Centrum voor Wiskunde en Informatica

OVERVIEW RESEARCH ACTIVITIES '94

Kruislaan 413, 1098 SJ Amsterdam
Postbus 94079, 1090 GB Amsterdam

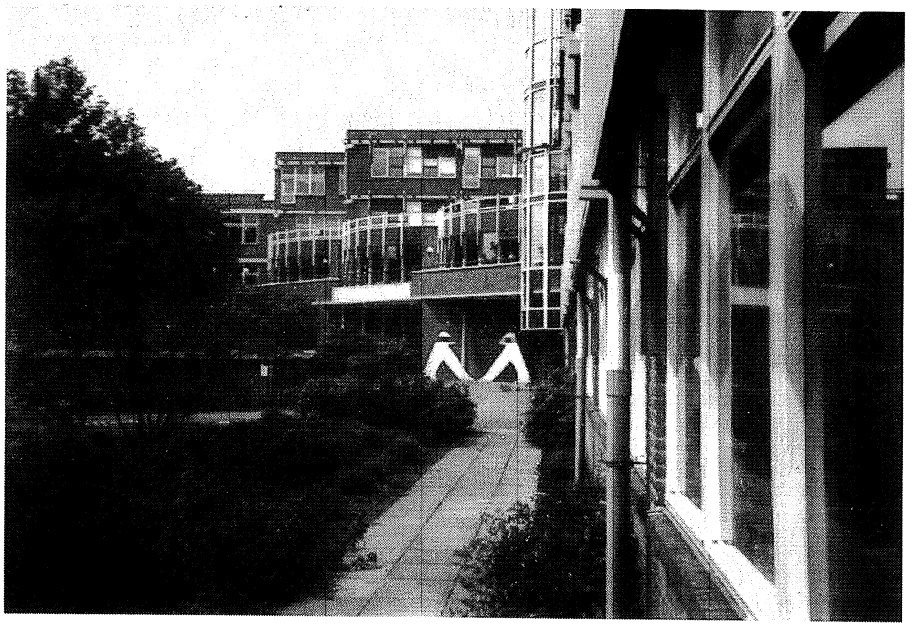

Photo: Jeroen van Helmond

CWI is the National Research Institute for Mathematics and Computer Science. CWI is part of the Stichting Mathematisch Centrum (SMC), the Dutch foundation for promotion of mathematics and computer science and their applications. SMC is sponsored by the Netherlands Organization for Scientific Research (NWO). CWI is a member of ERCIM, the European Research Consortium for Informatics and Mathematics.

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P.O. Box 94079, 1090 GB Amsterdam, The Netherlands
Kruislaan 413, 1098 SJ Amsterdam, The Netherlands
Telephone +31 20 592 9333
Telefax +31 20 592 4199
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This Overview Research Activities is complementary to the Jaarverslag SMC (in Dutch), which concentrates on SMC's National Activities in Mathematics. An Annual Report (in English) as well as SMC's Financial and Social Reports (in Dutch), are also available.

They can be ordered at CWI.
Please contact mrs. D.C.M. Amende (phone +31 20 592 4128).

INTRODUCTION

In this Overview Research Activities the CWI research departments present their research plan and details of their activities. The information is arranged by group and includes conferences, committees, visitors etc., and also a list of publications.

DEPARTMENT OF ANALYSIS, ALGEBRA AND GEOMETRY

General Introduction

Staff Department of Analysis, Algebra & Geometry, 1994

(CWI funded)

- M. Hazewinkel
- A.E. Brouwer
- A.M. Cohen
- T.H. Koornwinder
- O. Diekmann
- A.A. de Koeijer
- M.A.A. van Leeuwen
- B. Lisser
- J.A.J. Metz
- J.A. Sanders
- N.M. Temme
- J. de Vries
- M. Biemond
- St. van Dongen
- M. Louter-Nool

(Externally funded)

- H. Elbers
- N. Elhoussif
- J. Faux
- Th. Hantke
- R. Hoksbergen
- N. van den Hijligenberg
- R. Hirschfeld
- Yu.A. Kuznetsov
- S.A. Levitin
- M Kirkilonis
- W. Huyer
- A.M.A. van Leeuwen
- M. Roelofs
- A.M. de Roos
- S.M. Verduyn Lunel
- O. Weber

• Secretary: N. Mitrovic

Analysis, Algebra & Geometry (AM)

Staff

- M. Hazewinkel (head of department, 1.0; 0.2 Univ. of Utrecht)
- A.E. Brouwer (0.1)
- A.M. Cohen (0.2)
- T.H. Koornwinder (pm)
- O. Diekmann (0.6)
- A.A. de Koeijer (1.0)
- M.A.A. van Leeuwen (1.0)
- B. Lisser (programmer, 1.0)
- J.A.J. Metz (advisor)
- J.A. Sanders (0.4)
- N.M. Temme (0.5)
- J. de Vries (0.6)
- M. Biemond (1.0, since September 1)
- St. van Dongen (TEG, since September 5)
- M. Louter-Nool (programmer, 0.2)

(Externally funded)
- H. Elbers (ACELA project, STW, joint with dept. AA)
- N. Elhoussif (NUFFIC)
- J. Faux (student visitor, ACELA project, till September 1)
- Th. Hantke (NWO, Nonlinear systems)
- R. Hoksbergen (Kluwer Acad. Publ.)
- N. van den Hijligenberg (AIDA project, NWO)
- R. Hirschfeld (visitor)
- Yu.A. Kuznetsov (NWO, Nonlinear systems)
- S.A. Levitin (NWO, Nonlinear systems)
- M. Kirkilonis (NWO, Nonlinear Systems)
- W. Huyer (NUFFIC, till July 1)
- A.M.A. van Leeuwen (MathViews project, joint with dept. AA)
- M. Roelofs (WINST project, joint with dept. AP and Universities of Eindhoven and Nijmegen)
- A.M. de Roos (pm, AM2)
- S.M. Verduyn Lunel (pm, AM2)
- O. Weber (pm, WINST project)

Scientific Report

The department AM is organized in two main research groups which in turn are subdivided into several project groups as follows.

AM1: Algebra, discrete mathematics and computer algebra
- AM1.1. Algorithmic algebra and discrete mathematics
- AM1.2. Computer assisted mathematics

AM2. Modelling and Analysis
- AM2.1. Population dynamics and epidemiology
- AM2.2. Dynamical systems
- AM2.3. Asymptotics

The department AM has interactions with CAN (Computer Algebra Nederland, and RIACA (International Research Institute for the Applications of Computer Algebra). Separate reports on the activities of these institutions are or will be available.

The department maintains together with CAN the national facility DSL (Dynamical System Laboratory), that makes machines and software available to dynamical system activities throughout The Netherlands. A separate detailed report on the DSL activities of 1994 is available.

AM1.1. Algorithmic Algebra and Discrete Mathematics

Marc van Leeuwen continued his investigation in the combinatorics and algorithmics of tableaux. A report on the subject was delivered at the FPSAC94 conference, a corresponding preprint will appear in 1995.

M. Hazewinkel, Marc Biemond, Stijn van Dongen started a series of investigations concerning combinatorical problems coming out of mathematical taxonomy. A preliminary report was presented at the Bielefeld Nov. 94 ZIF conference on discrete metric spaces. Several reports concerning this will appear in 1995.

In Utrecht Ph.D. student Giavanna Carnovale started work on her topic: special functions and multiparameter quantum groups (thesis supervisors: M. Hazewinkel, W. van der Kallen).

At the Free University A. Scholten continued to make good progress on her thesis subject of noncommutative formal groups (thesis supervisors: E. Ditters and M. Hazewinkel).

AM1.2. Computer Assisted Mathematics

The last volume in the (printed version of the) Encyclopaedia of Mathematics was published in 1994 (volume 10, KAP). Work was started on the preparations for the electronic interactive CD ROM version. A preliminary design was sketched and presented to Kluwer Acad. Publ. (M. Hazewinkel, June 1994). Two different small demos were made (M. Hazewinkel, R. Hoksbergen) both based on Hypercard. Work on a third demo version is in progress (R. Hirschfeld).

The 'MathViews' project is concerned with the structure of mathematical objects in a computer environment and inter-operability matters. A first model for representing mathematical objects in structured

electronic documents was presented at the Human Interaction and Symbolic Computation Conference (RIACA, March 1994, Amsterdam) (A. van Leeuwen). A preprint on this will appear in 1995. A draft paper for the Febr. 1995 RIACA workshop on 'OpenMath' was written (A. van Leeuwen, M. Roelofs, O. Weber (Köln)).

The WINST project (M. Roelofs, H.J. Elbers) is concerned with communication between the three kinds of mathematical packages: Computer algebra systems, Term Rewriters, Proof checkers/suggesters. The investigations concentrated on proofs of simple theorems in Lie algebras in the context of LEGO (Interaction between provers and computer algebra systems). A parser for LEGO expressions has been implemented (to enable translation to REDUCE and back). A more detailed report on WINST 1994 is available.

The ACELA project is concerned with the creation of an interactive electronic book on Lie Algebras at the level of a graduate text, also the creation of authoring tools and an authoring environment for such tasks. Good progress has been made in the writing of several chapters. A detailed report for 1994 is available.

No progress was made in the writing of an interactive, electronic text on Hopf algebras (M. Hazewinkel).

The VEIG project (joint with the Inst. Math and Informatics, Lithuanian Acad. of Sciences, Vilnius, and the companies TEV and VTEX in Vilnius) was formulated and work started in late 1994. It aims to create an interactive, hypertext, electronic version of the *Handbook of Incidence Geometry* (F. Buekenhout (ed)) published by Elsevier in 1995.

N. van den Hijligenberg worked on extending the techniques and results of M. Hazewinkel, *Multiparameter Quntum Groups and Multiparameter R-matrices*, CWI report 1993, to the case of multiparameter quantum groups of types B,C,D. This has been largely successful and makes heavy use of REDUCE. A report on these results will appear in 1995.

The second problem tackled by N. van den Hijligenberg concerned noncommutative differential calculus (geometry). Sufficient and necessary conditions were computed for the De Rham complex to have the structure of a differential Hopf Algebra. These and related results will appear in a joint paper with R. Martini (University of Twente).

A proposal was formulated called BUC'M (Bottom-Up Classification in Mathematics and physics) (M. Hazewinkel). Various parts were submitted to: European Commission (6 month try out project, still under consideration), Math Review (Ann Arbor, USA; as a draft for a possible NSF project to be submitted in 1995), STN (Karlsruhe, Germany; as a draft for an EC project to be submitted in 1995).

A proposal was formulated and submitted for vector and parallel computation in algebra to MPR (Marc van Leeuwen). This proposal was not successful.

B. Lisser used MAPLE to solve a conjecture of B. Kostant.

AM2.1 Population Dynamics and Epidemiology

The initiative for a course on epidemic models was taken by Odo Diekmann, Hans Heesterbeek (GLW-DLO), Mart de Jong (ID-DLO), Mirjam Kretzschmar (RIVM) and Hans Metz and this idea met a very favourable response during a 'try out' day on October 14. The course itself is planned for 1995 and the notes are intended as a starting point for a multi-author book (we hope D. Mollison from Heriot-Watt University, Edinburgh will join us to strengthen the stochastic part).

Aline de Koeijer made further progress in analysing the data and the model for the 1988 seal epidemic. A first publication should be ready soon.

The work in collaboration with M.C.M. de Jong (ID-DLO) concentrated on the effect of repeated contacts between the same individuals. The problem turned out to be more tough than expected, but finally it was solved (publication in 1995).

Thomas Hantke analysed patch exploitation strategies of predatory mites by a combination of numerical and analytical tools. He found that in models with very frequent invasions the killer strategy is the best (publication in 1995).

Nour-Eddine Elhoussif and Waltraud Huyer analysed cohort solutions of structured population equations. In particular it was found that stability of a one-cohort solution within the class of n-cohort solutions may or may not hold, but does not depend on n (publication in 1995).

Markus Kirkilonis started the construction of numerical continuation methods for structured population models. He received much help from Margreet Nool (NW). Brainstorm sessions on this subject were also attended by Ben Sommeijer (NW), Andre de Roos (UvA-KNAW), Odo Diekmann and Thomas Hantke.

Concerning the general theory of structured population models a further refinement of the cumulative formulation (in which the construction is made at the individual level, i.e. operators are defined in terms

of kernels) turned out to eliminate many technical complications and obstructions.

AM2.3 Asymptotics (N.M. Temme)
A revision of translated Dutch book on special functions has been carried out (re-ordering of chapters, including more graphs and hints for exercises, more emphasis on the physical back ground of the functions, more details on numerical aspects). A contract has been signed with Wiley.

New uniform expansions of incomplete gamma functions have been derived. The emphasis is on large negative real parts of the parameters, and the new expansions give together with the existing expansions a complete covering of the parameter domains.

A paper is written (with M.A. Chaudhry (Saudi Arabia) and E.J.M. Veling (RIVM)) on asymptotics of generalized incomplete gamma functions, which occur in heat conduction problems and probability theory.

Another paper is written on the location of zeros of incomplete gamma functions in the complex plane; the results are obtained by using the earlier asymptotic expansions and asymptotic inversion methods for the incomplete gamma functions.

A survey paper on uniform asymptotic methods for integrals is presented in Delft at the *Conference Orthogonality, Moment Problems and Continued Fractions* (in honour of Thomas Jan Stieltjes Jr.); versions of the paper are used for talks during visits to Rostock, China and Indonesia.

With Prof. K. Driver (South Africa) investigations are started on non-diagonal quadratic Hermite-Padé approximations to the exponential function. New results are obtained by representing approximations and remainders as contour integrals in the complex plane from which asymptotic results can be obtained.

Thesis defenses

V.A.A. Jansen, Theoretical aspects of metapopulation dynamics, September 15, Univ. of Leiden; thesis advisor: O. Diekmann.

M.S. Dijkhuizen, On compact quantum groups and quantum homogeneous spaces, February 17, Univ. of Amsterdam; thesis advisor: T.H. Koornwinder.

Ralf Peeters, System identification based on Riemannian geometry. Theory and algorithms, Free Univ. of Amsterdam, February 8; thesis advisors: M. Hazewinkel, B. Hanzon.

Courses

Odo Diekmann: Ecole d'Eté 'Les Modeles et Problèmes Mathematiques lie a la Gestion des Ressources Renouvelables', Agadir, Morocco, July 15–30.

Odo Diekmann: Course mathematical models of population dynamics: an anthology, July 25–29.

M. Hazewinkel: (together with T. Springer, W. van der Kallen), Seminar on Crystal bases, Univ. of Utrecht.

M. Hazewinkel: Erasmus course on Systems and control theory, Univ. of Almeria, Spain.

M. Hazewinkel: Course on projective geometry, Univ. of Utrecht.

Conferences and meetings attended

Odo Diekmann:
- March 18–19, Leraren cursus Biologie & Wiskunde RUL.
- May 15–20, ESF Workshop Population Dynamics, Immunology and Sustainable Development.
- Augustus 29–September 2, NLS Summerschool 'Evolution and Population Dynamics in Spatially Structured Environments', Amsterdam.
- December 15–16, Jaarlijkse Bijeenkomst Ned. Ver. Theor. Biol., Texel.

Michiel Hazewinkel:
- AMS winter meeting, Cincinnati, USA, January 11–15.
- Regensburg system theory day, February 25.
- Combinatorics and algebra. Kaluznik memorial meeting. Dresden, Germany, March 6–13.
- Congress of the Belgian Mathematical Society, Antwerpen, May 4–6.
- Work visit München, May 27–29.
- Work visit Venezuela: Merida (Univ. of the Andes), Univ. S. Bolivar (Caracas), IVIC (Caracas), April 3–10.
- International Congress of Mathematicians, Zürich, August 2–12.
- Meeting European Math. Soc., Zürich, August 13–14.
- Work visit Urbana, IL, USA (Wolfram Research), Ann Arbor, MI, USA (Math Review), June 29–July 4.
- Evaluation of the National Mathematical Centre, Abuja, Nigeria, August 28–September 3.
- ECMI 1994, Kaiserslautern, September 8–9.
- Working visit Univ. of Bordeaux I, September 28–October 3.
- Conference on Discrete metric spaces, ZiF, Bielefeld, Germany, November 20–23.

- Electronische tijdschriften dag, Utrecht, December 14.
- STINFON 3, Univ. of Tilburg, December 16.

Waltraud Huyer:
- North West European Analysis Seminar, Noordwijkerhout, May 27–29.
- Fourth International Symposium 'Chaotic Dynamical Systems', June 12–15.

Aline de Koeijer:
- AIO course: Theoretical Ecology (Leiden/Utrecht).
- AIO course:Population Ecology (Texel).
- Summer schoolQuantitative Ecology of Pests and Diseases (Wageningen).
- Summer school and conference: Evolution and Population.
- Dynamics in spatially structured Environments (Amsterdam).
- Seminar Population and Evolutionary Dynamics (Leiden).
- Seminar: Dynamic Energy Budgets (Amsterdam).
- Seminar Dynamical Systems, CWI.

Yuri Kuznetsov:
- January 31–February 3, ZIB, work with K. Gatermann and B. Fiedler on bifurcation theory, Berlin, Germany.
- July 4–20, International Institute for Applied Systems Analysis, work with Prof. S. Rinaldy on bifurcation analysis of ecological models, Laxenburg, Austria.
- November 26–December 1, University of Bielefeld, work with Prof. W.-J. Beyn on numerical methods for bifurcation analysis, Germany.

Marc van Leeuwen:
- FPSAC '94 (DIMACS, Rutgers University, New Jersey, USA), May 23–27.
- CMLT workshop (Essen, Germany), August 15–19.
- LiE/GAP workshop, Eindhoven, October 17–20.

Bert Lisser:
- May, Sisal Workshop, Parallel Rekenen.

Nico Temme:
- April 7–8, Nederlands Mathematisch Congres, Leiden.
- April 21–22, Visit to University Trier, Germany. Lecture: Uniform asymptotic expansions of Stirling numbers.
- May 30–June 3, Visit to University of Rostock, Germany. Lectures: Asymptotics of integrals, basic steps and examples & Uniform asymptotic expansions of Stirling numbers.
- July 25–29, Leuven Asymptotics of Integrals: Basic steps and examples
- October 31–November 4, Orthogonality, Moment Problems and Continued Fractions, an international conference in honour of Thomas Jan Stieltjes.
- International Symposium on Methods and Applications of Analysis, December 16–19, Hong Kong.
- Working visit to: Tsinghua University, Beijing, China, November 28–December 3, University of Indonesia, Jakarta, December 5–6, Institut Teknologi Bandung, Bandung, December 7–8.

Lectures and colloquia given (including at meetings and conferences)

O Diekmann:
- Wiskundige epidemiologie in vogelvlucht (October 14, Infectious disease models introduction day).
- February 7, Reflections on structured population model, Seminaire Aubin-Frankowska, Paris.
- March 11, The cumulative formulation of structured population models, NLS population dynamics seminar, Free University.
- April 22, On biological populations and semigroups of operators, Belgisch-Niederlandisch-Nordrheinwestfalishes Sonderkolloquium, Köln.
- April 29, On biological populations and semigroups of operators, Operator Theory Day, TU Delft
- October 1, Semigroups of operators describing biological populations, 4th International Conference on Evolution Equations and Semigroups, Pisa, September 26–October 1.
- November 2, Semigroups of operators describing biological populations, Mathematical Analysis Seminar, Charles' University, Prague.
- November 30, Reflections on contact structure, Oberwolfach (Mathematical Models for Infectious Diseases), November 28–December 2.

M. Hazewinkel:
- Multiparameter quantum algebras and multiparameter R-matrices, Colloquium Regensburg February 25.
- Multiparameter R-matrices and applications, Dresden Combinatorics and Algebra meeting, March 9; Invited plenary lecture.
- Applied algebra, Univ. Simon Bolivar, Caracas, Venezuela, April 8.
- Hopf algebras and quantum groups and aplications, IVIC, Caracas, Venezuela, April 7.
- Identification and nonGauassian linear filtering and the symplectic group, Univ. of Merida, Venezuela, April 5.

- All Kalman - Bucy filters and the symplectic group, Univ. of Merida, Venezuela, April 5.
- Lie algebraic methods in filtering, Univ. of Los Andes, Merida, Venezuela, April 4.
- Hopf algebras and link invariants. Invited plenary lecture congress Belgian Math. Soc., Antwerpen, May 5.
- Colloquium Univ. of München, Multiparameter R-matrices and link invariants, May 28.
- Infinite mathematical information, June 3, Dordrecht. Invited lecture celebration appearance of the final volume of the Encyclopaedia of Mathematics.
- The Yang-Baxter equation and invariants of knots and links, Colloquium lecture, Univ. Bordeaux, September 29.
- Classification problems in mathematics, discrete metric spaces and approximating trees, Univ. Bordeaux, LABRI, September 29.
- Symmetry versus extremality, Univ. Bordeaux, LABRI, October 2.
- Classification in mathematics, discrete metric spaces and approximation by trees, ZiF, Bielefeld, November 21.

Yu.A. Kuznetsov:
- 'Bifurcation and chaos in a three species food chain: preliminary results', Biomathematische onderwerpen, CWI, Amsterdam, January 17.
- 'Numerical detection and continuation of codimension two homoclinic bifurcations'. Oberseminars FU, ZIB und IAAS, Berlin, February 1.
- 'Algorithmic problems of bifurcation theory'. Oficial Opening Day of DSL, June 10.
- Invited lecture 'Cutting of a "tea-cup" attractor and chaos in food chain dynamics', Fourth International Symposium 'Chaotic Dynamical Systems', Woudschoten, June 14.
- (with V. Levitin) 'CONTENT: A new generation continuation environment', CWI, November 25.
- Invited lecture 'Numerical continuation of homoclinic bifurcations', Wetenschappelijke vergadering 'Stroming en Warmte', Veldhoven, December 2.

V. Levitin:
- see Kuznetsov.

N.M. Temme:
- Uniform asymptotic expansions of Stirling numbers, Univ. of Trier, April 21.
- Uniform asymptotic expansions of Stirling numbers, Univ. of Rostock, May 31.
- Asymptotics of Integrals: Basic steps and examples, Univ. of Rostock, June 1.
- Asymptotics of Integrals: Basic steps and examples, Univ. of Leuven, July 28.
- Current problems in uniform asymptotic estimates of integrals. Invited lecture, Thomas Jan Stieltjes conference, October 31–November 4.
- Uniform asymptotics of incomplete gamma functions for negative values of the parameters. Invited lecture, Int Symp on methods and applications of analysis, Hong Kong, September 16–19.
- Asymptotics of Integrals: Basic steps and examples, December 3, Tsinghua Univ., Beijing.
- CWI: the Dutch Research Institute on Mathematics and Computer Science, December 4, Tsinghua Univ., Beijing.
- Asymptotics of Integrals: Basic steps and examples, December 5, Univ. of Indonesia, Jakarta.
- CWI: the Dutch Research Institute on Mathematics and Computer Science, December 6, Univ. of Indonesia, Jakarta.
- Asymptotics of Integrals: Basic steps and examples, December 7, Inst. Teknologi Bandung, Indonesia.
- CWI: the Dutch Research Institute on Mathematics and Computer Science, December 8, Inst. Teknologi Bandung, Indonesia.

Organisational activities; memberships of committees and boards

Odo Diekmann:
- Landelijk coordinator voor EG twinning project 'evolutionary systems'.
- Lid coordinating committee ESF project dynamics of complex systems in bio-sciences.
- Voorzitter NWO dwarsverbandcommissie, prioriteitsprogramma niet-lineaire systemen.
- Associate editor Japan Journal of Industrial and Applied Mathematics.
- Editor Journal of Mathematical Biology.
- Associate editor Canadian Applied Mathematics Quarterly.
- Honorary member and adviser Centre of Nonlinear Systems in Biology, University of Dundee.
- Akademie Raad voor de Wiskunde, lid.
- Organiser (with M.A. Kaashoek and B. de Pagter, North West European Analysis Seminar May 27–29, Noordwijkerhout).
- Organiser (with M.C.M. de Jong, J.A.P. Heesterbeek, M. Kretzschmar en J.A.J. Metz) course 'Infectious Disease Models' Introduction day, October 14, 1994 (to be continued in 1995).

Thomas Hantke:
- Organiser Seminar dynamical systems (CWI).

Michiel Hazewinkel:
- (Co)-managing Editor journal: Nieuw Archief voor Wiskunde, Wiskundig Genootschap (=Dutch Math. Society), 1977 ...
- Ass. Editor journal: Systems and Control Letters, North Holland Publ. Co., 1981 ...
- Co-managing Editor book series Mathematics and Geophysics, Reidel Publ. Co., 1981 ...
- Managing Editor book series: Mathematics and Its Applications, Kluwer Acad Publ, 1973– ... .
- Managing Editor journal: Acta Applicandae Mathematicae, Reidel Publ. Co., 1983 ...
- Co-managing Editor CWI Monographs, CWI Tracts, CWI Syllabi, 1984–...
- Managing Editor translation and revision Russian Encyclopaedia of Mathematics in 10 volumes), Reidel Publ. Co. and Kluwer Acad. Publ., 1987–1994.
- Managing editor, Electronic version of the Encyclopaedia of Mathematics, KAP, 1994– ... .
- Editor in chief journal Soviet Advances in Mathematics, Reidel Publ. Co.
- Managing Editor Handbook of Algebra (to be published in 9 volumes), North Holland Publ. Co.
- Editorial board Trends in Scientific Research, Unesco/Reidel, 1984–...
- Co-managing editor (with H. Neunzert, A.B. Tayler, Hj. Wacker), book series 'European Consortium for Mathematics in Industry', Reidel/Kluwer Academic, 1988– ... .
- Associate editor journal 'Chaos, Solitons, and Fractals', Pergamon, 1991– ... .
- Associate editor journal Multi-dimensional system theory, Kluwer Boston, 1994– ... .
- Member Steering Committee MTNS 1985– ...
- Chairman Dept. Pure Math. CWI, 1982– 1988; chairman Dept. AM (Analysis, Algebra and Geometry) CWI, 1988– ...
- Liaison member ECMI with the Euromath project.
- Member board CMF (Caribbean Mathematical Foundation).
- Member 'Benutzerbeirat STN', Karlsruhe.
- Member ERCIM taskforce: support for the former Soviet Union.
- Member board Wiskundig Genootschap, 1994– ...
- Representative board Wiskundig Genootschap in European Math Soc., 1994– ...

Marc van Leeuwen:
- Lid Ondernemingsraad SMC.

Nico Temme:
- Editor of Mathematics of Computation.
- Editor of Methods and Applications in Analysis.
- Editor of Zeitschrift für angewandte Mathematik und Physik (ZAMP).
- Editor of Nieuws Analyse (newsletter of the Werkgemeenschap Analyse).
- Editor of CWI Quarterly.
- Thomas Stieltjes Institute for Mathematics (advisory member of the board).
- Member of the organizing committee of the International Scientific Symposium on the occasion of the retirement of Prof.dr. P.C. Baayen, December 20, Amsterdam.

Visitors

- A.R. Champneys (UK)
- G.R. Chapman (Canada)
- M. Delest (France)
- J.-M. Fedou (France)
- R. Gamkrelidze (Russia)
- D. Greenhalgh (UK)
- M. Gyllenberg (Finland)
- H. Gzyl (Venezuela)
- A. Helemskii (Russia)
- M. Jane (UK)
- H. Kokubu (Japan)
- Y. Kossmann-Schwarzbach (France)
- D. Lozier (USA)
- R. Maliukevicius (Lithuania)
- P. Malyshev (Ukraina)
- G. Meszena (Hungary)
- A. Mogilner (Canada)
- S. Oharu (Japan)
- H.G. Othmer (USA)
- E. Rosinger (South Africa)
- N. Rouillon (France)
- K. Sigmund (Austria)
- B. Sleeman (Scotland)
- V. Statulevicius (Lithuania)
- A. Tempelman (USA)
- E. Zalys (Lithuania)

Miscellaneous

Odo Diekmann:
- June 10 opening DSL.
- July 15 Niet-Lineaire Analyse Dag.
- October 7 CWI in bedrijf: lecture 'Populatiedynamica, de verspreiding van besmettelijke ziekten'.
- Contract with ID-DLO (formerly known as CDI) 'Ontwikkeling van wiskundige technieken voor de bestudering van de populatiebiologie van infekties'.

