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DEPARTMENTS OF MATHEMATICS

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A Message from the Director

The Annual Report serves to publicize the work that has taken place during 2000. Along with other MCCM technical reports, information about the M.Sc. in Numerical Analysis and Computing, and MCCM seminar details, it is available from the MCCM Web page at

`http://www.ma.man.ac.uk/MCCM/`

The Department of Mathematics at The University of Manchester is linked to a number of 'Centres' of which the MCCM is the longest established, linking The University to sister departments at UMIST and to Chester (all have additional links, of course). The differing centres function in various rôles providing emphasis on several aspects of mathematics.

The MCCM functions as a collaborative Centre, to reflect and if possible to strengthen the existing collaboration between the Numerical Analysis Groups at The University of Manchester, at UMIST and in the Mathematics research group at University College Chester, and to provide for Visiting and Honorary Research Fellows. This collaboration has been manifest in *postgraduate teaching* in the M.Sc. in Numerical Analysis & Computing, in the *seminar programme*, and also in the organization of *symposia* and of *mini-symposia* at national and international meetings. *Research collaboration* is a particularly valuable feature that reveals itself in a number of jointly-authored papers. Evidence of all such collaboration will be found in the following pages. Those engaging in research have a responsibility to disseminate the results of their enquiries, and MCCM promotes this through its series of (electronic or hard-copy) Technical Reports and through access from its web site to pre-publication electronic versions of its research output.

Here is not the place to enter into a full scale philosophical debate on the nature of Numerical Analysis. To some, the emphasis should be on computational mathematics, to others the emphasis should be on a unifying perspective from the viewpoint of applied analysis. To the writer, numerical analysis is ideally a broad church and like other sections of applied mathematics should be informed by modelling considerations, investigations based on simulation or analysis, and the practicalities of modern computing. As an integrated part of applied mathematics, the skills developed in numerical analysis complement and are complemented by perspectives obtained from other areas; numerical analysis should be supported by insights from modelling, and from the more abstract areas of mathematics, and computer science.

Our subject thrives when there are healthy links with active groups in other areas of Mathematics and of Computer Science as well as the areas of science, technology or medicine in which it finds application. These links are seen in Manchester, in particular through the involvements in the Centre for Novel Computing, and in collaborative work with applied and pure mathematicians and probabilists, mathematical biologists, engineers, etc.

Christopher T. H. Baker
Director of MCCM

Christopher T. H. Baker

Professor of Mathematics, Manchester University;
Honorary Senior Research Fellow, Chester College
D.Phil., Oxford University, 1964

It has been a fairly eventful year. The chairmanship of the (RAE2001) Research Assessment Panel for Applied Mathematics made some inroads into my time during 2000. I feel the Mathematical Community can rely upon the members of the Applied Mathematics Panel to do their best in a difficult exercise, assisted by external advisers where appropriate. The wisdom and academic expertise is available and the legitimacy of the assessment derives from the application of sound academic judgments. While, in legal terms, the grading of research is the responsibility of HEFCE, I am very much aware that the academic members of the panel will be held by the Academic Community at large to be responsible for any unfortunate outcomes. Of course, the rôle of the academics in the exercise is to a certain extent subordinate to the mechanisms and procedures put in place by HEFCE and its RAE Team and, not least, the practical support forthcoming for the Panel from HEFCE (and from the Panel Secretary and Assistant Secretary). The scope for independence within the Panel is delineated by HEFCE and by legal advice provided to the HEFCE RAE Team. While the methodology may have its merits it is necessary to keep an observant eye for any demerits. The task facing those involved in RAE2001 is non-trivial, and an excess of confidence would be worrying!

At Manchester during the year 2000, the collaborative research group of which I am a member contained, in my department, myself, Chris Paul (his appointment now permanent, as University Research Fellow), Evelyn Buckwar (supported by her second Marie Curie Fellowship), Fathalla Rihan (O/S PhD student); Hongjiong Tian (O/S PhD student; ORS Award); 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). It 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. My cooperation with international contacts – that most active at present being with Prof Bocharov – continue to thrive. 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. Service as a special guest editor (with Guido Vanden Berge, Giovanni Monegato, and John Pryce) of Volume 6 in the NA2000 series of issues of the Journal of Computational and Applied Mathematics (devoted to ordinary differential equations, delay differential equations and integral equations) provided an increased load, though the outcome was in my eyes rewarding. Our volume had initially been intended to cover partial differential equations too, but our representations that this subject merited a separate volume were well received by Luc Wuytack, Principal Editor of the Journal, and it was with some pleasure that we saw the responsibility for this area handed over to David Sloan, Endre Süli, & Stefan Vandewalle as editors of a separate volume.

Appointments and Professional Activities

Chair, Applied Mathematics Panel RAE2001

Member of the EPSRC College (Mathematics Programme)

Director, MCCM;

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

Member of the Dean's Advisory Committee.

Editor, Journal of Computational & Applied Mathematics

Editor, Journal of Integral Equations & Applications

Honorary editor, Communications on Applied Nonlinear Analysis

Member of the accreditation board, Computer Abstracts

Referee for a number of journals and publishers.

Referee for research proposals

I have recently been asked to join further editorial boards but have not yet become active in these roles.

Conference organisation

Minisymposium on Causal Evolutionary Problems with Memory (organisers Christopher Baker, Evelyn Buckwar); BAMC April 2000.

Publications (Jan. - Dec. 2000)

Journal publications

Christopher T H Baker, *A perspective on the numerical treatment of Volterra equations* Numerical analysis 2000, Vol. VI, Ordinary differential equations and integral equations. J. Comput. Appl. Math. 125 (2000), no. 1-2, 217–249.

Christopher T H Baker, *Retarded differential equations* Numerical analysis 2000, Vol. VI, Ordinary differential equations and integral equations. J. Comput. Appl. Math. 125 (2000), no. 1-2, 309–335,

Christopher T H Baker & Evelyn Buckwar Evelyn, *Continuous Θ-methods for the stochastic pantograph equation.* Electron. Trans. Numer. Anal. 11 (2000), 131–151 (electronic).

Christopher T H Baker & Evelyn Buckwar, *Numerical analysis of explicit one-step methods for stochastic delay differential equations* LMS J. Comput. Math. 3 (2000), 315–335 (electronic).

Christopher T H Baker & David R Willé, *On the propagation of derivative discontinuities in Volterra retarded integro-differential equations* New Zealand Journal of Mathematics **29** 103–113 (2000)

Conference publications

Christopher T H Baker & Arsalang Tang *Generalized Halanay inequalities for Volterra functional differential equations and discretized versions*, Volterra equations and applications (Arlington, TX, 1996), 39–55, Stability Control Theory Methods Appl., 10, Gordon and Breach, Amsterdam, 2000

Christopher T H Baker & Arsalang Tang *Stability & Numerical Stability of Non-linear Delay Integro-Differential Equations via Approximating Equations*, Abstract #950-45-120, Abstracts of Papers Presented to the American Mathematical Society, **21(1)**, Issue 119 (2000) p. 110. ISSN 0192-5857.

