computing, and MCCM seminar details, it is available from the MCCM Web page at* `http://www.ma.man.ac.uk/MCCM`

Edited by N. J. Higham and F. Tisseur

1 A Message from the Director

I took over the position of Director, and David Silvester the position of Associate Director, at the beginning of 2002. Christopher Baker and Ron Thatcher had held the respective posts since the formation of the Manchester Centre for Computational Mathematics (MCCM) by the numerical analysts at the University of Manchester and UMIST in October 1992. Paraphrasing the words of Christopher Baker in an earlier Annual Report, *MCCM exists to provide an environment for quality research and postgraduate study in numerical and computational mathematics, encompassing researchers from nearby institutions and those visiting the two groups.* During its first 10 years the Centre has continually grown in activity, and its current health can be seen in two particular ways. First, one of the main activities of the Centre is the Numerical Analysis Report series, which is used by the members of the Centre as a way of pre-announcing research results prior to submission to a journal. Figure 1 charts the number of reports produced each year. (The numbers are approximate, since only reports made available electronically—which nowadays is all reports—are counted.) Clearly, the trend in research output of the Centre is upwards, with 2001 being a bumper year.

The second major activity of the Centre is delivering the *M.Sc. in Numerical Analysis and Computing*. This M.Sc. programme has run continuously at the University of Manchester since 1959, and upon the formation of MCCM it became jointly run with UMIST. With the change in mode of EPSRC funding for Masters courses, the two Departments of Mathematics submitted a proposal to EPSRC for funding of a new *M.Sc. in Applied Numerical Computing* under the Masters Training Package scheme. The proposal was funded and the new M.Sc. starts in September 2002. The new M.Sc. is a complete redesign, aimed at meeting the current needs of industry and commerce for people skilled in numerical modelling and numerical computation, and it includes substantial input from industrial partners. The continued M.Sc. funding helps to maintain the vitality of MCCM and is an important focus for expanding our contacts with industry.

As we approach the second decade of MCCM, David Silvester and I aim to build on the foundations laid by Christopher Baker and Ron Thatcher. We will be working to ensure the continued success of the Centre and hope to see its scope and activities expand.

Nicholas J. Higham
Dirctor of MCCM

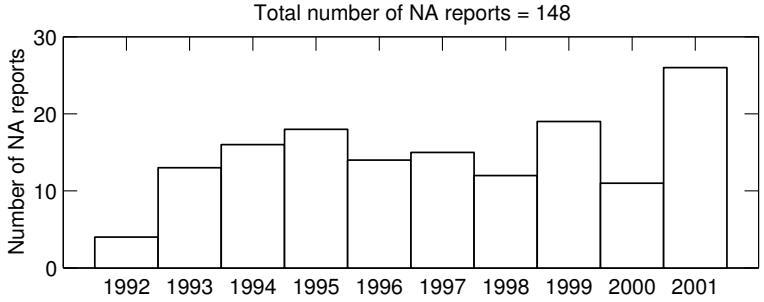

Figure 1: Histogram of (electronically available) Numerical Analysis Reports.

2 Members

Christopher T. H. Baker

Professor of Mathematics (Research Professor from October 1st 2001), University of Manchester; Honorary Senior Research Fellow, Chester College
D.Phil., Oxford University, 1964

At the start of October, I became a Research Professor. I relinquished the post of Director of MCCM and assumed the title of Founding Director.

The chairmanship of the (RAE2001) Research Assessment Panel for Applied Mathematics made considerable (and, indeed, unreasonable) inroads into my time. During most of 2001, every flat surface at home and in my office was covered with RAE paperwork. A similar burden fell on all involved in the exercise, which imposed an unreasonable load on panel members, advisers, and the like (and their families!).

We had announced the Applied Mathematics Panel's methodology and the criteria at earlier stages and we abided by them. We had our gradings completed in November 2001 but they were not to be published until 2002. Naturally, there were those who were disappointed with their grades and those who were pleasantly surprised; one can only say that the panel members exercised their professional judgment to the best of their ability and did not contribute to the assessment or feedback involving any institution in which they had an interest (in my case, I declared an interest in the University of Manchester, UMIST, and Chester College).

There is a considerable amount of good research in the UK applied mathematics community, and it ought to be adequately funded by HEFCE and the Research Councils; my personal view is that both the amount available for research in mathematics and the methodology and formulae for its distribution leave much to be desired. Since one can hardly feel sanguine about the teaching of mathematics in UK schools and its effect on university curricula and future generations of mathematicians, scientists, and engineers, I cannot claim to hold an optimistic view of the future of mathematics in the UK.

My RAE activities had the perverse effect of reducing the time I had available for research and I defer to next year's report evidence of my ongoing research activities. Nevertheless, I continued to function as part of a collaborative research group at Manchester that contained, during the year 2001, myself, Chris Paul, Evelyn Buckwar (supported up to April 2001 by her second Marie Curie Fellowship), Yihong Song (O/S PhD student; OSS Award); Ephraim Agyingi (O/S PhD student; ORS Award), and Eugene Parmuzin (O/S PhD student; OSS Award) and Fathalla Rihan (my former PhD student). Prof Genna Bocharov (Moscow) continues to hold an honorary Research Fellowship. This group continued to thrive as part of a larger sub-group of MCCM having components centered (at Chester) on Neville Ford with his colleagues John Edwards and Jason Roberts, and (at UMIST) Ruth Thomas. Julius Kaplunov (having recently joined the Applied Unit at The University) with his interest in Volterra equations, and Alan Jones (with an increasing involvement in issues of modelling using equations displaying a time lag), contribute to the activity of the group. Research themes have been concentrated on problems with memory, focusing on retarded (delay and neutral equations), problems with constraints (which are related to singularly perturbed problems), Volterra integral and integro-differential equations, and stochastic delay differential equations.

My regular membership of editorial boards has continued and includes those listed below.

Appointments and Professional Activities

Chair, Applied Mathematics Panel RAE2001.

Member of the EPSRC College (Mathematics Programme).

Founding Director, MCCM.

Associate Director, Chester-Manchester Group for Problems with Memory & After-effect.

Member of the Centre for Novel Computing in the Department of Computer Science, University of Manchester.

Member of the Dean's Advisory Committee (retiring September 2001).

Editor, Journal of Computational & Applied Mathematics.

Editor, Journal of Integral Equations & Applications.

Editor, Advances in Computational Mathematics (from its inception to December 2001).

Member of the accreditation board, Computer Abstracts.

Referee for a number of journals and publishers.

Referee for research proposals.

I recently joined further editorial boards but have not yet become active in these roles.

Conference organisation

As part of the celebrations of 150 years of the University of Manchester we held, on February 7th 2001, a One Day Meeting on Causal Problems (Organisers: C.T.H. Baker, N.J. Ford, C.A.H. Paul & E. Buckwar) with guest speakers Professor D. Roose (KU Leuven) (speaking on Numerical Stability and Bifurcation Methods in the Analysis of Delay Differential Equations: Algorithms and Applications); Professor G. Bocharov (INM, RAS Moscow) (speaking on Numerical Modelling in Biomathematics with Delay Equations).

Workshop Meeting: Chester-Manchester Group for Problems with Memory & After-effect Minisymposium on Causal Evolutionary Problems with Memory (organisers: Christopher Baker, Neville Ford) 12th–17th December 2001. Guest speakers included Dr John Appleby, Dublin (speaking on Exact decay rates of solutions of nonlinear functional differential equations and stochastic equations); Prof Verduyn Lunel, Leiden (speaking on Forward-Backward functional differential equations, holomorphic factorization and applications).

I presented lectures at both of the above meetings.

Publications

Contributions in an edited book

Christopher T H Baker, *A perspective on the numerical treatment of Volterra equations* in *Numerical Analysis: Historical Developments in the 20th Century*, edited by: C. Brezinski, L. Wuytack, Elsevier Science (2001), ISBN 0-444-50617-9.

Christopher T H Baker, *Retarded differential equations* in *Numerical Analysis: Historical Developments in the 20th Century*, edited by: C. Brezinski, L. Wuytack, Elsevier Science (2001), ISBN 0-444-50617-9.