Michiel Hazewinkel:
- Refereeing and evaluation jobs:
  - Univ. of Manchester (promotion to full professor)

- SIAM J Control and Optimization (3 papers)
- Univ. of Buffalo (promotion to full professor)
- Third world Academy of Science (Evalution of the national mathematical centre Abuja, Nigeria)
- Proc AMS
- Acta Appl Math (6 papers)
- Bull Soc Math FRance
- Ann Inst Fourier

Proposals:

- 2 Copernicus proposals on behalf of the Lithuanian Acad. of Sciences
- BUC'M proposal to EC, STN, and Math Review

Honours:

- Elected foreign member Ukrainian International Academy of Arts and Sciences, 1994.

Nico Temme:
- The proposal 'Wavelets: analysis of seismic signals' is submitted to STW.

Publications

AM 1:

A.E. BROUWER (1994). On the uniqueness of a regular thin near octagon on 288 vertices (or the semibiplane belonging to the Mathieu group M_{12}). *Discr. Math. 126,* 13–27.

A.E. BROUWER, A.M. COHEN, J.I. HALL & H.A. WILBRINK (1994). Near polygons and Fischer spaces. *Geometriae Dedicata 49,* 349–368.

A.E. BROUWER & M. NUMATA (1994). A characterization of some graphs which do not contain 3-claws. *Discr. Math. 124,* 49–54.

A.E. BROUWER (1994). Finite graphs in which the point neighbourhoods are the maximal independent sets. K. APT, A. SCHRIJVER & N. TEMME (eds.). *From Universal Morphisms to Megabytes - a Baayen Space Odyssey,* CWI, Amsterdam, 231–233.

A.M. COHEN (1994). Yet another lecture on the icosahedron. K. APT, A. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes - a Baayen Space Odyssee,* CWI, Amsterdam, 247–267.

A.M. COHEN (1994). Recent results on Coxeter groups. T. BISZTRICZKY, P. MCMULLEN, R. SCHNIEDER, A. IVIC WEISS (eds.). Kluwer Acad. Publ., 1–19.

M. HAZEWINKEL (ed.) (1994). *Encyclopaedia of Mathematics, Vol 10,* Kluwer Acad. Publ.

M. HAZEWINKEL (ed.) (1993). *Encyclopaedia of Mathematics, Vol 9,* Kluwer Acad. Publ., 1993 (not listed in Annual report 1993).

M. HAZEWINKEL (1994). Some problems of applied algebra. *Ueberblicke Mathematik 1993, Vieweg,* 131–154.

M. HAZEWINKEL (1994). The Wouthuyzen equation. K.R. APT, A. SCHRIJVER, N.M. TEMME (eds.). *From Universal Morphisms to Megabytes - a Baayen Space Odyssey, on the ocasion of the retirement of Prof.dr. P.C. Baayen,* CWI, Amsterdam.

M. HAZEWINKEL (1993). Wavelets understand fractals. T.H. KOORNWINDER (ed.). *Wavelets: an elementary treatment of theory and applications,* World Scientific, 209–219 (Not listed in Annual Report 1993).

M. HAZEWINKEL (1993). *Multiparameter quantum groups and multiparameter R-matrices,* CWI Report AM-R9307 (to appear Acta Appl Math 41 (Oct. 1995). (Not listed in Annual Report 1993).

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AM 2:

O. DIEKMANN, M. GYLLENBERG, J.A.J. METZ & H.R. THIEME (1994). The cumulative formulation of (physiologically) structured population models. PH. CLÉMENT & G. LUMER (eds.). *Evolution Equations, Control Theory and Biomathematics,* Marcel Dekker Lect. Notes in Pure Applied Math. 155, 145–154.

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O. DIEKMANN & J.A.J. METZ (1994). On the reciprocal relationship between life histories and population dynamics. S.A. LEVITIN (ed.). *Frontiers in Mathematical Biology,* Springer Lect. Notes in Biomath. 100, 263–279.

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YU.A. KUZNETSOV, C. PICCARDI (1994). Bifurcations and chaos in a periodically forced prototype adaptive control system. *Kybernetika 30,* 121–128.

A.R. CHAMPNEYS, YU.A. KUZNETSOV (1994). Numerical detection and continuation of codimension-two homoclinic bifurcations. *Int. J. Bifurcation & Chaos 4,* 795–822.

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N.M. TEMME (1994). Steepest descent paths for integrals defining the modified Bessel functions of imaginary order. *Methods and Applications in Analysis, 1,* 14–24.

A.B. OLDE DAALHUIS & N.M. TEMME (1994). Uniform Airy type expansions of integrals. *SIAM J. Math. Anal.25,* 304–321.

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K. APT, A. SCHRIJVER & N. TEMME (eds.) (1994). *From Universal Morphisms to Megabytes - a Baayen Space Odyssey, on the occasion of the retirement of Prof.dr. P.C. Baayen,* CWI, Amsterdam.

J. DE VRIES (1993). *Elements of Topological Dynamics,* KAP (Not listed in Annual Report 1993).

DEPARTMENT OF OPERATIONS RESEARCH, STATISTICS, AND SYSTEM THEORY

General Introduction

Staff Department of Operations Research, Statistics, and System Theory, 1994

- BS1

CWI funded

- A. Schrijver
- A.M.H. Gerards
- J.K. Lenstra
- A.G. Steenbeek
- H. van der Holst

Externally funded

- J. Coelho de Pina
- P.L. Erdös
- E. Györi
- M. Laurent

- BS2

CWI funded

- O.J. Boxma
- J. van den Berg
- J.W. Cohen

Externally funded

- N. Bayer
- S.C. Borst
- R.J. Boucherie
- M.B. Combé
- F.A. van der Duyn Schouten
- A. Ermakov
- S. Vos de Wael
- P.R. de Waal

- BS3

CWI funded

- J.M. van den Hof
- A.A.F. Overkamp
- J. Rosenthal
- A.J. van der Schaft
- J.M. Schumacher
- J.H. van Schuppen

Externally funded

- J. de Does
- H.J.C. Huijberts
- G.M. Koole
- A.A. Stoorvogel
- P.R. de Waal

- BS4

CWI funded

- A.J. Baddeley
- M.S. Keane
- A.J. Cabo
- K.O. Dzhaparidze
- R.D. Gill
- F.C.A. Groen
- H.J.A.M. Heijmans
- R. Helmers
- R. van der Horst
- F.K. Potjer
- A.G. Steenbeek
- S.J. van Strien

Externally funded

- R.H.P. Janssen
- M.N.M. van Lieshout
- A. Mancham
- I. Molchanov
- P. Nacken

- Secretary: L.M. Schultze

Combinatorial Optimization and Algorithmics (BS1)

Staff

- A. Schrijver, group leader
- A.M.H. Gerards, senior researcher
- J.K. Lenstra, senior researcher
- A. Steenbeek, programmer
- J. Coelho de Pina, oio (FAPESP)
- H. van der Holst, oio
- P.L. Erdös, visiting researcher (Budapest)
- E. Györi, visiting researcher (Stieltjes)
- M. Laurent, visiting researcher (ENS Paris)

Scientific Report

Graphs and polyhedra. Together with M. Conforti (Italy), A. Sebo (France) and F.B. Shepherd (United Kingdom), A.M.H. Gerards studied the structure of certain types of graphs for which related combinatorial optimization problems can be formulated as linear programs.
With F.B. Shepherd a decomposition theorem of graphs without certain type homeomorphs of K_4 has been derived. This provides not only a recognition algorithm for this class of graphs but also a simpler proof of an earlier result saying that these graphs are 't-perfect' (a report is under preparation). With M. Conforti graphs with no 'odd-K_5' are investigated. First steps have been made, but final answers seem still far ahead.

Minimum-length disjoint paths. J. Coelho de Pina and H. van der Holst designed some new polynomial-time algorithms for finding disjoint paths where the longest path is as short as possible, for certain classes of planar instances of the problem. This applies to the design of VLSI-circuits.

The CdV-invariant. Together with L. Lovász (Yale University), H. van der Holst and A. Schrijver investigated the mu-invariant for graphs designed by Y. Colin de Verdiere. In particular, a short proof of Colin de Verdiere's planarity characterization was found, the invariance of the invariant under clique-sums was characterized, a related invariant based on dimension of certain spaces was considered, and the work on Robertson, Seymour, and Thomas' conjecture concerning flat graphs was continued.

Graphs and curves on surfaces. A. Schrijver concluded his research on homotopic circulations and Reisemeister moves, done jointly with M. de Graaf (University of Amsterdam). In particular, a new characterization of kernels on compact surfaces was given. This relates to recent work of Robertson and Seymour on the representativity of graphs embedded on a surface and to the problem of finding flows in networks on surfaces of a prescribed homotopy.

Disjoint paths algorithms with free partially commutative groups. A. Schrijver extended the free partially commutative group method for solving the cohomology feasibility problem. In particular, methods where investigated relating to time-tabling problems.

Routing, scheduling, and time-tabling for the Dutch Railways. A. Schrijver and A.G. Steenbeek continued the development of new methods for two problems coming from the Dutch Railways: 1. determining the minimum railway stock necessary to run a given time-table with lower bounds on the number of seats in each of the train-stages; 2. determining a periodic time-table, given the running and waiting times, the desired connections, and the safety distance between trains. Both problems required developing new tools, based on polyhedral combinatorics, integer programming, and graph theory. In particular, in 1994 a faster implementation was made, the system was extended so as to find a minimum 'blocker', a method was made to determine the variance in making a minimal not-solvable system feasible, and an algorithm was made designed to optimize a given time-table within given bounds.

Matching. A.M.H. Gerards completed a chapter on matchings for the volume 'Networks' edited by M.O. Ball. T.L. Magnanti, C.L. Monma and G.L Nemhauser, which will appear in the series: Handbook in Operations Research and Management Science. (A.M.H. Gerards, Matching, CWI Report BS-R9424, July 1994).

Books. J.K. Lenstra and A. Schrijver continued their preparations on the books 'Polyhedral Combinatorics' (A. Schrijver), 'Scheduling' (E.L. Lawler, J.K. Lenstra, A.H.G. Rinnooy Kan, and D.B. Shmoys) and 'Local search' (E.H.L. Aarts and J.K. Lenstra).

Organisation of Conferences, Workshops, Courses, etc.

- 'Nineteenth Conference on the Mathematics of Operations Research/Fifth International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 11–14, 1994.
  A.M.H. Gerards, member Organizing Committee.
- 'CO94', Amsterdam, The Netherlands, April 5–8, 1994.
  A.M.H. Gerards, member Organizing Committee
  J.K. Lenstra, member Organizing Committee.
- Fifteenth International Symposium on Mathema-

tical Programming, Ann Arbor, USA, August 15–19, 1994.
J.K. Lenstra, member Symposium Advisory Committee and International Advisory Committee
A. Schrijver, member International Advisory Committee.
- Second Annual European Symposium on Algorithms, Utrecht, September 26–28, 1994.
J.K. Lenstra, member Program Committee.
- Workshop 'Optimization in Production and Transportation', Scheveningen, November 9–11, 1994.
A.M.H. Gerards, member Organizing Committee
M. Laurent, member Organizing Committee
A. Schrijver, chairman.
- 'Twentieth Conference on the Mathematics of Operations Research/Sixth International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 10–12, 1995
A.M.H. Gerards, member Organizing Committee.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- Congres 'OR/AI', Utrecht, January 10: A. Schrijver.
- 'Nineteenth Conference on the Mathematics of Operations Research/Fifth International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 11–14: A.M.H. Gerards, J.K. Lenstra, A. Schrijver.
- CO'94 Combinatorial Optimization 1994, Amsterdam, April 5–8: A.M.H. Gerards, H. van der Holst, J. Coelho de Pina, A. Schrijver.
- ORSA/TIMS National Meeting, Boston, USA, April 24–27: J.K. Lenstra.
- 1st DONET Workshop (Discrete Optimization), Trento, May 12–20: A.M.H. Gerards, H. van der Holst, A. Schrijver.
- 3rd SCIENCE-Workshop 'Algorithmic Approaches to Large and Complex Combinatorial Optimization Problems', Giens, May 23–27: A.M.H. Gerards, H. van der Holst.
- Annual Meeting of the Israel Operations Research Society, Mitzpe Ramon, Israel, June 1–2: J.K. Lenstra.
- Fifteenth International Symposium on Mathematical Programming, Ann Arbor, USA, August 15–19: A.M.H. Gerards, J.K. Lenstra, A. Schrijver.
- International Conference on Convexity, Marne, September 5–9: M. Laurent.
- 2nd DONET Workshop (Discrete Optimization), Casteljau, September 25–October 1: A.M.H. Gerards, H. van der Holst, M. Laurent, A. Schrijver.
- Conference of the 'Chinese Society for Industrial and Applied Mathematics' Xi'an Jiaotong University, Xi'an, China, October 13–16: J.K. Lenstra.
- Workshop 'Optimization in Production and Transportation', Scheveningen, November 9–11: A.M.H. Gerards, M. Laurent, A. Schrijver.
- Colloquium on Combinatorics, November 15–16: A. Schrijver.

Memberships of Committees and Other Professional Activities

Ph.D. Committees

- M. van den Akker (Eindhoven University of Technology): A. Schrijver, M. de Graaf (University of Amsterdam): A.M.H. Gerards, A. Schrijver, K. Padayachee (University of Waterloo): A. Schrijver, M. Schaffers (Catholic University of Louvain): A. Schrijver, B. Spieker (University Twente): A. Schrijver, K. Vuskovic (Carnegie Mellon University): A.M.H. Gerards, P. Zwietering (Eindhoven University of Technology): A. Schrijver.

Organisational Activities

- Akademie Raad voor de Wiskunde, J.K. Lenstra, lid bestuur.
- EIDMA - Euler Institute for Discrete Mathematics and Its Applications, A. Schrijver, member Bestuur.
- Fields Medal Committee 1994, A. Schrijver, member.
- Fulkerson Prize Committee 1994, A. Schrijver, chairman.
- Landelijk Netwerk Mathematische Besliskunde, A.M.H. Gerards, J.K. Lenstra, A. Schrijver, member AB.
- Mathematical Programming Society, J.K. Lenstra, chairman.
- Stichting Mathematisch Centrum, A. Schrijver, member Wetenschappelijke Raad.
- Stichting Wetenschappelijk Onderzoek Verkeersveiligheid, J.K. Lenstra, lid Wetenschappelijke Adviesraad.
- Stieltjes Instituut voor Wiskunde, A. Schrijver, member Wetenschapscommissie.
- Vereniging voor Statistiek, J.K. Lenstra, member of jury for VVS-Prize.
- Werkgemeenschap Mathematische Besliskunde en Systeemtheorie, A.M.H. Gerards, ondervoorzitter A. Schrijver, member Wetenschapscommissie.
- Werkgemeenschap Discrete Wiskunde, A. Schrijver, member Wetenschapscommissie.

- Wiskundig Genootschap, J.K. Lenstra, bestuurslid.

Editorial Activities

- Combinatorica, A. Schrijver, editor-in-chief.
- CWI Monographs, CWI Tracts, CWI Syllabi, J.K. Lenstra, Managing Editor.
- CWI-Quarterly, A.M.H. Gerards, editor.
- Discrete Applied Mathematics, A. Schrijver, editor.
- Excerpta Informatica, J.K. Lenstra, member Advisory Board.
- International Journal of Foundations of Computer Science, J.K. Lenstra, Associate Editor.
- Journal of Combinatorial Theory, Series B, A. Schrijver, editor.
- Journal of Combinatorics, Information and System Sciences, A. Schrijver, editor.
- Kluwer Series in Operations Research/Computer Science Interface, J.K. Lenstra, member Editorial Advisory Board.
- Mathematics of Operations Research, J.K. Lenstra, Editor-in-Chief
  A. Schrijver, associate editor.
- North-Holland Mathematical Library, A. Schrijver, advisory editor.
- ORSA Journal on Computing, J.K. Lenstra, Area Editor for Design and Analysis of Algorithms.
- SCIMA Special Series, J.K. Lenstra, member Advisory Board.
- SIAM Journal on Discrete Mathematics, A. Schrijver, editor.
- SIAM Journal on Optimization, A. Schrijver, editor.
- Statistica Neerlandica, J.K. Lenstra, Associate Editor.
- Wiley/Interscience Series in Discrete Mathematics and Optimization, J.K. Lenstra, Advisory Editor.

Visitors

- M. Grötschel (Germany)
- M. Conforti (Italy)
- B. Mohar (Slovenia)
- S. Poljak (Germany)

Miscellaneous (Consultancy, contract research, and relations with industry)

External orders:

- Dienstregelingontwikkeling Nederlandse Spoorwegen/Railned
- Toewijzing busplatforms Nederland-Haarlem

Graduate courses:

- Combinatorial Optimization, combinatorial algorithms and Graph Theory 1, EIDMA, January–March
  A.M.H. Gerards, J.K. Lenstra, A. Schrijver
- Combinatorial Optimization, combinatorial algorithms and Graph Theory 2, EIDMA, April–June
  A.M.H. Gerards, J.K. Lenstra, A. Schrijver
- Binary spaces and polyhedra - the max-flow min-cut property February 28–March 11, University of Padua (Italy)
  A.M.H. Gerards
- Combinatorial Optimization ENS Paris, January–February
  A. Schrijver

Papers in Journals and Proceedings

E.H.L. AARTS, P.J.M. VAN LAARHOVEN, J.K. LENSTRA, N.L.J. ULDER (1994). A computational study of local search algorithms for job shop scheduling. *ORSA Journal on Computing 6,* 118–125.

J.M. ANTHONISSE, J.K. LENSTRA (1994). Operational operations research at the Mathematical Centre. K. APT, A. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey,* CWI, Amsterdam, 59–64.

C. DE SIMONE, M. DEZA, M. LAURENT (1994). Collapsing and lifting for the cut cone. *Discrete Mathematics 127,* 105–130.

M. DEZA, M. LAURENT (1994). ℓ_1-rigid graphs. *Journal of Algebraic Combinatorics 3,* 153–175.

M. DEZA, M. LAURENT (1994). Applications of cut polyhedra. *Journal of Computational and Applied Mathematics 54.*

A.M.H. GERARDS (1994). An orientation theorem for graphs. *Journal of Combinatorial Theory, Series B, 62,* 199–212.

M. DE GRAAF, A. SCHRIJVER (1994). Grid minors of graphs on the torus. *Journal of Combinatorial Theory, Series B 61,* 57–62.

K.M. VAN HEE, J.K. LENSTRA (1994). Editorial: A comparative study in DSS development. *European Journal of Operational Research 79,* 153–157.

J.A. HOOGEVEEN, J.K. LENSTRA, B. VELTMAN (1994). Three, four, five, six, or the complexity of scheduling with communication delays. *Operations Research Letters 16,* 129–137.

J.H.M. KORST, E.H.L. AARTS, J.K. LENSTRA, J. WESSELS (1994). Periodic assignment and graph colouring. *Discrete Applied Mathematics 51,* 291–305.

C. MCDIARMID, B. REED, A. SCHRIJVER, B. SHEPHERD (1994). Induced circuits in planar graphs. *Journal of Combinatorial Theory, Series B 60,* 169–176.

A. SCHRIJVER (1994). Classification of minimal graphs of given face-width on the torus. *Journal of Combinatorial Theory, Series B 61,* 217–236.

A. SCHRIJVER (1994). Finding k disjoint paths in a directed planar graph. *SIAM Journal on Computing 23,* 780–788.

A. SCHRIJVER (1994). Paths in graphs and curves on surfaces. A. JOSEPH, ET AL. (eds.). *'First European Congress of Mathematics Volume II',* Birkhäuser Verlag, Basel, 381–406.

A. SCHRIJVER (1994). Rambling along paths, trees, flows, curves, knots, and rails. K. APT, A. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey,* CWI, Amsterdam, 493–534.

A. SCHRIJVER, P.D. SEYMOUR (1994). Packing odd paths. *Journal of Combinatorial Theory, Series B 62,* 280–288.

CWI Reports

BS-R9414 A.M.H. GERARDS, F.B. SHEPHERD. *Strong orientations without even directed circuits.*

BS-R9424 A.M.H. GERARDS. *Matching,* (to appear in: M.O. BALL. T.L MAGNANTI, C.L. MONMA, G.L NEMHAUSER (eds.), Networks, Handbook in Operations Research and Management Science, North-Holland, 1995, 135–224).

Analysis and Control of Information Flows in Networks (BS2)

Staff

- Prof. dr. ir. O.J. Boxma, department head and group leader
- Dr. N. Bayer, postdoc, ESPRIT; since May 1
- Dr. J. van den Berg, researcher
- Ir. S.C. Borst, junior researcher (OIO), LNMB; until September 1
- Dr. R.J. Boucherie, postdoc, ERCIM; until March 1, and 0.2 since September 1
- Prof. dr. ir. J.W. Cohen, advisor
- Drs. M.B. Combé, junior researcher (OIO), NFI; until October 1
- Prof. dr. F.A. van der Duyn Schouten, researcher (0.2 appointment), Tilburg University
- Mr. A. Ermakov, junior researcher (OIO), NWO; since April 1
- Mr. S. Vos de Wael, trainee (Tilburg University); since September 16
- Dr. ir. P.R. de Waal, postdoc, Shell fellowship; until August 1

Note: Only those activities, publications etc. of J.W. Cohen (advisor) and F.A. van der Duyn Schouten (0.2 appointment) have been mentioned, that have a direct relation with BS2.

Scientific Report

BS2.1 Analysis of mathematical queueing models (Bayer, Boucherie, Boxma, Cohen)

J.W. Cohen has continued his analysis of the concept of effective bandwidth. His results, for the case of arbitrary message length distributions, lead to new insight in the effects of bursty traffic in multiplexing systems. He has also completed a report on periodical Pollaczek waiting time processes. They provide an alternative modelling of bursty traffic.

Cohen has further shown that the mathematical analysis of the symmetrical shortest queue, a classical problem in queueing theory, can be simplified in an essential way. This also leads to quite simple analytic expressions for the performance characteristics. The new approach is of much wider applicability, and leads to simple results for the 2×2 symmetric clocked buffered switch.

The analytic approach of Flatto-Hahn has been used to analyze two-dimensional random walks, and has led to a more profound insight into the mathematical structure of the stationary distributions of a certain class of random walks.

Boucherie has completed a detailed study of the behaviour of the maximum number of customers present during a busy cycle and during a number of busy cycles for a single queue with general service effort function. In particular, limit theorems are discussed for this system.

Boucherie and Boxma have analysed the workload process in an M/G/1 queue with additional negative customers. The solution is based on the Wiener-Hopf technique. The results are also relevant for risk and inventory theory. A report is in preparation. Bayer and Boxma have obtained results for the queue length process in a closely related M/G/1 queue, again using boundary value techniques.

BS2.2 Stochastic processes on networks (Van den Berg, Ermakov)

Ermakov has joined the project in April 1994.

Van den Berg and Ermakov have studied a cellular automaton introduced by Coffman, Courtois, Gilbert and Piret. The problem is to show that this system locally stabilizes, and the idea is to do this by comparison with percolation processes. This research is still in progress.

Partly motivated by the previous problem, van den Berg and Ermakov have obtained a new lower bound

for the critical probability of site percolation on the square lattice.
Van den Berg has given a new proof that, for marked Poisson point processes, the probability that two events 'occur disjointly' is smaller than the product of the two individual probabilities. In contrast with existing proofs (by Bezuidenhout and Grimmett, and by Roy and Sarkar), this proof requires no special topological conditions on the events.
Van den Berg and Gandolfi (Rome) have studied the conjecture that, for any finite ferromagnetic Ising model, the covariance of two given spins (as a function of the external fields) is maximal if all external fields are 0. This conjecture, if true, would imply that the standard ferromagnetic Ising model on the d-dimensional cubic lattice is completely analytic above the critical temperature. Special cases of this conjecture have led to algebraic problems, which might be solvable by methods of computational algebraic geometry. One of these methods (based on Gröbner basis techniques) has been tried, but the algorithm (available in Maple) appears to require too much computer resource. Other methods will be tried in the near future.
In a paper by Baddeley and Van Lieshout on point processes, the use of the function $J = (1 - G)/(1 - F)$ is advocated as a non-parametric measure of spatial interaction. Here G is the nearest-neighbour distance distribution function and F the empty space function of the process. M. Keane raised the question whether every process with $J \equiv 1$ is Poisson. It appears that a classical construction by Szasz provides a 1-dimensional counterexample. This construction is still 'Poisson-like' in the sense that the distances between consecutive points are exponentially distributed. Van den Berg has sketched the construction of a process where $J \equiv 1$, but the distances between consecutive points are bounded. The construction uses a coupling method of Bedford and Meilijson. T. Bedford (Delft University of Technology) has recently explained how to generalize this method to make it suitable for the purpose mentioned above.
Finally, van den Berg and Maes (Catholic University of Leuven) have discussed possible extensions of their 'disagreement percolation' method for studying uniqueness of Gibbs measures. There seems to be quite some interest in such extensions (for instance in the group of Dobrushin), which motivates further research in this field.

BS2.3 Reliability and availability of networks (Boxma, Van der Duyn Schouten, Vos de Wael, De Waal)

- Optimization of maintenance
  In the context of a consultancy project several multi-component maintenance strategies for corrective and preventive replacement of light bulbs in traffic control lights have been proposed and analysed. This project, which started in September, will be continued in 1995. Together with Charles Tapiero from ESSEC (Paris), Van der Duyn Schouten has prepared a special issue for EJOR 'OR-models for maintenance optimization and quality control'.
- Coordination of maintenance and production
  Van der Duyn Schouten has investigated the optimal preventive maintenance schedule for a production system consisting of a number of identical, parallel production units. It is assumed that production losses are convexly increasing with the number of non-available units (a situation typically occurring in process and steel industry). It is shown that the optimal policy has some structural (monotonicity and control limit type) properties.
  De Waal has analysed a system that consists of a failure prone production unit with a buffered output. An exact analysis of the equilibrium system effectiveness is presented and two approximation methods are introduced for the computation of equilibrium and transient performance measures.

BS2.4 Performance analysis and control of computer and communication networks (Bayer, Van den Berg, Borst, Boucherie, Boxma, Combé)

- Polling systems
  Borst has completed his PhD thesis *Polling Systems* (November 4, Tilburg University, cum laude), as well as several reports. He has analyzed polling systems with multiple *coupled* servers, exploring the class of systems that allow an exact analysis, which includes several single-queue systems, two-queue two-server systems, and infinite-server systems.
  Borst and Van der Mei have extensively studied polling systems with multiple *independent* servers. Motivated by the seemingly unsurmountable analytical difficulties, they have demonstrated how the performance of these models may be evaluated numerically by means of the power series algorithm (PSA). In view of the considerable time and memory requirements of the PSA, they have also derived waiting-time approximations for those models that appear to capture the influence of the visit order very well.
  Borst and Boxma have extensively studied the relationship between polling models with and without switch-over times. For a broad class of service disciplines they have exposed a strong relationship between the queue length, as well as the

waiting-time, distributions in both models, which allows for a very efficient numerical computation of the mean waiting times under different switch-over time scenarios.
Boxma, jointly with Koole and Mitrani, has studied two-queue polling systems in which the service policy at the low-priority queue is of threshold type: the server switches to the other queue as soon as the size of that queue reaches a certain level. Such a threshold discipline is of interest in meeting quality-of-service requirements in communication networks with different types of traffic. Boxma has developed a general framework for polling systems in which the arrival process is influenced by the position of the server, and in which customers can move from queue to queue.