Christopher T H Baker *The issue of local Lipschitz conditions in the numerics of nonlinear delay differential equations.*
`http://imacs2000.epfl.ch/Documents/Sessions/173-1.pdf`

Technical Reports

Christopher T. H. Baker and Evelyn Buckwar *Continuous Θ-methods for the Stochastic Pantograph Equation* MCCM Technical Report 361, May 2000, ISSN 1360-1725

Christopher T H Baker *Retarded Differential Equations and their Numerical Treatment* MCCM Technical Report 365, December 2000, ISSN 1360-1725

Christopher T H Baker *Volterra Equations and their Numerical Treatment* MCCM Technical Report 366, December 2000, ISSN 1360-1725

C T H Baker, C A H Paul and H Tian *Differential Algebraic Equations with After-Effect* MCCM Technical Report 367, October 2000, ISSN 1360-1725

Lectures

- AMS-SIAM-AMA Joint Mathematical Meetings Washington 19th – 22nd January 2000 American Mathematical Society: Invited 40 minute lecture, at the invitation of Prof Corduneanu. Title: Stability & Numerical Stability of Non-linear Delay Integro-Differential Equations via Approximating Equations (joint work with Arsalang Tang).

  In the discussion of stability and numerical stability for delay and integro-differential equations, it is common to examine *test equations*, such as

  $$u'(t) = au(t) + bu(t-\tau_\star) \quad \text{or} \quad u'(t) = au(t) + \int_{t-\tau_\star}^{t} k(t-s)y(s)ds. \qquad (\ddagger)$$

  In Washington, my talk addressed a number of questions which relate to the choice of such equations; in particular: What can be said about the relationship between the stability of the zero solution of

  $$u'(t) = f\Big(t,\ u(t),\ u(t-\tau(t,u(t))), \int_{t-\tau(t,u(t))}^{t} K(t,s,u(t),u(s))ds\Big)$$

  and the zero solution of suitable approximating equations? Of such approximating equations, (‡) are the simplest examples (approximations of first order) but amongst the possible alternatives are approximations of higher orders in u, such as $u'(t) = A\{u(t)\}^3$. The resulting theoretical insight is a basis for progress in answering similar questions for the discretized problems based on simple numerical methods, which were addressed in the context of the Θ-methods.

- BAMC, UMIST April 25th-28th 2000: Title: Asymptotic stability of equations with after effect from generalizations of Halanay's inequality

- ICCAM 2000 July 17-21 2000 Katholieke Universiteit Leuven. Invited (opening) plenary lecture. Title: Numerics of Differential Algebraic Equations with After-effect.

  My talk at Leuven concerned constrained delay differential equations. Such problems can frequently be reduced (by manipulating the constraining equations) to differential equations with deviating arguments.

- 16th IMACS World Congress 2000 on Scientific Computation, Applied Mathematics and Simulation, August 21– 25th 2000, EPFL École Polytechnique Fédérale de Lausanne Switzerland. Minisymposium talk presented at the invitation of Prof. Dirk Roose. Title: The issue of local Lipschitz conditions in the numerics of nonlinear delay differential equations.

  When analyzing the numerical solution of delay differential equations (DDEs) using methods employing variable step-sizes, it is commonplace to simplify the analysis by assuming global Lipschitz conditions. A variety of numerical methods give rise to implicit equations to be solved for the approximate solution on a grid (from which a densely defined approximation is subsequently obtained). The implicit equations, being nonlinear, may have non-unique solutions if one relaxes the global assumptions and adopts more realistic ones. Thus, if we require local (rather than global) Lipschitz conditions, we have to re-examine the issues of existence, uniqueness, and convergence of the numerical approximation. My talk at Lausanne addressed such issues.

- Afscheidssymposium voor Pieter van der Houwen. CWI Amsterdam October 20th., 2000: Invited lecture in tribute to Prof van der Houwen. Title: Propagation of discontinuities in Volterra evolutionary problems.
  `http://www.cwi.nl/colloquia/VdHsympos.html3.30`

- Various seminars in the UK.

Research Grants

I am currently Scientific supervisor EU TMR Fellowship (Dr E Buckwar) Proposal # HPMF-CT-1999-00090 on the numerical treatment of stochastic functional differential equations.

Evelyn Buckwar

Marie Curie Research Fellow
Dr. rer. nat. Free University of Berlin, 1997

I work 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, based on the Euler-Maruyama-method and the stochastic Θ-method for stochastic ordinary differential equations, for approximations of trajectories of the solution process.

Appointments and Professional Activities

From January to April 2000 I was employed as a research assistant by the University of Manchester. (I had previously been employed as a Marie Curie Fellow under TMR Grant # ERBFMB IC T983282.) Having been successful with a second proposal for a TMR Fellowship, my second 12 month term as a Marie-Curie-Fellow (Project # MCFI-1999-00437, operated under the current framework, Framework 5) started in May.

Publications

On a Nonlinear Volterra Integral Equation, Proceedings of the Volterra Centennial Symposium, Arlington, Texas, USA, 23.-25.5. 1996, Editoren: C. Corduneanu und I.W. Sandberg, Gordon and Breach Science Publishers, pp. 157–162, 2000.

Introduction to the Numerical Analysis of Stochastic Delay Differential Equations, Proceedings of Equadiff 99, Editoren: B. Fiedler, K. Gröger und J. Sprekels, pp. 1021–1023, 2000.

Introduction to the Numerical Analysis of Stochastic Delay Differential Equations, Journal of Computational and Applied Mathematics 125, pp. 297–307, 2000.

Numerical Analysis of Explicit One-step Methods for Stochastic Delay Differential Equations, with C. T. H. Baker, LMS-Journal of Computational Mathematics, 3, pp. 315–335, 2000.

Continuous Θ-methods for the Stochastic Pantograph Equation, with C.T.H. Baker, Electronic Transactions on Numerical Analysis11, pp. 131–151, 2000.

Lectures

Invited Minisymposium-talk at BAMC 2000, Manchester, UK, 2000, Continuous Θ-methods for the Stochastic Pantograph Equation.

Invited speaker at the 'Colloquium on the Occasion of the 70th Birthday of Prof. Dr. Rudolf Gorenflo', Freie Universität Berlin, December 2000, Numerische Analysis für Stochastische Delaydifferentialgleichungen.

J. T. Edwards

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

My research work continues in the area of numerical and analytical solution of integro-differential equations. I have continued to collaborate with Neville Ford and Jason Roberts at Chester on the stability analysis of integro-differential equations of Volterra type with fading memory kernels and have been working more recently on bifurcating solutions and their numerical approximation in a neighbourhood of the bifurcation point. I have also begun some work with Neville Ford on the relationship between boundedness and stability of solutions of difference equations. As is well known, these two properties coincide for simple linear problems but the situation is, in general, far more complicated. Within my management role at Chester College I have been continuing to enable all my colleagues to undertake a greater involvement in research work through careful management of the teaching timetable and of administrative duties among the staff team.