Technical Reports

C. T. H. Baker and E. Buckwar Exponential Stability in p-th Mean of Solutions, and of Convergent Euler-type Solutions, of Stochastic Delay Differential Equations MCCM Technical Report 390, 2001, ISSN 1360-1725.

Sheung Hun Cheng

Research Associate, University of Manchester
Ph.D. University of Manchester, 1998

I completed successfully the EPSRC-funded project "Parallel Computations of Matrix Functions" (PCMF) in October, 2001. Since December 2001 I have been working as a Numerical Analyst at The MathWorks, Inc. I would like to take this opportunity to thank all my colleagues in CNC and MCCM for giving me such an enjoyable time in Manchester.

The PCMF project has produced a steady output of technical reports since it started in October 1998 and has now been completed. The final report of the project can be found on the project home page (`http://www.ma.man.ac.uk/~higham/PCMF/`).

In 2001, I performed more experiments on the the new block 1-norm estimator of Higham and Tisseur in Fortran 77 with the LAPACK and ScaLAPACK programming style. The experimental results were

summarized in two publications and presented in two conferences with good feedback. The LAPACK style Fortran 77 subroutines have been made available on the web through our project web page.

Moreover, I have made available on our project homepage, a Fortran 77 implementation in LAPACK programming style of the Cheng, Higham, Kenney and Laub variant of the Inverse Scaling and Squaring algorithm for computing the matrix logarithm.

Professional Activities

Editor, Journal of Inequalities in Pure and Applied Mathematics.

Publications

S. H. Cheng, N. J. Higham, C. S. Kenney, A. J. Laub. Approximating the Logarithm of a Matrix to Specified Accuracy, SIAM J. Matrix Anal. Appl., 22(4): 1112-1125, 2001.

S. H. Cheng, N. J. Higham. Parallel Implementation of a Block Algorithm for Matrix 1-Norm Estimation, In R. Sakellariou, J. Keane, J. Gurd, and L. Freeman, editors, Euro-Par 2001, Parallel Processing, volume 2150 of Lecture Notes in Computer Science, pages 568-577. Springer-Verlag, Berlin, 2001.

S. H. Cheng, N. J. Higham. Implementation for LAPACK of a Block Algorithm for Matrix 1-Norm Estimation, NA Report 393, MCCM, August 2001. Also as LAPACK Working Note 152.

Lectures

Dundee Biennial Conference on Numerical Analysis, June 2001, "Parallel Implementation of a Block Algorithm for Matrix 1-Norm Estimation".

European Conference on Parallel Computing (Euro-Par), Manchester, August 2001, "Parallel Implementation of a Block Algorithm for Matrix 1-Norm Estimation".

Evelyn Buckwar

Marie-Curie-Fellow and Honorary Research Fellow at the University of Manchester;
Research and Teaching Assistant at the Humboldt Universität zu Berlin
Dr. rer. nat. Freie Universität Berlin, 1997

My research interests continue to be in the area of numerical approximations of solutions of stochastic delay differential equations. These arise by taking into account delays in the arguments (e.g. nerve reaction times in physiology models) as well as random noise in the parameters of problems which are modeled by differential equations. Together with C. T. H. Baker we developed and analysed algorithms to simulate trajectories of the solution process. In particular we have analysed stability properties of solutions of stochastic delay differential equations as well as stochastic delay difference equations; the latter arise by the application of numerical methods, such as the Euler-Maruyama-method. In collaboration with T. Shardlow (University of Durham) I have worked on weak numerical methods for stochastic delay differential equations.

Appointments and Professional Activities

From January to April 2001 I was employed as a research assistant on the basis of my second term as a Marie-Curie-Fellow, Project Nr. MCFI-1999-00437. From May 2001 on I am appointed as Honorary Research Fellow at the Department of Mathematics at the University of Manchester. Also from May 2001 I am research and teaching assistant at the Department of Mathematics of the Humboldt Universität zu Berlin.

Publications

E. Buckwar and T. Shardlow. Weak approximation of stochastic differential delay equations. Discussion Paper of the Sonderforschungsbereich 373, Nr. 88, 2001. Submitted to IMA Journal of Numerical Analysis.

C.T.H. Baker and E. Buckwar. Exponential Stability in p-th Mean of Solutions, and of Convergent Euler-type Solutions of Stochastic Delay Differential Equations. Discussion Paper of the Sonderforschungsbereich 373, Nr. 94 and MCCM Technical Report 390, 2001, ISSN 1360-1725

Lectures

University of Durham, Durham, January 26th, 2001, "Numerical Analysis of Stochastic Delay Differential Equations".

Stochastic Numerics 2001, Conference on Numerical Simulations of Stochastic Differential Equations, Feynman-Kac representations and path integrals, February 2001, ETH, Zürich, Switzerland, "Continuous methods for SDDEs with variable delay.

Computational Stochastic Differential Equations, 26th-31st March, 2001, Warwick, UK, "Analysis of Strong Approximation Schemes for Stochastic Delay Differential Equations.

Minisymposium on Numerical methods for stochastic differential equations, Org.: D. Higham and T. Mitsui, SciCADE'01, Vancouver, British Columbia, Kanada, 29 July—3 August, 2001, "Strong Approximation Schemes for Stochastic Delay Differential Equations.

Memorial University, St. John's, Newfoundland, Canada, August 7th, "Introduction to Analysis and Numerics of Stochastic Delay Differential Equations".

Minisymposium on Applications of Stochastic Simulations, Org.: Wesley Petersen, Denis Talay, First SIAM-EMS Conference, APPLIED MATHEMATICS IN OUR CHANGING WORLD, 2nd - 6th September 2001, Berlin,"Strong Approximation Schemes for Stochastic Functional Differential Equations.

ÖMG-Kongress, Jahrestagung der Deutschen Mathematikervereinigung, 16—22 September 2001, Wien, "Numerische Verfahren fr stochastische Differentialgleichungen mit Gedchtnis".

LMS-supported Half-Day Meeting on Numerical Methods and Stochastic Simulation 7th December, 2001, Glasgow, "Stability in p-th Mean of Stochastic Delay Differential Equations and Numerical Solutions".

University of Leeds, Leeds, 11th December 2001, "Some Aspects in the Analysis and Numerics of Stochastic Delay Differential Equations".

Chester-Manchester Group for Problems with Memory and After-effect, Workshop Meeting, 12th-17th December 2001, "Numerical methods for SDDEs with small noise".

Philip I. Davies

Research Associate, University of Manchester
Ph.D. University of Manchester, 2000

Following the completion of my PhD, I took up the position as Research Associate on the EPSRC-funded project "Numerical Analysis of Matrix Functions". In collaboration with Nick Higham I have been working on a Schur–Parlett algorithm for the computation of $f(A)$ for a general function f. Our aim is to produce an algorithm that is more robust and numerically reliable than MATLAB's existing `funm` routine.

Professional Activities

Referee for Computational Statistics and Data Analysis.

Publications

P. I. Davies, N. J. Higham, and F. Tisseur. Analysis of the Cholesky method with iterative refinement for solving the symmetric definite generalized eigenproblem. *SIAM J. Matrix Anal. Appl.* 23(2): 472-493, 2001.

Lectures

19th Biennial Dundee Conference on Numerical Analysis, June 26-29, 2001. "Analysis of the Cholesky method for solving the symmetric definite generalized eigenproblem".

J. T. Edwards

Head of Department, Chester College
Ph.D. University of Birmingham, 1972

I am continuing to work on the numerical and analytical solution of integro-differential equations. I have collaborated with Neville Ford and Jason Roberts at Chester on the stability and bifurcation analysis of integro-differential equations of Volterra type with fading memory kernels. I have also continued to work with Neville Ford on the relationship between boundedness and stability of solutions of difference equations and have extended this work to include some Volterra difference equations with unbounded memory. Recently I have started to work on some fractional differential equations including multiple fractional derivatives. This work also involves students and former students within the Chester group. I was co-author of papers presented at the A4A4 meeting in Huddersfield in July 2001 and at the HERCMA meeting in Athens in September 2001.