- Markovian Arrival Processes
Markovian Arrival Processes (MAP) have recently become very important for the modeling of arrival streams in telecommunication networks, as they combine mathematical tractability with the flexibility of representing bursty and dependent traffic. MAP's play a central role in the Ph.D. thesis of Combé, *Queueing Models with Dependence Structures*, to be defended in January 1995. In 1994 he has published three reports concerning (batch) Markovian arrival processes. He has exploited (B)MAP for the modeling and analysis of dependence between interarrival and service times, he has generalized known results on queues with impatient customers, and he has analysed the queue length process for the BMAP/M/s queue.
- Load balancing and scheduling
Borst has considered the problem of finding an optimal allocation of distinct customer types to parallel servers. He has exposed the structure of an optimal allocation and described for some special cases in detail how the structure may be exploited in actually determining an optimal allocation.
- Product forms
The structure of Petri nets required to obtain product form results is characterized in detail. In particular, the relation between the traffic equations for batch routing queueing networks and the T-invariants for stochastic Petri nets is analysed.
- Distributed systems
Boxma, Koole and Liu have written a survey of queueing-theoretic solution methods for the performance analysis of parallel and distributed systems. Bayer has continued his study of Branching-Queueing networks, a new formalism for modeling and analyzing the behaviour of MIMD architectures. A joint paper with Coffman and Kogan is almost completed. Transition operators for Branching-Queueing networks may be expressed as compound operators, where the components correspond to product-form networks with clusters; work has commenced in estimating the fixed point of a compound operator using the known fixed points of the components.

Organisation of Conferences, Workshops, Courses, etc.

- Boxma and Koole have published the proceedings of the ESPRIT BRA QMIPS workshop 'Solution methods for parallel systems', as CWI Tracts 105 and 106.
- Two one-day seminars on queueing theory have been organized at CWI by De Waal and Boxma.
- A Workshop on Reliability and Maintenance Modelling, September 29-30, Amsterdam, has been organised by Van der Duyn Schouten jointly with Dekker (Tinbergen Institute).

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Working visit* University Zürich, January 1–8 (continuation of visit which started in December 1993): Van den Berg (minicourse).
- *19th Conference on the Mathematics of Operations Research*, Lunteren, January 11–14: Van den Berg, Borst (1 lecture), Boucherie, Boxma, Cohen, Combé (1 lecture), De Waal.
- *Working visit* Tel-Aviv University, Tel-Aviv, February 13–18: Boxma.
- *Working visit* Technion, Haifa, February 17: Boxma
- *LNMB Colloquium*, Utrecht, lectures by Boucherie (January 31), Borst (February 28), Combé (March 21).
- *Working visit* Mathematical Institute of the Academy of Sciences, Budapest, March 19–25: Van den Berg (2 lectures).
- *Netherlands Conference on Mathematics*, April 7–8: Van den Berg, Boxma, Ermakov.
- *Stochastics Seminar, TU Eindhoven*, April 13: Van den Berg (1 lecture).
- *ESPRIT QMIPS Workshop*, London, April 14–15: Borst (1 lecture), Boxma.
- *Stieltjes workshop on Applied Probability*, Leiden, April 25–29: Boxma (1 lecture), Cohen (1 lecture).
- *ITC-14*, Juan-les-Pins, June 6–10: Borst (1 lecture), Boxma, Combé, Cohen, De Waal (1 lecture).

- *CWI National Queueing Seminar*, Amsterdam, June 21: Borst (1 lecture), and October 5: Bayer (1 lecture); participation by all group members.
- DGOR Tagung, Berlin, August 27– September 2: Van der Duyn Schouten (1 lecture).
- *ESPRIT QMIPS Workshop*, Newcastle, October 26–27: Bayer (1 lecture), Boxma.
- *Lunteren Stochastics conference*, November 14–16: Van den Berg, Ermakov.
- *Working visit* Department of Theoretical Physics, Catholic University of Leuven, November 21–22: Van den Berg (1 lecture).
- *Workshop on Applied Probability*, Oberwolfach, December 5–9: Boxma (1 lecture).
- *Stieltjes workshop on Stochastic Modeling*, Leiden, December 12–16: Bayer, Boxma (1 lecture).
- *Spatial Stochastics Seminar, CWI*, weekly: Van den Berg, Ermakov (1 lecture).
- *Mark Kac Seminar*, monthly: Van den Berg (1 lecture), Ermakov.
- *Dynamical Systems Seminar, CWI and UvA*: occasionally attended by Van den Berg and Ermakov.
- *Stochastics Seminar RUU*, occasionally attended by Van den Berg and Ermakov.
- *Stochastics Seminar TUD*, occasionally attended by Van den Berg and Ermakov.

Memberships of Committees and Other Professional Activities

J. van den Berg:
- Participation in the organization of a workshop on 'Probability and Physics' (in connection with the NWO project 'Computationally Intensive Methods in Stochastics').

O.J. Boxma:
- Professor of Operations Research, Tilburg University.
- Editor of the journals Mathematics of Operations Research; Performance Evaluation; Queueing Systems.
- Secretary/treasurer of IFIP Working Group 7.3.
- Member of the Committee for Conferences on Stochastic Processes of the Bernoulli Society for Mathematical Statistics and Probability.
- Member of the program committee of the 23nd Conference on Stochastic Processes and their Applications (Singapore, June 1995).
- Member of the program committee of ACM Sigmetrics/Performance '95 (Ottawa, May 1995).
- Member of the program committee of the 7th Int. Conference on Modelling Techniques and Tools for Computer Performance Evaluation (Vienna, May 1994).
- Member of the program committee of the 8th Int. Conference on Modelling Techniques and Tools for Computer Performance Evaluation (Heidelberg, September 1995).
- Member of the national committee for the ITC Seminar in Teletraffic Modelling and Measurement (PTT Research, November 7–9, 1995).
- Ph.D. advisor of S.C. Borst (Polling Systems, Tilburg University, November 4).
- Project leader NFI project 'Performance analysis and control of distributed computer systems'.
- Leader of the Workpackage on Solution Methods of ESPRIT BRA project QMIPS.

J.W. Cohen:
- Chairman of the National Committee of the ITC Seminar in Teletraffic Modelling and Measurement (PTT Research, November 7–9, 1995).
- Member of the advisory board of Telecommunication Systems.
- Honorary member of the IAC of ITC.
- Member of the program committee of the ITC congresses and seminars.

F.A. van der Duyn Schouten:
- Chairman of 'Landelijke Werkgemeenschap MBST'.

A. Ermakov:
- Teaching assistance UvA (Dept. of Mathematics and Computer Science).

Visitors

- U. Yechiali (Tel-Aviv University, Tel-Aviv), March 28 – April 1.
- A. Gandolfi (Univ. Rome, Rome), August 28 – September 23.
- I. Eliazar (Tel-Aviv University, Tel-Aviv), September 19 – October 7.
- G. Yamazaki (Tokyo Metropolitan Inst. of Technology, Tokyo), September 19 – October 10.
- C. Maes (Leuven), October 17–19.
- G. Grimmett (Cambridge), December 12–13.

Miscellaneous

- The positions of the following members of BS2 have been externally funded: Bayer (ESPRIT), Borst (LNMB), Boucherie (ERCIM/KNAW), Combé (NFI), Ermakov (NWO), De Waal (Shell).
- Boxma has given a graduate course in Queueing Theory for the Dutch Graduate Network of Operations Research (LNMB).

- *Consultancy:*
  (i) PTT Post BV (Borst, Boxma; Helmers and Van der Horst from BS4)
  (ii) NS (Boxma, Combé)
  (iii) Direct Advertising Company (Boxma, De Waal)
  (iv) Nederland-Haarlem (Van der Duyn Schouten, Vos de Wael).

Papers in Journals and Proceedings

J. VAN DEN BERG, J.E. STEIF (1994). Percolation and the hard-core lattice gas model. *Stochastic Processes and their Applications 49*, 179–197.

J. VAN DEN BERG, C. MAES (1994). Disagreement percolation in the study of Markov fields. *Annals of Probability 22*, 749–763.

S.C. BORST (1994). A pseudo-conservation law for a polling system with a dormant server. J. LABETOULLE, J.W. ROBERTS (eds.). *The Fundamental Role of Teletraffic in the Evolution of Telecommunications Networks* (Proc. ITC-14), (North-Holland, Amsterdam), 729–742.

S.C. BORST, O.J. BOXMA, J.H.A. HARINK, G.B. HUITEMA (1994). Optimization of fixed-time polling schemes. *Telecommunication Systems* **3**, 31–59.

O.J. BOXMA, G.J. VAN HOUTUM (1994). The compensation approach applied to a 2 × 2 switch. O.J. BOXMA, G.M. KOOLE (eds.). *Performance Evaluation of Parallel and Distributed Systems*, (CWI Tract 105), 59–80.

O.J. BOXMA, M. KELBERT (1994). Stochastic bounds for a polling system. *Annals of Oper. Res. 48*, 295–310.

O.J. BOXMA, G.M. KOOLE, Z. LIU (1994). Queueing-theoretic solution methods for models of parallel and distributed systems. O.J. BOXMA, G.M. KOOLE (eds.). *Performance Evaluation of Parallel and Distributed Systems*, (CWI Tract 105), 1–24.

O.J. BOXMA, J.A.C. RESING (1994). Tandem queues with deterministic service times. *Annals of Oper. Res. 49*, 221–239.

O.J. BOXMA, P.R. DE WAAL (1994). Multiserver queues with impatient customers. J. LABETOULLE, J.W. ROBERTS (eds.). *The Fundamental Role of Teletraffic in the Evolution of Telecommunications Networks* (Proc. ITC-14), (North-Holland, Amsterdam), 743–756.

J.W. COHEN (1994). On a class of two-dimensional nearest-neighbour random walks. J. GALAMBOS, J. GANI (eds.). *Studies in Applied Probability – Papers in honour of Lajos Takács*, J. Appl. Probab. 31A (Special Volume), 207–237.

M.B. COMBÉ, O.J. BOXMA (1994). Optimization of static traffic allocation policies. *Theor. Comp. Science 125*, 17–43.

F.A. VAN DER DUYN SCHOUTEN, P. WARTENHORST (1994). Transient analysis of a two-unit standby system with Markovian degrading units. *Management Science 40*, 418–428.

E. KRANAKIS, D. KRIZANC, J. VAN DEN BERG (1994). Computing Boolean functions on anonymous networks. *Information and Computation 114*, 214–236.

CWI Reports

BS-R9401 R.J. BOUCHERIE. *Product forms based on backward traffic equations.*

BS-R9402 R.J. BOUCHERIE, M. SERANO. *A structural characterisation of product form stochastic Petri nets.*

BS-R9406 J.W. COHEN. *On the effective bandwidth in buffer design for the multi-server channels.*

BS-R9407 J.W. COHEN. *On periodic Pollaczek waiting time.*

BS-R9408 S.C. BORST. *Polling systems with multiple coupled servers.*

BS-R9410 R.D. VAN DER MEI, S.C. BORST. *Analysis of multiple-server polling systems by means of the power-series algorithm.*

BS-R9412 M.B. COMBÉ. *Modelling dependence between interarrival and service times with Markovian arrival processes.*

BS-R9413 M.B. COMBÉ. *Impatient customers in the MAP/G/1 queue.*

BS-R9415 S.C. BORST. *Optimal probabilistic allocation of customer types to servers.*

BS-R9420 J.W. COHEN. *On the analysis of the symmetrical shortest queue.*

BS-R9421 S.C. BORST, O.J. BOXMA. *Polling models with and without switchover times.*

BS-R9423 R.J. BOUCHERIE. *On the maximum number of customers simultaneously present in a queue.*

BS-R9425 O.J. BOXMA, G.M. KOOLE, Z. LIU. *Queueing-theoretic solution methods for models of parallel and distributed systems.*

BS-R9427 J.W.COHEN. *On the determination of the stationary distribution of a symmetric clocked buffered switch.*

BS-R9428 S.C. BORST, R.D. VAN DER MEI. *Waiting-time approximations for multiple-server polling systems.*

BS-R9435 M.B. COMBÉ. *The BMAP/M/s queue.*

BS-R9437 J.W. COHEN. *Analysis of a two-dimensional algebraic nearest-neighbour random*

walk (Queue with paired services).

Other Publications

J. VAN DEN BERG (1994). *A Note on Disjoint-occurrence Inequalities for Marked Poisson Point Processes.* Preprint, submitted for publication.

J. VAN DEN BERG, A. ERMAKOV (1994). *An Improvement of the Menshikov-Pelikh Lower Bound for the Critical Probability of Site Percolation on the Square Lattice.* Preprint, submitted for publication.

S.C. BORST (1994). *Polling Systems.* Ph.D. Thesis, Tilburg University.

O.J. BOXMA (1994). Polling systems. K.R. APT, A. SCHRIJVER, N.M. TEMME (eds.). *From Universal Morphisms to Megabytes: a Baayen Space Odyssey*, (CWI, Amsterdam), 215–230.

O.J. BOXMA, G.M. KOOLE (eds.) (1994). *Performance Evaluation of Parallel and Distributed Systems - Solution Methods. Parts I and II.* CWI Tract 105,106; Part I 1–156, Part II 157–376.

O.J. BOXMA, G.M. KOOLE, I. MITRANI (1994). *A Two-queue Polling Model with a Threshold Service Policy.* Preprint, University of Newcastle, to appear in a Liber Amicorum for E.G. Coffman, Jr.

O.J. BOXMA, P.R. DE WAAL, A.C.J.M. SMIT (1994). *Multiserver Queues with Impatient Customers.* Report Koninklijke/Shell Lab. Amsterdam, AMER 94.002.

System and Control Theory (BS3)

Staff

- Prof. dr. ir. J.H. van Schuppen (Group leader and senior researcher; part time 70%; CWI funded; also Director of the Systems and Control Theory Network and full Professor at University of Groningen)
- Prof. dr. J.M. Schumacher (Senior researcher; part time 80%; CWI funded; also full Professor at University of Tilburg)
- Dr. A.J. van der Schaft (Senior researcher; part time 10%; CWI funded)
- Dr. A.A. Stoorvogel (Senior researcher; part time 10%; funded by KNAW through a fellowship and in part by CWI)
- Prof. J. Rosenthal (Long term visitor; from 1994:07:01 till 1995:07:01; funded in part by CWI)
- Dr. G.M. Koole (Post-doc; from 1994:01:01 till 1994:09:01; funded by NWO through a NFI project)
- Dr. ir. P.R. de Waal (Post-doc; since 1994:10:01; funded by NWO through a NFI project)
- Dr. ir. H.J.C. Huijberts (Seconded researcher; from 1994:06:01 till 1995:01:01; part time 40 %; funded by the CEC through DRIVE II Project DYNA)
- Drs. J. de Does (Doctoral student (OIO); till 1994:03:01; funded by Netwerk Systeem- en Regeltheorie, University of Groningen)
- Ir. A.A.F. Overkamp (Doctoral student (OIO); CWI funded)
- Drs. J.M. van den Hof (Doctoral student (OIO); CWI funded)

External Funding and International Cooperation

National projects:

Project NFI 62-354
- *Performance analysis and control of distributed computer systems.* Funded by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) through the Nationale Faciliteit Informatica (NFI), BS 2.4 and BS3.6.

Projects funded by the Commission of the European Communities (CEC):
- *System identification*, funded through the SCIENCE program of the CEC, for work visits and workshops, BS3;
- *System identification*, funded through the Human Capital and Mobility Program of the CEC, for work visits and workshops, BS3;
- *DYNA*, funded through the DRIVE II Program of the CEC, BS3.

Scientific Report

J.H. van Schuppen, A.A. Stoorvogel, and H.J.C. Huijberts. Stoorvogel and Van Schuppen investigated the relation between H-infinity optimization, optimal stochastic control with an exponential-of-quadratic criterion, and maximum likelihood identification. Lectures on this research topic were presented at the University of Padova, at the IFAC Symposium System Identification, and at the NATO ASI 'From identification to learning'. A short manuscript appeared in the Proceedings of an IFAC Symposium and a long manuscript was submitted for inclusion in the Proceedings of a NATO ASI.
Huijberts and Van Schuppen performed research on routing control of a motorway network as part of DRIVE II Project DYNA. Cooperation and contacts took place with the other partners of this project. The final report was submitted in December 1994. It will be published as a CWI report in 1995.

The joint work with G. Picci (Padova) on the finite stochastic realization problem was continued. The classification of primes in the positive matrices was pursued. A manuscript has been written and remains to be completed.

J.M. Schumacher, A.J. van der Schaft, and J. Rosenthal. Schumacher completed a series of two manuscripts with A.H.W. Geerts on the description of impulsive-smooth behavior. The manuscripts were published as CWI reports and submitted for publication in *Automatica*. Impulsive-smooth behavior may occur in systems containing both discrete and continuous parts (so-called *hybrid systems*). Research in this area has continued in joint work of Schumacher and Van der Schaft, which now aims at giving rules for jumps in systems with switches induced by the continuous state. Hybrid systems will also be the subject of research in a Ph.D. project that was proposed by Schumacher together with P.P.J. van den Bosch (Eindhoven), and that will be carried out in Eindhoven and Tilburg under the supervision of the proposers, with funding provided by SOBU (Samenwerkingsorgaan Brabantse Universiteiten).
The cooperation of Rosenthal and Schumacher with U. Helmke (Regensburg) and M.S. Ravi (East Carolina Univ.) has focused on topics around the realization of homogeneous systems and compactifications of the space of linear systems. Two manuscripts were produced that were accepted for presentation at the IFAC conference in Nantes, one (with Ravi) on an algorithmic approach and one (with Helmke) on a controllability test. Extended versions for journal submission are under preparation.
Cooperation of Rosenthal and Schumacher with J.C. Willems (Groningen) on a simplified proof of the main result in pole placement by static output feedback for generic linear systems has led to a manuscript that was published as a CWI report and submitted to *Systems & Control Letters*. Continued work of M.K.K. Cevik (Istanbul) and Schumacher on robustness in connection with the regulator problem led to a manuscript submitted to *Linear Algebra and Its Applications*.
Work of Schumacher for Tilburg University has included supervision of a Ph.D. project on cooperation and coordination, carried out by A.J.T.M. Weeren, and collaboration with T.P. Kocken (ING Bank) on a portfolio selection problem.

G.M. Koole. Koole investigated problems of load balancing with a delayed sharing information pattern and initiated research on team problems with a discrete state and action set.

P.R. de Waal. De Waal started research on models for control of decentralized computer systems. He has set up an investigation of team problems with a discrete state and action set.

J. de Does. The affiliation of De Does with CWI, which was financed by the Systems and Control Theory Network in the Netherlands, ended on March 1, 1994. De Does defended his Ph.D. thesis on December 6 at Tilburg University. Also several journal papers by De Does appeared in 1994.

A.A.F. Overkamp. Overkamp worked on the supervisory control problem for nondeterministic systems with the use of failure semantics. The first results were presented at a conference on discrete event systems in Sophia Antipolis. Extended results have led to a paper submitted to a conference. A manuscript for a journal is in preperation. Overkamp also worked on decentralized control problems for discrete event systems.
With Van Schuppen, Overkamp studied control problems for discrete event systems and hybrid systems. They published an expository paper.

J.M. van den Hof. Van den Hof studied the realization of positive linear systems. A short paper appeared in the Proceedings of the 33rd CDC and a long manuscript was submitted to a journal. Structural identifiability of case studies from RIVM (Rijksinstituut voor Volksgezondheid en Milieubeheer, National Institute for Public Health and Environmental Protection), Bilthoven, has been studied and generalized.

Organisation of Conferences, Workshops, Courses, etc.

- Organization of the 3rd ERNSI Workshop System Identification, that was held September 21-23, 1994 in Noordwijkerhout. Co-Organizer J.H. van Schuppen.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- Work visit Department of Mathematics, University of Regensburg, Germany, January 12–14, J.M. Schumacher. Cooperation with U. Helmke; lecture *Topology and linear systems.*
- Rijksinstituut voor Volksgezondheid en Milieubeheer (National Institute for Public Health and Environmental Protection), Bilthoven, January 13, and many other days during 1994, J.M. van den Hof, J.H. van Schuppen. Cooperation on research project with Dr. P.H.M. Janssen and Dr. P.S.C. Heuberger.
- ASCOM Hasler B.V., Arnhem, January 14, J.H. van Schuppen. Discussion on potential project on

access control of motorways.

- Hague Consulting Group B.V., The Hague, January 18, J.H. van Schuppen. Discussion on project DYNA.
- Laboratory of Theoretical Electricity, University of Gent, January 20–21, J.H. van Schuppen. Cooperation with Prof. R.K. Boel on load balancing.
- Work visit to the research institute LADSEB in Padova, Italy, February 9–23, J.H. van Schuppen (cooperation with Prof. G. Picci on system theory). Lecture *System identification, LEQG optimal stochastic control, and H-infinity optimal control with an entropy criterion*, at the Department for Electrical Engineering, University of Padova, Padova, Italy, on February 17, 1994. Financed by SCIENCE Project System Identification and by LADSEB.
- Participation in the *13th Benelux Meeting on Systems and Control*, Veldhoven, March 2–4, J.M. Schumacher, J.M. van den Hof, A.A.F. Overkamp. Lecture by J.M. Schumacher: *The regulator problem with robust stability.* Lecture by J.M. van den Hof: *Structural identifiability from observations in case of a given input sequence.* Lecture by A.A.F. Overkamp: *Supervisory control for nondeterministic systems.*
- Participation in QMIPS Workshop, Imperial College, London, United Kingdom, April 12–14, G. Koole. Lecture *Nearly optimal policies for asymmetric polling models.*
- Participation in *Workshop Data assimilation in large-scale nonlinear models*, Delft, April 25, J.H. van Schuppen. Financed in part by the Waterloopkundig Laboratorium (Delft Hydraulics).
- Participation in *ACP94, Workshop on Algebra of Communicating Processes*, Utrecht, May 16–17, A.A.F. Overkamp.
- Participation in meeting of DYNA project, Rome, Italy, May 31 – June 2, J.H. van Schuppen.
- Participation in *Summer School on Model Based Predictive Control*, Zeist, June 6, 9, and 10, J.H. van Schuppen.
- Participation in *11th International Conference on Analysis and Optimization of Systems - Discrete Event Systems*, Sophia Antipolis, France, June 15–17, A.A.F. Overkamp and J.H. van Schuppen. Van Schuppen was member of the Scientific Committee, organizer of an invited session on hybrid systems, and chairman of a plenary session. Lecture of A.A.F. Overkamp *Supervisory control for nondeterministic systems.*
- Work visit to INRIA Centre Sophia Antipolis, Sophia Antipolis, France. June 13–22, 1994, J.M. van den Hof and A.A.F. Overkamp. Lecture of J.M. van den Hof *Realization of positive linear systems.* Lecture of A.A.F. Overkamp *Partial observation and partial specification in nondeterministic discrete event systems.*
- Participation in *1994 IEEE International Symposium on Information Theory,* Trondheim, Norway, June 27 – July 1, 1994, J. Rosenthal. Lecture *An ideal theoretic approach for classifying high rate convolutional codes.*
- Participation in *10th IFAC Symposium on System Identification*, Copenhagen, Denmark, July 2–6, J.H. van Schuppen. Lecture of Van Schuppen and Stoorvogel presented by Van Schuppen *An H_∞-parameter estimator and its interpretation*, on July 6. Meeting of team leaders of ERNSI, J.H. van Schuppen coordinator. Financed in part by SCIENCE Project System Identification.
- Work visit to Centre for Research in Environmental Systems and Statistics, University of Lancaster, Lancaster, United Kingdom, July 13–17, J.H. van Schuppen. Discussions with P.C. Young, A. Chotai, and C.J. Taylor on project DYNA.
- Participation in the *Fourth Conference of the International Linear Algebra Society (ILAS)*, Rotterdam, August 15–19, J. Rosenthal and J.M. Schumacher. Lecture by J.M. Schumacher: *Realization of ℓ_2-behaviors.* Lecture by J. Rosenthal: *Grassmannians, a link between linear algebra, linear systems theory and geometry.*
- Participation in NATO Advanced Study Institute 'From identification to learning', Como, Italy, August 22 – September 2, 1994, J.M. van den Hof and J.H. van Schuppen. Invited lectures of J.H. van Schuppen *Interaction of identification and control: Adaptive control of Gaussian stochastic control systems* and *System identification, LEQG optimal stochastic control, and H_∞ optimal control with entropy criterion.* Lecture of J.M. van den Hof *Results on the realization of positive linear systems.* Participation of J.H. van Schuppen financed in full and of J.M. van den Hof financed in part by conference organizers.
- Colloquium Systems and Control Theory Network, September 12, 1994, Utrecht. Lecture of J.M. van den Hof *Realization of positive linear systems and identifiability of compartmental systems.*
- Participation in 3rd ERNSI Workshop System Identification, September 21–23, 1994, Noordwijkerhout, J.M. van den Hof, A.A. Stoorvogel, and J.H. van Schuppen (Co-organizer). Lecture by A.A. Stoorvogel *Relation between H_∞ and*

Kalman filtering with application to identification. Lecture of J.M. van den Hof *Positive realizations.* Financed in full by SCIENCE Project System Identification.

- Work visit to Prof. J.E. Rooda, Department of Mechanical Engineering, Eindhoven University of Technology, Eindhoven, September 28, 1994, J.H. van Schuppen and A.A.F. Overkamp. Discussion on hybrid systems.
- Seminar at Department of Mathematics, University of Groningen, October 6, J. Rosenthal. Title: *The behavior of convolutional codes.*
- Work visit to Prof. R.K. Boel, University of Gent, Belgium, October 24 and 25, 1994, J.H. van Schuppen. Discussions on discrete event systems and control of queueing systems.
- Participation in audit of DRIVE II project DYNA, Brussels, Belgium, October 25, 1994 and preparation on October 24, J.H. van Schuppen.
- Colloquium talk at Department of Mathematics, Eindhoven University of Technology, November 2, J. Rosenthal. Lecture *On the algebraic structure of a convolutional code.*
- Seminar at Department of Electrical Engineering, Eindhoven University of Technology, November 16, J. Rosenthal. Title: *An elementary proof of Wang's pole placement result.*
- Participation in meeting of DRIVE II Project DYNA, Paris, France, November 29, 1994, H.J.C. Huijberts, J.H. van Schuppen. Financed in full by Project DYNA.
- Participation in First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems, Paris, France, November 30 – December 2, 1994. H.J.C. Huijberts, J.H. van Schuppen. Financed in full by Project DYNA.
- Participation in Workshop on Stochastic Models, University of Leiden, Leiden, December 12–13, 1994. P.R. de Waal.
- Participation in the 33rd Conference on Decision and Control, Lake Buena Vista, Florida, USA, December 14–16, 1994, J.M. van den Hof, A.A.F. Overkamp, and J.H. van Schuppen. Lecture of L. Gerencsér, J.H. van Schuppen, J. Rissanen, and Z. Vágó, presented by J.H. van Schuppen *Stochastic complexity and the selftuning regulator.* Lecture of J.M. van den Hof and J.H. van Schuppen presented by J.M. van den Hof *Realization of positive linear systems using polyhedral cones.* J.H. van Schuppen was chair of the session System identification and system theory.

Memberships of Committees and Other Professional Activities

J.H. van Schuppen:
Outside appointment
- Director of the Netwerk Systeem- en Regeltheorie (Systems and Control Theory Network) and as such Professor at the University of Groningen (part time 0.3) since 1990.

Editorial work
- Co-Editor (Editor-in-Chief) of the journal *Mathematics of Control, Signals and Systems* since 1994.
- Department Editor of *Journal of Discrete Event Dynamic Systems* since 1990.

Organizational and administrative tasks
- Coordinator of the project *System identification* that is funded by the Commission of the European Communities through the SCIENCE Program, 1992–1995.
- Coordinator of the project *System identification* that is funded by the Commission of the EC through the Human Capital and Mobility Program, 1993–1996.
- Secretary of the Adviescommissie van de afdeling Besliskunde, Statistiek en Systeemtheorie (Advisory Committee of the Department of Operations Research, Statistics, and System Theory).

Conference organization
- Member of the Steering Committee, of the International Symposia on the Mathematical Theory of Networks and Systems since 1989.
- Member of the EUCA Council since 1994. (EUCA = European Community Control Association).
- Member of the International Program Committee of the 1995 European Control Conference. Handled the review process of selected papers.
- Member of IFAC Technical Committee on Modeling, Identification, and Signal Processing since 1994. (IFAC - International Federation of Automatic Control)
- Member of IFAC Technical Committee on Stochastic Systems since 1994.
- Organizer of a special session on hybrid systems at the *INRIA Conference on Systems and Control - Discrete Event Systems* that was held June 15–17, 1994 at Sophia Antipolis, France. Member of Scientific Committee. Handled the review process of selected papers.
- Organizer of the special session *System identification and system theory* at the *33rd Conference on Decision and Control* that was held December 14–16, 1994 at Lake Buena Vista, Florida, USA.