Appointments and Professional Activities

Head of Mathematics Department, Chester College.

Publications

J.T. Edwards, J.A. Roberts & N.J. Ford *The numerical simulation of an integro-differential equation close to bifurcation points* Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 213–3.

J.T. Edwards, J.A. Roberts, N.J. Ford, & L.E. Shaikhet *Stability of a numerical approximation to an integro-differential equation of convolution type*, Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 154–3

J.T. Edwards, J.A. Roberts, N.J. Ford, & L.E. Shaikhet *Stability of a discrete non-linear integro-differential equation of convolution type* Stability and Control: Theory and Applications, **3.1**, pp. 24–37.

Sheung Hun Cheng

Research Associate
Ph.D. University of Manchester, 1998

I continued working on the EPSRC-funded project "Parallel Computations of Matrix Functions". This project has produced a steady output of technical reports since it started in October 1998. A project homepage (`http://www.cs.man.ac.uk/~scheng/PCMF/`) has been established to give background materials and summarize progress. In 2000, my main contribution was to implement the new block 1-norm estimator of Higham and Tisseur in Fortran 77 with the LAPACK and ScaLAPACK programming style and measure performance of our implementations against their counterparts in LAPACK and ScaLAPACK respectively. Experimental results show that the new block algorithm can achieve better quality of estimates with less execution time, thanks to the accelerated convergence and the exploitation of level 3 BLAS. Overhead analysis for our parallel code also leads to a different programming paradigm than that of the ScaLAPACK code, which minimizes the communication costs. This is essential to achieve good performance.

Higham and I continue the collaboration with Kenney (UC Santa Barbara) and Laub (UC Davis). Together we developed a half-angle iteration for the logarithm of a unitary matrix. At the BAMC conference I presented a variant of the methods based on an arctangent formula which is suitable for parallel machines.

Professional Activities

Editor, Journal of Inequalities in Pure and Applied Mathematics.

Publications

S. H. Cheng, N. J. Higham, C. S. Kenney, A. J. Laub. Return to the Middle Ages: A Half-Angle Iteration for the Logarithm of a Unitary Matrix. In Proceedings of the Fourteenth International Symposium of Mathematical Theory of Networks and Systems, Perpignan, France, 2000. CD-ROM

Lectures

British Applied Mathematics Colloquium, UMIST, April 2000, "Novel Parallel Computation of Structured Matrix Functions".

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 with several collaborators both within the UK and beyond on the numerical and analytical solutions of various classes of functional differential equations. I have been working, in particular, 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. I am continuing with this project (which has been supported by the Anglo-Dutch research foundation) with a PhD student, Pat Lumb, and we have begun working on the corresponding vector problem. With Kai Diethelm of Braunschweig and a second PhD student, 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. I have continued to work with John Edwards and Jason Roberts at Chester on stability theory for integro-differential equations of Volterra type. We have been considering especially the limitations in the existing linear stability theory especially when it is applied to problems with fading memory kernels. We have gone on to consider the question of bifurcations in behaviour of solutions which seems to be a new area that has not previously been given much attention. Through collaboration with Christopher Baker, we have run a series of joint seminars on the solution of problems with memory and after-effect (supported by a LMS grant). I gave a lecture at the ICCAM meeting in Leuven in July and an invited feature talk at the IMACS meeting in Milwaukee in May. We also participated in a mini-symposium at the IMACS meeting in Lausanne in August. I visited Kurt Frischmuth (Rostock) and Sjoerd Verduyn Lunel (Leiden). Kai Diethelm (Braunschweig) visited Chester to continue work on our joint project. My student, Jason Roberts, completed his PhD.

Appointments and Professional Activities

Director, Applied Mathematics Research Group, Chester College.

Honorary Research Fellow, University of Manchester

Research Officer for Science and Health, Chester College

Member of Chester City Council Joint Research Planning Group

Publications

N.J. Ford, *Numerical approximation of the characteristic values for a delay differential equation* Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, 2000, 213–7.

J.T. Edwards, J.A. Roberts & N.J. Ford *The numerical simulation of an integro-differential equation close to bifurcation points* Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 213–3.

J.T. Edwards, J.A. Roberts, N.J. Ford, & L.E. Shaikhet *Stability of a numerical approximation to an integro-differential equation of convolution type*, Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 154–3

J.T. Edwards, J.A. Roberts, N.J. Ford, & L.E. Shaikhet *Stability of a discrete non-linear integro-differential equation of convolution type* Stability and Control: Theory and Applications, **3.1**, pp. 24–37.

N.J. Ford & V. Wulf *Numerical Hopf bifurcation for a class of delay differential equations* JCAM **115** pp. 601–616.

N.J. Ford & S.M. Verduyn Lunel *Numerical approximation of delay differential equations with small solutions* Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 173–3.

N.J. Ford & A.C. Simpson *The approximate solution of fractional differential equations of order greater than one* Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 213–1.

N.J. Ford & A.C. Simpson *Numerical and analytical treatment of differential equations of fractional order* in D. Schultz, B. Wade, J. Vigo-Aguiar, S. Dey (eds) Proceedings of the IMACS International Conference on Mathematical Modelling and Computers in Simulation, Milwaukee, pp. 60–65.

J.M. Ford, K. Chen & N.J. Ford *Small-scale Parallel implementation of fast wavelet transforms* in D. Schultz, B. Wade, J. Vigo-Aguiar, S. Dey (eds), proceedings of the IMACS International Conference on Mathematical Modelling and Computers in Simulation, Milwaukee, pp. 110–115.

N.J. Ford, P. Crofts & R.H.T. Edwards *Sensitivity of hospital clinic queues to patient non-attendance*, International Journal of Applied Science and Computations, **7**, pp. 148–154.

Lectures

Invited lectures during visits to the University of Leiden (September) and the University of Rostock (April).

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

Invited plenary lecture at IMACS, Milwaukee, May 2000.

Invited minisymposium lecture at IMACS, Lausanne, August 2000

Lecture at ICCAM, Leuven, July 2000.

Research Grants

I received a Royal Society conference grant to support my participation in IMACS Lausanne..

T. L. Freeman

Senior Lecturer in Computer Science & Mathematics
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:

- Design and analysis of loop scheduling algorithms.
  Given a parallel loop, how should the loop iterations be scheduled to the processors? We are particularly interested in situations where the parallel loop is contained within a serial outer loop and performance information about a given execution of the parallel loop should be used to guide the scheduling of the subsequent execution of the loop.

- 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.

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, Advances in Computational Mathematics.

Editor, Parallel and Distributed Computing Practices.