Appointments and Professional Activities

Head of Mathematics Department, Chester College.

Publications

J T Edwards, N J Ford & J A Roberts *The numerical solution of an integro-differential equation close to bifurcation points*, MCCM Report 380, 2001

J T Edwards & N J Ford *Boundedness and stability of difference equations*, MCCM Report 384, 2001

Neville J. Ford

Professor of Computational Applied Mathematics, Chester College;
Honorary Research Fellow, Manchester University
Ph.D. University of Liverpool, 1991

I am continuing to work on the numerical and analytical solutions of various classes of functional differential equations.

I have been working with Teresa Diogo and Pedro Lima on numerical solutions of some singular integral equations which do not have a unique solution. The project has led to the development of both new theoretical results and new numerical insights. The work is supported by the British Council and the Portuguese Universities funding body.

I have continued to work with Sjoerd Verduyn Lunel at Leiden on a project in which we have shown that an infinite dimensional property of a non-autonomous delay differential equation (the existence or otherwise of small solutions) can be detected, in the scalar case at least, through the use of a finite dimensional approximation. With my student, Pat Lumb, I have developed corresponding results for both the vector and complex problems.

With Kai Diethelm from Braunschweig and Charles Simpson, I have been developing efficient algorithms for the solution of differential equations of fractional order. We have considered, in particular, ways in which multi-term scalar equations can be solved as a system of fractional equations and also ways in which the amount of computational work involved in calculating the solution can be reduced.

With John Edwards and Jason Roberts at Chester I have been working on various bifurcation problems relating to solutions of integro-differential equations of Volterra type.

With John Edwards I have also been concerned with the development of a unified stability theory for difference equations. The theory we have developed is in a form that makes it easily exploited in numerical solution of integral equations. In this respect our work is currently targeted towards analyzing difference equations of unbounded order.

Working with Christopher Baker and Judy Ford (Liverpool) I have undertaken some initial investigations into bifurcations in solutions of Stochastic Delay Differential Equations. It is our hope that we can continue with this investigation in the future.

Through collaboration with Christopher Baker, we have run a series of joint seminars on the solution of problems with memory and after-effect. I gave a lecture at the A4A4 meeting in Huddersfield in July and a talk at the HERCMA meeting in Athens in September, where I also organized the largest mini-symposium (11 speakers).

I visited Kai Diethelm (Braunschweig) and Teresa Diogo (Lisbon). I was visited by Teresa Diogo, Hermann Brunner (St John's), Sjoerd Verduyn Lunel (Leiden), John Appleby (DCU, Dublin).

My PhD student A. C. Simpson successfully completed his PhD in October 2001.

Appointments and Professional Activities

Director, Applied Mathematics Research Group, Chester College.

Honorary Research Fellow, University of Manchester.

Director of Chester-Manchester Research Unit on Problems with Memory and After-effect.

Publications

C T H Baker, G A Bocharov, A Filiz, N J Ford, C A H Paul, F A Rihan, A Tang, R M Thomas, H Tian & D R Will *Numerical modelling by retarded functional differential equations*, Hellenic European Research on Mathematics and Informatics Science Vol 2, (2001) 29-52

N J Ford & A C Simpson *The numerical solution of fractional differential equations: speed versus accuracy*, Numerical Algorithms, 26 4 2001, 333-346.

N J Ford & K Diethelm *Numerical solution methods for distributed order differential equations*, Fractional Calculus and Applied Analysis 4 2001, 531-542.

J M Ford, K Chen & N J Ford *Small-Scale Parallel Implementation of Fast Wavelet Transforms*, MCCM Report 388 2001.

J M Ford, K Chen & N J Ford *Parallel Implementation of Fast Wavelet Transforms*, MCCM Report 389, 2001.

J T Edwards, N J Ford & J A Roberts *The numerical solution of an integro-differential equation close to bifurcation points*, MCCM Report 380, 2001

J T Edwards & N J Ford *Boundedness and stability of difference equations*, MCCM Report 384, 2001

P D Crofts, N J Ford & R H T Edwards *Sensitivity of Hospital Clinic Queues to Patient Non-Attendance*, MCCM Report 383, 2001.

N J Ford & K Diethelm *Analysis of fractional differential equations*, MCCM Report 377, 2001.

N J Ford & K Diethelm *Numerical solution of the Bagley Torvik Equation*, MCCM Report 378, 2001.

N J Ford & K Diethelm *The numerical solution of Linear and Non-Linear Fractional Differential equations involving Fractional Derivatives of several orders*, MCCM Report 379, 2001.

N J Ford & S M Verduyn Lunel *Characterising Small Solutions in Delay Differential Equations*, MCCM Report 381, 2001

N J Ford & S M Verduyn Lunel *Numerical approximation of delay differential equations with small solutions*, MCCM Report 382, 2001.

N J Ford & A C Simpson *The Numerical Solution of Fractional Differential Equations: Speed Versus Accuracy*, MCCM Report 385, 2001.

N J Ford & A C Simpson *The Approximate Solution of Fractional Differential Equations of Order Greater than 1*, MCCM Report 386, 2001.

N J Ford & A C Simpson *Numerical and Analytical Treatment of Differential Equations of Fractional Order*, MCCM Report 387 2001.

Lectures

Invited lectures during visits to the University of Lisbon (November) and the University of Braunschweig (April).

I co-organised (with Christopher Baker) various seminar days in Manchester and Chester.

Minisymposium organizer at HERCMA, Athens, September 2001.

Lecture at A4A4 Huddersfield, July 2001.

Research Grants

I received a Royal Society conference grant to support my participation in HERCMA, Athens and an LMS grant to support my collaboration with Kai Diethelm.

T. L. Freeman

Senior Lecturer in Computer Science & Mathematics, University of Manchester
Ph.D. University of Liverpool, 1974

My research interests remain centred on the solution of practical problems in Science and Engineering on high performance computers. This includes development and analysis of numerical algorithms on parallel computers, and the development of numerical libraries and programming tools for parallel computers.

I continue to act as Director of the Centre for Novel Computing (CNC), an interdisciplinary research group in the Department of Computer Science whose mission is the investigation of techniques and tools to support high performance (parallel) computing. Through the CNC I am involved directly in a number of research projects:

- An Overhead Profiler for Single-Address-Space Parallel Programs.
  The objective is to design and build a tool that can automatically generate and display an overheads profile for a parallel program.
- Object-Oriented Description of High-Performance Numerical Algorithms.
  There is a perception that a clean, high-level, abstract description of an application must affect performance; in fact, for most high-performance application development, the first thing that is sacrificed in order to obtain high performance, is a high-level abstract description of the application. Our view is that one should maintain the high-level abstract description for as long as possible and only sacrifice this abstraction when it is essential for performance; in an ideal scenario, the high-level abstraction would be maintained throughout, and "compilers" would take care of restructuring for performance. Thus far we have designed an Object-Oriented Numerical Linear Algebra Library; we are able to show how a Java-implementation of the library could have Fortran-like performance if the Java compilers implemented some well-known (to Fortran compilers) optimisation techniques.
- Numerical Algorithms for Grid Computing.
  The Grid provides a dynamic, distributed, heterogeneous computing environment for numerical computations. The objective of this project is to investigate techniques by which numerical algorithms can adapt to make optimal use of such a computing environment.

Appointments

Director, Centre for Novel Computing, Department of Computer Science, University of Manchester.

External examiner for the M.Sc. taught course, Royal Military College of Science, Shrivenham.

External examiner for B.Sc. honours degree courses in Mathematics, University of Salford.

Professional Activities

Editor, Parallel and Distributed Computing Practices.

Member of the Technical Committee of the series of International Workshops on High Performance Scientific and Engineering Computing with Applications (HPSECA), Toronto, Canada, August, 2000; Valencia, Spain, September, 2001; Vancouver, Canada, August, 2002.

Finance Chair, Euro-Par 2001, Manchester, August, 2001.

Member of the IASTED Technical Committee on "Parallel & Distributed Computing & Systems" for the period 2001-2004.