Doctoral thesis committees
- Member of doctoral thesis committee of Dr. ir. R.L.M. Peeters, Free University, Amsterdam, February 8, 1994.
- Member doctoral thesis committee of Dr. ir. D.K. de Vries, Delft University of Technology, September 26, 1994.

J.M. Schumacher:
Outside appointment
- Professor of Mathematics (0.2), Tilburg University, since 1987.

Editorial work
- Member of editorial board, SIAM Journal on Control and Optimization, since 1990.

Organizational and administrative work
- Committee preparing the foundation of the Dutch Institute of Systems and Control (DISC).
- Chairman, working group on System and Control Theory, Dutch Foundation for Measurement and Control Technology (SMBT), until March 1994.

Conference organization
- Program Committee, Benelux Meeting on Systems and Control 1994.
- International Program Committee, IFAC Conference on System Structure and Control (Nantes, July 5–7, 1995).
- Organizing Committee, ERNSI Econometric Workshop *Dynamic Models in Economics and Finance*, Oegstgeest, May 30 – June 2, 1995.

Doctoral thesis committees
- Ph.D. committee J.M.A. Scherpen, Balancing for nonlinear systems, Twente University, March 18.
- Ph.D. committee J.S. Luo, Stability and performance robustness analysis and design of automatic control systems, Delft University of Technology, March 28.
- Ph.D. committee L.C.G.J.M. Habets, Algebraic and computational aspects of time-delay systems, Eindhoven University of Technology, June 1.
- Ph.D. committee P. Bujakiewicz, Maximum weighted matching for high index differential algebraic equations, Delft University of Technology, June 15.
- Ph.D. committee P.M.M. Bongers, Modeling and identification of flexible wind turbines and a factorizational approach to robust control, Delft University of Technology, June 16.
- Ph.D. committee M. Weiss, Riccati equations in Hilbert spaces: a Popov function approach, University of Groningen, June 20.
- Ph.D. committee P.F. Lambrechts, The application of robust control theory concepts to mechanical servo systems, Delft University of Technology, September 20.
- Ph.D. committee E.J. van Henten, Greenhouse climate management: an optimal control approach, Wageningen Agricultural University, December 20.

Other committees
- Ph.D. advisory committee C. Simões, Department of Applied Mathematics, Twente University.
- Ph.D. advisory committee F. Kraffer, Department of Applied Mathematics, Twente University.
- Graduation committee A. Boverhof, Department of Applied Mathematics, Twente University, December 8.

Visitors

- Prof. D. Aeyels, University of Gent, Gent, Belgium, March 22. Lecture *Pole assignment by periodic output feedback for linear discrete time systems.*
- Prof. Ü. Kotta, Estonian Academy of Sciences, Tallinn, Estonia, April 22. Lecture *Linearization of discrete-time nonlinear systems via state feedback.*
- Dr. P. Kozak, Czech Academy of Sciences, Prague, Czech Republic, May 2–6. Lecture on May 2 *Supervisory control of real-time discrete event systems with hybrid controllability of events.*
- Prof. M.S. Ravi, East Carolina University, Greenville, Carolina, USA, July 5. Lecture *Realization theory of autoregressive systems.*
- Drs. J. Schut, Twente University, Enschede, July 19.
- Prof. A.V. Sarychev, University of Aveiro, Aveiro, Portugal, September 8. Lecture *Second-order optimality conditions for Pontryagin extremals.*
- Mr. C.J. Taylor, Centre for Research on Environmental Systems and Statistics, University of Lancaster, Lancaster, United Kingdom, September 8–9. Lecture on September 8 *True digital control.*
- Prof. H. Kimura, Osaka University, Osaka, Japan, September 12. Lecture *Chain-scattering approach to H-infinity control.*
- Prof. L. Gerencsér, Computer and Automation Institute, Hungarian Academy of Sciences, Budapest, Hungary, September 19–20.
- Prof. M. Spathopoulos, University of Strathclyde, Glasgow, UK, September 20–21. Lecture *Distributive control for DES using logical objectives.*
- Dr. C.T. Chou, Dept. Economics and Econometrics, Free University, Amsterdam, October 4. Lecture *Geometry of classes of linear systems.*

- Dr. S. Čelikovský, Institute of Information Theory and Automation, Czech Academy of Sciences, Prague, Czech Republic, November 15. Lecture *Nonsmooth feedback stabilization of nonlinear systems.*
- Prof. U. Helmke, University of Regensburg, Regensburg, Germany, November 21–22. Lecture November 22 *Isospectral flows and numerical linear algebra.*

Doctoral degrees

- A.L. Rijkeboer, *Differential Geometric Models for Time-Varying Coefficients of Autoregressive Processes*, Tilburg University, April 29. Promotors: M.H.C. Paardekooper, J.M. Schumacher. Copromotor: J.C. Engwerda.
- J. de Does, *The Gap Topology for Linear Systems. A Geometric Approach*, Tilburg University, December 6. Promotor: J.M. Schumacher.

Miscellaneous (Consultancy, contract research, and relations with industry)

- Project DYNA. Contacts on routing control of a motorway network with Hague Consulting Group B.V., Rijkswaterstaat Adviesdienst Verkeer en Vervoer, Delft University of Technology, and the University of Lancaster.
- Consultancy for Direct Advertisement Company. P.R. de Waal with O.J. Boxma.
- Demonstration day CWI-in-Bedrijf, October 7. J.M. van den Hof en J.H. van Schuppen.

Werkgroep Systeemtheorie (Seminar Systems and Control)
The purpose of the Werkgroep Systeemtheorie is to study new developments of system and control theory. The doctoral students of the research group and the senior staff members are the main beneficiaries of this activity. A small number of participants from universities in The Netherlands participate in the study group. At the meetings part of a book or papers are presented by one of the participants.

The following topics were covered:

- System and control theory of game and team problems, Spring 1994. Organizer J.H. van Schuppen.
- Algebro-geometric methods for linear systems, Fall 1994. Organizers J. Rosenthal and J.M. Schumacher.

Public relations
Open day, 9 October. J.M. van den Hof en J.H. van Schuppen.

Doctoral students taking courses
Training course in presentation techniques. J.M. van den Hof and A.A.F. Overkamp.

Participation in course *Process modelling and dynamics*, Graduate program of System and Control Theory Network, Winter trimester 1994/95, J.M. van den Hof.

Papers in Journals and Proceedings

J. DE DOES, J.M. SCHUMACHER (1994). Interpretations of the gap topology: a survey. *Kybernetika 30*, 105–120.

J. DE DOES, J.M. SCHUMACHER (1994). Continuity of singular perturbations in the graph topology. *Linear Algebra and Its Applications 205/206*, 1121–1144.

J.H. VAN SCHUPPEN (1994). Stochastic realization of a Gaussian stochastic control system. *Acta Applicandae Mathematicae 35*, 193–212.

J.H. VAN SCHUPPEN (1994). Tuning of Gaussian stochastic control systems. *IEEE Trans. Automatic Control 39*, 2178–2190.

L. GERENCSÉR, GY. MICHALECZKY, R. OBER, J.H. VAN SCHUPPEN, Z. VÁGÓ (1994). Balancing for identification and control. U. HELMKE, R. MENNICKEN, J. SAURER (eds.). *Systems and networks: Mathematical theory and applications - Proceedings of the International Symposium MTNS'93*, Akademie Verlag, Berlin, 141–144.

J.M. VAN DEN HOF, J.H. VAN SCHUPPEN (1994). Realization of positive linear systems using polyhedral cones. *Proceedings of the 33rd Conference on Decision and Control,* December 14–16, Lake Buena Vista, USA, 3889–3893.

A. OVERKAMP (1994). Supervisory control for nondeterministic systems. *Proceedings of the 11th International Conference on Analysis and Optimization of Systems: Discrete Event Systems,* June 15–17, Sophia-Antipolis, France, 59–65.

G. PICCI, J.M. VAN DEN HOF, J.H. VAN SCHUPPEN (1994). Positive linear algebra for stochastic realization of finite-valued processes. U. HELMKE, R. MENNICKEN, J. SAURER (eds.). *Systems and networks: Mathematical theory and applications - Proceedings of the International Symposium MTNS'93*, Akademie Verlag, Berlin, 425–428.

A.A. STOORVOGEL, J.H. VAN SCHUPPEN (1994). An H_∞-parameter estimator. *Proceedings of the 10th IFAC Symposium on System Identification,* Danish Automation Society, Copenhagen, 3267–3270.

A.J.T.M. WEEREN, J.M. SCHUMACHER, J.C. ENGWERDA (1994). Asymptotic analysis of Nash equilibria in nonzero-sum linear-quadratic differential

games: the two-player case. M. BRETON, G. ZACCOUR (eds.). *Preprint Volume Sixth International Symposium on Dynamic Games and Applications*, Grande École des Hautes Études Commerciales, Université de Montréal, Canada, 30–40.

CWI Reports

BS-R9431 A.H.W. GEERTS, J.M. SCHUMACHER. *Impulsive-smooth behavior in multimode systems. Part I: State-space and polynomial representations.*

BS-R9432 A.H.W. GEERTS, J.M. SCHUMACHER. *Impulsive-smooth behavior in multimode systems. Part II: Minimality and equivalence.*

BS-R9411 A.A.F. OVERKAMP. *Supervisory control for nondeterministic systems.*

BS-R9438 J. ROSENTHAL, J.M. SCHUMACHER, J.C. WILLEMS. *Generic eigenvalue assignment by memoryless real output feedback.*

BS-R9434 A.A. STOORVOGEL, J.H. VAN SCHUPPEN. *An H_∞-parameter estimator and its interpretation.*

BS-N9401 R.A.B. VAN DER GEEST. *Load sharing in models with communication delays.*

Other Publications

M.K.K. CEVIK, J.M. SCHUMACHER. *The regulator problem with robust stability*, accepted for presentation at and inclusion in the proceedings of the IFAC Conference on System Structure and Control, Nantes, July 5–7, 1995.

J. DE DOES (1994). *The Gap Topology for Linear Systems - A Geometric Approach*, Doctoral thesis, University of Tilburg, Tilburg, December 6.

L. GERENCSÉR, J.H. VAN SCHUPPEN, J. RISSANEN, Z. VÁGÓ (1994). *Stochastic complexity and the self-tuning regulator*. Preprint. Submitted for publication in a journal.

U. HELMKE, J. ROSENTHAL, J.M. SCHUMACHER, *A controllability test for behavior systems*, accepted for presentation at and inclusion in the proceedings of the IFAC Conference on System Structure and Control, Nantes, July 5–7, 1995.

J.M. VAN DEN HOF (1994). *Realization of Positive Linear Systems*. Preprint, submitted for publication to a journal.

H.J.C. HUIJBERTS, J.H. VAN SCHUPPEN (1994). *Routing Control of a Motorway Network*. Final report of CWI team of Project DYNA, submitted in December.

A. OVERKAMP (1994). *Control of Nondeterministic Discrete Event Systems Using Failure Semantics*. Preprint, submitted for presentation at a conference.

A. OVERKAMP, J.H. VAN SCHUPPEN (1994). Control of discrete event systems - Research at the interface of control theory and computer science, K. APT, L. SCHRIJVER, N. TEMME (eds.). *From universal morphisms to megabytes: A Baayen space odyssey*, Stichting Mathematisch Centrum, Amsterdam, 453–467.

M.S. RAVI, J. ROSENTHAL, J.M. SCHUMACHER. *A realization theory for homogeneous systems: an algorithmic approach*, accepted for presentation at and inclusion in the proceedings of the IFAC Conference on System Structure and Control, Nantes, July 5–7, 1995.

J.M. SCHUMACHER (1994). Review of: G. Basile, G. Marro, Controlled and Conditioned Invariants in Linear System Theory, *IEEE Transactions on Automatic Control AC-39*, 250–251.

J.M. SCHUMACHER (1994). Review of: H.F. Chen, L. Guo, Identification and stochastic adaptive control, *Mededelingen Wiskundig Genootschap 37*, 302–303.

Statistical Image Analysis (BS4)

Staff

- A.J. Baddeley, group leader (until February 1)
- A.J. Cabo, oio (until June 1)
- K.O. Dzhaparidze, senior researcher
- R.D. Gill, advisor (until June 1)
- F.C.A. Groen, advisor (until June 1)
- H.J.A.M. Heijmans, senior researcher
- R. Helmers, senior researcher
- R. van der Horst, programmer (0.5 fte)
- R.H.P. Janssen, aio (TUD)
- M.S. Keane, group leader (0.8 fte from February 1)
- M.N.M. van Lieshout, aio (VUA, until March 1)
- A. Mancham, aio (NWO, from October 1)
- I. Molchanov, postdoctoral fellow (NWO, from May 1)
- P. Nacken, oio (SION, until May 1)
- F.K. Potjer, oio (from October 1)
- A.G. Steenbeek, programmer (0.5 fte)
- S.J. van Strien, advisor (UvA, from October 1)

Scientific Report

The year 1994 has brought considerable change to BS4. On February 1, Keane took over the group leadership from Baddeley, who returned to Australia. Three Ph.D. theses of high quality were successfully defended, and the resulting vacancies were filled by

two new Ph.D. students. The group broadened its research, keeping the core activity in image analysis and adding many topics in spatial stochastics to the investigations. From 1995 on, the name will be changed to Image Analysis and Spatial Stochastics. Two new weekly seminars were initiated by Keane, one called the Spatial Stochastics Seminar (Tuesdays), and the other being the Dynamics in Amsterdam (Thursdays), the latter in collaboration with our new advisor Van Strien and also Verduyn Lunel, both from the University of Amsterdam. Support for Dynamics in Amsterdam from AM was important, through the participation of de Vries and Diekmann. The following short details are indicative of the activity of BS4 in 1994.

A method for determining the explicit expression of the Gaussian likelihood, developed by K. Dzhaparidze and R.H.P. Janssen, is based on an extension of the classical Christoffel-Darboux formula for the Szegö polynomials associated with a class of spectral distribution functions, including functions with rational densities. The results were reported at the *12th Prague Conference on Information theory, Statistical decision functions and Random processes,* August 29 – September 2, 1994 and the Workshop on Stochastics and Finance, September 5–10, 1994, Berlin. As is shown in the CWI Report BS-R9418, the method is applicable even in the more complicated case of matrix-valued spectral distribution functions.

Dzhaparidze and Janssen completed a paper on a stochastic approach to the Abel-Goncharov interpolation problem, which leads to a class of interpolation formulas useful e.g. for characterization of the Arithmetic-Geometric mean relationship or expansion of the Hellinger integral.

K. Dzhaparidze and P. Spreij (Free University, Amsterdam) contributed to the project 'Statistical Inference for Stochastic Processes' (in persuance of the Human Capital programme of the EEC) by publishing 2 papers and submitting 1 paper.

A.J. Cabo completed her Ph.D. thesis on set functionals in stochastic geometry. The results of Ch.5 in this thesis uses the material of the CWI Report BS-R9418 by Cabo and Janssen.

An important activity is that of geometry-based image processing methods, in particular, mathematical morphology. The research carried out in BS4 is mainly focussed upon theoretical issues. An important problem in mathematical morphology is the design of morphological filters. Heijmans has developed some new methods for the construction of morphological filters. His work has resulted in a number of new filters for image restoration. Recently, Heijmans and Potjer have started investigations in the direction of connectivity filters. Such filters can be used for multiscale image decompositions.

In collaboration with P. Maragos (Georgia Institute of Technology) Heijmans is writing a paper on the so-called 'slope transform', the morphological analogue of the Fourier transform.

Nacken's work on (i) mathematical morphology based on chamfer metrics, and (ii) the hierarchical description of images has been finished. His work has resulted in a dissertation.

The research of R. Helmers in the general area of computer intensive stochastics was mainly concerned with the study of various bootstrap resampling schemes. He obtained a new result concerning bootstrapping the local time of the empirical process. Further, with M. Wegkamp, a paper on wild bootstrapping in finite populations with auxiliary information was almost completed. With D. Gilat a strong law for generalized L-statistics with dependent data was obtained. Joint research with R. Zitikis focussed on a problem in spatial statistics. Consider a single realization of an inhomogeneous spatial Poisson process, observed only through a 'window'. The problem is to estimate the intensity function and to develop an asymptotic theory for suitable estimators and their bootstrapped counterparts in this setup. Finally, with S.N. Lahiri, a joint research project concerning wild bootstrap confidence intervals in nonparametric regression was started.

Keane has published papers in 1994 on fractal coding of monochrome images (together with scientists from Delft University of Technology and Philips Research Laboratory in Eindhoven), skewness of distributions (with mathematicians from Toronto and Corvallis), simulation of stochastic processes (in collaboration with O'Brien) and central limit theorems for a process suggested by Wellner (Seattle) (in collaboration with Hooghiemstra from Delft). In addition, a first version of his work with Hamachi (Fukuoka) on classification of non-commutative Bernoulli schemes has appeared, and a large article on this subject is almost completed. Mancham has started investigations under Keane's direction concerning stochastic lung models, in collaboration with Delft University of Technology and the Daniel den Hoed clinic in Rotterdam.

Baddeley, Van Lieshout and Kendall (University of Warwick) investigated extensions of Baddeley's and Van Lieshout's area-interaction point process, replacing area by other geometric measures such as the Euler characteristic and various surface integrals. Exciting connections to semi-Markov properties of

random closed sets have been found.

Baddeley, Van Lieshout and Dr. J. Möller (University of Aarhus) finished their research on Markov properties of cluster process. In particular, they proved the surprising result that Poisson cluster processes, the standard model of clustering in point processes, belong to the class of nearest-neighbour Markov processes.

Van Lieshout and Baddeley proposed a new statistic for quantifying the strength and range of interpoint interactions in a point pattern. The statistic is based on a re-interpretation of a central result of Palm distribution theory. A report has been accepted for publication in *Statistica Neerlandica.* Extensions to multivariate point processes are the topic of further research.

Van Lieshout completed her Ph.D. thesis entitled 'Stochastic geometry models in image analysis and spatial statistics' which was defended at the Free University, Amsterdam on April 7.

Molchanov studied statistical problems related to random closed sets. Special attention was paid to statistical problems for samples of independent identically distributed random compact sets. Molchanov and Prof.Stoyan (TU Bergakademie Freiberg) analyzed models of random polyhedral particles and worked out statistical methods applicable to statistical analysis of particle samples. The corresponding paper has been submitted to the journal *Statistical Models.*

Baddeley and Molchanov found a new way of averaging of random closed sets based on the concept of their distance function. This concept gives a possibility to average effectively non-convex sets. The report will be finished in 1995.

Mancham and Molchanov began working on averaging and stochastic models of star-shaped sets. Molchanov continued his work on abstract shapes and landmarks in functional spaces. The corresponding results are accepted as a lecture (Molchanov) and a poster (Mancham) at the conference *Current Issues in Shape Analysis* (April 5–7, Leeds, UK).

Molchanov continued his studies of statistical problems for stationary random closed sets, and, in particular, Boolean models. The Boolean model is the most used model of overlapping particle systems. Molchanov and Stoyan published a paper, where asymptotic variances for some classical estimators for parameters of the Boolean model were found. This subject was pursued further by Molchanov, who found a way to estimate all parameters of the Boolean model via higher-order characteristics of special point processes related to them. These results will be published in 1995. Further studies in this direction will be done with Dr. L. Heinrich (TU Bergakademie Freiberg). Heinrich and Molchanov proved a central limit theorem for a class of random measures defined for the Boolean model (and even in more general case), which includes most of earlier results on limit theorems in statistics of the Boolean model. This paper will be finished in 1995. The cooperation with TU Bergakademie Freiberg will be continued further.

Molchanov completed a report on limit theorems for uncovered regions for high-intensity Boolean models. It is shown that the 'typical' uncovered region looks like a Poisson polyhedron and the corresponding distribution parameters are found. An earlier result of P. Hall on this subject has been considerably extended and a new proof is given. The corresponding paper is submitted for publication.

Molchanov worked on random sets techniques in statistical image analysis. In particular he dealt with random sets (or set-valued processes) defined by grey-tone images. This research will be finished in 1995.

Molchanov was working on a bibliography on random sets and related topics in probability, statistics and image analysis. The completed parts are distributed via *Morphological Digest* edited by Heijmans.

Molchanov started a lecture notes 'Estimation of the Boolean model parameters', which will be submitted to publication as a book. These notes are intended both to engineers and to statisticians interested in spatial statistics. They will contain a survey on all existing estimation methods for the Boolean model, recommendation related to their applications, and several examples computed for real microscopic pictures.

Organisation of Conferences, Workshops, Courses, etc.

- Seminar *Spatial Stochastics*: A weekly seminar on mathematical aspects of image analysis, stochastic geometry, and spatial statistics. Tuesdays.
- Seminar *Dynamics in Amsterdam*: A weekly seminar on dynamical systems and ergodic theory. Thursdays.
- Mini-symposium on Image Analysis, June 10, CWI, organized by H.J.A.M. Heijmans and P. Nacken
- Lunteren conference on Stochastics, November 14–16. Organized by R. Helmers (joint with J.Th. Runnenburg (Amsterdam), W.R. van Zwet (Leiden)).
- Toekomst van de Visie, Twente, November 11.

Organized by M.S. Keane in collaboration with the working group ITW of the Dutch Mathematical Society; other organizers were Van Beckum (Twente) and Ter Morsche (Eindhoven).

- International Workshop on Ergodic Theory, Delft, August 15–29. Organized by M.S. Keane, together with Bedford, Dekking, and Kraaikamp (all from Delft University of Technology).

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- Meeting of the research group on the project 'Statistical inference for stochastic processes', Université Paris VI, France, January 26–28: K. Dzhaparidze (+ lecture).
- 12th Prague Conference on Information theory, Statistical decision functions and Random processes, Czech Republic August 29–September 2: K. Dzhaparidze and R.H.P. Janssen (+ lecture).
- Workshop on Stochastics and Finance, Berlin, September 5–10: K. Dzhaparidze (+ lecture).
- Symposium on Orthogonal Polynomials, Namen, Belgium, December 8: K. Dzhaparidze and R.H.P. Janssen (+ lecture).
- Course *Random Structures*, Fontainebleau, France, September 5–6: H.J.A.M. Heijmans.
- Workshop *Mathematical Morphology and its Applications to Signal Processing II*, Fontainebleau, France, September 7–9: H.J.A.M. Heijmans (+ lecture).
- Working visit (+ lecture) Inst. für Automation, Technische Universität Wien, September 28–October 2: H.J.A.M. Heijmans.
- Working visit, Dept. of Electrical Engineering, Georgia Institute of Technology, Atlanta, USA, November 9–12: H.J.A.M. Heijmans.
- *IEEE International Conference on Image Processing* (+ lecture), Austin, Texas, USA, November 14–16: H.J.A.M. Heijmans.
- Working visit (+ lecture), Dept. of Electrical and Computer Engineering, Johns Hopkins University, Baltimore, Maryland, USA, November 17–20: H.J.A.M. Heijmans.
- Working visit (+ two lectures), Dept. of Electrical Engineering and Computer Science, University of Illinois at Chicago, Chicago, Illinois, USA, November 20–22: H.J.A.M. Heijmans.
- Minisymposium in honour of Jaroslav Hájek, Prague, Czech Republic, June 8: R. Helmers (+ lecture).
- Working visit City University New York, Queens College, USA, June 13: R. Helmers.
- 26th Symposium on the Interface: Computing Science and Statistics: Computationally intensive Statistical Methods, June 15–18, Research Triangle Park (NC), USA: R. Helmers.
- Third World-Congres of the Bernoulli Society, 57th Annual IMS meeting, June 20–25, Chapel-Hill (NC), USA (+ lecture): R. Helmers.
- Lunteren conference on Stochastics, November 14–16, Lunteren: M.S. Keane, K. Dzhaparidze, R. Helmers, R.H.P. Janssen, A.J. Cabo, I. Molchanov, F.K. Potjer, A. Mancham.
- Working visit (+ lecture), Institute of Mathematics, Polish Academy of Sciences, Wroclaw, Poland, November 27–December 4: R. Helmers.
- Working visit (+ lecture), ETH Zurich, Switzerland, February 15–17: M.S. Keane.
- Lecture, Stafcolloquium Leiden, February 10: M.S. Keane.
- Working visit (+ lectures in Tel Aviv and Jerusalem), Tel Aviv University, Israel, March 26–April 4: M.S. Keane.
- Working visit (+ lectures in Tokyo, Sapporo, Osaka, Fukuoka), Japan, May 21–June 17: M.S. Keane.
- Working visit (+ lecture), University of Marseille, Laboratoire de Mathématiques Discrètes, France, July 2–August 1: M.S. Keane.
- Conference on Percolation, Oberwolfach, Germany, May 15–20: M.S. Keane.
- Working visit (+ lecture), Hewlett Packard Laboratories, Bristol, September 19–30: M.S. Keane.
- Working visit, Isaac Newton Institute, Cambridge, UK, October 10–11: M.S. Keane.
- Lecture, Mark Kac Seminar, Utrecht, November 4: M.S. Keane.
- *Mathematical Institute, University of Utrecht*, lecture 'An integral-geometric approach to limit theorems for coverage processes', September 28: I. Molchanov.
- Working visit (+ lecture) TU Bergakademie Freiberg, Freiberg, Germany, October 26–November 3: I. Molchanov.
- *Colloquium Kansrekening en Stochastiek*, University of Amsterdam, lecture 'Set-valued extremes, multivalued regular variation and applications', November 21: I. Molchanov.
- Working visit (+ 2 lectures) University of Warwick, Coventry, UK, November 28–December 11: I. Molchanov.
- Conference 'Likelihood, Time Series with Econometric and Other Applications', Oxford, UK, December 12–December 17: I. Molchanov (+ lecture).

Memberships of Committees and Other Professional Activities

A.J. Baddeley:
- Committee member, European Science Foundation Network on Highly Structured Stochastic Systems.
- Editor, *Advances in Applied Probability – Journal of Applied Probability.*
- Member of Editorial Board, *Journal of Microscopy.*
- Associate Editor, *Journal of the Royal Statistical Society, series B* (until july 1993).
- Professor in the endowed chair in the Applications of Mathematics, University of Leiden.

K. Dzhaparidze and R.H.P. Janssen:
- Members of the research network in pursuance of the Human Capital Programme, EC, project 'Statistical inference for stochastic processes'.

H.J.A.M. Heijmans:
- Member Technical Committee of the Workshop *Mathematical Morphology and its Applications to Signal Processing II*, Fontainebleau, France, September 7–9.
- Editorial Officer of *International Society for Mathematical Morphology.*
- Chairman of Algemeen CWI Colloquium Commissie.
- Editor of electronic newsletter *Morphology Digest.*
- Participant of the COPERNICUS (1994) project *BENEFIT Concerted Action for Stimulation of East-West Collaborations in the Areas of Microelectronics and Signal Processing.*

R. Helmers:
- Advisor Coopers & Lybrand, Amsterdam.
- Member organizing committee 'Lunteren conference on Stochastics'.
- Participation (indirect) in NWO priority program 'Non linear Systems', project 'Nonlinearity and Prediction' (H.G. Dehling, F. Takens (Groningen)).
- Member of the A-team, CWI.

M.S. Keane:
- Chairman, Scientific Committee, Stieltjes Research School.
- Member of University Council, Delft University of Technology.
- Member of Ph.D. committees H. Bruin (Delft, June 24), J. Gouweleeuw (Free University, Amsterdam, September 1).
- Member of Governing Board, Mathematical Research Institute (Research School).
- Regular Member of the Royal Netherlands Academy of Arts and Sciences.
- Editorial Boards: Indagationes Mathematicae, CWI Tracts, Dynamics and Stability of Systems, Wroclaw Mathematical Journal.
- Member of the van Dantzig Prize Committee, VVS.