Technical reviewer for the Information Technologies Programme (Esprit) of the European Commission.

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.

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

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.

Principal investigator (with Professor J. R. Gurd, Department of Computer Science) of an EPSRC Visiting Fellowship Grant for Professor David Haglin, Minnesota State University, (£14,723), January 2000.

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

Publications

Hancock, D. J., Bull, J. M., Ford, R. W. and Freeman, T. L. (2000) *An Investigation of Feedback Guided Dynamic Scheduling of Nested Loops*. In **Proceedings of the 2000 ICPP Workshops**, ed. Sadayappan, P., IEEE Computer Society, pp. 315–321.

Luján, M., Freeman, T. L. and Gurd, J. R. (2000) OoLaLa*: an Object Oriented Design and Analysis of Numerical Linear Algebra*, In **Proceeding of the 2000 ACM SIGPLAN Conference on Object-oriented Programming, Systems, Languages and Applications**, pp. 229–252, ACM Press.

Freeman, T. L. , Hancock, D. J., Bull, J. M. and Ford, R. W. (2000) *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.

Lectures

Feedback Guided Dynamic Scheduling of Nested Loops, PARA2000, Workshop on Applied Parallel Computing, University of Bergen, Norway, June 2000.

An Investigation of Feedback Guided Dynamic Scheduling of Nested Loops, Workshop on High Performance Scientific and Engineering Computing with Applications (HPSECA-00), in conjunction with the International Conference on Parallel Processing (ICPP-2000), Toronto, Canada, August, 2000.

Nicholas J. Higham

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

My Royal Society Leverhulme Trust Senior Research Fellowship continued until September 2000. In March/April 2000 I was a Visiting Professor for two weeks in the Department of Mathematical Engineering, Catholic University of Louvain, Belgium. During the visit joint work was begun with Paul Van Dooren on overdamped quadratic eigenvalue problems. In May I spent a week visiting Zhaojun Bai and Alan Laub in the Computer Science Department at the University of California, Davis.

Pseudospectra, developed and popularized mainly by Trefethen, are a valuable tool for assessing the global sensitivity of matrix eigenvalues to perturbations in the matrix. Most research has focussed on pseudospectra of standard and generalized eigenvalue problems. In joint work with Françoise Tisseur, we extended the theory in two respects, by treating the polynomial eigenvalue problem and by allowing structured perturbations of a type arising in control theory. Two main approaches for computing pseudospectra have been developed. One is based on a transfer function and employs a generalized Schur decomposition of the companion form pencil. The other, intended for quadratic polynomials, solves the associated quadratic matrix equation and thereby factorizes the quadratic λ-matrix. The methods have been applied to examples from control theory, acoustics and fluid mechanics.

Work on matrix functions continued, with a paper analyzing several methods for evaluating Padé approximants of the matrix logarithm. A clear-cut winner emerged: a method based on partial fraction expansions. Postdoc Bobby Cheng, Charles Kenney (UC Santa Barbara), Alan Laub and I developed a tangent formulation of a half-angle iteration for computing the logarithm of a unitary matrix.

A standard technique for solving the symmetric definite generalized eigenproblem $Ax = \lambda Bx$ (A symmetric, B positive definite) is to compute a Cholesky factorization $B = LL^T$ (optionally with complete pivoting) and solve the equivalent standard symmetric eigenvalue problem $Cy = \lambda y$ where $C = L^{-1}AL^{-T}$, using the QR algorithm. Standard error analysis says that the computed eigenvalues are exact for $A + \Delta A$ and $B + \Delta B$ with $\max(\|\Delta A\|_2/\|A\|_2, \|\Delta B\|_2/\|B\|_2)$ bounded by a multiple of $\kappa_2(B)u$, where u is the unit roundoff. Jointly with Philip Davies and Françoise Tisseur we showed that if the Jacobi method is taken as the eigensolver then backward error bounds potentially much smaller than $\kappa_2(B)u$ can be obtained, and we also obtained insight into the stability of the QR-based method.

We showed how in cases of instability iterative refinement based on Newton's method can be used to produce eigenpairs with small backward errors.

Philip Davies, supported by an EPSRC CASE Studentship with NAG Ltd. (Oxford) as the cooperating body, received his Ph.D. in December 2000. My PhD. student H.-M. Kim, working on quadratic matrix equations, graduated at the same time.

The book *MATLAB Guide*, co-written with Des Higham (Strathclyde), was published by SIAM in August 2000. It was the first book to cover MATLAB 6, which was released towards the end of 2000. The book is aimed at all MATLAB users, from beginners through to experienced users wanting to catch up on the latest MATLAB developments.

Appointments

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.

Professional Activities

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.

SIAM News representative of SIAM Activity Group on Linear Algebra.

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 and Nomination Committee (2000).

Member of SIAM Activity Group on Linear Algebra Prize Committee, 2000.

Member of EPSRC Peer Review College.

Organizer of minisymposium "Numerical Analysis", British Applied Mathematics Colloquium, UMIST, April 2000.

Organizer of minisymposia "Rounding Error Analysis" (with J. F. Grcar) and "Advances in Numerical Linear Algebra" (with F. Tisseur), SIAM Annual Meeting, Puerto Rico, July 2000.

Chair of organizing committee of Householder Symposia.

External examiner for C. Keller, *Constraint preconditioning for indefinite linear systems*, Ph.D. thesis, Oxford University, September 2000.

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. Return to the middle ages: A half-angle iteration for the logarithm of a unitary matrix. In *Proceedings of the Fourteenth International Symposium of Mathematical Theory of Networks and Systems, Perpignan, France*, 2000. CD ROM.

P. I. Davies and N. J. Higham. Numerically stable generation of correlation matrices and their factors. *BIT*, 40(4):640–651, 2000.

P. I. Davies, N. J. Higham, and F. Tisseur. Analysis of the Cholesky method with iterative refinement for solving the symmetric definite generalized eigenproblem. Numerical Analysis Report No. 360, Manchester Centre for Computational Mathematics, Manchester, England, June 2000. 21 pp. To appear in SIAM J. Matrix Anal. Appl.

D. J. Higham and N. J. Higham. *MATLAB Guide*. Society for Industrial and Applied Mathematics, Philadelphia, PA, USA, 2000. ISBN 0-89871-469-9. xxii+283 pp.

N. J. Higham. Computing the nearest correlation matrix. Numerical Analysis Report No. 369, Manchester Centre for Computational Mathematics, Manchester, England, Oct. 2000. 14 pp.

N. J. Higham. Evaluating Padé approximants of the matrix logarithm. Numerical Analysis Report No. 358, Manchester Centre for Computational Mathematics, Manchester, England, Mar. 2000. 10 pp. To appear in SIAM J. Matrix Anal. Appl.

N. J. Higham. QR factorization with complete pivoting and accurate computation of the SVD. *Linear Algebra and Appl.*, 309:153–174, 2000.