Research Grants

Co-investigator (with Professor N. J. Higham, Department of Mathematics and Professor J. R. Gurd, Department of Computer Science) of the project, *Parallel Computation of Matrix Functions*, (£148,000) funded by the EPSRC from July 1998.

Principal investigator (with Professor J. R. Gurd, Department of Computer Science) of the project, *An Overhead Profiler for Single-Address-Space Parallel Programs*, (£132,790) funded by the EPSRC from October 1999.

Principal Investigator of the project *Exploiting the Benefits of Parallelism with New and Inexperienced HPC Users*, (£40,000 (excluding overheads) + manpower from Manchester Computing, providing two postdoctoral research associates) funded by Manchester Research Centre for Computational Science from 1999.

Co-investigator of the project, *High-Performance Object-Oriented Computational Science*, funded by the EPSRC Strategic Equipment Initiative, (£60,000), June 2000.

Co-investigator (with Professor J. R. Gurd and Dr. R. Sakellariou, Department of Computer Science) of the project, *Tools and Techniques to Support the Development of HPC Applications that are Efficient, Maintainable and Extendible*, funded by the EPSRC Joint Research Equipment Initiative, (£119,943), from March 2001.

Co-investigator (with Mr. W. T. Hewitt, Manchester Visualisation Centre) of the project, *North West Research Centre for Advanced Virtual Prototyping*, funded by the North West Science Review and administered by EPSRC, (£228,860), from April 2001.

Publications

Sakellariou, R., Keane, J., Gurd, J. and Freeman, L. (editors) (2001) **Euro-Par 2001: Parallel Processing**, Lecture Notes in Computer Science, vol. 2150, Springer-Verlag, Berlin.

Tabirca, T., Freeman, L. and Tabirca, S. (2001) *An $O(\log\ p)$ Parallel Algorithm for Feedback Guided Dynamic Loop Scheduling*, Parallel Algorithms and Applications, to appear.

Freeman, T. L. , Hancock, D. J., Bull, J. M. and Ford, R. W. (2001) *Feedback Guided Scheduling of Nested Loops*, In Applied Parallel Computing, ed. T. Sørevik, F. Manne, R. Moe, A. H. Gebremedhin, Lecture Notes in Computer Science, vol. 1947, pp. 149–159, Springer-Verlag, Berlin.

Tabirca, T., Freeman, L., Tabirca, S. and Yang. L. T. (2001) *Feedback Guided Dynamic Loop Scheduling; A Theoretical Approach*, In **Proceedings of the 2001 ICPP Workshops**, ed. Pinkston, T. M., IEEE Computer Society, pp. 115–121.

Tabirca, T., Freeman, L., Tabirca, S. and Yang. L. T. (2001) *A Theoretical Application of Feedback Guided Dynamic Loop Scheduling*, In **Proceedings of the NATO Advanced Research Workshop on Advanced Environments, Tools and Applications for Cluster Computing**, ed. D. Grigoras, A. Nicolau, B.Toursel and B. Folliot.

Nicholas J. Higham

Richardson Professor of Applied Mathematics, University of Manchester
Ph.D. University of Manchester, 1985

An EPSRC grant "Numerical Analysis of Matrix Functions" began in February, with Dr Philip Davies as the RA. We have initially been working on developing a method for computing arbitrary functions of a matrix by use of a Schur decomposition and the block form of Parlett's recurrence on the triangular Schur form.

RA Bobby Cheng and I developed Fortran implementations in both serial (LAPACK) and parallel (ScaLAPACK) style of the block matrix 1-norm estimator of Higham and Tisseur. This estimator has already been incorporated into MATLAB, as function `normest1`, called by `condest`. Upon completion of the project, Bobby Cheng took up a position as Numerical Analyst at The MathWorks in Natick, USA.

Work on generalized and polynomial eigenvalue problems continued jointly with Françoise Tisseur and Paul Van Dooren. Françoise Tisseur and I worked on bounds for eigenvalues of matrix polynomials and also on theory, computation and visualization of pseudospectra for rectangular matrix polynomials expressed in homogeneous form. In joint work with Paul Van Dooren we derived new methods for testing for definiteness of a Hermitian matrix pair and hyperbolicity of a quadratic eigenvalue problem, and also treated some corresponding nearness problems.

My PhD student Matthew Smith won a SIAM Student Paper Prize for his paper[1] on computing pth roots of matrices. With the aid of a SIAM Student Travel Fund, he attended the 2001 SIAM Annual Meeting in San Diego, where he was presented with his award.

Professor Adam Bojanczyk, from Cornell University, visited on an EPSRC Visiting Fellowship from August until early 2002. We worked, together with PhD student Harikrishna Patel, on the indefinite least squares problem. We developed an algorithm based on hyperbolic QR factorization and were able to prove its forward stability; the analysis required a quite different approach than is taken for the analysis of algorithms for the standard least squares problem.

Much of my time in the second half of the year was spent in preparing a second edition of my 1996 SIAM monograph *Accuracy and Stability of Numerical Algorithms*, which will be published in 2002. The book has been completely revised, with much new material added and numerous improvements made to the original material. Some random thoughts after completing the revision: I don't know how I managed in 1996 working on a machine that took 7.5 minutes to LaTeX the book—now it takes 10–20 seconds; producing (almost) perfect figures in MATLAB is surprisingly difficult; and I don't know how I managed previously with only hard copy access to most journals—now the University of Manchester has electronic access to virtually all the mathematics journals to which it subscribes and this is a tremendous research aid.

Appointments and Professional Activities

Head of the Numerical Analysis Group.

Member of Executive Committee of the Centre for Novel Computing in the Department of Computer Science, University of Manchester.

Editorial board, SIAM Journal on Matrix Analysis and Applications.

Editorial board, IMA Journal of Numerical Analysis.

Editorial board, Linear Algebra and Applications.

Editorial board, Foundations of Computational Mathematics.

Editorial board, SIAM News.

Member of Society for Industrial and Applied Mathematics (SIAM) Council.

Member of Executive Committee of Foundations of Computational Mathematics.

Member of Board of Directors of International Linear Algebra Society.

[1] See [23] in Section 5.

Member of EPSRC Peer Review College.

Organizer of minisymposium "Matrix Approximation Problems", SIAM Annual Meeting, San Diego, July 2001.

Chair of (permanent) organizing committee of Householder Symposia.

Member of organizing committee of Eighth SIAM Conference on Applied Linear Algebra, College of William and Mary, Williamsburg, July 2003.

Publications

(These publications are available from my Web page at `http://www.ma.man.ac.uk/~higham/`)

S. H. Cheng, N. J. Higham, C. S. Kenney, and A. J. Laub. Approximating the logarithm of a matrix to specified accuracy. *SIAM J. Matrix Anal. Appl.*, 22(4):1112–1125, 2001.

S. H. Cheng and N. J. Higham. Implementation for LAPACK of a block algorithm for matrix 1-norm estimation. Numerical Analysis Report No. 393, Manchester Centre for Computational Mathematics, Manchester, England, Aug. 2001. 19 pp. LAPACK Working Note 152.

S. H. Cheng and N. J. Higham. Parallel implementation of a block algorithm for matrix 1-norm estimation. In R. Sakellariou, J. Keane, J. Gurd, and L. Freeman, editors, *Euro-Par* 2001*, Parallel Processing*, volume 2150 of *Lecture Notes in Computer Science*, pages 568–577. Springer-Verlag, Berlin, 2001.

P. I. Davies, N. J. Higham, and F. Tisseur. Analysis of the Cholesky method with iterative refinement for solving the symmetric definite generalized eigenproblem. *SIAM J. Matrix Anal. Appl.*, 23(2):472–493, 2001.

N. J. Higham. Evaluating Padé approximants of the matrix logarithm. *SIAM J. Matrix Anal. Appl.*, 22 (4):1126–1135, 2001.

N. J. Higham and H.-M. Kim. Solving a quadratic matrix equation by Newton's method with exact line searches. *SIAM J. Matrix Anal. Appl.*, 23(2):303–316, 2001.