Visitors
- E. Valkeila (Computer Centre, University of Helsinki), June 10–16.
- W. Kropatsch (Technische Universität Wien) June 8–10.
- P.K. Ghosh, National Centre for Software technology, Bombay , India, December 1,1994–May 31, 1995.
- S.N. Lahiri (Iowa State University, Ames, USA), 16–23 July, Asymptotic properties of block bootstrap.
- R. Zitikis (Carleton University, Ottawa, Canada), October 8–23.
- Visiting lecturers in the seminar Dynamics in Amsterdam: S. Verduyn Lunel (Amsterdam), B. Stratman (Göttingen), M. Nicol (Coventry), T. Kamae (Osaka), A.J. Homburg (Amsterdam), J. Gunawardena (Bristol), M. Mori (Tokyo).
- Visiting lecturers in the Spatial Stochastics Seminar: N. Leonenko (Kiev), G. Watson (Princeton), M. Hansen (Copenhagen), M. Menshikov (Moscow), A. Gandolfi (Rome), C. Kooperberg (Seattle), D. Gilat (Tel Aviv), P. Shields (Toledo, Budapest), T. Chessa (Delft), C. Maes (Leuven), M. Dekking (Delft), A. Bulinskii (Moscow), S.N. Chiu (Freiberg), G. Grimmett (Cambridge).

Miscellaneous (Consultancy, knowledge transfer, etc.)

- PTT-Post: A consultation project involving efficient model-based stratification in finite populations was carried out (R. Helmers, M.H. Wegkamp (stagiaire; aio RU Leiden)).
- RWS: In September a consultation project for the North Sea Directorate, Ministry of Transport and Public Works, was started. The problem is to estimate the intensity of oil pollution on the North-Sea. This project is part of CWI's research program Mathematics & the Environment. (R. Helmers, R. van der Horst).
- R. Helmers gave M. Das (aio,Tilburg) a graduate course on 'Bootstrap Methods'.
- Coopers-Lybrand: Research concerning inference on rare errors using asymptotic expansions and bootstrap calibration is being carried out as part of an ongoing consultation project. A report on these matters will appear in 1995 (R. Helmers).

- M.S. Keane gave a graduate course for the national Stochastics graduate network in the spring semester on ergodic theory.
- M.S. Keane consulted for a two-week period in September at Hewlett Packard Laboratories in Bristol.
- M.S. Keane and A. Mancham are working on a project for stochastic lung models in collaboration with the Daniel den Hoed clinic in Rotterdam. This is planned to be part of Mancham's dissertation.

Papers in Journals and Proceedings

T. BEDFORD, F.M. DEKKING, M.BREEUWER, M.S. KEANE, D. VAN SCHOONEVELD (1994). Fractal coding of monochrome images. *Signal Processing: Image Communication 6*, 405–419.

R.M. BURTON, M. KEANE, G.L. O'BRIEN (1994). When are distributions skewed to the right? *Indagationes Mathematicae N.S. 5(1)*, 37–44.

K. DZHAPARIDZE AND P. SPREIJ (1994). On optimality of regular projective estimators for semimartingale models, part II: asymptotically linear estimators. *Stochastics and Stochastic Reports 47*, 247–268.

K. DZHAPARIDZE AND P. SPREIJ (1994). Spectral characterization of the optional quadratic variation process, *Stochastic Processes and their Appl. 54*, 165–174.

K. DZHAPARIDZE AND R.H.P. JANSSEN (1994). A stochastic approach to an interpolation problem with applications to Hellinger integrals and Arithmetic-Geometric mean relationship, *CWI Quarterly*. To appear.

K. DZHAPARIDZE, J. KORMOS, T. VAN DER MEER, M.C.A. VAN ZUIJLEN (1994). Parameter estimation for nearly nonstationary AR(1) processes. *Mathl. Comput. Modelling 19*, 29–41.

T. HAMACHI, M.S. KEANE (1994). Finitary codes and non-commutative Bernoulli schemes. ARAIK, KAWAHIGASHI, KOSAKI (eds.). *Proceedings of the Taniguchi Symposium on Operator Algebras,* World Scientific Publishing Company, ISBN 981-02-1803-6, 190–205.

H.J.A.M. HEIJMANS (1994). Mathematical morphology as a tool for shape description. Y.-L. O, A. TOET, D. FOSTER, H.J.A.M. HEIJMANS, P. MEER (eds.). *Shape in Picture: Mathematical Description of Shape in Grey-level Images*, Springer-Verlag, 147–176.

H.J.A.M. HEIJMANS (1994). On the construction of morphological operators which are selfdual and activity-extensive. *Signal Processing 38*, 13–19.

H.J.A.M. HEIJMANS (1994). Construction of self-dual morphological operators and modifications of the median. *Proceedings of the IEEE Conference on Image Processing* (Austin, Texas), vol. II, 492–496.

H.J.A.M. HEIJMANS, A.J. BADDELEY (1994). Dominance and incidence structures with applications to stochastic geometry and mathematical morphology. J. SERRA, P. SOILLE (eds.). *Mathematical Morphology and its Applications to Image Processing*, Kluwer Academic Publishers, 171–178.

P.F.M. NACKEN (1994). Chamfer metrics in mathematical morphology. *Journal of Mathematical Imaging and Vision 4*, 233–253.

P.F.M. NACKEN, A. TOET (1994). Model-based bottom-up grouping of geometric image primitives. Y.-L. O, A. TOET, D. FOSTER, H.J.A.M. HEIJMANS, P. MEER (eds.). *Shape in Picture: Mathematical Description of Shape in Grey-level Images*, Springer-Verlag, 549–558.

R. HELMERS, M. HUSKOVÁ (1994). Bootstrapping multivariate U-quantiles and related statistics. *Journal of Multivariate Analysis, 49,* 97–109.

R. HELMERS (1994). Minisymposium in Honour of Jaroslav Hájek, 8th June 1994, Charles University, Prague, Czech Republic, CWI Quarterly, 7:3, 1–8.

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I.S. MOLCHANOV (1994). On statistical analysis of Boolean models with non-random grains. *Scand. J. Statist.*, v.21, 73–82.

I.S. MOLCHANOV, D. STOYAN (1994). Asymptotic properties of estimators for parameters of the Boolean model. *Advances in Applied Probability*, v.26, 301–323.

L. HEINRICH, I.S. MOLCHANOV (1994). Some limit theorems for extremal and union shot-noise processes. *Math. Nachrichten*, v.168, 139–159.

I.S. MOLCHANOV, D. STOYAN (1994). Directional analysis of fibre processes related to Boolean models. *Metrika*, v.41, 183–199.

A.J. BADDELEY, M.N.M. VAN LIESHOUT (1994). Area-interaction point processes. Abstract to the IMS–Bernoulli Society meeting, Chapel Hill. *Bulletin of the Institute of Mathematical Statistics.*

M.N.M. VAN LIESHOUT (1994). Stochastic annealing for nearest-neighbour point processes with application to object recognition. *Advances in Applied Probability* 26:281–300.

M.N.M. VAN LIESHOUT (1994). Contribution to discussion of U. Grenander and M.I. Miller. Representations of knowledge in complex systems, *Journal of the Royal Statistical Society, Series B* 56:585.

CWI Reports

BS-R9418 K.O. DZHAPARIDZE, R.H.P. JANSSEN. *On orthonormal polynomials associated with a matrix spectral distribution functions.*

BS-R9426 A.J. CABO, R.H.P. JANSSEN. *Cross-covariance, functions characterise bounded regular closed sets.*

BS-R9409 H.J.A.M. HEIJMANS. *Self-dual morphological operators and filters.*

BS-R9416 P.F.M. NACKEN. *Top-down image analysis by cost minimization in hierarchical graph structures.*

BS-R9417 P.F.M. NACKEN. *Image segmentation by connectivity preserving relinking in hierarchical graph structures.*

BS-R9419 J. GOUTSIAS, H.J.A.M. HEIJMANS, K. SIVAKUMAR. *Morphological operators for image sequences.*

BS-R9422 R. HELMERS. *A note on bootstrapping the local time of the empirical process.*

BS-R9436 D. GILAT, R. HELMERS. *On strong laws for generalized L-statistics with dependent data.*

BS-R9429 I.S. MOLCHANOV. *A limit theorem for scaled vacancies of the Boolean model.*

Other Publications

SERGUEI FOSS, GERARD HOOGHIEMSTRA, MICHAEL KEANE (1994). *On a Problem of Jon Wellner.* TU Delft Report 94–22, 14 p.

GERARD HOOGHIEMSTRA, MICHAEL S. KEANE (1994). *A Central Limit Theorem for Sums of Correlated Products.* TU Delft Report 94–35, 10 p.

M. KEANE (1994). The essence of the law of large numbers, in CWI volume on the occasion of the retirement of P.C.Baayen.

M. KEANE (1994). Trends in de Wiskunde, in Trends in de Wetenschap, NWO.

H.J.A.M. HEIJMANS (1994). *Morphological Image Operators*, Academic Press, Boston.

O.Y.L., TOET, A., FOSTER, D., HEIJMANS, H.J.A.M., MEER, P. (eds.) (1994). *Shape in Picture: Mathematical Description of Shape in Grey-Level Images*, vol. 126 of *NATO ASI Series F.* Springer, Berlin.

P.F.M. NACKEN (1994). *Image Analysis Methods Based on Hierarchies of Graphs and Multi-Scale Mathematical Morphology.* Ph.D. Thesis, University of Amsterdam.

I.S. MOLCHANOV, D. STOYAN, O.YU. VOROBEV (1994). Statistics of random compact sets. *Bulletin of the IMS*, **23**, p. 360.

I.S. MOLCHANOV, D. STOYAN, O.YU. VOROBEV (1994). *Statistics of Compact Sets.* A collection of 3 papers. Research report 94-04, Fakultät für Mathematik und Informatik, TU Bergakademie Freiberg.

M.N.M. VAN LIESHOUT (1994). *Stochastic Geometry Models in Image Analysis and Spatial Statistics.* Dissertation Free University, Amsterdam.

A.J. BADDELEY, M.N.M. VAN LIESHOUT, J. MÖLLER (1994). *Markov Properties of Cluster Processes.* Research report 278, University of Aarhus.

DEPARTMENT OF NUMERICAL MATHEMATICS

General Introduction

Staff Department of Numerical Mathematics, 1994

- NW1
  - Dr. J.G. Verwer
  - Prof. dr. P.J. van der Houwen
  - Drs. J.G. Blom
  - Dr. W.H. Hundsdorfer
  - Dr. B.P. Sommeijer
  - Nguyen huu Cong
  - Ir. M. van Loon
  - Drs. E.J. Spee
  - Drs. J.J.B. de Swart
  - Drs. ir. W.A. van der Veen
  - Dr. K.J. in 't Hout
  - Drs. J. Kok
  - Drs. W.M. Lioen
- NW2
  - Prof. dr. P.W. Hemker
  - Dr. ir. B. Koren
  - Drs. P.M. de Zeeuw
  - Drs. C.T.H. Everaars
  - Ir. W.J.H. Stortelder
  - Ir. J. Noordmans
- NW3
  - Dr. ir. H.J.J. te Riele
  - Prof. dr. H.A. van der Vorst
  - P.L. Montgomery
  - M.C. Dracopoulos
  - Drs. J. Kok
  - Drs. W.M. Lioen
  - Drs. M. Nool
  - D.T. Winter
  - Drs. H. Boender
  - Dr. A. Booten
  - Drs. R.-M. Huizing
- Secretary: S. Panka-de Wolff

Discretization of Evolution Problems (NW1)

Staff

- Dr. J.G. Verwer, group leader
- Prof. dr. P.J. van der Houwen, researcher, head of department
- Drs. J.G. Blom, researcher
- Dr. W.H. Hundsdorfer, researcher
- Dr. B.P. Sommeijer, researcher
- Nguyen huu Cong, visiting researcher Hanoi University, until March '94
- Ir. M. van Loon, junior researcher (OIO)
- Drs. E.J. Spee, junior researcher (OIO)
- Drs. J.J.B. de Swart, junior researcher (OIO)
- Drs. ir. W.A. van der Veen, junior researcher (OIO)
- Dr. K.J. in 't Hout, post-doc researcher Stieltjes, until September '94
- Drs. J. Kok, project member, detached from NW3
- Drs. W.M. Lioen, project member, detached from NW3

Scientific Report

In 1994 research concentrated on four projects:

- Equations of fluid mechanics and related topics (EC/HCM project)
  This HCM project is a 3-year activity from 1-1-1994 until 12-31-1996. Seventeen research groups from Europe participate. The available budget is used mainly for long-term visitors and working visits. Within this HCM project new cooperation has been started with the University of Valladolid on research into splitting methods.
- Algorithms for transport equations arising in pollution studies and studies on sediment transport in shallow seas and rivers (belongs to CWI's research program 'Mathematics and the Environment')
  In the 1993 NCF/CRAY project entitled 'CRAY Y-MP4 Software for the Three-dimensional Transport Model for Shallow Seas', the suitability of several time-integration techniques for a single transport equation has been investigated. As a result, the partially implicit Odd-Even Line Hopscotch (OELH) method turned out to be superior.
  In 1994, a start has been made to couple this numerical transport model with a biochemical model. The research is carried out as part of the international EC/NOWESP program; financial support has been obtaind via the NCF/CRAY project 'Three-Dimensional Transport of Pollutants in Shallow Seas'.
  The modeling of various pollutants together with their chemical interactions gives rise to a system of PDEs which are only coupled by means of the ODEs describing the chemistry. Splitting methods have been designed to treat the PDE part and the ODE part separately. As a consquence of the splitting, the PDE part results in a sequence of uncoupled transport equations (one for each pollutant), which can be efficiently solved by the OELH technique. In fact, this can be done in parallel. Then, in each step, the (nonstiff) ODE part is solved by a standard technique. The difficult point in this last part is that we are faced with an enormous number of (nonlinear) small ODE systems, i.e. one for each grid point. To obtain good performance on multi-vectorprocessor computers, we applied a 'vectorization-across-the-ODE-systems' approach. Results of the total algorithm, when implemented on the CRAY C90 machine, will be reported early 1995.
- Parallel IVP algorithms
  This project deals with parallel Runge-Kutta and other block methods for ordinary differential equations. A minor part of the project is Ph.D. research carried out jointly with the University of Hanoi (financed by the University of Amsterdam) and is devoted to the development of parallel methods for the solution of initial-value problems for second-order differential equations. The major activity is concentrated in an STW project for the design of parallel algorithms for solving circuit analysis and control engineering problems. One of the main topics this year was the implementation and performance evaluation of methods that efficiently exploit parallelism-across-the-steps. This kind of parallelism can be placed on top of the parallelism-across-the-method, which has been developed in previous years. The combination of both kinds of parallelism yields improved efficiency and is a step forward in the direction of massive parallelism. A second main topic was the convergence analysis of step-parallel methods. This analysis provides guidelines for improving the iteration strategy. The incorporation of a new iteration strategy will be subject of future research.
- Algorithms for atmospheric flow problems (belongs to CWI's research program 'Mathematics and the Environment')
  The aim of this project is the development of algorithms for large-scale atmospheric transport-chemistry problems modeling air pollution. Cooperation with the RIVM, KNMI and IMAU (UU)

was continued. The project is financially supported by the RIVM and Cray Research through NCF. The research focuses on two air pollution models from the actual practice, viz. EUSMOG, which is a model for regional air-pollution and smog prediction, and CIRK, which is a global tropospheric model. EUSMOG started January 1992 and CIRK October 1993. Main research issues in 1994 include local grid refinement for EUSMOG, summer chemistry solver for EUSMOG, flux-limited spherical advection for CIRK, time-splitting for spherical advection, development of a first prototype for CIRK based on advection and methane chemistry, fast explicit solvers for the stiff ODEs describing the atmospheric chemistry, operator splitting for advection-reaction models, a method-of-lines scheme for 3D regional models, parallelism and vectorization research.

Organisation of Conferences, Workshops, Courses, etc.

- Symposium 'Topics in Environmental Mathematics': Numerical Algorithms for Atmospheric Transport-Chemistry Problems. May 18, CWI. Lectures include: Application of numerical methods in long period atmospheric chemistry modeling (D. Simpson, Norwegian Meteorological Institute, Oslo), Explicit methods for stiff ODEs from atmospheric chemistry (J.G. Verwer, CWI), Application of a new solution algorithm for chemical models included in a 3D dispersion model (Ch. Kessler, University of Karlsruhe), Large-eddy simulation for turbulent reacting fluids (C. Beets, Utrecht University), Experiences with QUICKEST in MOGUNTIA (Han The, RIVM), Dimension splitting for advection on a sphere (W. Hundsdorfer, CWI).
- Ph.D.-course for the Thomas Stieltjes Institute, September – December, Numerical methods for advection–diffusion–reaction equations (W. Hundsdorfer, CWI).

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- Workshop Atmosferische Chemie en Modellen, RIVM, Bilthoven, February 24, J.G. Verwer (An explicit ODE solver for atmospheric chemistry problems).
- Symposium on the occasion of the 60th birthday of Prof. dr. O. Axelsson, University of Nijmegen, March 24, P.J. van der Houwen (Parallelism across the steps in IVP solvers)
- 30e Nederlands Mathematisch Congres, Leiden, April 7–8, P.J. van der Houwen (Three-dimensional transport of pollution in shallow water)
- 30e Nederlands Mathematisch Congres, Leiden, April 7–8, M. van Loon (Numerieke smogvoorspelling).
- 30e Nederlands Mathematisch Congres, Leiden, April 7–8, J.J.B. de Swart (Geïtereerde Blok Runge-Kutta Methoden).
- 30e Nederlands Mathematisch Congres, Leiden, April 7–8, W.A. van der Veen (Parallelle methoden voor stijve beginwaardeproblemen).
- Working Visit Dutch NOWESP-partners, Delft, April 14, B.P. Sommeijer (Tijdsintegratie van gekoppelde transportvergelijkingen).
- Summerschool Parallel Computing in Fluid Dynamics (J.M. Burgerscentrum), Delft, May 31, B.P. Sommeijer (Parallel computing for three-dimensional transport models for shallow water flows: algorithmic aspects).
- Summerschool Parallel Computing in Fluid Dynamics (J.M. Burgerscentrum), Delft, June 1, B.P. Sommeijer (Parallel computing for three-dimensional transport models for shallow water flows: implementation aspects).
- ERCIM Parallel Processing and Networking Workshop, Crete, June 8–10, J.G. Verwer (Algorithms for Differential Equations).
- Symposium on the occasion of the 60th birthday of Prof. dr. K. Strehmel, University of Halle, Germany, June 9, P.J. van der Houwen (Step-parallel Runge-Kutta methods)
- International conference on Massively Parallel Processing; Applications and Development, Delft, June 21–23, B.P. Sommeijer (Time integration of 3-D numerical transport models).
- International conference on Massively Parallel Processing; Applications and Development, Delft, June 21–23, J. Kok (Efficient solution of linear systems for the time integration of 3-D numerical transport models).
- NOWESP bijeenkomst met MAST-Modeling Committee, Brussels, Belgium, June 6, B.P. Sommeijer (Time integration of a three-dimensional transport model in shallow seas).
- 14-th IMACS World Congress, Atlanta, USA, July 11–15, P.J. van der Houwen (Runge-Kutta methods for time-dependent partial differential equations)
- 14-th IMACS World Congress, Atlanta, USA, July 11–15, W. Hundsdorfer (Splittings for advection–reaction equations in air pollution modeling).

- Symposium: Resolution numerique des equations differentielles, INRIA Rocquencourt, France, September 2, P.J. van der Houwen (Convergence aspects of step-parallel iteration of RK methods).
- Symposium: Resolution numerique des equations differentielles, INRIA Rocquencourt, France, September 2, B.P. Sommeijer (Time integration of a three-dimensional transport model in shallow seas).
- Numerical Treatment of Differential Equations NUMDIFF-7, Halle, Germany, September 19–23, W. Hundsdorfer (Dimension and operator splittings for advection–reaction equations).
- ICCAM 94 Conference, University of Leuven, Belgium, July 27, P.J. van der Houwen (Parallel predictor-corrector methods).
- Numerical Treatment of Differential Equations NUMDIFF-7, Halle, Germany, September 19–23, J.G. Verwer (Explicit methods for stiff ODEs from atmospheric chemistry).
- Numerical Treatment of Differential Equations NUMDIFF-7, Halle, Germany, September 19–23, J.J.B. de Swart (Parallel Predictor-Corrector Methods).
- Numerical Treatment of Differential Equations NUMDIFF-7, Halle, Germany, September 19–23, W.A. van der Veen (Convergence aspects of step-parallel iteration of Runge-Kutta methods).
- 19e Conferentie van Numeriek Wiskundigen, Zeist, September 26–28, J.J.B. de Swart (Diagonally Implicit Iteration Methods for IVP solvers).
- Second International Conference on Air Pollution, Barcelona, Spain, September 27–29, M. van Loon (Numerical Methods in Smog Prediction).
- HPCN Colloquium, University of Leiden, October 6, P.J. van der Houwen (Numerical simulation of transport of pollution in shallow water).
- CWI in Bedrijf, CWI, October 7, P.J. van der Houwen (Numerical simulation of transport of pollution in shallow water).
- Working Visit STW-project 'Parallel codes for circuit analysis and control engineering', University of Twente, October 21, B.P. Sommeijer, J.J.B. de Swart, W.A. van der Veen.
- Symposium Numerieke oplossing van beginwaardeproblemen, Leiden, November 29, B.P. Sommeijer (Time integration of a 3D transport model for shallow seas).
- 11de Supercomputergebruikersdag, Amsterdam, December 16, J.G. Blom (VLUGR: Vectorized Local Uniform Grid Refinement codes for a general class of PDEs in 2D and 3D).
- A Nonlinear Symphony, CWI-Philips-UU Symposium, December 16, P.J. van der Houwen (Solving Runge-Kutta equations).
- A Nonlinear Symphony, CWI-Philips-UU Symposium, December 16, J.G. Verwer (Nonlinear Gauss-Seidel iteration for the atmospheric reaction-diffusion equation used in air pollution modeling).

Memberships of Committees and Other Professional Activities

P.J. van der Houwen:
- Professor of Applied Mathematics, University of Amsterdam
- Managing editor Letter Section Journal of Computational and Applied Mathematics (JCAM)
- Associate Editor Zeitschrift für Angewandte Mathematik und Mechanik (ZAMM)
- Advisor PDE chapters Numerical Algorithms Group (NAG)
- Editor NUMDIFF-7 Proceedings
- Co-chairman Biennial Conference on Numerical Methods for Differential Equations (NUMDIFF)
- Member Board of International Association for Mathematics and Computers in Simulation (IMACS)
- Chairman Users Committee STW project 'Parallel Codes for Circuit Analysis and Control Engineering'
- Member Committee Wetenschappelijk Gebruik Supercomputers (WGS)
- Member Board Numerical Mathematics Society (WGN)
- Member Scientific Committee Institute for Advanced Studies 'Stieltjes'
- Promotor R.A. Trompert: Local uniform grid refinement for time-dependent partial differential equations, University of Amsterdam, January 26.
- Member of Thesis committee D.W. Dunsbergen, Technical University of Delft, November 22.
- Member of Thesis committee J.L.M. van Dorsselaer, University of Leiden, December 8.

W. Hundsdorfer:
- Editor CWI-Quarterly
- Member Users Committee STW project 'Parallel Codes for Circuit Analysis and Control Engineering'

B.P. Sommeijer:
- Secretary of the Organizing Committee for the annual Numerical Conference in Woudschoten (September 26-28)
- Co-promotor Ph.D. thesis Nguyen huu Cong: Parallel Runge-Kutta-Nyström methods, University of Amsterdam, March 29.

J.G. Verwer:

- Senior Editor 'Applied Numerical Mathematics'
- Program Leader of CWI's research program 'Mathematics and the Environment'
- Scientific Coordinator Research Consortium TASC (Transport Algorithms and Scientific Computing)
- Co-promoter R.A. Trompert: Local uniform grid refinement for time-dependent partial differential equations, University of Amsterdam, January 26.

Visitors

- D. Simpson (Norwegian Meteorological Institute, Oslo) May 16–18. Application of numerical methods in long period atmospheric chemistry modeling.
- Ch. Kessler (University of Karlsruhe) May 18–20. Application of a new solution algorithm for chemical models included in a 3D dispersion model.
- M. Berzins (Leeds University, UK) June 21–22. Positive and adaptive 2D unstructured mesh finite volume methods.
- L.N. Trefethen (ETH-Zürich, Switzerland and Cornell University, USA) July 4. What eigenvalues don't tell you.
- L. Blank (University of Bonn, Germany) August 3. Stability of the collocation method applied to Volterra integral equations with delay.
- J.M. Sanz-Serna (University of Valladolid, Spain) October 13–15. Reversible integration of Hamiltonian systems.
- B. Garcia-Archilla (University of Valladolid, Spain) October 13–15. Computational efficiency of nonlinear Galerkin methods.

Papers in Journals and Proceedings

J.G. BLOM, J.G. VERWER (1994). Vectorizing matrix operations arising from PDE discretization on 9-point stencils. *The J. of Supercomputing 8*, 29–51.

J.G. BLOM, J.G. VERWER (1994). VLUGR3: A vectorizable adaptive grid solver for PDEs in 3D. I. algorithmic aspects and applications. *Appl. Numer. Math. 16*, in December issue.

J.G. BLOM, P.A. ZEGELING (1994). Algorithm 731: A moving-grid interface for systems of one-dimensional time-dependent partial differential equations. *ACM Trans. Math. Software 20*, 194–214.

P.J. VAN DER HOUWEN, B.P. SOMMEIJER (1994). Butcher-Kuntzmann methods for nonstiff problems on parallel computers. *Appl. Numer. Math. 15*, 357–374.

P.J. VAN DER HOUWEN, B.P. SOMMEIJER (1994). Preconditioning in parallel Runge-Kutta methods for stiff initial value problems. *Computers Math. Applic. 28*, 17–31.

W. HUNDSDORFER, R. TROMPERT (1993). Method of lines and direct discretization: A comparison for linear advection. *Appl. Numer. Math. 13*, 469–490.

J.L.M. VAN DORSSELAER, W. HUNDSDORFER (1994). Stability estimates based on numerical ranges with an application to a spectral method. *BIT 34*, 228–238.

W. HUNDSDORFER (1994). On the error of general linear methods for dissipative stiff differential equations. *IMA J. Numer. Anal. 14*, 363–379.

M. VAN LOON (1993). Testing interpolation and filtering techniques in connection with a semi-Lagrangian method. *Atmospheric Environment 27A*, 2351–2364.

M. VAN LOON (1994). Numerical methods in smog prediction. J.M. BALDASANO ET AL. (eds.). *Air Pollution II, Vol. 1*, Computational Mechanics Publications, Southampton-Boston, 563–570.

B.P. SOMMEIJER, P.J. VAN DER HOUWEN, J. KOK (1994). Time integration of three-dimensional numerical transport models. *Appl. Numer. Math. 16*, in December issue.

R.A. TROMPERT (1994). Local uniform grid refinement and transport in heterogeneous porous media. *Advances in Water Resources 16*, 293–304.

J.G. VERWER, M. VAN LOON (1994). An evaluation of explicit pseudo-steady state approximation schemes for stiff ODEs from chemical kinetics. *J. Comput. Phys. 113*, 347–352.

J.G. VERWER (1994). Gauss-Seidel iteration for stiff ODEs from chemical kinetics. *SIAM J. Sci. Comput. 15*, 1243–1250.