N. J. Higham. Review of "Jack J. Dongarra, Iain S. Duff, Danny C. Sorensen, and Henk A. van der Vorst, Numerical Linear Algebra for High-Performance Computers, SIAM, 1998". *SIAM Review*, 42(3): 529, Sept. 2000.

N. J. Higham and H.-M. Kim. Numerical analysis of a quadratic matrix equation. *IMA J. Numer. Anal.*, 20(4):499–519, 2000.

N. J. Higham and F. Tisseur. A block algorithm for matrix 1-norm estimation, with an application to 1-norm pseudospectra. *SIAM J. Matrix Anal. Appl.*, 21(4):1185–1201, 2000.

F. Tisseur and N. J. Higham. Structured pseudospectra for polynomial eigenvalue problems, with applications. Numerical Analysis Report No. 359, Manchester Centre for Computational Mathematics, Manchester, England, Apr. 2000. 22 pp. To appear in SIAM J. Matrix Anal. Appl.

Lectures

Leicester Y2K Applied Maths Day, University of Leicester, January 2000, "Computing the Matrix Logarithm".

British Applied Mathematics Colloquium, UMIST, April 2000, "Why and How to Compute Functions of a Matrix".

SEA2000 Workshop on Symbolic and Numerical Methods, Toulouse, France, June 2000, "Structured Pseudospectra for Polynomial Eigenvalue Problems".

Mathematical Theory of Networks and Systems, Perpignan, France, June, 2000. Talk in invited session on "State-of-The-Art Techniques for Computational Control, Systems, and Signals", "Solving the Indefinite Least Squares Problem".

Third International Workshop on Accurate Solution of Eigenvalue Problems, FernUniversität Hagen, Germany, July 2000, "Structured Pseudospectra for Polynomial Eigenvalue Problems".

SIAM Annual Meeting, Puerto Rico, July 2000. Talk in minisymposium "Rounding Error Analysis": "Recent Results in Error Analysis for Linear Equations and Least Squares Problems".

Conference in Honor of G. W. (Pete) Stewart on the occasion of his 60th Birthday, University of Maryland, October 2000, "A Personal Perspective on Pete's Work".

Seventh SIAM Conference on Applied Linear Algebra, Raleigh, North Carolina, October 2000. "Analysis of the Cholesky Method for Solving the Symmetric Definite Generalized Eigenproblem"

Seminars at Liverpool University, Catholic University of Louvain (Belgium), Rutherford Appleton Laboratory (Didcot), Sandia National Laboratories (Albuquerque).

Research Grants

Royal Society Leverhulme Trust Senior Research Fellowship, for one year from October 1999.

Royal Society travel grant to attend Seventh SIAM Conference on Applied Linear Algebra, Raleigh, North Carolina, October 2000.

Principal investigator on project "Numerical Analysis of the Generalized Eigenvalue Problem" funded by EPSRC Mathematics Committee for three years from January 1998 (value £117,284). Grant GR/L76532.

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.

Christopher A. H. Paul

Temporary Lecturer/Research Associate; then University Research Fellow in Numerical Aanalysis
Ph.D. University of Manchester, 1992

I have continued my research on delay differential equations, with particular emphasis on delay differential algebraic equations. During the writing of the EPSRC final report for grant GR/L35218, on which I had previously been employed, additional avenues of investigation were considered, and I have spent most of my research time pursuing them. At the same time I have been writing a Fortran code for solving a general class of delay differential algebraic equations based on the numerical strategies that had been developed during the EPSRC grant. Whilst the code is still far from complete, it already has several features that, I believe, represent significant advances in software for solving (neutral) delay differential equations. I expect that the task of producing robust and reliable numerical methods for solving these types of equation will take several more years.

My non-research activity has been dominated by maintaining the Departmental computer systems—work that supports the research of others in the department. I have continued the expansion of postgraduate computing facilities within the Mathematics Department, almost doubling the availability of PCs in postgraduate offices. My roles as the Departmental Procurement Officer and Departmental Data Protection Officer have also placed increasing demands on my time through the year.

On November 1st, I was appointed as a permanent Research Fellow in Numerical Mathematics.

Appointments and Professional Activities

Computer Support Officer, Mathematics Department

Data Protection Officer, Mathematics Department

Procurement Officer, Mathematics Department

Referee for five journals

Publications

Technical Reports

C.T.H. Baker, C.A.H. Paul & H. Tian Differential algebraic equations with after-effect MCCM Report 367

C.A.H. Paul Designing efficient software for solving delay differential equations MCCM Report 368,

Other publications

C.T.H. Baker & C.A.H. Paul, *Numerical strategies for delay and Volterra differential algebraic equations*, EPSRC final report for grant GR/L35218.

C.A.H Paul, *Designing efficient software for solving delay differential equations*, Journal of Computational and Applied Mathematics, **15**, pp. 287–295.

Jason A Roberts

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

Following completion of my PhD I have continued to work in collaboration with Neville Ford and John Edwards on the numerical solution of Volterra equations. We have been working on bifurcations in solutions to some linear integrodifferential equations with fading memory kernels. I attended the IMACS World Congress in Lausanne in August 2000 and gave a paper on this work.

Publications

J.T. Edwards, J.A. Roberts & N.J. Ford *The numerical simulation of an integro-differential equation close to bifurcation points* Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 213–3.

J.T. Edwards, J.A. Roberts, N.J. Ford, & L.E. Shaikhet *Stability of a numerical approximation to an integro-differential equation of convolution type*, Proceedings of the IMACS World Congress on Mathematics and Computers in Simulation, Lausanne, paper 154–3

J.T. Edwards, J.A. Roberts, N.J. Ford, & L.E. Shaikhet *Stability of a discrete non-linear integro-differential equation of convolution type* Stability and Control: Theory and Applications, **3.1**, pp. 24–37.

Lectures

Lecture at IMACS, Lausanne, August 2000

David J. Silvester

Reader
Ph.D. University of Manchester, 1984

Over the year my research effort continued to revolve around writing a research text: *Elliptic Partial Differential Equations in Fluid Mechanics: Numerical Analysis and Computation*. This is an ongoing project involving two erudite collaborators: Professor Howard Elman (University of Maryland) and Dr Andy Wathen (Oxford University Computing Laboratory). One of the first fruits of our labour is MATLAB software to support the M.Sc course on *Elliptic Variational Methods*. This can be downloaded from the link on my personal web page: `http://www.ma.umist.ac.uk/djs`

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 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. Using a combination of analytic and empirical results it is demonstrated that the preconditioned linearised systems that arise at each level of the outer nonlinear iteration have an eigenvalue distribution consisting of a tightly clustered set together with a small number of outliers. The structure of these distributions is independent of the mesh size, but the cardinality of the set of outliers increases slowly

as the Reynolds number is increased. These characteristics are directly correlated with the convergence properties of Krylov subspace solvers.