N. J. Higham and F. Tisseur. Bounds for eigenvalues of matrix polynomials. Numerical Analysis Report 371, Manchester Centre for Computational Mathematics, Manchester, England, Jan. 2001. 16 pp. To appear in Linear Algebra Appl.

N. J. Higham and F. Tisseur. More on pseudospectra for polynomial eigenvalue problems and applications in control theory. Numerical Analysis Report 372, Manchester Centre for Computational Mathematics, Manchester, England, Jan. 2001. 21 pp. To appear in Linear Algebra Appl.

N. J. Higham, F. Tisseur, and P. M. Van Dooren. Detecting a definite Hermitian pair and a hyperbolic or elliptic quadratic eigenvalue problem, and associated nearness problems. Numerical Analysis Report 373, Manchester Centre for Computational Mathematics, Manchester, England, Feb. 2001. 18 pp. To appear in Linear Algebra Appl.

F. Tisseur and N. J. Higham. Structured pseudospectra for polynomial eigenvalue problems, with applications. *SIAM J. Matrix Anal. Appl.*, 23(1):187–208, 2001.

N. J. Higham. Review of "Michael Alley, The Craft of Editing: A Guide for Managers, Scientists and Engineers. Springer-Verlag, 2000". *SIAM Rev.*, 43(1):202, Mar. 2001.

Lectures

25th Annual Conference of the South African Society for Numerical and Applied Mathematics, Stellenbosch, South Africa, April 2001, "Pseudospectra for Polynomial Eigenvalue Problems: Theory, Computation and Application".

Linear Algebra and Arithmetic: Numerical, Symbolic and Parallel Computation, Rabat, Morocco, May 2001, "How to Detect and Destroy Definiteness of Generalized and Quadratic Eigenvalue Problems".

Workshop on Uncertainty in Geometric Computations (EPSRC MathFIT sponsored), University of Sheffield, July 2001, "Accuracy and Stability of Numerical Algorithms".

Dundee Biennial Conference on Numerical Analysis, June 2001. "Computing the Nearest Correlation Matrix—A Problem from Finance".

SIAM Annual Meeting, San Diego, July 2001. Talk in minisymposium "Matrix Approximation Problems": "Computing the Nearest Correlation Matrix—A Problem from Finance".

Seminar at Technische Universität München, May 2001.

Research Grants

Principal investigator on project "Parallel Computation of Matrix Functions" funded by 50% by EPSRC Systems Architecture Committee and 50% by DERA, Malvern for three years from October 1998 (value £156,157). Co-investigators Dr T. L. Freeman and Professor J. R. Gurd. Grant GR/L94314.

Co-investigator with Professor A. I. Ruban on project "Advanced Numerical Methods to Calculate 3D Flow Separation" funded by EPSRC Mathematics Committee for three years from October 1998 (value £114,630). Grant GR/L62580.

Principal investigator on project "Numerical Analysis of Matrix Functions" funded by EPSRC Mathematics Committee for three years from February 2001 (value £129,092). Grant GR/R22612.

EPSRC Visiting Fellowship for Professor A. Bojanczyk (Cornell University) on project "Hyperbolic Transformations: Numerical Algorithms and Stability", August 2001–January 2002. Grant GR/R22414 (value £8159).

Principal investigator on Masters Training Package "Numerical Analysis and Computing" funded by EPSRC for one year from September 2001 (value £51,897). Grant GR/RN26883/01.

Christopher A. H. Paul

Research Fellow in Numerical Analysis, University of Manchester
Ph.D. University of Manchester, 1992

Once again my year has been dominated by non-research activity. However I have maintained my interest in the mathematical modelling of cell proliferation, working closely with Christopher Baker and his Ph.D. student Fathalla Rihan. I have also been involved in the informal research group that Prof. Baker has established to promote interest and further investigations into "differential equations with memory". As part of the celebrations of the 150th anniversary of the founding of Owens College, I co-organised with Christopher Baker, Neville Ford (Chester College) and Evelyn Buckwar a series of three one-day conferences on the topic of functional differential equations. Each conference had two plenary talks by invited international speakers and four 30-minute talks by local speakers.

I have continued writing my successor to *archi*—the code that I wrote for my Ph.D. for solving neutral delay differential equations. The design of the new code has changed several times over the past year as I have adopted new strategies for solving stiff differential equations and for dealing with the derivative discontinuities that generally occur in delay differential equations.

Appointments and Professional Activities

Computer Support Officer, Mathematics Department.

Data Protection Officer, Mathematics Department.

Procurement Officer, Mathematics Department.

Referee for three journals.

Lectures

Numerical solution of delay algebraic-differential equations with non-constant lags, One day meeting on Causal Problems at the University of Manchester, 7th February 2001.

Runge-Kutta defect control applied to delay differential equations, Workshop meeting for problems with memory and after-effect, Chester College, 12th-17th December 2001.

Jason A Roberts

Assistant, Mathematics Department, Chester College
Ph.D. Liverpool University, 2000

I have continued to work with John Edwards and Neville Ford on stability and bifurcations in numerical solutions of integral and integro-differential equations. Recently I have started to study these equations when they are in a noisy environment and I am currently engaged in some numerical investigations in this case.

Publications

J T Edwards, N J Ford & J A Roberts *The numerical solution of an integro-differential equation close to bifurcation points*, MCCM Report 380, 2001

J T Edwards & N J Ford *Boundedness and stability of difference equations*, MCCM Report 384, 2001

David J. Silvester

Reader, UMIST
Ph.D. University of Manchester, 1984

Over the year my research effort continued to revolve around writing a research textbook: *Finite Elements and Fast Iterative Solvers: with applications in fluid dynamics*. This ongoing project involves two erudite collaborators: Professor Howard Elman (University of Maryland) and Dr Andy Wathen (Oxford University Computing Laboratory). We expect to finish writing the book before the end of 2002 and we anticipate publication in 2003.

Simulation of the motion of an incompressible fluid remains an important and very challenging research problem. In particular, the resources required for accurate three-dimensional simulation of practical flows test even the most advanced supercomputer hardware. Our most recent research on this topic (see /1/) discusses the effect of the fundamental parameters (the spatial mesh size, and the Reynolds number) on the convergence of our solver methodology in the most demanding case of arbitrarily large time-steps.

Dr Philip Gresho from Lawrence Livermore National Laboratory in USA is one of the world's leading experts in the topic of incompressible computational fluid dynamics. Having recently retired from LLNL, and funded by an EPSRC Visiting Fellowship grant, he visited the UK between June and December 2001. Together with David Griffiths (University of Dundee) significant progress was made on evaluating adaptive time-stepping procedures in the context of advection-diffusion equations. We also had intensive technical exchanges with David Kay (University of Sussex) exploring the use of self-adaptive time-stepping in the context of a super-efficient three-dimensional Navier-Stokes solver that is being currently developed.

Professional Activities

Editorial board, SIAM Journal on Scientific Computing.

I was part of an international panel that evaluated a Special Research Programme on 'Numerical and Symbolic Scientific Computing' at the the Johannes Kepler University in Linz, Austria. The evaluation took the form of a one-day hearing held at Linz in December 2000.

Research Grants

Principal Investigator on project "Analysis of Numerical Methods for Incompressible Fluid dynamics", EPSRC Visiting Fellowship for Professor P.M. Gresho to visit the UK, (value £50,147). Grant GR/R26092/01.

Publications

All of these publications are available via the WWW; see `http://www.ma.umist.ac.uk/djs/`

Silvester, D., Elman, H., Kay, D. and Wathen, A. Efficient preconditioning of the linearised Navier-Stokes equations for incompressible flow, J. Computational and Applied Mathematics (special millennium issue vol. 7), **128**, pp. 261–279, 2001.

Kay, D. and Silvester, D. The reliability of local error estimators for convection-diffusion equations, IMA J. Numerical Analysis, **21**, pp. 107–122, 2001.

Norburn, S. and Silvester, D. Fourier analysis of stabilised Q_1–Q_1 mixed finite element approximation, SIAM J. Numerical Analysis, **39**, pp. 817–833, 2001.