CWI Reports

NM-N9401 P.J. VAN DER HOUWEN. *Parallel iteration schemes for implicit ODEIVP methods.*

NM-R9401 NGUYEN HUU CONG. *Explicit parallel two-step Runge-Kutta-Nyström methods.*

NM-R9402 B.P. SOMMEIJER, J. KOK. *Implementation and performance of a three- dimensional numerical transport model.*

NM-R9403 J.G. BLOM, R.A. TROMPERT, J.G. VERWER. *VLUGR2: A vectorizable adaptive grid solver for PDEs in 2D.*

NM-R9404 J.G. BLOM, J.G. VERWER. *VLUGR3: A vectorizable adaptive grid solver for PDEs in 3D. I. Algorithmic aspects and applications.*

NM-R9405 J.G. BLOM, J.G. VERWER. *VLUGR3: A vectorizable adaptive grid solver for PDEs in 3D.*

II. Code description.

NM-R9408 P.J. VAN DER HOUWEN, B.P. SOMMEIJER, J.J.B. DE SWART. *Parallel predictor-corrector methods.*

NM-R9409 J.G. VERWER, D. SIMPSON. *Explicit methods for stiff ODEs from atmospheric chemistry.*

NM-R9416 W.H. HUNDSDORFER, E.J. SPEE. *Dimensional splitting with unconditional stability for advection on a sphere.*

NM-R9417 J.J.B. DE SWART. *Efficient parallel predictor-corrector methods.*

NM-R9418 J.G. BLOM, W. HUNDSDORFER, J.G. VERWER. *Vectorization aspects of a spherical advection scheme on a reduced grid.*

NM-R9420 P.J. VAN DER HOUWEN. *The development of Runge-Kutta methods for partial differential equations.*

NM-R9422 J.G. VERWER, B.P. SOMMEIJER. *Stability analysis of an odd-even-line hopscotch method for three-dimensional advection-diffusion problems.*

NM-R9424 W. HUNDSDORFER, J.G. VERWER. *A note on splitting errors for advection-reaction equations.*

NM-R9426 W.A. VAN DER VEEN, J.J.B. DE SWART, P.J. VAN DER HOUWEN. *Convergence aspects of step-parallel iteration of RK methods.*

Other Publications

RON TROMPERT (1994). *Local Uniform Grid Refinement for Time-Dependent Partial Differential Equations*. Ph.D. Thesis, University of Amsterdam, January 26.

NGUYEN HUU CONG (1994). *Parallel Runge-Kutta-Nyström Methods*. Ph.D. Thesis, University of Amsterdam, March 29.

Boundary Value Problems, Multigrid and Defect Correction (NW2)

Staff

- Prof. dr. P.W. Hemker, group leader (0.95 fte)
- Dr. ir. B. Koren, senior researcher
- Drs. P.M. de Zeeuw, senior programmer
- Drs. C.T.H. Everaars, programmer
- Ir. W.J.H. Stortelder, Ph.D. student
- Ir. J. Noordmans, Ph.D. student (from November 1)

Scientific Report

P.W. Hemker and *P.M. de Zeeuw* continued research on multigrid related algorithms for three-dimensional problems. The work aims at the use of adaptive box-methods for sparse grids. In the framework of the second phase of the BRITE-EURAM Aeronautics R & D Programme of the European Union (Contract No. AERO-CT-0040/PL-2037), the purpose of this research is the efficient solution of 3D flow problems. The theoretical work uses Fourier analysis to estimate the convergence rate of iteration algorithms. A multi-level algorithm was developed which relies on multiple semi-coarsening and a simple smoothing procedure. Because of the semi-coarsening the process is robust with respect to both flow-alignment and anisotropic diffusion. Generalisation towards sparse grids is under investigation. A report on the subject was completed and will be published as soon as consent has been obtained from the other project partners.

Based on a special grant by NWO to stimulate cooperation with researchers from the former Soviet Union, in cooperation with *Prof. G.I. Shishkin* (Institute of Mathematics and Mechanics, Ekaterinburg, Russia), who visited CWI for three weeks during the year 1994, *P.W. Hemker* continued research on singular perturbation problems. Here adapted difference schemes and adapted mesh methods were studied with the aim to construct ϵ-uniformly convergent algorithms. This resulted in the preparation of a number of papers that will be published later. The work was also reported by Prof. Shishkin in the *Conference on Boundary and Interior Layers, Computational and Asymptotic Methods (BAIL VII)*, that was held in Beijing, China, September 5–8, 1994. From October 13 to December 3, *Dr. P.A. Farrell* (On sabbatical leave from Dept. Comp. Sc. Kent State University, Kent, USA) visited CWI to reinforce the activities in the field of singular perturbations. This resulted in the preparation of a joint report with Hemker and Shishkin, that will be published in 1995.

By cooperative efforts of *W.J.H. Stortelder*, *C.T.H. Everaars* and *P.W. Hemker*, in the framework of the STW project 'Parameter-identificatie en model-analyse voor niet-lineaire dynamische systemen', a new working version of an interactive parameter estimation tool has been developed. This tool, a descendent of the earlier program PEIDE, is called spIds and makes use of computer algebra, numerical methods, visualisation, computational steering and inter-machine communication. Stortelder was responsible for the numerical software and performed a series of tests with the developed software on real-life problems from the chemical industries. Everaars took care for the graphical user interface (GUI). Until July 31, the STW-project was assisted by the trainee *J.C. Kok*, who did his practical work partly

at the AKZO Research Laboratories, Arnhem, and partly at CWI. He studied global optimisation problems that can be used in parameter estimation problems.
C.T.H. Everaars also provided general visualization-support to other members of the department.

Together with *P. Wesseling, P.W. Hemker* edited the proceedings of the *Fourth European Multigrid Conference,* that was held in Amsterdam, June 6–9, 1993. Beside the official proceedings that were published by Birkhäuser Verlag, Basel, a second volume of contributions to the conference was prepared. This volume appeared as CWI Tract number 103.

B. Koren finished his work on methods for the compressible Euler equations at low Mach numbers for the BRITE-EURAM project. As in 1993, this work was partly done in cooperation with Prof. B. van Leer (Department of Aerospace Engineering, University of Michigan, Ann Arbor, USA). Further, a start was made with the coding of prototype software for the 3-D Euler equations. The BRITE-project was somewhat slackened by the delayed appointment of a junior researcher.

As fundamental research, *B. Koren* derived a second-order accurate, monotone finite-volume scheme with good parallelization properties, and he investigated a discretization method for source terms occurring in advection-diffusion equations. Furthermore, he made pilot studies of (i) Euler flow separation from smooth surfaces of delta wings, and of (ii) noise generation in shock absorbers of train bogies. The first pilot study is expected to lead to a joint research proposal by Koren and Prof. P.G. Bakker (Faculty of Aerospace Engineering, Delft University of Technology). In the second pilot study Koren investigated the possibilities of an extension of the classical piston problem from gas dynamics to two space dimensions. He wrote a computer code for the solution of the unsteady Euler equations in axial-symmetric coordinates, that was transferred to F.P.M. Michielsen (TUD, trainee at Koni B.V., Oud-Beijerland). This pilot study is intended to lead to some joint research. Also, in cooperation with Ir. C. Beets (Institute for Marine and Atmospheric Research Utrecht) Koren continued to work on an alternative discretization method for the equations of large eddy simulation. This last work had a lower priority in 1994.

K.G. Powell (on sabbatical leave from the Department of Aerospace Engineering, University of Michigan, Ann Arbor, USA) visited CWI for four weeks to work and to exchange ideas on computational fluid dynamics. He wrote a report on the development of an approximate Riemann solver for the equations of ideal magneto hydrodynamics (MHD).

P.M. de Zeeuw finished a report [NM-R9410] which is an extended version of an earlier published paper on multigrid and advection. With *M. Nool* he also co-authored a report [NM-R9423] on Numerical Multigrid Software. Further, he continued a cooperation with *S.P. Spekreijse* from the National Aerospace Laboratory (NLR).

Organisation of Conferences, Workshops, Courses, etc.

- B. Koren: 29ste Werkgemeenschapscolloquium Numerieke Wiskunde, CWI, October 21.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- Tenth GAMM Seminar Kiel, Kiel, BRD, January 14–16: Hemker (Two applications of adaptive finite-volume multigrid methods, January 15).
- Maple Course, CWI, February 24–25: De Zeeuw.
- Symposium on the occasion of the 60th birthday of Prof. A.O.H. Axelsson, University of Nijmegen, March 24: Hemker (What are sparse grids?).
- CWI–RUU Symposium, Fifth Meeting, on Parallel Numerical Algorithms and Software, CWI, March 25: De Zeeuw.
- Dutch Mathematical Congress, University of Leiden, April 7–8: Stortelder (Parameter estimation in non-linear differential equations).
- ISNaS–BC Symposium 8, Delft University of Technology, April 28: De Zeeuw.
- CWI–RUU Symposium, Sixth Meeting, on Parallel Numerical Algorithms and CFD–Applications, Delft University of Technology, June 3: De Zeeuw.
- Working visit NLR, Amsterdam, June 24: Koren.
- ITW symposium: Vernuft en nut van neurale netwerken, Delft University of Technology, June 7: Hemker.
- BRITE Meeting, Brussels, Belgium, July 4: Hemker (Sparse-grid finite-volume multigrid), Koren.
- Working visit University of Limburg, Biomedisch centrum: July 12–13: Hemker, Stortelder.
- STW User Committee meeting, CWI, September 8: Everaars, Hemker, Stortelder.
- Working visit and practical laboratory training, University of Limburg, Maastricht, September 12–16: Stortelder.
- Negentiende Conferentie Numerieke Wiskunde, Conferentiecentrum Woudschoten, Zeist, September 26–28: Stortelder, De Zeeuw.

- International Workshop on Solution Techniques for Large-Scale CFD problems, CERCA Montréal, Canada, September 26–28: Hemker (Nonlinear multigrid and Defect Correction for the steady Euler equations, September 27), Koren (Improving Euler computations at low Mach numbers, September 28).
- Working visit Faculty of Aerospace Engineering, University of Michigan, Ann Arbor, USA, September 29–30: Koren ('Improving multigrid Euler-flow computations at low Mach numbers', and 'Limiting and large eddy simulation').
- Weekly AIO course on numerical methods for initial value problems, organised by the Stieltjes Institute, Leiden, September 29–December 1: Stortelder.
- Demonstration 'Dynamical Systems Identification' at the CWI Presentation Day, October 7: Stortelder, Everaars.
- Bijeenkomst van de KennisKring Amsterdam 'Natuurwetenschappen en haar toepassingen', Amsterdam, October 7: Hemker.
- Working visit, DSM, Geleen, October 12: Stortelder.
- Working visit Faculty of Aerospace Engineering, Delft University of Technology, October 18: Koren.
- 29ste Werkgemeenschapscolloquium Numerieke Wiskunde, CWI, October 21: Koren, De Zeeuw.
- 40ste Bijeenkomst Kontaktgroep Numerieke Stromingsleer, Ingenieursbureau SVASEK B.V., Rotterdam, October 31: De Zeeuw.
- Working visit, Delft University of Technology, Department of Chem. Engineering, November 18: Stortelder.
- C++ course, Utrecht, November 21–24: Everaars.
- Meeting on Finite Volume Methods. Oberwolfach, Germany, October 30–November 5: Hemker, Koren (A monotone, central finite volume scheme for advection, and an advection-based finite-volume scheme for source terms).
- Working visit, RIVM, December 6: Stortelder.
- Symposium, afscheid Prof. Baayen, Krasnapolsky, Amsterdam, December 20: Hemker, Koren, De Zeeuw.

Memberships of Committees and Other Professional Activities

P.W. Hemker:
- Professor of Industrial Mathematics, University of Amsterdam
- Working Group 2.5 on Numerical Software, IFIP (member)
- International Steering Committee BAIL Conferences (member)
- International Program Committee ESM'94 (member)
- International Program Committee IMACS
- Iterative Linear Algebra Symposium (member)
- Numerical Algorithms Group, NAG Inc. (member)
- Ph.D. committee G.A.L. van de Vorst (TU Eindhoven, January 21) (member)
- Ph.D. committee R. Trompert (UvA, January 26) (member)
- Ph.D. committee Nguyen huu Cong (UvA, March 29) (member)
- Ph.D. committee R. Struijs (TU Delft, June 24) (member)
- M.Sc. committee J.C. Kok (UvA, November 23) (chairman)

B. Koren:
- Secretary Werkgemeenschap Numerieke Wiskunde
- Editor of 'Het Nummer' (newsletter of the Werkgemeenschap Numerieke Wiskunde)

P.M. de Zeeuw:
- Member ADSARA (SARA User Committee)

Visitors

- Prof. K.G. Powell (Department of Aerospace Engineering, University of Michigan, Ann Arbor, USA) February 28–March 24 'Solution-adaptive techniques for solving the governing equations of gas dynamics and magnetohydrodynamics', March 2.
- Dr. R. Teigland (Christian Michelsen Research AS, Fantoft, Norway) March 31.
- Dr. T. Gjesdal (Christian Michelsen Research AS, Fantoft, Norway) June 28.
- Dr. A. Craig (ERCIM fellow) June 6–August 31.
- Dr. H. Guillard (INRIA, Sophia Antipolis, Valbonne, France) August 1–31.
- Prof. G.I. Shishkin (Institute for Mathematics and Mechanics, Ural Branch of the Russian Academy of Sciences, Ekaterinburg, Russia) October 12–November 2 'On disturbed boundary conditions for parabolic, singularly perturbed equations', October 21.
- Dr. P.A. Farrell (Computer Science Department, Kent State University, Kent, USA) October 13–December 3.

Miscellaneous (Consultancy and education)

- *P.W. Hemker* was a consultant for Philips Research Laboratory, Eindhoven and he reviewed papers or projects for: the National Science Foundation (US NSF), Mathematical Reviews, Stichting voor de Technische Wetenschappen (STW), Applied Numerical Mathematics, Journal of Computational and Applied Mathematics, Computational Fluid Dynamics Journal. Further he was a member of the 83th jury panel for STW and he presented a capita selecta course 'Advanced Scientific Computing' on 'Finite Element Methods' at the University of Amsterdam (September to December).
- *B. Koren* reviewed papers for the Journal of Computational Physics and some other journals. He was consulted on test problems for advection schemes by Dr. Lie (the Christian Michelsen Research Institute, Fantoft, Norway), and on the aeroacoustics of shock absorbers in train bogies by the Koni company (Oud-Beijerland).
- *P.M. de Zeeuw* reviewed papers for the Journal of Applied Numerical Mathematics and the Journal of Computational Physics and a project for the National Science Foundation (US NSF). He was consulted on the application of multigrid methods by R.N. Godshall (Dept. of Civil and Environmental Engineering at the Duke University, USA) and on black box solvers for numerical simulations of fluid flow by E. Kjoersvik (Dept. of Applied Mechanics, Thermo- and Fluid-dynamics of the Norwegian Institute of Technology).

Papers in Journals and Proceedings

P.W. HEMKER, B. KOREN (1994). Defect correction and nonlinear multigrid for steady Euler equations. W.G. HABASHI (ed.) (1994). *Proceedings of the International Workshop on Solution Techniques for Large-Scale CFD Problems, Montréal, 1994*, pages 223–241, Montréal, Centre de Recherche en Calcul Appliqué.

P.W. HEMKER, G.I. SHISHKIN (1994). Discrete approximation of singularly perturbed parabolic PDEs with a discontinuous initial condition. *Computational Fluid Dynamics Journal*, 2:375–392.

P.W. HEMKER, G.I. SHISHKIN (1994). On a class of singularly perturbed boundary value problems for which an adaptive mesh technique is necessary. D. BAINOV, V. COVACHEV (eds.). *Proceedings of the Second International Colloquium on Numerical Analysis*, pages 83–92, Utrecht, The Netherlands, VSP, International Science Publishers. Proceedings of the 'Second International Colloquium on Numerical Analysis', August 13–17, 1993.

P.W. HEMKER, P.M.C. THOOLEN (1994). Approximation methods for n-component solute transport and ion-exchange. *J. Comp. Appl. Math.*, 53:275–290.

B. KOREN (1994). Improving Euler computations at low Mach numbers. W.G. HABASHI (ed.). *Proceedings of the International Workshop on Solution Techniques for Large-Scale CFD Problems, Montréal, 1994*, pages 333–357, Montréal, Centre de Recherche en Calcul Appliqué.

H.T.M. VAN DER MAAREL, P.W. HEMKER (1994). Structured adaptive finite-volume multigrid for compressible flows. *Proceedings of the Tenth GAMM Seminar Kiel.*

CWI Reports

NM-R9407 K.G. POWELL. *An approximate Riemann solver for magneto hydrodynamics (that works in more than two dimensions).*

NM-R9410 P.M. DE ZEEUW. *Multigrid and advection.*

NM-R9412 B. KOREN. *Preconditioning and multigrid for Euler flows with low-subsonic regions.* (submitted to *Advances in Computational Mathematics*).

NM-R9413 B. KOREN. *Condition improvement for point relaxation in multigrid, subsonic Euler-flow computations.* (submitted to *Applied Numerical Mathematics*).

NM-R9423 M. NOOL, P.M. DE ZEEUW. *Numerical multigrid software for elliptic PDEs. Routines: MGD1M and MGD5M.*

NM-R9427 P.W. HEMKER. *Remarks on sparse-grid finite-volume multigrid.*

Other Publications

J.-A. DÉSIDÉRI, P.W. HEMKER, B. KOREN, M.-H. LALLEMAND (1994). Research in computational fluid dynamics, stimulated by ERCIM. K.R. APT, A. SCHRIJVER, N.M. TEMME (eds.). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey*, pages 269–286, Stichting Mathematisch Centrum, Amsterdam.

P.W. HEMKER, P. WESSELING (eds.) (1994). *Contributions to Multigrid*, volume 103 of *CWI Tract Series*, Stichting Mathematisch Centrum, Amsterdam.

P.W. HEMKER, P. WESSELING (eds.) (1994). *Multigrid methods IV*, volume 116 of *Internatio-*

nal Series of Numerical Mathematics, Basel, 1994. Birkhäuser Verlag. Proceedings of the Fourth European Multigrid Conference, held in Amsterdam, July 6–9, 1993.

B. KOREN (ed.) (1994). *Het Nummer*, volumes 30 and 31, Stichting Mathematisch Centrum, Amsterdam.

Large-Scale Computing (NW3)

Staff

- Dr. ir. H.J.J. te Riele, group leader
- Prof. dr. H.A. van der Vorst, advisor
- P.L. Montgomery, Ph.D., guest researcher, January 17 – August 10, Thomas Stieltjes Institute for Mathematics (RUL)
- M.C. Dracopoulos, Ph.D., ERCIM - Fellow, March 1 – August 31
- Drs. J. Kok, researcher
- Drs. W.M. Lioen, programmer
- Drs. M. Nool, programmer
- D.T. Winter, programmer (0.4 fte on detachment from CST)
- Drs. H. Boender, junior researcher (AIO), on detachment from RUL
- Dr. A. Booten, junior researcher since Sept. 6, 1993; researcher since Sept. 15, 1994
- Drs. R.-M. Huizing, junior researcher (OIO), NWO/ RUL

Scientific Report

The central research theme of NW3 is High Performance Scientific Computing. Attention is focused on the optimization and comparison of mathematical and numerical algorithms on massively parallel processors, on parallel vector processors and on clusters of workstations, and the development and use of tools for enhancing portability of parallel software, and for performance evaluation of parallel hardware. In addition, members of this group support parallel computing projects in other CWI groups (NW1, NW2, and AM3).

For these tasks the group had access to the SGI workstations and compute servers and the Cray S-MP in the CWI network, to the Cray C98/4256, the IBM SP1 at SARA, the IC^{3}A Parsytec PowerXplorer and GCel-3 systems at SARA, and to the CM-5 parallel processor at Groningen University.

Scientific collaboration exists with the groups of Prof. H.A. van der Vorst (Utrecht University), Prof. J.P. Goedbloed (FOM Institute for Plasmaphysics Rijnhuizen), Prof. R. Tijdeman (Leiden University), Dr. A.K. Lenstra (Bellcore, USA), Prof. J. Buchmann (Univ. of Saarbrücken, Germany), Prof. R.P. Brent (The Australian National University, Canberra, Australia), and Prof. G. Cohen (Univ. of Technology of Sydney, Australia).

The research in NW3 is split up in the two projects
NW 3.1: Parallel numerical algorithms and
NW 3.2: Computational number theory.

Report on NW3.1: Parallel numerical algorithms

- *Parallel computation of eigenvalues of non-Hermitian generalized eigenproblems arising in linear magnetohydrodynamics (MHD)* (A. Booten, H.A. van der Vorst, H.J.J. te Riele). This project was started in September 1993, jointly with Utrecht University and the FOM Institute for Plasmaphysics Rijnhuizen.
  The following new iterative techniques have been developed and tested on sequential computers: (1) an Arnoldi method, that has the special feature of computing interior eigenvalues of matrices without inverting them; (2) the Jacobi-Davidson method of Sleijpen and Van der Vorst for computing the extreme eigenvalues and associated eigenvectors of a general matrix, applied to general eigenproblems. The latter method also avoids inversion of matrices and proved to be extremely suitable for computing MHD spectra. The time-consuming kernels of these methods, like inner products or matrix vector products, have already been extensively tested on distributed memory parallel computers like the Parsytec GCel and the Parsytec PowerXplorer.
- *Approximation of inverse submatrices for parallel finite element preconditioning* (M.C. Dracopoulos). Derivation of global preconditioners from entirely element-level information for the stiffness equations in structural finite element analysis. A report (NM-N9402) investigates how to build preconditioners based on approximate inverses of certain sub-blocks of the coefficient matrix. The derived preconditioners are meant to be suitable for the iterative solution of finite element problems on parallel computers.
- *Matrix decomposition algorithms* (M. Nool, H.J.J. te Riele). Matrix decomposition algorithms, like Cholesky decomposition, were studied on parallel machines. In particular, block structured algorithms were implemented and optimized with respect to load-balancing on CWI's Cray S-MP parallel shared memory system with 28 processing elements. A report has appeared as NM-R9425.

- *Job scheduling on a parallel shared memory bus architecture* (H.J.J. te Riele). Given a parallel shared memory machine configuration consisting of b buses where each bus contains $p(>1)$ processing elements. A typical bottleneck for such machines is that processing elements which reside on the same bus cannot access the shared memory concurrently. It is shown that the total processing time of a parallel job on a bus-type parallel computer may depend on the *order of execution* of the subjobs on the different nodes. Since this order of execution cannot, in general, be influenced by the programmer, this phenomenon must be accepted as an inherent uncertainty in the timing and reproducibility of jobs on bus-architecture parallel computers. A report will appear in the beginning of 1995.

Report on NW 3.2: Computational number theory

- *Factorization with the number field sieve (NFS)* (R.-M. Huizing, H. Boender, W.M. Lioen, P.L. Montgomery, H.J.J. te Riele). In this project the number field sieve method and its suitability to factor general numbers is being studied. Huizing and Montgomery worked on improving Montgomery's NFS package. Much time was spent on the step in NFS where the square root of the product of many algebraic numbers has to be computed. A new method of Montgomery (see Papers in Journals and Proceedings) for computing this square root was implemented with the help of H. Cohen's computer algebra package Pari. A report will appear early 1995. Montgomery and Huizing contributed many improvements to Pari (substantiated in release 1.39, announced January 16, 1995).
  In June – July some large numbers of record size were factored at CWI with the NFS. The software used was developed by researchers at Oregon State University in USA, and by Montgomery and Huizing at CWI. With the *special* NFS (called SNFS), the factorization of a Cunningham number of 162 decimal digits was completed, and with the *general* NFS (called GNFS) a 105-digit number was factored. These two numbers were new world records for the SNFS and GNFS, respectively. (About one month after the 105-digit number was completed, Arjen Lenstra, Bruce Dodson, and Peter Montgomery lifted the GNFS-record to a 116-digit number. Another four months later (in November 1994), Contini, Dodson, A.K. Lenstra and Peter Montgomery factored a 119-digit number with the GNFS in about 250 mips years CPU-time). The CPU-time needed to factor the 105-digit number (and the 116- and 119-digit numbers) indicates that GNFS can beat the multiple polynomial quadratic sieve algorithm (which was the best method for general numbers before the NFS was discovered) for much smaller numbers than was estimated before (about 110 digits). In addition to the above numbers, Huizing and Montgomery have factored several other numbers with SNFS (of 98, 99, 106, 119, 123, and 135 decimal digits) and with GNFS (a 87-digit number).
  An important tool used in these large-scale, massively parallel computations, was a new block Lanczos iterative algorithm for finding dependencies over GF(2), developed by Montgomery (a report will appear early 1995). This made it possible to increase the size of the factor bases considerably, compared with the size which can be handled by the well-known structured Gaussian elimination method of LaMacchia and Odlyzko.
- *Experiments with the double-large-prime variation of the quadratic sieve method* (H. Boender, R.-M. Huizing, W.M. Lioen, P.L. Montgomery, H.J.J. te Riele). H. Boender worked on the implementation of the double-large-prime variation of the multiple polynomial version of the quadratic sieve factoring algorithm (PPMPQS) on an SGI workstation and on the Cray Y-MP and C90. The factorization of the numbers yielding the two large primes is done by means of the so-called SQUFOF method of Shanks (because of their relatively small size). Elimination of the large primes is done by means of a method for finding cycles in a graph. A report will appear early 1995.
- *Extending the Cunningham table* (P.L. Montgomery, H.J.J. te Riele, H. Boender, R.-M. Huizing, W.M. Lioen). Montgomery vectorized his ECM/FFT program on the Cray Y-MP and the Cray C90. With this program it is possible to find some prime factors up to 35 digits of 100-digit numbers in about 3 CPU-hours on the Y-MP and in about 1.5 CPU-hours on the C90. Apart from many factors of Cunningham numbers (see below), Montgomery found eight cofactors of Fibonacci numbers with this program. A report will appear in 1995.
  By means of the factoring software available at CWI (PMPQS, the self-initialization version of PMPQS, PPMPQS, and Montgomery's ECM/FFT program) hundreds of previously incompletely factored numbers from the extended Cunningham Table (R.P. Brent, H.J.J. te Riele, *Factorizations of* $a^n \pm 1, 13 \leq a < 100$, Report NM-R9212, June

1992), were factored on CWI workstations, and on the Cray Y-MP and C90 of SARA (with financial support from the Stichting NCF). An update to Report NM-R9212, containing more than 500 new factorizations, appeared in September (Report NM-R9419).

- *Numerical sieve methods for number-theoretical problems* (W.M. Lioen, J. van de Lune). Using a vectorized numerical sieving algorithm, Lioen and Van de Lune performed systematic computations on $M(x)$, the first summatory function of the Möbius function. Using about 400 CPU-hours on a Cray C90 they established the bounds $-0.513 < M(x)/\sqrt{x} < 0.571$, valid for $200 < x \leq 1.78 \cdot 10^{13}$. The sieve algorithm used, is a generalization of Eratosthenes' sieve for finding prime numbers and, in its turn, it is generalizable to a much wider class of problems. Lioen and Van de Lune showed it to be generalizable to arbitrary arithmetical functions $f : \mathbf{N} \rightarrow \mathbf{Z}$ as long as there exists a fairly simple relation between $f(p^e q)$ and $f(p^{e-1}q)$, where $e, p, q \in \mathbf{N}$, p prime, $p \nmid q$. These algorithms can be applied to many number-theoretical problems like Dirichlet's divisor problem, Gauss' lattice point problem, Liouville's function, and amicable numbers, to name a few. A report including the above mentioned computations on $M(x)$, and computations on Dirichlet's divisor problem, will appear in the beginning of 1995.
- *Amicable triple* (H.J.J. te Riele). An algorithm suggested by Erdös and Pomerance, developed for finding amicable number *pairs* (see Papers in Journals and Proceedings), was extended to amicable triples and higher tuples (as introduced by L.E. Dickson). Many hundreds of new amicable triples were found with this algorithm. A report will appear in the beginning of 1995.

Organisation of Conferences, Workshops, Courses, etc.