Professor Stefan Turek from the University of Dortmund is one of the leading experts in this area, and visited UMIST in April for a week of intensive discussion with my collaborative team working on the topic. The main outcome of these technical exchanges was the realisation that our preconditioning framework really did seem to offer the possibility of uniformly fast convergence independent of the problem parameters (namely; the mesh size, the time step and the Reynolds number). In contrast, conventional approaches tend to work well if the time-step is sufficiently small, but efficiency deteriorates rapidly if either the time-step or the Reynolds number is increased. One practical consequence is that our methodology is being implemented into Turek's state-of-the-art FEATFLOW software; see `http://www.featflow.de/ture` for details.

Research Grants

Principal Investigator on project "Efficient Solvers for Incompressible Flow Problems", EPSRC Visiting Fellowship for Professor S. Turek to visit the UK, April 2000 (value £750). Grant GR/N25565.

Publications

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

Elman, H., Silvester, D. and Wathen, A. Performance and analysis of saddle-point preconditioners for the discrete steady-state Navier-Stokes equations, University of Maryland Report UMIACS–TR–2000–54, July 2000.

Silvester, D. and Mihajlović, M. Efficient preconditioning of the biharmonic equation, MCCM Report # 362, August 2000.

Lectures

"Efficient preconditioning of the linearized Navier-Stokes equations," University of Liverpool, April 2000.

Invited speaker at a *Meeting on Software Support for Metrology*, held at the University of Huddersfield, September 2000.

"Incompressible Flow Modelling can be a dodgy business," University of Oxford, November, 2000 University of Leicester, November, 2000.

R. W. Thatcher

Senior Lecturer
Ph.D. University of London, 1972

I have continued to work on least squares techniques for fluid flow with my research student, Paul Bolton. We have produced interesting results concerning the stress/stream function approach, some of which were reported at the BAMC meeting held at UMIST in March. One of the most significant features of our work is the poor results of both our method and other popular methods for relatively simple problems which seem to originate from poor mass conservation. Indeed, weighting the mass conservation term by a suitably large amount in any of the least squares methods gives significantly better results. Additionally, this work has been extended from modelling the Stokes equations to modelling the Navier Stokes equations obtaining broadly similar results. The analysis for two dimensional flow has been completed showing optimal convergence in $H^1(\Omega)$ and is a special application of the more general analysis for the biharmonic equation.

I have also continued to work, with Prof John Dold, on Numerical Modelling in Combustion. I have been working on two problems concerning modelling flame edges and modelling flame balls. This latter work, in collaboration with a research student Akeel Shah, has produced some very interesting results that has cast serious doubt on the validity of the most common method for modelling flames. These issues are now being thoroughly investigated both theoretically and numerically.

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.

Publications

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

Edges of flames that don't exist, (with J.W. Dold), Preprint 1683, IMA, University of Minnesota (2000).

Stability of a spherical flame ball in a porous medium, (with A.A. Shah and J.W. Dold), Preprint 1713, IMA, University of Minnesota (2000).

Reaction sheet jump conditions in premixed flames, (with J.W. Dold and A.A. Shah), Preprint 1732, IMA, University of Minnesota (2000).

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.

Ruth M. Thomas

Senior Lecturer
Ph.D. University of Manchester, 1979

In 2000, I worked on four main research projects. The first project involves an investigation of numerical strategies for delay differential algebraic equations. This work was carried out with a M.Sc. student, Mr. Carl Gibson, who successfully completed his M.Sc. dissertation during the year, and then started work for the Ph.D. degree, under my supervision.

The second project concerns the numerical solution of periodic initial value problems with oscillatory solution. Together with my Ph.D. student Muhammad Gul, 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.

During the year, I also worked on methods for solving differential algebraic boundary value problems, arising in the modelling of detonation, in collaboration with Professor Ian Gladwell of Southern Methodist University, Dallas.

Appointments and Professional Activities

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

External Examiner, Ph.D. Degree, Imperial College, University of London.

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. Manchester Centre for Computational Mathematics, Report No. 356 (2000).

Françoise Tisseur

Research Associate
Ph.D. University of St. Etienne, 1997

My research associate position on an EPSRC grant continued until December 2000. In spring 2000, I was invited to spend two weeks at the University of Louvain, Belgium to give lectures in a postgraduate course on polynomial eigenvalue problems. At this time joint work was begun with Paul Van Dooren on quadratic eigenvalue problems satisfying the overdamping condition.

In May, I visited Rich Lehoucq at Sandia National Laboratory, New-Mexico and spent a week visiting Zhaojun Bai in the Computer Science Department at the University of California, Davis.

As part of my effort to investigate structured eigenvalue problems, I have considered standard eigenvalue problems in which the matrices are Hamiltonian or skew-Hamiltonian and also symmetric or skew-symmetric; these arise in various applications. I showed how to compute structured backward errors that are useful for testing the stability of numerical methods for the solution of these four classes of structured eigenproblems and investigated the numerical stability of some recently developed Jacobi-like algorithms.

With Higham I have developed theory, algorithms and applications for pseudospectra of polynomial eigenvalue problems. This work includes development of basic theory and characterizations, covering structured perturbations; numerical methods for efficiently evaluating pseudospectra; applications to problems in control theory, acoustics and fluid mechanics; in particular, the use of pseudospectra to gain insight into the spatial stability of the Orr–Sommerfeld equation in fluid mechanics.

The quadratic eigenvalue problem (QEP) $(\lambda^2 M + \lambda C + K)x = 0$ is currently receiving much attention because of its extensive applications in areas such as the dynamic analysis of mechanical systems in acoustics and linear stability of flows in fluid mechanics. With Meerbergen I surveyed the QEP, treating its many applications, its mathematical properties, and a variety of numerical solution techniques. We emphasise exploiting both the structure of the matrices in the problem (dense, sparse, real, complex, Hermitian, skew-Hermitian) and the spectral properties of the problem. We also classify the available choices of methods and catalogue available software.

Professional Activities

Organizer of minisymposium "Advances in Numerical Linear Algebra" (with N. J. Higham), SIAM Annual Meeting, Puerto Rico, July 2000.

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. Numerical Analysis Report No. 360, Manchester Centre for Computational Mathematics, June 2000. 21 pp. To appear in SIAM J. Matrix Anal. Appl.

N. J. Higham and F. Tisseur. A block algorithm for matrix 1-norm estimation, with an application to 1-norm pseudospectra. *SIAM J. Matrix Anal. Appl.*, 21(4):1185–1201, 2000.

F. Tisseur. Backward error and condition of polynomial eigenvalue problems, *Linear Algebra and Appl.*, 309:339–361, 2000.

F. Tisseur. Stability of structured Hamiltonian eigensolvers. Numerical Analysis Report 357, Manchester Centre for Computational Mathematics, Manchester, Feb. 2000. 23 pp. To appear in SIAM J. Matrix Anal. Appl.