Elman, H., Silvester, D. and Wathen, A., Saddle point preconditioners for the discrete Navier-Stokes equations, *Proceedings of the ICFD conference on Numerical Methods for Fluid Dynamics.* Editor M. Baines, Oxford University Press, 2001.

Lectures

Invited speaker at a *Symposium on Finite Element Methods,* held at the Technical University Chemnitz, Germany, September 2001. All expenses paid by the organisers.

Invited seminar: "Incompressible Flow Modelling can be a dodgy business",
University of Pavia, January, 2001 and University of Sussex, November, 2001.

R. W. Thatcher

Senior Lecturer, UMIST
Ph.D. University of London, 1972

Work on least squares techniques for fluid flow with my research student, Paul Bolton, has continued and I expect him to submit for his PhD early in 2002. We have produced interesting results concerning the stress/stream function approach for Stokes equations which have been extended to modelling the Navier Stokes equations.

My main area of research work has been concerned with Numerical Modelling in Combustion. I have continued to work in modelling flame edges and have also been working in a new area concerning the use of chain branching models of the Chemistry. This latter work has arisen out of our previous work on flame balls where we showed that the use of one-step Chemistry can, in certain circumstances, give rise to quite poor results. This work is being done in collaboration with Prof John Dold at UMIST. Although no publications have been produced in 2001 three papers have been sent off for journal publication and conference presentation.

Appointments and Professional Activities

Head of the Mathematics Department, UMIST.

Member of the Academic Establishment Committee at UMIST.

Member of the Academic Studies Committee at UMIST.

Member of various UMIST working parties including the Dean's Working Party on Modularisation and Credit Weighting and the Dean's Working Party on flexible entry requirements for able students.

Publications

A least squares method for biharmonic problems, SIAM J. Numer Anal. **38** (2000), 1523-1539.

Edges of flames that don't exist: flame-edge dynamics in a non-premixed counterflow (with J.W. Dold), Combustion Theory and Modelling **4** (2000), 435-457.

Stability of a spherical flame ball in a porous medium (with A.A. Shah and J.W. Dold), Combustion Theory and Modelling **4** (2000), 511-534.

Technical Reports

P. Bolton, J. Stratakis and R.W. Thatcher, *Mass conservation in least squares methods for Stokes flow* MCCM Technical Report 374, June 2001,

Ruth M. Thomas

Senior Lecturer, UMIST
Ph.D. University of Manchester, 1979

In 2001, I worked on three main research projects. The first project involves an investigation of numerical strategies for delay differential algebraic equations. This work was carried out with a Ph.D. student, Mr. Carl Gibson.

The second project concerns the numerical solution of periodic initial value problems with oscillatory solution. Together with my Ph.D. student, Muhammad Gul, and my M.Sc. student, Paul Roberts, I worked on developing efficient predictors and interpolants for use with a family of hybrid methods for solving second order initial value problems in ordinary differential equations. I also collaborated with Dr. John Coleman of the University of Durham on collocation methods for solving problems of this type.

In the third project, I worked on moving mesh methods for parabolic partial differential equations, in particular for problems arising when modelling the propagation of a narrow flame in a detonator delay element. This work was in collaboration with Thebe Basebi, a Ph.D. student.

Appointments and Professional Activities

External Examiner, Ph.D. Degree, University of Newcastle.

External Examiner, M.Sc. Course in Computational Mathematics and Modelling, University of Brunel.

Referee of numerous papers for academic journals.

Referee of several research proposals for the EPSRC.

Departmental responsibilities include being Assistant Head of Department, Director of Undergraduate Studies and Undergraduate Tutor.

Publications

J. A. Sturgeon, R. M. Thomas and I. Gladwell. Solving a Singular DAE Model of Unconfined Detonation. Computers and Chemistry, 25, 83-95 (2001).

C. T. H. Baker, G. A. Bochorov, A. Filiz, N. J. Ford, C. A. H. Paul, F. A. Rihan, A. Tang, R. M. Thomas, H. Tian and D. R. Willé. Numerical Modelling by Delay and Volterra Functional Differential Equations. Hellenic European Research on Mathematics and Informatics Science, 2, 29-52 (2001).

T. Basebi and R. M. Thomas. A Study of Moving Mesh Methods Applied to a Thin Flame Propagating in a Detonator Delay Element. Manchester Centre for Computational Mathematics, Report No. 375 (2001).

Françoise Tisseur

Colin Roscoe Lecturer, University of Manchester
Ph.D. University of St. Etienne, 1997

My Colin Roscoe Lectureship started in January 2001 and soon after I applied for two grants for newly appointed lecturers. In March I was awarded a grant from the Nuffield Foundation to work on the numerical solution of quadratic eigenvalue problems with symmetric coefficient matrices. In July I was awarded an EPSRC grant to fund a PhD studentship on the polynomial eigenvalue problem.

Polynomial root finding is an old subject on which much has been written. When the coefficients of the polynomial are generalized from scalars to matrices we obtain the polynomial eigenvalue problem

$$P(\lambda)x = (\lambda^m A_m + \lambda^{m-1} A_{m-1} + \cdots + A_0)x = 0,$$

where the A_i are complex matrices and λ is an eigenvalue with corresponding eigenvector x. Little or nothing has been published on bounds for eigenvalues of matrix polynomials, except for special classes of coefficient matrices. With Nick Higham I derived upper and lower bounds for the absolute values of the eigenvalues of $P(\lambda)$. The bounds are based on norms of the coefficient matrices and involve the inverses of the leading and trailing coefficient matrices. They generalize various existing bounds for scalar polynomials and single matrices. Numerical experiments show that the bounds can be surprisingly sharp on practical problems.

As part of my effort to further my understanding of polynomial eigenvalue problems I investigated, with J. P. Dedieu (Toulouse University, France), polynomial eigenvalue problems $P(A, \alpha, \beta)x = 0$ in which the matrix polynomial

$$P(\alpha, \beta) = \alpha^m A_m + \alpha^{m-1}\beta A_{m-1} + \cdots + \beta^m A_0$$

is homogeneous in the eigenvalue $(\alpha, \beta) \in \mathbb{C}^2$. In this framework infinite eigenvalues are on the same footing as finite eigenvalues. By viewing the problem in projective spaces to avoid normalization of the eigenpairs, we obtained new eigenvalue and eigenvector condition numbers and showed that the distance to the nearest ill-posed problem is equal to the reciprocal of the condition number of the eigenvector x. We also described a bihomogeneous Newton method for the solution of the homogeneous polynomial eigenvalue problem.

With Nick Higham I defined and characterized pseudospectra for rectangular homogeneous matrix polynomials. For such problems stereographic projection onto the Riemann sphere is a convenient way to visualize pseudospectra. Lower bounds for the distance to the nearest non-regular polynomial and the nearest uncontrollable dth order system (with equality for standard state-space systems) were obtained in terms of pseudospectra, showing that pseudospectra are a fundamental tool for reasoning about matrix polynomials in areas such as control theory.

As part of my effort to investigate structured eigenvalue problems, I have considered standard eigenvalue problems in which the matrices are singly or doubly structured; these arise in various science and engineering applications. I derived a chart of structured backward errors for approximate eigenpairs of singly and doubly structured eigenvalue problems. My aim was to give, wherever possible, formulae that are inexpensive to compute so that they can be used routinely in practice. I identified a number of problems for which the structured backward error is within a factor $\sqrt{2}$ of the unstructured backward error.

Professional Activities

Member of Scientific Committee of Algèbre Linéaire et Arithmétique, Calcul Numérique, Symbolique et Parallèle, Rabat, Morocco, 2001.

Organizer of minisymposium "Quadratic Eigenvalue Problems", SIAM Annual Meeting, San Diego, July 2001.

Publications

F. Tisseur. Newton's Method in Floating Point Arithmetic and Iterative Refinement of Generalized Eigenvalue Problems. *SIAM J. Matrix Anal. Appl.*, 22(4):1038-1057, 2001.