- CWI/RUU Symposia on Massively Parallel Computing and Applications
  In 1993 – 1994, CWI (Te Riele) and the University of Utrecht (Van der Vorst) have organised a series of bi-monthly symposia on Massively Parallel Computing and Applications. Each meeting was centred around a special topic. In 1994 three meetings took place, the first two at CWI and the third at Delft University of Technology (following a three-day Summerschool on Parallel Computing in Fluid Dynamics from May 31 – June 2, organised by P. Wesseling). Below are listed the topics and dates of the three meetings, and the speakers and their subjects.
  Parallel numerical algorithms and software, February 4:
  Eric ten Cate (speaker) and Edwin Vollebregt (Delft University of Technology), Rigorous abstraction and specification in parallel software development;
  Maya Neytcheva (Catholic University Nijmegen), Experience in implementing the algebraic multilevel iteration method on an SIMD-type computer;
  Martin van Gijzen (Utrecht University), Experiences with element-by-element iterative solution methods on parallel and vector computers;
  Johan De Keyser (Catholic University Leuven, Belgium), Spatial accuracy and parallel nonlinear solvers for convective partial differential equations.
  Parallel numerical algorithms and software, March 25:
  Ivan Graham (speaker) and R.K. Coomer (School of Mathematical Sciences, Univ. of Bath, UK), Massively parallel methods for semiconductor device modelling;
  Rudnei Dias da Cunha (speaker) and Tom Hopkins (Computing Laboratory, Univ. of Kent at Canterbury, UK), Designing a portable numerical package for parallel architectures: the Parallel Iterative Methods package.
  Parallel Numerical Algorithms and CFD - Applications, June 3:
  C.W. Oosterlee (GMD, Bonn), Parallel multiblock multigrid solution techniques for the Euler equations and robustness aspects of a non-standard multigrid method;
  R. Verstappen (speaker) and A.E.P. Veldman (University of Groningen), Direct Numerical Simulation of Turbulence on a Connection Machine CM-5;
  K. Burrage (speaker, ETH Zürich and Univ. of Queensland, Brisbane, Australia) and A. Williams (Univ. of Queensland), Adaptive acceleration of iterative schemes for linear systems;
  E. De Sturler (Swiss Scientific Computer Center CSCS, ETH Zürich), IBLU Preconditioners on Overlapping Subdomains for Massively Parallel Computing;
  Peter Michielse (CONVEX Computer BV, Utrecht), Parallel Multigrid using PVM.
  The Proceedings of these Symposia will appear in 1995 as a Special Issue of the journal 'Applied Numerical Mathematics'.
- Symphony on 'Non-linear Problems'
  On December 16, a 'Symphony' meeting (the se-

cond in its kind) was organised at CWI by Philips Eindhoven (W. Schilders), Utrecht University (H.A. van der Vorst and D. Fokkema), and CWI (H.J.J. te Riele), with the purpose to bring together experts in fields with an overlap in non-linear problems, and to 'conduct a symphony of inspiration, intelligence and motivation'. Twenty participants from Delft, Eindhoven, Nijmegen, Utrecht, Amsterdam, Namen (België), Enschede, and Groningen discussed a wide spectrum of non-linear problems and their numerical treatment. Invited lectures were presented by C. Roos (Delft Univ. of Technology) on 'A nonlinear approach to linear optimization', by Ph. Toint (FUNDP, Namur, Belgium) on 'Nonlinear optimization: why and how, today and tomorrow', and by O. Axelsson (Univ. of Nijmegen) on 'Two-level mesh method for non-linear partial differential equations'.

- Working Group Large-Scale Computing
  This group met once every three or four weeks, and discussed new developments in high performance scientific computing. Participants came from the Universities of Amsterdam, Utrecht and Delft, the FOM Institute for Plasmaphysics Rijnhuizen, and CWI. In 1994, twelve meetings were organised (Te Riele). The dates, the speakers and their subjects were:
  on February 16:
  Peter M. Meijer (FOM-Institute for Plasmaphysics Rijnhuizen), Parallel magnetohydrodynamics: performance of the essential parts of MHD codes on the CM-5
  Gera Pronk (University of Amsterdam), Eerste ervaringen met het IBM-dialect van PVM op de SP1
  on March 4:
  Ramon Oostveen (Utrecht University), De rol van inproducten in parallel Generalized Conjugate Residuals
  Albert Booten, An iterative Arnoldi method for computing internal eigenvalues of large non-Hermitian matrices
  on March 18:
  Michael C. Dracopoulos (ERCIM - Fellow), Finite element solution procedures for multi-processor computer architectures
  on April 27:
  Henk van der Vorst (Utrecht University), A generalized Jacobi-Davidson iteration method for linear eigenvalue problems
  on May 11:
  Jan Kok, Treatment of linear systems for the solution of a 3D transport model
  on June 17:
  Albert Booten, A preconditioned Jacobi-Davidson method for generalized eigenvalue problems
  Peter L. Montgomery (Thomas Stieltjes Institute for Mathematics Leiden), A block Lanczos algorithm for finding dependencies over GF(2)
  on July 1:
  Henk van der Vorst (Utrecht University), Iterative methods for nonsymmetric systems
  Herman te Riele, On the eigenvalues of Redheffer's matrix and the Riemann hypothesis
  on August 19:
  D. Sorensen (Dept. of Mathematical Sciences, Rice University, Houston, USA), Implicitly restarted Arnoldi methods for large scale eigenvalue problems
  on September 2:
  G. Sleijpen (Utrecht University), Can stagnation be avoided in the BiCGSTAB process?
  Herman te Riele, Some experiences with Bailey's high-performance multiple-precision package MPFUN
  on October 14:
  Henk van der Vorst (Utrecht University), Approximate and incomplete factorizations
  on November 11:
  Lex Wolters (HPC Division, Department of Informatics, Leiden University), Data-parallelle numerieke weersverwachting
  Gerard Sleijpen (Utrecht University), Reliable updated residuals in CGS and other hybrid Bi-CG methods
  on December 2:
  Martin van Gijzen (Utrecht University), Eerste T3D ervaringen
  Henk van der Vorst (Utrecht University), Indrukken van Supercomputing '94 (Washington)
  Herman te Riele, Multi-lengte kettingbreukberekening voor het oplossen van Diophantische vergelijkingen

- Working Group Parallel Computation in Magnetohydrodynamics and Astrophysics
  This group started in October 1993 to discuss the progress in the NWO pilot MPR (Massaal Parallel Rekenen) project 'Parallel Computation in Magnetohydrodynamics and Astrophysics'. In this project are collaborating the FOM Institute for Plasmaphysics Rijnhuizen, Utrecht University (Departments of Astrophysics and Mathematics) and CWI. One goal of this project is to investigate the suitability of parallel computers like the Parsytec GCel of SARA, the CM-5 of Groningen University, and the Cray T3D, for solving larger problems in magnetohydrodynamics and in astrop-

hysics than could be handled so far on serial computers.
The group met eight times, namely on January 24 (FOM Rijnhuizen), March 2 (Mathematical Institute, Utrecht University), April 26 (Buys Ballot Laboratory, Utrecht University), June 14 (FOM Rijnhuizen), August 16 (FOM Rijnhuizen), September 21 (CWI), October 26 (FOM Rijnhuizen), and December 14 (FOM Rijnhuizen). Albert Booten gave the following two presentations: Progress with the Arnoldi algorithm (January 24) and The Davidson method applied to the generalized eigenvalue problem of MHD (June 14), and Piet Hemker gave an introductory talk on Approximate Riemann solvers for numerical flux functions (September 21).

- Workshop on Factorization and Primality Testing Methods
  Within the framework of the Thomas Stieltjes Institute for Mathematics, Leiden University and CWI have collaborated in a workshop on factorization and primality testing. The workshop was given at CWI in a series of five Friday morning meetings in the period January 28 – May 9. The following topics were discussed:
  - Het Cunningham - Factorisatieproject (H.J.J. te Riele, January 28)
  - Maple (Peter L. Montgomery, February 18)
    Long integer arithmetic (Dik T. Winter, February 18)
  - Implementation of Modular Multiplication (Peter L. Montgomery, March 4)
    Optimal choice of parameters for one-step ECM (Nils Bruin, RU Leiden, March 4)
  - Primality testing of N based on (partial) knowledge of the prime factors of $N-1$ (Roberto Akkal, Leiden University, April 29)
    On the square root step in the general number field sieve (Marije Huizing, April 29)
  - Solving linear systems over finite fields by iterative methods, with application in factorization (Henk Boender, May 9)

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *AMS/MAA Joint Mathematics Meeting*, Cincinnati, Ohio, USA, January 12–15: P.L. Montgomery (Number field sieve with several large primes).
- *ERCIM Symposium Affordable Parallel Processing for Industry and Commerce - steering committee meeting*, London Heathrow, January 14: H.J.J. te Riele.
- *ERCIM Parallel Processing Network Workshop – steering committee meeting*, Amsterdam Schiphol, February 11: H.J.J. te Riele.
- *CWI Cryptography Working Group*, February 18: H. Boender, R.-M. Huizing, W.M. Lioen, P.M. Montgomery (Modular arithmetic and cryptography).
- *IBM SP1 Course*, ESTEC, Noordwijk, March 3: W.M. Lioen, H.J.J. te Riele, D.T. Winter.
- *NCF Symposium Tasting Tomorrow Today*, Amsterdam, March 28: H. Boender, R.-M. Huizing, W.M. Lioen, P.L. Montgomery, H.J.J. te Riele (ABC-vermoeden, Diophantus, en C98: een aeuwige diamanten combinatie?).
- *Dertigste Nederlands Mathematisch Congres*, Leiden University, April 7–8: H. Boender (Factoriseren met versies van MPQS), R.-M. Huizing, W.M. Lioen, P.L. Montgomery, H.J.J. te Riele (Bevriende getallentripels).
- *HPCN Europe 1994*, München, Germany, April 18–20: A. Booten (Parallel Arnoldi method for the construction of a Krylov subspace basis: an application in magnetohydrodynamics).
- *Afscheid J. van de Lune*, CWI, May 11: J. Kok, W.M. Lioen, H.J.J. te Riele (De laatste stelling uit Jan's proefschrift: toepassingen in de getaltheorie), D.T. Winter.
- *Thomas Stieltjes Institute Workshop on Constructive Methods for Diophantine Equations and Elliptic Curves*, Erasmus University Rotterdam, May 31: H.J.J. te Riele (Numerical experiments on the abc-conjecture using the LLL-algorithm).
- *ERCIM Parallel Processing Network Workshop*, June 8–10, Crete, Greece: H.J.J. te Riele (Highlights and future research interest in parallel processing at CWI Amsterdam), J.G. Verwer (Parallel algorithms for differential equations).
- *Getaltheoriedag ter herdenking van de 100e geboortedag van de russische wiskundige N.G. Chebotarev*, June 15, University of Amsterdam: R.-M. Huizing, W.M. Lioen, P.L. Montgomery, H.J.J. te Riele.
- *Conference on Programming Languages Design and Implementation*, June 21–24, Orlando, Florida, USA: P.L. Montgomery (Division by invariant integers using multiplication).
- *Symposium on Parallel Algorithms and Architectures*, June 25–29, Cape May, New Jersey, USA: P.L. Montgomery.
- *Lecture by M. Livny on Condor and PVM*, July 6, Amsterdam (FWI, University of Amsterdam): W.M. Lioen.
- *NCF-lezing door Prof. C. Roothaan*, July 26, 's-Gravenhage: J. Kok, W.M. Lioen.

- *Conferentie van Numeriek Wiskundigen*, September 26–28, Zeist: A. Booten, J. Kok, W.M. Lioen, M. Nool, H.J.J. te Riele.
- *8th International Workshop on Distributed Algorithms, WDAG '94*, September 29 – October 1, Terschelling: H. Boender, R.-M. Huizing (both only on September 29).
- *Sup'Eur 94 Conference*, October 3–5, Amsterdam (Free University): W.M. Lioen, H.J.J. te Riele.
- *Cray T3D Applications Programming Course*, SARA, Amsterdam, October 10–13: J.G. Blom, W.M. Lioen, M. Nool; October 17–20: J. Kok.
- *Dagstuhl Seminar on Algorithms and Number Theory*, October 10–14, Schloß Dagstuhl, Wadern, Germany: H.J.J. te Riele (Amicable Number Triples).
- *Fachbereich Informatik, Universität des Saarlandes, Saarbrücken, Germany*, October 17–18: H.J.J. te Riele (Recent factorizations with SNFS, GNFS, ECM and MPQS at CWI Amsterdam).
- *CWI Cryptography Working Group*, October 21: H. Boender, R.-M. Huizing, W.M. Lioen, H.J.J. te Riele (Recent factorizations with SNFS, GNFS, ECM and MPQS at CWI Amsterdam).
- *Institut für Informatik, Universität zu Köln*, Germany, November 18: R.-M. Huizing (Experiments with the Number Field Sieve).
- *UCS '94 Symposium 'Parallel Computing Applications: A Path Towards The Future'*, Utrecht University Center for Computational Science, November 18: A. Booten, J. Kok, M. Nool, H.J.J. te Riele, B.P. Sommeijer.
- *EuroBen Workshop on Performance Evaluation and Benchmarking of Parallel Systems*, University of Warwick, Coventry, UK, December 15–16, M. Nool (Parallel Processing on the Attached Parallel Processor of the CRAY S-MP).
- *Elfde supercomputer-gebruikersdag*, SARA, Amsterdam, December 16: W.M. Lioen, M. Nool.

Memberships of Committees and Other Professional Activities

H.J.J. te Riele:
- Member steering committee ERCIM Symposium 'Affordable Parallel Processing'
- Member steering committee ERCIM 'Parallel Processing Network'
- Driver (together with B. Philippe of INRIA/IRISA) of ERCIM proposal 'Parallel and Distributed Applications Enabling Environments' for the EU Fourth Framework Program
- Editor Nieuw Archief voor Wiskunde (Section Expository Papers)
- Referee of papers submitted to 'Mathematics of Computation' and 'Applied Numerical Mathematics'
- Reviewer for 'Mathematical Reviews' and the 'Zentralblatt für Mathematik'
- Member Redactieraad NCF-cursus 'Methods in Computational Research'
- Chairman CWI-Bibliotheekcommissie

J. Kok:
- Member CWI committee Overleg Computer-Voorzieningen
- Member CWI A-team
- Member Algemeen CWI Colloquium

P.L. Montgomery:
- Referee of several papers for journals and conferences

Visitors

- J. De Keyser (Catholic University of Leuven, België), February 4 (see Organisation of Conferences, Workshops, Courses, etc.)
- I. Graham (School of Mathematical Sciences, University of Bath, UK), March 24–26 (see Organisation of Conferences, Workshops, Courses, etc.)
- R. Dias da Cunha (Computing Laboratory, University of Kent at Canterbury, UK), March 24–26 (see Organisation of Conferences, Workshops, Courses, etc.)
- H.C. Williams (University of Manitoba, Winnipeg, Canada), Beeger - Fellow, April 2–13 (Beeger lecture at Thirtieth Dutch Mathematical Congress, Leiden: Numerical sieving devices, their history and some applications (April 7); lecture at CWI: Units of real quadratic fields (April 11))
- Johannes Buchmann (Fachbereich Informatik, Universität des Saarlandes, Saarbrücken, Germany), August 8–12 (Quadratic Forms and Cryptography)
- D.C. Sorensen (Dept. of Mathematical Sciences, Rice University, Houston, USA), August 19 (Implicitly restarted Arnoldi methods for large-scale eigenvalue problems)

Papers in Journals and Proceedings

J.G.L. BOOTEN, P.M. MEIJER, H.J.J. TE RIELE, H.A. VAN DER VORST (1994). Parallel Arnoldi method for the construction of a Krylov subspace basis: an application in magnetohydrodynamics, pp. 196–201 in: W. GENTZSCH and UWE HARMS (eds.). *High-Performance Computing and Networking* (International Conference and Exhibition, Munich, Germany, April 18–20, Volume II: *Networking and Tools,* Springer-Verlag, Berlin etc..

J. KOK (1994). Validation of metrology reference software, 231–238 in: P. CIARLINI, M.G. COX, R. MONACO, and F. PAVESE (eds.). *Advanced Mathematical Tools in Metrology* (International Workshop, Torino, Italy, October 20–22, 1993), World Scientific, Singapore, etc.

M. LOUTER-NOOL (1994). A parallel multigrid code with a fast vectorized ILU-relaxation. *Future Generation Computer Systems, vol. 10,* 309–313.

Peter L. Montgomery (1994). Square roots of products of algebraic numbers, in: WALTER GAUTSCHI (ed.). 'Mathematics of Computation 1943–1993', *Proceedings of Symposia in Applied Mathematics,* American Mathematical Society.

PETER L. MONTGOMERY (1994). A survey of modern factorization algorithms. *CWI Quarterly, Volume 7, Number 4.*

P.M. MOREE, H.J.J. TE RIELE, J. URBANOWICZ (1994). Divisibility properties of integers x, k satisfying $1^k + 2^k + \ldots + (x-1)^k = x^k$. *Math. Comp., vol. 63, number 208,* 799–816.

H.J.J. TE RIELE (1994). A new method for finding amicable pairs, in: WALTER GAUTSCHI (ed.). 'Mathematics of Computation 1943–1993', *Proceedings of Symposia in Applied Mathematics,* American Mathematical Society.

H.J.J. TE RIELE (1994). Computational Number Theory at CWI in 1970–1994. *CWI Quarterly, Volume 7, Number 4.*

CWI Reports

NM-R9406 J.G.L. BOOTEN, P.M. MEIJER, H.J.J. TE RIELE, H.A. VAN DER VORST. *Parallel Arnoldi method for the construction of a Krylov subspace basis: an application in magnetohydrodynamics.*

NM-R9414 J.G.L. BOOTEN, H.A. VAN DER VORST, P.M. MEIJER, H.J.J. TE RIELE. *A preconditioned Jacobi-Davidson method for solving large generalized eigenvalue problems.*

NM-R9415 A. STEWART, M. LOUTER-NOOL, H.J.J. TE RIELE, D.T. WINTER. *An investigation of data reuse on the Cray S-MP System 500.*

NM-R9419 R.P. BRENT, P.L. MONTGOMERY, H.J.J. TE RIELE. *Update 1 to: Factorizations of* $a^n \pm 1$, $13 \leq a < 100$.

NM-N9402 M.C. DRACOPOULOS. *Approximating inverse submatrices for parallel finite element preconditioning.*

NM-R9423 M. NOOL AND P.M. DE ZEEUW. *Numerical multigrid software for elliptic PDEs, Routines: MGD1M and MGD5M.*

NM-R9425 M. NOOL. *Explicit parallel block Cholesky algorithms on the Cray APP.*

Other Publications

TORBJÖRN GRANLUND, CIGNUS SUPPORT, P.L. MONTGOMERY (1994). *Division by Invariant Integers Using Multiplication,* SIGPLAN Notices.

DEPARTMENT OF SOFTWARE TECHNOLOGY

General Introduction

Staff Department of Software Technology, 1994

- AP1
  - J.W. de Bakker
  - B.P.F. Jacobs
  - C.H.M. van Kemenade
  - J.J.M.M. Rutten
  - D. Turi
  - H. Wiklicky
- AP2
  - F.W. Vaandrager
  - D.J.B. Bosscher
  - A. Bouali
  - W.J. Fokkink
  - W.O.D. Griffioen
  - A.S. Klusener (joint AP2/AP3)
  - H.P. Korver
- AP3
  - P. Klint
  - A. van Deursen
  - T.B. Dinesh
  - J.J. Ganzevoort
  - J. Heering
  - J. Kamperman
  - A.S. Klusener (joint AP2/AP3)
  - E.A. van der Meulen
  - F. Tip
  - H.R. Walters
- AP4
  - J.W. Klop
  - H.P. Barendregt
  - I. Bethke
  - C. Brovedani
  - H. Elbers
  - F. van Raamsdonk
  - F.-J. de Vries
- AP5a
  - K.R. Apt
  - J.J. Brunekreef
  - S. Etalle
  - M. Gabbrielli
  - E. Marchiori
  - M.C. Meo
  - F. Teusink
- AP5b
  - D.J.N. van Eijck
  - D. Ben Shalom
  - G. Cepparello
  - A.V. Groenink
  - J. Jaspars
  - W. Meyer Viol
  - M. de Rijke
  - W.C. Rounds
  - Y. Venema
- Secretary: J.J. Bruné-Streefkerk

Semantics (AP1)

Staff

- Prof. dr. J.W. de Bakker, department head and group leader
- Dr. B.P.F. Jacobs, post-doc, from September 1
- Drs. C.H.M. van Kemenade, OIO, from September 1
- Dr. J.J.M.M. Rutten, researcher
- Drs. D. Turi, junior researcher (OIO)
- Dr. H. Wiklicky, visitor (Austria)

Scientific Report

De Bakker continued his work on the preparation of a comprehensive textbook/monograph entitled Control Flow Semantics, describing more than a decade of the research of AP1 and its associates. A general semantic methodology is developed, based on (metric) topology and aiming at a unified treatment of both sequential and concurrent programming. For 27 languages, operational and denotational semantic models are presented, and precise statements relating the models are given. Coauthor of the book is dr. E. de Vink (VUA); it will be completed in 1995 and published by MIT Press.
The proceedings 'A Decade of Concurrency - Reflections and Perspectives' (jointly edited by De Bakker, prof. W.P. de Roever (Kiel) and prof. G. Rozenberg (University of Leiden)) appeared as final publication of the REX project (1988–1993). The former REX project member ir. F.C. van Breugel (VUA) - member of AP1 in 1992, 1993 - defended his Ph.D. thesis entitled Topological Models in Comparative Semantics on September 28.

Rutten has continued the work on transition systems and coalgebras (in the context of the SION project 'Non-well-founded sets'). In particular, a calculus of transition system has been developed, with as main ingredients coalgebras, homomorphisms and bisimulations, along the lines of universal algebra. Many of the results that are standard in algebra (such as isomorphism theorems) also hold in their coalgebraic version. Some others are still under investigation, in particular, a counterpart to the two famous Birkhoff theorems (see also the description of Jacobs).
Rutten has continued his work on generalized (ultra)metric domain theory, based on the work of F. Lawvere on generalized metric spaces. In addition to offering a suitable framework for the unification of order and metric domain theory, these generalized spaces seem to be of relevance as a semantic tool for their own sake. A number of basic results has been established, notably the solution of recursive domain equations (unifying the standard order-theoretic and metric approaches) by means of metric adjoint pairs. Furthermore first results have been obtained—in joint work with M. Bonsangue (Free University of Amsterdam) and F. van Breugel (McGill University)—on generalized powerdomains.

Jointly with P. Gastin, Rutten has guest-edited a special issue of TCS, dedicated to the proceedings of the workshop on 'Topology and completion in semantics', which was held in Chartres, 1993.

Jacobs has started on September 1, 1994 as SION post-doc at the 'aandachtsgebied' Higher Order and Object-Oriented Processes (HOOP). Most of the time was spent on getting acquainted with the research field and with the topics of the project. Investigations of objects and classes in object-oriented languages have begun, starting from the co-algebraic perspective. This research is coordinated with similar investigations by Jan Rutten. First results will appear in 1995 in proceedings of the conferences Mathematical Foundations of Program Semantics (MFPS) and Algebraic Methods and Software Technology (AMAST).

Turi has designed a calculus of typed processes. This calculus is derived from classical linear logic by means of the propositions-as-types and proofs-as-programs correspondence. It improves previous work by Girard and by Abramsky by adding non-determinacy and a parallel composition operator. The latter extends in the concurrent setting the application operator of the lambda calculus. A draft paper on this work is available.

Wiklicky. The main focus was on the continuation of investigations towards a mathematical semantics of neural networks. Two semantic levels have to be distinguished: on one the hand we have the specification of neural networks and their basic mechanisms themselves, and on the other hand the handling of information stored in a neural network after (successful) training. The later is of particular interest when questions like how to initialize neural networks are considered.

A promising approach toward this aim, based on functional analytical elements was proposed. In particular, so called, C*-algebras were intensively studied in this context. Furthermore, the relation of such a model to several other relevant areas which range from Girard's proof theory for linear logic to dynamical systems and stochastic processes – to mention just a few – was looked at.

Van Kemenade started his research on solving Constrained Optimization problems by means of Evolutionary Algorithms (EAs) and Artificial Neural Networks (ANNs). Work on application of EAs in Air Traffic Control has been continued together with J.N. Kok (RUU) and C.F.W. Hendriks (NLR). Together with A.E. Eiben (RUU) and J.N. Kok (RUU) the effectiveness of two new recombination operators, with an adjustable arity, have been studied for function optimization tasks. Furthermore EAs have been applied to a time-constrained routing problem.

Organisation of Conferences, Workshops, Courses, etc.

- SCIENCE-MASK. The CWI is coordinator of the MASK project–devoted to Mathematical Structures in Concurrency Semantics. Partners are the CWI, the Universities of Koblenz, Mannheim, Pisa and Udine, and INRIA-Rennes. Action manager is Rutten. The fourth workshop of MASK was organized by INRIA (Rennes) and the fifth workshop took place in Mannheim.
- ACG - the Amsterdam Concurrency Group. ACG is an –on average biweekly– seminar in which ongoing research on semantics is discussed by members and former members of AP1, and invited visitors. External participants include dr. E. de Vink (VUA), dr. J.N. Kok (RUU), M. Bonsangue (VUA), dr. F.C. van Breugel, prof. A. de Bruin (EUR), drs. R. van der Goot (EUR), dr. J.M. Jacquet (Namur), and prof. W. Rounds (visitor AP5).

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Austrian Research Institute for Artificial Intelligence*, Vienna, Austria, January 26, H. Wiklicky (invited lecture Elemente einer analytischen Algorithmik: Operatoren, Algebren und (neuronale) Netzwerke).
- *ICALP '94 Program Committee Meeting*, Paris, France, February 2–4, J.W. de Bakker.
- *Working visit University of Edinburgh* (prof. Plotkin), UK, February 13–25 and September 9–17, D. Turi (Final Coalgebra Semantics).
- *EC Human Capital and Mobility Programme, Panel on Mathematics and Computer Science*, Brussels, Belgium, February 14, 15 and July 14: J.W. de Bakker.
- *Working visit University of Torino and and University of Udine*, Italy, February 27–March 5, J.J.M.M. Rutten (A calculus of transition systems).
- *Three Days of Bisimulation*, CWI, Amsterdam, April 20–22, J.J.M.M. Rutten (A calculus of transition systems).
- *Fourth MASK Workshop*, Rennes, France, April 27–29, J.W. de Bakker, J.J.M.M. Rutten.
- *Working visit University of Edinburgh*, Edinburgh, UK (Prof. G. Plotkin), June 1–5, J.J.M.M. Rutten (Elements of metric domain theory).
- *Universitaet Koblenz-Landau*, Ph.D. Examination D. Nolte, July 13: J.W. de Bakker, J.J.M.M. Rutten.
- *ECAI '95, European Conference on Artificial Intelligence* and Workshop on Combining Symbolic and Connectionist Processing, Amsterdam, August 2–8, H. Wiklicky.
- *European Science and Technology Assembly*, Brussels, Belgium, September 6, 7: J.W. de Bakker.
- *Working visit University of Edinburgh*, Edinburgh, UK (Prof. G. Plotkin and M. Fiore), September 9–17, D. Turi.
- *Advanced School on Typed Lambda calculus and Functional Programming*, Udine, Italy, September 18–October 1, D. Turi.
- *Project meetings HOOP project*, RU Leiden, September 30 and December 2: J.W. de Bakker (Second-order assignment), B.P.F. Jacobs (Process objects), J.J.M.M. Rutten.
- *Fifth MASK Workshop*, Mannheim, Germany, October 11–13, J.W. de Bakker, J.J.M.M. Rutten, D. Turi.
- *Workshop Optimization in Production and Transportation*, Scheveningen, November 9–11, K. van Kemenade.
- *Working visit University of Edinburgh*, Edinburgh, UK (prof. G. Plotkin), D. Turi, November 1–December 31.
- *Technical University Berlin*, Berlin, Germany, December 8, 9, J.J.M.M. Rutten (invited lecture on Transition systems and coalgebras).
- *PSSL: 56th Peripatetic Seminar on Sheaves and Logic*, Aarhus, Denmark, December 10, 11, B.P.F. Jacobs (Mongruences and Cofree Coalgebras).