F. Tisseur and N. J. Higham. Structured pseudospectra for polynomial eigenvalue problems, with applications. Numerical Analysis Report 359, Manchester Centre for Computational Mathematics, Manchester, Apr. 2000, 22 pp. To appear in SIAM J. Matrix Anal. Appl.

F. Tisseur and K. Meerbergen. The quadratic eigenvalue problem. Numerical Analysis Report 370, Manchester Centre for Computational Mathematics, Manchester, Nov. 2000, 49 pp. To appear in SIAM Review, 43(2) 2001.

Lectures

March/April 2000, Department of Mathematical Engineering, Catholic University of Louvain, Belgium. Lectured in course *Special Topics In Numerical Linear Algebra: Polynomial Matrix Problems And Related Questions*.

British Applied Mathematics Colloquium, UMIST, Manchester, U.K., April 25-28, 2000. "Pseudospectra for Polynomial Eigenvalue Problems, with Applications".

Sandia National Laboratories, Albuquerque, New Mexico, May 2000, "A Survey on Quadratic Eigenvalue Problems"

SEA2000 Workshop on Symbolic and Numerical Methods, Toulouse, France, June 2000. "Condition Numbers for Generalized Polynomial Eigenvalue Problems "

Mathematical Theory of Networks and Systems Conference, Perpignan, France, June, 2000. Talk in invited session on "State-of-The-Art Techniques for Computational Control, Systems, and Signals", "Structured Pseudospectra for Polynomial Eigenvalue Problems".

Third International Workshop on Accurate Solution of Eigenvalue Problems, FernUniversität Hagen, Germany, July 2000, "Stability of Structured Hamiltonian Eigensolvers".

SIAM Annual Meeting, Puerto Rico, July 2000. Talk in minisymposium "Rounding Error Analysis": " Stability of Structured Hamiltonian Eigensolvers".

Seventh SIAM Conference on Applied Linear Algebra, Raleigh, North Carolina, October 2000. "The Quadratic Eigenvalue Problem: Theory, Methods and Applications".

Visits

March/April 2000, Department of Mathematical Engineering, Catholic University of Louvain, Belgium. Lectured in course *Special Topics In Numerical Linear Algebra: Polynomial Matrix Problems And Related Questions*.

Computer Science Department, University of California, Davis, May 2000 (one week).

Research Grants

Royal Society travel grant to attend Seventh SIAM Conference on Applied Linear Algebra, Raleigh, North Carolina, October 2000

Jack Williams

Senior Lecturer (retired)
D.Phil. University of Oxford, 1968

My main research interests continue to be in the numerical solution of stiff ordinary differential with special interest in aspects of the BDF and implicit Runge–Kutta methods. My M.Sc. and Ph.D. students continued working in these areas.

Publications

J. Williams (with J.A. King–Hele) (2000) *On gas flow circulation in detonator delay elements.* Combust. Sci. and Tech., v161, 233–350.

Theses Supervised

R. Tshelametse (2000) *Algebraic equations arising in the numerical solution of stiff systems*, Ph. D. thesis.

A. P. Watson (2000) *Aspects of the numerical solution of stiff differential equations.* M.Sc. thesis.

Numerical Analysis Seminars

Joint University-UMIST Seminars in Applied Mathematics (including Numerical Analysis), 2000

January 12, 2000
Dr. Nick Hill (Dept. of Applied Mathematics , University of Leeds) Modelling the onset of atherosclerosis followed by
Dr. Sarah Waters (DAMTP, University of Cambridge) Mathematical modelling of cardiovascular and respiratory flow

February 9, 2000
Dr. Nico Gray (Dept. of Mathematics, University of Manchester) Particle size segregation, shock waves and pattern formation in rapid granular flows

February 11, 2000
Prof. Igor I. Lipatov (Moscow) Some aspects of the viscous-inviscid interaction in 3D flows

February 23, 2000
Prof. David Halpern (Dept. of Mathematics, University of Alabama) The saturation of the Rayleigh-Taylor instability

March 1, 2000
Prof. Jack Carr (Dept. of Mathematics, Heriot-Watt University) The dynamics of phase transitions

March 8, 2000
Dr. Sergei Timoshin (Dept. of Mathematics, UCL) Feedback instabilities in boundary-layer flows

March 15, 2000
Dr. Michael Tretyakov (Dept. of Mathematics, UMIST) Numerical solution of Dirichlet problems for semilinear parabolic equations based on probability approach
followed by
Dr. Jan Cilliers (Dept. of Chemical Engineering, UMIST) A mathematical model of flotation froths

March 17, 2000
Prof. Luca Diegi (School of Mathematics , Georgia Tech; currently at the University of Florence) Computation of Lyapunov exponents of linear systems: Overview and algorithms

March 22, 2000
Dr. Oliver Harlen (Dept. of Applied Mathematics, University of Leeds) Molecular Pom-poms: the flow of branched polymer melts

March 29, 2000
Prof. Arieh Iserles (DAMTP , Cambridge University) Computation in Lie Groups

April 12, 2000
Prof. Gregory Vilensky (Marine Equipment, St. Peterburg, Russia) 3D boundary-layer flow past a rib

May 3, 2000
Dr. David Kay (School of Mathematical Sciences , University of Sussex) An iterative solver for the Navier-Stokes equations in two and three dimensions
followed by
Dr. Bill Lionheart (Dept. of Mathematics, UMIST) The inverse conductivity problem – analysis, geometry and applications

May 17, 2000
Dr. Darren Crowdy (Dept. of Mathematics , Imperial College) Hele-Shaw Flows and Water Waves

July 11, 2000
Prof. M.R. Foster (Dept. of Aerospace Engineering, Applied Mechanics & Aviation, The Ohio State University) The effects of rotation on Bridgman crystal growth

September 27, 2000
Dr. Elena Grekova (Institute for Problems in Mechanical Engineering, St. Petersburg) Moment interactions of rigid bodies

October 3, 2000
Prof. T. Kambe (Dept. of Physics, University of Tokyo; currently at the Isaac Newton Institute, Cambridge Geometrical description of fluid flows and dynamical systems

October 4, 2000
Dr. Peter Hydon (Dept. of Mathematics and Statistics, University of Surrey) Symmetry methods - a beginners' guide

October 18, 2000
Prof. Richard B. Pelz (Dept. of Mechanical and Aerospace Engineering, Rutgers University; currently at the Isaac Newton Institute, Cambridge) On the Hydrodynamic Blowup Problem

October 25, 2000
Dr. Hinke Osinga (School of Mathematical Sciences, University of Exeter) Two-dimensional global manifolds of vector fields

November 8, 2000
Dr. Vanessa Styles (School of Mathematical Sciences, University of Sussex) Analysis of vortex density models in superconductivity

November 15, 2000
Dr. John Billingham (School of Mathematics and Statistics, University of Birmingham) Zero gravity sloshing