F. Tisseur. Stability of Structured Hamiltonian Eigensolvers. *SIAM J. Matrix Anal. Appl.*, 23(1):103-125, 2001.

F. Tisseur and N. J. Higham. Structured Pseudospectra for Polynomial Eigenvalue problems, with Applications. *SIAM J. Matrix Anal. Appl.*,23(1):187-208, 2001.

F Tisseur and K. Meerbergen. The Quadratic Eigenvalue Problem. *SIAM Review*, 43(2):235-286, 2001.

P. I. Davies, N. J. Higham and F. Tisseur. Analysis of the Cholesky Method with Iterative Refinement for Solving the Symmetric Definite Generalized Eigenproblem. *SIAM J. Matrix Anal. Appl.*,23(2):472-493, 2001.

N. J. Higham and F. Tisseur. Bounds for Eigenvalues of Matrix Polynomials. Numerical Analysis Report 371, Manchester Centre for Computational Mathematics, January 2001, *To appear in Linear Algebra and Appl.*

N. J. Higham and F. Tisseur. More on Pseudospectra for Polynomial Eigenvalue Problems and Applications in Control Theory. Numerical Analysis Report 372, Manchester Centre for Computational Mathematics, January 2001. *To appear in Linear Algebra and Appl.*

N. J. Higham, F. Tisseur and P. M. Van Dooren. Detecting a Definite Hermitian Pair and a Hyperbolic or Elliptic Quadratic Eigenvalue Problem, and Associated Nearness Problems. Numerical Analysis Report 373, Manchester Centre for Computational Mathematics, February 2001. *To appear in Linear Algebra and Appl.*

J.-P. Dedieu and F. Tisseur. Perturbation Theory for Homogeneous Polynomial Eigenvalue Problems. Numerical Analysis Report 363, Manchester Centre for Computational Mathematics, March 2001. *To appear in Linear Algebra and Appl.*

J.-P. Dedieu, M.-H. Kim, M. Shub and F. Tisseur. Implicit Gamma Theorems (I): Pseudoroots and Pseudospectra. Numerical Analysis Report 394, Manchester Centre for Computational Mathematics, November 2001. Submitted to *Foundations of Comp. Math.*

F. Tisseur. A Chart of Backward Errors and Condition Numbers for Singly and Doubly Structured Eigenvalue Problems, Numerical Analysis Report 395, Manchester Centre for Computational Mathematics, December 2001. Submitted to *SIAM J. Matrix Anal. Appl.*

Lectures

Congrès Algèbre Lineaire et Arithmétique: Calcul Numérique, Symbolique et Parallèle, Rabat, Marocco, May 2001. Tutorial on "Le problème quadratique de valeurs propres".

25th Annual Conference of the South African Society for Numerical and Applied Mathematics, Stellenbosch, South Africa, April 2001, "Bounds for Eigenvalues of Matrix Polynomials".

19th Dundee Biennial Conference on Numerical Analysis, June 2001. "Bounds for Eigenvalues of Matrix Polynomials".

SIAM Annual Meeting, San Diego, July 2001. Talk in minisymposium "Quadratic Eigenvalue Problems": "Recent Developments in Quadratic Eigenvalue Problems".

SIAM Annual Meeting, San Diego, July 2001. Talk in minisymposium "Matrix Approximation Problems": "Bounds for Eigenvalues of Matrix Polynomials".

Technische Universität München, May 2001, "Pseudospectra for Polynomial Eigenvalue Problems: Theory, Computation and Applications".

University of Cambridge, DAMTP, England, October 2001, "Recent developments in quadratic eigenvalue problems".

Research Grants

Award to Newly Appointed Lecturers in Science, Engineering and Mathematics from the Nuffield Foundation. Amount of grant: £4,845 (maximum award is £5K), 2001-2003. Grant Number: NAL/00216/G.

Principal Investigator on project "Numerical Analysis of Polynomial Eigenvalue Problems" funded by EPSRC Mathematics Committee under the "Fast Stream" scheme for three years from September 2001 (value £62,553). Grant GR/R45079/01.

3 Long-Term Visitors

Adam W. Bojanczyk

Visiting Scientist
Associate Professor, Cornell University
Ph.D. University of Warsaw, 1981

Over the year I worked on issues related to speeding-up computations in signal processing systems as well as propagation of roundoff errors in numerical computing.

I continued working on parallelization, benchmarking, modelling and new heuristics for Space-Time Adaptive Processing (or STAP) systems. Together with graduate students we were able to port software previously develped for the IBM SP2 computer to a cluster based system operated by Cornell Theory Center. In connection with the STAP project I investigated numerical stability of weight vector computations in the so-called sample covariance inversion method.

In a project with Professor Adam Lutoborski we considered structured orthogonal Procrustes problems. We proposed relaxation methods for solving the orthogonal Procrustes problem when the solution is sought in the form of a Kronecker product.

In the fall semester I visited Professor Nick Higham and Dr Françoise Tisseur at the Department of Mathematics, University of Manchester, supported by an EPSRC Visiting Fellowship. During the visit we worked on the indefinite least squares problem, and investigated the numerical properties of hyperbolic transformations in linear algebra problems.

Research Grants

Principal Investigator on project "Variable-Precision and Reconfigurable Systems", DARPA, June 1997—May 2001.

Publications

A.W. Bojanczyk, Sensitivity analysis of weights computation in the Space-Time Adaptive Signal Processing systems. Technical Note, July 2001.

A.W. Bojanczyk and Hsien-Lung Yang, Benchmarking the Velocity cluster. Technical Note, May 2001.

A.W. Bojanczyk and A. Lutoborski, The Procrustes Problem for Orthogonal Kronecker Products, Cornell Computer System Lab Technical Report CSL-TR-2001-1012, April 2001, (http://www.csl.cornell.edu).

A.W. Bojanczyk, A Jacobi Method for Computing Generalized Hyperbolic SVD. Cornell Computer System Lab Technical Report CSL-TR-2001-1011, January 2001, (http://www.csl.cornell.edu).

Lectures

University of Warsaw, "Procrustes Problems", University of Warsaw, October 2001

University of Oxford, "A Generalized Hyperbolic SVD", November 2001.

QinetiQ, Malvern, "ALPS, Algorithmic Library for Parallel STAP", December 2001.

Technical University of Denmark, Lyngby, Denmark, "Orthogonal Kronecker Procrustes Problem", December 2001.

Manchester Research Centre for Computational Science seminars, "Space-Time Adaptive Processing", November 2001.

4 Joint University of Manchester-UMIST Seminars in Applied Mathematics (including Numerical Analysis)

January 31, 2001, David Sumpter (Centre for Mathematical Biology Oxford University) Foraging by Social Insect Colonies: Does Size Matter?

February 7, 2001, All day, Organiser: Christopher Baker. Causal problems—problems with after-effect or delay.

February 21, 2001, John Blackman (Dept. of Physics, University of Reading) Growth, scaling, and coalescence in droplet deposition models. General seminar

February 21, 2001, Prof Iain Stewart (Leicester) EPSRC MathFIT Programme: Program schemes, finite model theory and computational complexity

February 27, 2001, Dr. Mario Pytka & Andrew Brogden (Abbey National Financial Products) From Wall Street to Baker Street and A New Approach to Pricing Equity Derivatives

February 28, 2001, Demetrios Papageorgiou (New Jersey Inst. Tech.) Fluid dynamics of bubble motion in surfactant solutions

March 7, 2001, Vanessa Styles (School of Math. Sciences, Univ. of Sussex) Analysis of vortex density models in superconductivity

March 14, 200 Clive Temperton (European Centre for Medium-Range Weather Forecasts) Numerical Weather Prediction

March 14, 2001, Joint Applied-Statistics Seminar, Salah-Eldin A. Mohammed (Department of Mathematics, Southern Illinois University) Stochastic Systems with Memory: Dynamics and Some Numerics.

March 21, 2001, Andrew Hogg (Dept. of Mathematics University of Bristol) zAsh, silt, similarity solutions and fifth-order Legendre functions: models of particle-driven motion

March 28, 2001, Alistair Fitt (Dept. of Mathematics, University of Southampton) The unsteady flapping of flags and blowing of sails

April 25, 2001, David Parker (Dept. of Mathematics and Statistics, University of Edinburgh) Nonlocal evolution equations for nonlinear elastic surface waves

May 9, 2001, Roger Grimshaw (Loughborough University) Solitary waves with vortex cores in stratified and rotating fluids

June 20, 2001 Rodney Weber (School of Mathematics & Statistics, ADFA) Modelling Bushfires and Combustion

September 26, 2001, Dr. Joel Daou (Mathematics Department, UMIST) Flame propagation in a parallel flow: Asymptotic and numerical investigation of the effect of the flow scale and intensity.

October 3, 2001, Dr. Andrew Hazel (Dept. of Mathematics University of Manchester) The steady propagation of semi-infinite bubbles into rigid and flexible tubes

October 17, 2001, Prof. Yibin Fu (Mathematics Department, Keele University) Computing surface wave speeds without knowledge of the Stroh Formalism

October 24, 2001, Dr. Philip Gresho (Lawrence Livermore National Lab.) On the stability of a particular steady incompressible flow at Reynolds number & A 2D time-periodic thermal convection proble

October 31, 2001, Dr. R. Eddie Wilson (Dept. of Engineering Mathematics, University of Bristol) Highway traffic models and their nonlinear wave solutions

November 7, 2001, Prof. Alan Champneys (Dept. of Engineering Mathematics, University of Bristol) Embedded solitons"; solitary waves in resonance with linear spectrum

November 14, 2001, Dr. David Harris (Mathematics Department, UMIST) Rotation, hyperbolicity and linear well-posedness in the flow of granular materials

November 21, 2001, Dr. Allan McRobie (Department of Engineering, University of Cambridge) On the Millennium Bridge

November 28, 2001, Prof. Michael Siegel (Mathematics Department, New Jersey Institute of Technology) Tip streaming instabilities for some free boundary problems in materials science and fluid dynamics

December 12, 2001, Prof. Philip Hall (Department of Mathematics, Imperial College) The role of flow unsteadiness in the formation of bars and meanders

5 Numerical Analysis Reports

The following reports may be identified by the ISSN number `ISSN 1360-1725` and are available in hard copy (contact The Secretaries, Mathematics Department, The University, Oxford Road, Manchester, M13 9PL, England) and in electronic form via the MCCM web pages at `http://www.ma.man.ac.uk/MCCM/MCCM.html` or `http://www.maths.man.ac.uk/~nareports` to go directly to the reports.

Many reports form the basis of papers subsequently published in journals.

[1] Jean-Pierre Dedieu and Françoise Tisseur. Perturbation theory for homogeneous polynomial eigenvalue problems. Numerical Analysis Report No. 363, Manchester Centre for Computational Mathematics, Manchester, England, March 2001. 21 pp.

[2] Manchester Centre for Computational Mathematics. Annual report: January–December 1999. Numerical Analysis Report No. 364, Manchester Centre for Computational Mathematics, Manchester, England, March 2001. 24 pp.

[3] Nicholas J. Higham and Françoise Tisseur. Bounds for eigenvalues of matrix polynomials. Numerical Analysis Report 371, Manchester Centre for Computational Mathematics, Manchester, England, January 2001. 16 pp.

[4] Nicholas J. Higham and Françoise Tisseur. More on pseudospectra for polynomial eigenvalue problems and applications in control theory. Numerical Analysis Report 372, Manchester Centre for Computational Mathematics, Manchester, England, January 2001. 21 pp.

[5] Nicholas J. Higham, Françoise Tisseur, and Paul M. Van Dooren. Detecting a definite Hermitian pair and a hyperbolic or elliptic quadratic eigenvalue problem, and associated nearness problems. Numerical Analysis Report 373, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 18 pp.

[6] Sheung Hun Cheng and Nicholas J. Higham. Parallel implementation of a block algorithm for matrix 1-norm estimation. Numerical Analysis Report No. 374, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 9 pp.

[7] Thebe Basebi and Ruth M. Thomas. A study of moving mesh methods applied to a thin flame propagating in a detonator delay element. Numerical Analysis Report No. 375, Manchester Centre for Computational Mathematics, Manchester, England, October 2001.

[8] P. Bolton, J. Stratakis, and R. W. Thatcher. Mass conservation in least squares methods for Stokes flow. Numerical Analysis Report No. 376, Manchester Centre for Computational Mathematics, Manchester, England, June 2001. 22 pp.

[9] N. J. Ford and K. Diethelm. Analysis of fractional differential equations. Numerical Analysis Report No. 377, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 17 pp. To appear in Journal of Mathematical Analysis and Applications.

[10] N. J. Ford and K. Diethelm. Numerical solution of the Bagley Torvik equation. Numerical Analysis Report No. 378, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 12 pp. Submitted to BIT.

[11] N. J. Ford and K. Diethelm. The numerical solution of linear and non-linear fractional differential equations involving fractional derivatives of several orders. Numerical Analysis Report No. 379, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 14 pp.

[12] J. A. Roberts J. T. Edwards and N. J. Ford. The numerical solution of an integro-differential equation close to bifurcation points. Numerical Analysis Report No. 380, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 6 pp.

[13] Neville J. Ford and Sjoerd M. Verduyn Lunel. Characterising small solutions in delay differential equations through numerical approximations. Numerical Analysis Report 381, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 15 pp.

[14] Neville J Ford and Sjoerd M Verduyn Lunel. Numerical approximation of delay differential equations with small solutions. Numerical Analysis Report 382, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 6 pp.

[15] N. J. Ford, P. D. Crofts, and R. H. T. Edwards. Sensitivity of hospital clinic queues to patient non-attendance. Numerical Analysis Report 383, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 6 pp.

[16] J. T. Edwards and N. J. Ford. Boundedness and stability of difference equations. Numerical Analysis Report No. 384, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 14 pp.

[17] N. J. Ford and A. C. Simpson. The numerical solution of fractional differential equations: Speed versus accuracy. Numerical Analysis Report No. 385, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 12 pp.

[18] N. J. Ford and A. C. Simpson. The approximate solution of fractional differential equations of order greater than 1. Numerical Analysis Report No. 386, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 6 pp.

[19] N. J. Ford and A. C. Simpson. Numerical and analytical treatment of differential equations of fractional order. Numerical Analysis Report No. 387, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 7 pp.

[20] J. M. Ford, K. Chen, and N. J. Ford. Small-scale parallel implementation of fast wavelet transforms. Numerical Analysis Report No. 388, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 7 pp.

[21] J. M. Ford, K. Chen, and N. J. Ford. Parallel implementation of fast wavelet transforms. Numerical Analysis Report No. 389, Manchester Centre for Computational Mathematics, Manchester, England, February 2001. 15 pp.

[22] Manchester Centre for Computational Mathematics. Annual report: January–December 2000. Numerical Analysis Report No. 391, Manchester Centre for Computational Mathematics, Manchester, England, March 2001. 23 pp.

[23] Matthew I. Smith. A Schur algorithm for computing matrix pth roots. Numerical Analysis Report No. 392, Manchester Centre for Computational Mathematics, Manchester, England, July 2001. 18 pp.

[24] Sheung Hun Cheng and Nicholas J. Higham. Implementation for LAPACK of a block algorithm for matrix 1-norm estimation. Numerical Analysis Report No. 393, Manchester Centre for Computational Mathematics, Manchester, England, August 2001. 19 pp. LAPACK Working Note 152.

[25] Jean-Pierre Dedieu, Myong-Hi Kim, Michael Shub, and Françoise Tisseur. Implicit gamma theorems (I): Pseudoroots and pseudospectra. Numerical Analysis Report No. 394, Manchester Centre for Computational Mathematics, Manchester, England, November 2001. 25 pp.

[26] Françoise Tisseur. A chart of backward errors and condition numbers for singly and doubly structured eigenvalue problems. Numerical Analysis Report No. 395, Manchester Centre for Computational Mathematics, Manchester, England, December 2001. 23 pp.