November 20, 2000
Prof. Peter Lancaster, FRSC (Dept. of Mathematics and Statistics, University of Calgary) Spectra and stability of quadratic eigenvalue problems

November 22, 2000
Prof. Andrew Stuart (Mathematics Institute, University of Warwick) Analysis and Simulation for Coupled Particle-Field Models

November 30, 2000
Special Seminar Dr. Keith Briggs (BTexaCT Research, Suffolk) Simultaneous Diophantine approximation and linearization of C2 maps

December 8, 2000
Prof. John Harris (Dept. of Theoretical and Applied Mechanics, University of Illinois at Urbana-Champaign) Rayleigh wave propagation in curved waveguides

December 13, 2000
Dr. Dwight Barkley (Mathematics Institute, University of Warwick) Twisted scrolls in excitable media
December 20, 2000

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

356 **J. A. Sturgeon, R. M. Thomas and I. Gladwell**
Solving a Singular DAE Model of Unconfined Detonation Jan 2000

357 **F. Tisseur**
Stability of Structured Hamiltonian Eigensolvers February 2000

358 **N. J. Higham**
Evaluating Padé Approximants of the Matrix Logarithm March 2000

359 **F. Tisseur and N. J. Higham**
Structured Pseudospectra for Polynomial Eigenvalue Problems, with Applications April 2000

360 **P. I. Davies, N. J. Higham and F. Tisseur**
Analysis of the Cholesky Method with Iterative Refinement for Solving the Symmetric Definite Generalized Eigenproblem June 2000

361 **Chriistopher T. H. Baker and Evelyn Buckwar**
Continuous Θ-methods for the Stochastic Pantograph Equation May 2000

362 **David Silvester and Milan Mihajlovic**
Efficient Preconditioning of the Biharmonic Equation August 2000

363 **Jean-Pierre Dedieu and Françoise Tisseur**
Perturbation Theory for Homogeneous Polynomial Eigenvalue Problems March 2001

364 **MCCM**
MCCM Annual Report for 1999 (Released for distribution December 2000)

365 **Christopher T H Baker**
Retarded Differential Equations and their Numerical Treatment (Released for distribution December 2000)

366 **Christopher T H Baker**
Volterra Equations and their Numerical Treatment (Released for distribution December 2000)

367 **Christopher T H Baker, C A H Paul and H Tian**
Differential Algebraic Equations with After-Effect October 2000

368 **C A H Paul**
Designing Efficient Software for Solving Delay Differential Equations October 2000

369 **N. J. Higham**
Computing the Nearest Correlation Matrix October 2000

370 **F. Tisseur and K. Meerbergen**
A Survey of the Quadratic Eigenvalue Problem November 2000

Postgraduates in Numerical Analysis and Computing

M.Sc. by Method I (organized jointly by The University and UMIST)

Students who entered September 1999:

Name	support	first degree	Institution	Comment
Andrew Bowery	EPSRC	B.Sc.	Surrey	
Carl Gibson	EPSRC	M.Math	Manchester	
Simon Howlett	EPSRC	B.Sc.	Manchester	
David Onley	EPSRC	M.Math	Manchester	
Catherine Powell	EPSRC	B.Sc	UMIST	(UMIST Registered)
Menelaos Theocharides	self	B.Sc	Patras	(UMIST Registered)
Rebecca Wain	EPSRC	B.Sc	Manchester	(UMIST Registered)

Students who entered September 2000:

Name	support	first degree	Institution	Comment
Craig Lucas	EPSRC	B Sc	UMIST	
Ceri Mellor	EPSRC	B Sc	UMIST	
Paul Roberts	EPSRC	B Sc	UMIST	
Chan Wilson	EPSRC	B.Sc	UMIST	(UMIST Registered)
Kipourou	EPSRC	B.Sc	Lancaster	(UMIST Registered)
Tate	EPSRC	B.Sc	Newcastle	(UMIST Registered)

Students reading for the degree of PhD

PhD students registered at The University

Students registering September 2000

Entering Year 1

Name	support	first degree	Institution	PhD Supervisor
Eugene Parmuzin	OSS	M Sc	MIPT, Moscow	C T H Baker

Entering Year 2

Name	support	first degree	Institution	PhD Supervisor
Ephraim Agyingi	ORS	M Sc	Ilorin, Nigeria	C T H Baker
Joseph Haig	Endowment	M Sc	York & Warwick	T L Freeman
Harikrishna Patel	EPSRC	M Math	Manchester	N J Higham
Iain Smith	EPSRC	M Math	Manchester	N J Higham
Yihong Song	Endowment	MS	Zhejang, China	C T H Baker

Entering Year 3, and higher

Name	support	first degree	Institution	PhD Supervisor
Philip Davies	EPSRC Case	B Sc	Manchester	N J Higham
Hyun Min Kim	self	M Sc	Pusan, Korea	N J Higham
(writing up Sept 2000)	degree awarded 2000			
Hongjiong Tian	ORS	MS	Shanghai	C T H Baker
(writing up Sept 2000)	degree awarded 2000			
Ali Filiz	Turkey	B Sc	Turkey	C T H Baker
(writing up Sept 1999)	degree awarded 2000			
Fathalla Rihan	Egypt Missions	B Sc	Egypt	C T H Baker
(writing up Sept 1999)	degree awarded 2000			

PhD students registered at UMIST

Entering Year 1

Name	support	first degree	Institution	PhD Supervisor
Catherine Powell		B Sc	UMIST	
Carl Gibson		B Sc	UMIST	R Thomas

Entering Year 3 and higher

Name	support	first degree	Institution	PhD Supervisor
Thebe Basebi	Scholarship	BSc	Botswana	R.M. Thomas
Paul Bolton	EPSRC	BSc	UMIST	R.W. Thatcher
Muhammad Gul	Pakistan Scholarship	BSc	Pakistan	R.M. Thomas
Syamsudhuha	Scholarship	BSc	Indonesia	D.J. Silvester

PhD students registered at Chester College

Ph.D. Year 3 and higher

Jason Roberts completed his PhD

Ph.D. Year 2

Name	support	first degree	Institution	PhD Supervisor
Simpson, A. Charles	Bursary	B.Sc.	Manchester	N.J. Ford

Ph.D. Year 1 (Part Time)

Name	support	first degree	Institution	PhD Supervisor
Lumb, Patricia	Employer	B.Sc.	York	N. J. Ford
Norton, Stewart	Employer	B.Sc.	Manchester	N.J. Ford

MSc students registered at Chester College

The MSc course at Chester College can be taken part-time; this list indicates those completing the course this year (the total number of students registered being considerably higher).

Postgraduate (M.Sc.) Programme Leavers

Name	support	first degree	University	Comment
Crowle, Colin	Self	B.Sc.	Liverpool	
Prince, Leeann	Self	BA	Liverpool	
Woo, Hawk Yan	Self	B.Ed	Liverpool	