Memberships of Committees and Other Professional Activities

J.W. de Bakker
- Professor of Computer Science, Vrije Universiteit Amsterdam
- Member Koninklijke Nederlandse Akademie van Wetenschappen
- Member Akademieraad voor de Wiskunde
- Member Selection committee Natuurwetenschappen, Programma Akademieonderzoekers

- Member Academia Europaea and chairman Committee on Computing, A.E.
- Member EU European Science and Technology Assembly
- Editor Cambridge University Press Tracts in Theoretical Computer Science
- Consulting editor, Wiley Series in Parallel Computing
- Editor Theoretical Computer Science
- Editor Fundamenta Informaticae
- Associate editor Journal of Computer and System Sciences
- Member panel Mathematics and Computing, EC Program on Human Capital and Mobility
- Member IFIP Working Group 2.2 on Formal Description of Programming Concepts
- Member Program Committee ICALP94, Jerusalem
- Boardmember IPA, Dutch Graduate School Institute for Programming and Algorithmics
- Member SION Beoordelingscommissie Onderzoeksvoorstellen
- Projectleader SION project HOOP: Higher Order and Object-Oriented Processes
- Member Ph.D. Committee, P. Spruit (VUA), P.W. Hoogers (RUL), W.J. Fokkink (UvA)
- Promotor F.C. van Breugel (VUA) - Topological Models in Comparative Semantics
- External examiner Ph.D. thesis D. Nolte (University of Koblenz)

J.J.M.M. Rutten

- Coordinator SCIENCE project MASK (Mathematical Structures in Concurrency Semantics)
- Project Leader SION project 'Non-well-founded sets and programming language semantics'
- Member of the SION 'Aandachtsgebied' HOOP (Higher-Order and Object-Oriented Processes).
- Course on 'Semantics' at the University of Utrecht.
- External referee of the Ph.D. thesis of D. Nolte, Univ. of Koblenz. (Promotor was L. Priese.)

Visitors

- K. Wagner, CMU Pittsburgh, USA/Uni-Linz, Austria, January 25 (Abstract Preorders).
- R.J. Back, Univ. Turku/Univ. Utrecht, April 12 (A Game-Theoretic Semantics for Predicate Transformers).
- M. Fiore, Univ. Edinburgh, UK, April 19 (Algebraically Compact Categories).
- M. Kwiatkowska, Univ. Leicester, UK, April 20–22.
- A. Corradini, Univ. Pisa, Italy, May 10 (From Petri Nets to (Algebraic) Graph Grammars. Basic Notions and Truly Concurrent Semantics).
- L. Pooyan, Univ. Berlin, Germany, May 17 (Epsilon-Structures as Semantic Models of Labelled Transition Systems).

Papers in Journals and Proceedings

J.W. DE BAKKER, E.P. DE VINK (1994). Bisimulation semantics for concurrency with atomization and action refinement. *Fundamenta Informaticae*, 20:3–34.

J.W. DE BAKKER, F.C. VAN BREUGEL (1994). Topological models for higher order control flow. S. BROOKES ET AL (eds.). *Proceedings 9th MFPS Conference*, LNCS 802, Springer-Verlag, 122–142.

G. DORFFNER, H. WIKLICKY, E. PREM (1994). Formal neural network specification and its implications on standardization. *Computer Standards and Interfaces*, 16:205–219, special issue on artificial neural network standards, Elsevier Science Publishers, Amsterdam.

E. HORITA, J.W. DE BAKKER, J.J.M.M. RUTTEN (1994). Fully abstract denotational models for nonuniform concurrent languages. *Information and Computation*, Vol. 115, No.1, 125–178.

B. JACOBS (1994). Semantics of Weakening and Contraction. *Annals of Pure and Applied Logic*, 69:73–106.

B. JACOBS (1994). Coalgebras and Approximation. A. NERODE AND YU. V. MATIYASEVICH (eds). *Logic Foundations of Computer Science*, St. Petersburg, LNCS 813, Springer-Verlag, 173–183.

J.J.M.M. RUTTEN (1994). A structural coinduction theorem. S. BROOKES ET AL (eds.). *Proceedings of the Ninth Conference on the Mathematical Foundations of Programming Semantics*, LNCS 802, Springer-Verlag, 83–102.

J.J.M.M. RUTTEN, D. TURI (1994). Initial algebra and final coalgebra semantics for concurrency. J.W. DE BAKKER, W.P. DE ROEVER, G. ROZENBERG (eds.). *Proceedings REX School/ Symposium 'A decade of concurrency'*, LNCS 803, Springer-Verlag, 530–582.

H. WIKLICKY (1994). On the non-existence of a universal learning algorithm for recurrent neural networks. *Advances in Neural Information Processing Systems*, Vol. 6, Morgan Kaufmann, San Mateo, CA, 431–436.

H. WIKLICKY (1994). The neural network loading problem is undecidable. *Proceedings of the EuroCOLT '93 - European Conference on Computational Learning Theory*, IMA Conference Proceedings Series, Oxford University Press, Oxford, 183–192.

CWI Reports

CS-R9409 J.J.M.M. RUTTEN, D. TURI. *Initial algebra and final coalgebra semantics for concurrency.*

CS-R9424 F. VAN BREUGEL, J. WARMERDAM. *Solving domain equations in a category of compact metric spaces.*

Other Publications

J.W. DE BAKKER, W.P. DE ROEVER, G. ROZENBERG (eds.) (1994). *Proceedings REX School/Symposium A Decade of Concurrency - Reflections and Perspectives*, LNCS 803, Springer, 684 pp.

F.C. VAN BREUGEL (1994). *Topological Models in Comparative Semantics*, Ph.D. Thesis, Vrije Universiteit Amsterdam.

Concurrency and Real-Time Systems (AP2)

Staff

- Dr. F.W. Vaandrager, group leader
- Drs. D.J.B. Bosscher, junior researcher (OIO)
- Dr. A. Bouali, ERCIM fellow
- Dr. W.J. Fokkink, project member
- Drs. W.O.D. Griffioen, junior researcher (OIO)
- Dr. A.S. Klusener, project member
- Dr. H.P. Korver, project member

Scientific Report

Frits Vaandrager continued his cooperation with Nancy Lynch (MIT). Together they prepared two journal versions of papers on simulation proof techniques and timed I/O automata. Jointly with Bosscher and Polak, Vaandrager finalised a paper on the verification of an audio control protocol from Philips. Besides the verification itself, another contribution of this paper is the establishment of a firm connection between the model of linear hybrid automata of Alur, Courcoubetis, Henzinger and Ho, and the timed I/O automata model of Lynch and Vaandrager. This connection has allowed Griffioen to mechanically proof check the verification using a theorem prover (see below), and Wong-Toi and Ho from Cornell University to fully automatically verify an instance of the protocol using their model of hybrid automata. The paper with Bosscher and Polak received the 'Best paper award' at the FTRTFT'94 Symposium in Lübeck.

Jointly with Jan Friso Groote (UU) and Ed Brinksma (Twente), Vaandrager prepared a research proposal for Philips. The primary objective of this project will be to demonstrate and assess the effectiveness of using formal methods in the software development process within Philips. To support the work in this project, Philips will pay one junior researcher at CWI from 1995 onwards. Together with Ed Brinksma, Vaandrager also prepared a SION proposal entitled 'Testing and Verification of Timed Systems'. The aim of this project, which was approved in October, will be to develop a methodological framework for the validation of real-time distributed systems that supports both empirical and formal validation methods, i.e., testing and verification.

Doeko Bosscher was involved in the Philips case study described above. In addition he finished working on the TACS paper on 'Term rewriting properties of SOS axiomatizations' and started working on practical applications of process algebra. With Steven Klusener and Wilco Koorn he developed a simulator for a realtime specification of a traffic regulation algorithm. The study was designed to find out the effectiveness of the Toolbus, a piece of software with process algebra primitives for control. After this he wrote a proposal for building a modal logic checker for μCRL a project which he is currently carrying out. He has done the groundwork building a translator for μCRL specifications to symbolic transition graphs using the ASF+SDF system.

Amar Bouali joined AP2 as an ERCIM fellow for 9 months (from 11/01/93 to 07/31/94), following a first period of his fellowship of 9 months at CNR-IEI in Pisa (Italy). His research at CWI was concerned with verification over finite state models of process algebraic structures and the development of software tools for automatic application of verification methods. Most of his work was carried out in the context of the ESPRIT-BRA project CONCUR2, in which CWI is involved. In particular, he made efforts in developing tool interfaces and tool integration environments based on a common interchanging format called FC2, defined in the CONCUR2 project. Another part of Bouali's work was dedicated to the study of the relationship between behavioral equivalences expressed over labeled transition systems, known as *bisimulations*. This led to the characterisation of *branching bisimulation* equivalence as a *strong bisimulation* equivalence leading to a new algorithm for the computation of the former equivalence, that has a lowest theoretical time complexity than the best algorithm know so far.

Wan Fokkink defended his Ph.D. thesis successfully on December 1. In addition, three of his papers appeared in journals and two other papers have been accepted for journal publication. Also, he pre-

sented his paper on the tyft/tyxt format, proving a conjecture from Groote and Vaandrager, at the TACS Symposium in Japan. Together with Rob van Glabbeek, he improved and extended this paper, and submitted the result to *Information and Computation*. With Chris Verhoef, Fokkink started to write a joint paper on conservative extensions in operational semantics with variable bindings. Right now, this paper is almost finished. Further, he wrote a paper on idempotent most general unifiers for infinite sets, and submitted it to *Theoretical Computer Science*. In the context of the BOOST project, Arek Lesch (Alcatel/SEL, Stuttgart), Cinzia Bonini (Intecs Sistemi, Pisa) and Fokkink finished a Z specification for teleconferencing systems. Jointly with Bas van Vlijmen and Jan Friso Groote from the University of Utrecht, Fokkink started to work on a project for the NS (Dutch Railway Company), concerning a new technique to check automatically whether a railway yard is safe.

David Griffioen mechanically checked the verification of the audio control protocol by Bosscher, Polak and Vaandrager using the Larch Prover (LP). Jointly with Henri Korver, he verified a smaller 'bakery' protocol with the help of LP. Although LP only supports first order logic, a satisfying formalisation of both protocol verification could be given. The syntax of LP is very natural, so specifications are easy to read. Currently proof-management and arithmetic are not very well developed in LP.

Steven Klusener's activities are described in the scientific report of the group AP3. In addition we point at the joint work with Doeko Bosscher and Wilco Koorn described above.

Henri Korver finished his Ph.D. thesis and defended it successfully on June 29. Furthermore three of his papers where published this year, two of them in Lecture Notes and one in The Computer Journal. Following the visit in 1993 of Lars-Ake Fredlund from SICS (supported by the ERCIM Internal Fellowship Programme), Korver had a fruitful collaboration with Fredlund, and a paper on 'A Formal Verification of a Leader Election Protocol in Process Algebra' has now been finished. This work can be considered as one of the more advanced case-studies in process algebra. Together with Wan Fokkink and Mieke Bruné, Korver organised a joint BOOST/SCORE meeting in Amsterdam. At the last day of this meeting the organisers got a standing ovation. At the final BOOST meeting in Edinburgh officials from the European Commission declared that the RACE/BOOST project has been a success.

Organisation of Conferences, Workshops, Courses, etc.

- *Workshop HCM network EXPRESS*, CWI, Amsterdam, March 21–23: F.W. Vaandrager and J.W. Klop (organisation).
- *BOOST meeting*, Amsterdam, April 12–14: W.J. Fokkink, H.P. Korver and Mieke Bruné (organisation).
- PAM – the Process Algebra Meeting
  A weekly seminar on concurrency theory, with an emphasis on process algebra, coordinated by W.J. Fokkink. Besides the members of AP2, the PAM is attended by members of the research groups of Prof. Bergstra (UvA/UU) and Prof. Baeten (TUE). Besides presentation and discussion of ongoing research, also external speakers are invited.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Working visit University of Hildesheim* (Prof. Goltz/Rensink), Hildesheim, Germany, February 8: F.W. Vaandrager (Verification of an audio protocol).
- *Working visit Philips Industrial Activities*, International Technology Centre (Vanherck/Therssen), Leuven, Belgium, February 23: D.J.B. Bosscher, F.W. Vaandrager.
- *Specification of Systems: Theory on Search of Practice*, Hildesheim, Germany, March 7–9: A.S. Klusener (Verification of an audio protocol).
- *Workshop HCM EXPRESS*, CWI, Amsterdam, March 21–23: W.J. Fokkink (The tyft/tyxt format reduces to tree rules), F.W. Vaandrager.
- *Working visit Massachusetss Institute of Technology* (Prof. Lynch), Cambridge, USA, March 24–April 7: F.W. Vaandrager (Verification of an audio protocol).
- *Working meeting CONCUR II*, Brighton, UK, March 28–29: D.J.B. Bosscher, A. Bouali.
- *Working visit University Twente* (Prof. Brinksma), Enschede, April 12: F.W. Vaandrager (Verification of an audio protocol).
- *BOOST meeting*, Amsterdam, April 12–14: W.J. Fokkink, H.P. Korver.
- *TACS '94*, Sendai, Japan, April 17–22: D.J.B. Bosscher (Term rewriting properties of SOS axiomatisations), W.J. Fokkink (The tyft/tyxt format reduces to tree rules).
- *ACP '94*, Utrecht, May 16–17: W.J. Fokkink, A.S. Klusener, H.P. Korver (A correctness proof of the bakery protocol in μCRL), F.W. Vaandrager (Timed process algebra = untimed process algebra + timer operators).

- *Working visit SICS* (Prof. Parrow), Kista, Sweden, May 20–June 16: F.W. Vaandrager.
- *Working visit University of Roma* (Prof. De Nicola), Roma, Italy, May (10 days): A. Bouali (Branching bisimulation as a Strong bisimulation).
- *Working visit Uppsala University* (Prof. Jonsson), Uppsala, Sweden, June 14: F.W. Vaandrager.
- *Working visit INRIA Sophia Antipolis* (Dr. De Simone/Dr. Madelaine), Sophia Antipolis, France, June (1 week): A. Bouali (Tools and the Fc2 format).
- *BOOST meeting*, Samos, Greece, July 12–17: W.J. Fokkink, H.P. Korver.
- *IPA school/workshop on Programming and Algorithms*, Terschelling, September 19–20: W.O.D. Griffioen.
- *Third International School and Symposium on Formal Techniques in Real Time and Fault Tolerant Systems (FTRTFT'94)*, Lübeck, Germany, September 21–23: W.O.D. Griffioen, F.W. Vaandrager (Verification of an audio control protocol).
- *CONCUR2 Project Meeting and Review*, Stockholm, Sweden, September 27–28: F.W. Vaandrager (SOS rule formats for parametrized and state bearing processes).
- *The Influence of Automath*, Eindhoven University of Technology, October 6: H.P. Korver.
- *Symposium Dirk Struik 100*, CWI, Amsterdam, October 14: H.P. Korver, F.W. Vaandrager.
- *Second National Specification Day*, Eindhoven University of Technology, October 19: A.S. Klusener, F.W. Vaandrager (Analysis of an audio control protocol using timed I/O automata).
- *BOOST meeting*, Edinburgh, UK, November 1–3: H.P. Korver.
- *Working visit Philips Research Labs* (H. Streng), Technology, November 10: F.W. Vaandrager.
- *Petri Algebra Meeting*, Eindhoven University of Technology, December 13: F.W. Vaandrager (I/O automata theory).
- COST 247 working visit to INRIA Sophia-Antipolis (Dr. E. Madelaine), December 13–20: D.J.B. Bosscher.

Memberships of Committees and Other Professional Activities

AP2:
- RACE project 2076: BOOST – Broadband Object-Oriented Service Technology. (August 1992 – December 1994)
- ESPRIT Basic Research Action 7166: CONCUR2 – Calculi and Algebras of Concurrency: Extensions, Tools and Applications. (1 September 1992 – 1 September 1995)
- HCM Cooperation Network EXPRESS – Expressiveness of Languages for Concurrency. (10 December 1993 – 10 December 1996)
- European Research Action on Verification and Validation Methods for Formal Descriptions (COST Project 247)
- Society for Theoretical Computer Science in the Netherlands 'Vereniging voor Theoretische Informatica' (all members AP2 except A. Bouali)

F.W. Vaandrager:
- Associate professor (Universitair Hoofddocent) at the University of Amsterdam
- Scientific manager CONCUR2 project
- Coordinator (together with J.W. Klop) of HCM cooperation network EXPRESS
- Programme Committee Fourth International Conference on Algebraic Methodology and Software Technology (AMAST'95), Montreal, Canada
- Programme Committee Fifteenth IEEE Real-Time Systems Symposium (RTSS'94), San Juan, Puorto Rico
- Programme Committee Fifth International Conference on Concurrency Theory (CONCUR'94), Uppsala, Sweden
- Referee Ph.D. thesis W.J. Fokkink, University of Amsterdam, December 1994
- Referee Ph.D. thesis H.P. Korver, University of Amsterdam, June 1994
- Opponent at the Ph.D. defence Fredrik Orava, University of Uppsala, Sweden, June 1994
- Referee Ph.D. thesis Gioia Ristori, Università di Pisa, Italy, January 1994
- Moderator of CONCURRENCY email forum (`concurrency@cwi.nl`). Active forum focusing on concurrency theory, with a subscription list of about 600, including approximately 25 subsidiary lists
- Member Dutch Graduate School 'Institute for Programming Research and Algorithmics'
- Member Dutch Graduate School in Logic
- Observer IFIP Working Group 2.2 on Formal Description of Programming Concepts

D.J.B. Bosscher:
- Member Dutch Graduate School in Logic

W.O.D. Griffioen:
- Member Dutch Graduate School 'Institute for Programming Research and Algorithmics'.

Visitors

- Alan Fekete, Australia
- Clemens Cap, Switserland
- Sreeranga Rajan, USA

- Jens Ulrik Skakkebaek, Denmark
- Bard Bloom, USA
- Nancy Lynch, USA

Papers in Journals and Proceedings

L. ACETO, B. BLOOM, F.W. VAANDRAGER (1994). Turning SOS rules into equations. *LICS'92 Special Issue of Information and Computation*, 111(1):1–52.

D.J.B. BOSSCHER (1994). Term rewriting properties of SOS axiomatisations. M. HAGIYA, J.C. MITCHELL (eds.). *Proceedings of the International Symposium on Theoretical Aspects of Computer Software (TACS'94)*, Sendai, Japan, LNCS 789, Springer-Verlag, 425–439.

D.J.B. BOSSCHER, I. POLAK, F.W. VAANDRAGER (1994). Verification of an audio control protocol. H. LANGMAACK, W.-P. DE ROEVER, J. VYTOPIL (eds.). *Proceedings of the Third International School and Symposium on Formal Techniques in Real Time and Fault Tolerant Systems*, Lübeck, Germany, September 1994, LNCS 863, Springer-Verlag, 170–192.

D.J.B. BOSSCHER, I. POLAK, F.W. VAANDRAGER (1994). Verification of an audio control protocol. T. RUS, C. RATTRAY (eds.). *Theories and Experiences for Real-Time System Development*, AMAST Series in Computing, Vol 2, World Scientific, Singapore, 147–176.

J. VAN DEN BRINK, W.O.D. GRIFFIOEN (1994). Formal semantics of interworkings with discrete absolute time. A. PONSE, C. VERHOEF, S.F.M. VAN VLIJMEN (eds.). *Algebra of Communicating Processes*, Utrecht, 1994, Workshops in Computing, Springer-Verlag, 106–123.

R. FOKKINK, W.J. FOKKINK, J. VAN DE LUNE (1994). Fast computation of an alternating sum. *Nieuw Archief voor Wiskunde*, 1/2(12):13–18.

W.J. FOKKINK (1994). A complete equational axiomatization for prefix iteration. *Information Processing Letters*, 52:333–337.

W.J. FOKKINK (1994). The tyft/tyxt format reduces to tree rules. M. HAGIYA, J.C. MITCHELL (eds.). *Proceedings of the International Symposium on Theoretical Aspects of Computer Software (TACS'94)*, Sendai, Japan, LNCS 789, Springer-Verlag, 440–453.

W.J. FOKKINK, H. ZANTEMA (1994). Basic process algebra with iteration: Completeness of its equational axioms. *The Computer Journal*, 37(4):259–267.

J.F. GROOTE, H. HÜTTEL (1994). Undecidable equivalences for Basic process algebra. *Information and Computation*, 115(2):354–371.

J.F. GROOTE, H.P. KORVER (1994). A correctness proof of the bakery protocol in μCRL. A. PONSE, C. VERHOEF, S.F.M. VAN VLIJMEN (eds.). *Algebra of Communicating Processes*, Utrecht, 1994, Workshops in Computing, Springer-Verlag, 63–86.

J.F. GROOTE, A. PONSE (1994). Process algebra with guards. Combining Hoare logic and process algebra. *Formal Aspects of Computing*, 6:115–164.

J.F. GROOTE, A. PONSE (1994). Proof theory for μCRL: a language for processes with data. D.J. ANDREWS, J.F. GROOTE, C.A. MIDDELBURG (eds.). *Proceedings of the International Workshop on Semantics of Specification Languages*, Workshops in Computing, Springer-Verlag, 232–251.

J.F. GROOTE, A. PONSE (1994). The syntax and semantics of μCRL. A. PONSE, C. VERHOEF, S.F.M. VAN VLIJMEN (eds.). *Algebra of Communicating Processes*, Utrecht 1994, Workshops in Computing, Springer-Verlag, 26–62.

L. HELMINK, M.P.A. SELLINK, F.W. VAANDRAGER (1994). Proof-checking a data link protocol. H. BARENDREGT, T. NIPKOW (eds.). *Proceedings International Workshop TYPES'93*, Nijmegen, The Netherlands, May 1993, LNCS 806, Springer-Verlag, 127–165.

H.P. KORVER (1994). A theory for simulators. *The Computer Journal*, 37(4):279–287.

H.P. KORVER, J. SPRINGINTVELD (1994). A computer-checked verification of Milner's scheduler. M. HAGIYA, J.C. MITCHELL (eds.). *Proceedings of the International Symposium on Theoretical Aspects of Computer Software (TACS'94)*, Sendai, Japan, LNCS 789, Springer-Verlag, 161–178.

A. PONSE (1994). Process algebra and dynamic logic. J. VAN EIJCK, A. VISSER (eds.). *Logic and Information Flow*, MIT Press, 125–148.

CWI Reports

CS-R9405 D.J.B. BOSSCHER. *Term rewriting properties of SOS axiomatisations.*

CS-R9415 W.J. FOKKINK. *A complete equational axiomatisation for prefix iteration.*

CS-R9420 L. HELMINK, M.P.A. SELLINK, F.W. VAANDRAGER. *Proof-checking a data link protocol.*

CS-R9442 W.J. FOKKINK. *Idempotent most general unifiers for infinite sets.*

CS-R9443 A. BOUALI, S. GNESI, S. LAROSA. *The integration project for the JACK environment.*

CS-R9445 D.J.B. BOSSCHER, I. POLAK, F.W. VAANDRAGER. *Verification of an audio control protocol.*

CS-R9452 A. BOUALI, R. DE NICOLA. *Branching bisimulation as a strong bisimulation.*

CS-R9460 N.A. LYNCH, F.W. VAANDRAGER. *Ac-*

tion transducers and timed automata.

CS-R9473 J.F. GROOTE, H.P. KORVER. *A correctness proof of the bakery protocol in μCRL.*

Other Publications

W.J. FOKKINK (1994). *Clocks, Trees and Stars in Process Theory.* Ph.D. Thesis, University of Amsterdam.

H.P. KORVER (1994). *Protocol Verification in μCRL.* Ph.D. Thesis, University of Amsterdam.

N.A. LYNCH, F.W. VAANDRAGER (1994). *Forward and Backward Simulations Part I: Untimed Systems.* Technical Memo MIT/LCS/TM-486.b, MIT LCS, Cambridge, MA, USA.

N.A. LYNCH, F.W. VAANDRAGER (1994). *Action Transducers and Timed Automata.* Technical Memo MIT/LCS/TM-480.b, MIT LCS, Cambridge, MA, USA.

F.W. VAANDRAGER (1994). Verification of a distributed summation algorithm. K.R. APT, A. SCHRIJVER, N.M. TEMME (eds.). *From Universal Morphisms to Megabytes – a Baayen Space Odyssey*, CWI, Amsterdam, 593–608.

Extensible Programming Environments (AP3)

Staff

- Drs. A. van Deursen, junior researcher (OIO) (till October 30)
- Dr. T.B. Dinesh, project member (from September 1 supported by SION)
- Drs. J.J. Ganzevoort, project member
- J. Heering, senior researcher
- Drs. J. Kamperman, project member
- Dr. A.S. Klusener (joint AP2/AP3), acquisition
- Prof. dr. P. Klint, group leader
- Drs. E.A. van der Meulen, project member (from January 1 for 0.2; till November 1)
- Drs. F. Tip, project member
- Dr. H.R. Walters, senior researcher (from November 1, for 0.6 supported by SION)

Scientific Report

The group is involved in the design and implementation of the ASF+SDF system for interactive language development and incremental programming environment generation. The system is distributed to commercial and academic customers by the Connexité company in Sophia-Antipolis as well as by CWI itself. The system has been developed in the ESPRIT/GIPE and GIPE II projects since 1984. With the final review meeting of GIPE II in February in Amsterdam, AP3's involvement in GIPE came to an end. Especially the long term cooperation with INRIA Sophia-Antipolis (G. Kahn and others) as part of GIPE has been very fruitful and inspiring.

Further work on the ASF+SDF system involves a complete rebuilding of the system. On the one hand, the system is being rewritten in the ASF+SDF language itself. This will eliminate the increasingly problematic dependence on the LeLisp implementation language. On the other hand, the system is restructured using the ToolBus interconnection architecture which is being developed by P. Klint in cooperation with J.A. Bergstra (University of Amsterdam).

The 4 year NWO Computer Science Priority Program 'Incremental Program Generation' ended by July 1. E.A. van der Meulen defended her Ph.D. thesis 'Incremental Rewriting' in January. A. van Deursen, the other member of the project, finalized his Ph.D. thesis 'Executable Language Definitions—Case Studies and Origin Tracking Techniques' and obtained his degree in September.

The ESPRIT/COMPARE project (Compiler Generation for Parallel machines–ESPRIT Project 5399) entered its final year. S. Klusener became the new leader on the part of CWI, with H.R. Walters stepping back. The project as a whole suffered from serious internal tensions which affected CWI's contribution adversely. Nevertheless, Kamperman and Walters managed to turn over to COMPARE the definitions and prototype implementations of the Full Structure Definition Language fSDL and the GEL Graph Exchange Language. Also, in view of the ever increasing demands on the ASF compiler on the part of COMPARE, they started the development of a higher-capacity ASF compiler. J.J. Ganzevoort worked with ACE, COMPARE's main contractor, on software distribution, tool integration, and version management. The sheer size of the COMPARE effort mandates a large effort in these areas.

F. Tip completed his Ph.D. thesis on generic debugging. He worked on dynamic dependence tracking and parametric program slicing in cooperation with J. Field and G. Ramalingam (IBM Thomas J. Watson Research Center).

In September the new SION project 'Generic Tools for Program Analysis and Optimization' started with T.B. Dinesh and H.R. Walters as researchers. Its purpose is the development of language independent tools for program analysis and optimization in an algebraic setting. Heering worked with

Bergstra, Dinesh, and Field on the the logical enrichment of PIM, an algebraic machine for imperative languages. Kamperman and Walters transferred the notion of 'lazy evaluation' from functional languages to rewrite systems.

Within AP2 and AP3 Walters and Klusener each spent 50% of their time selling AP2/AP3 developed technology to industry. Proposals were submitted to KLM, Cap Volmac, Nederland Haarlem and other companies. The proposal to Nederland Haarlem, submitted jointly with CWI's BS department and the group for Applied Logic at RUU, was accepted. It concerns the development of a dynamic regulation system for a bus station, and a study for optimal strategies for the replacement of light bulbs in traffic lights. Apart from this, two STW proposals were written, one on a real-time extension to the ToolBus of Bergstra and Klint, and another one jointly with RUU and TUE on the specification and verification of railway interlockings. Unfortunately, both were rejected.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *COMPARE Integration/Management Meeting*, Paris, France, January 31 – February 2: J.J. Ganzevoort, A.S. Klusener.
- *COMPARE Review Meeting/Working visit INRIA*, Rocquencourt, France, February 21–24: J.J. Ganzevoort, A.S. Klusener, H.R. Walters.
- *GIPE II Fifth Review*, CWI, Amsterdam, February 23: Arie van Deursen (Origin tracking), J. Heering, P. Klint.
- *Working visit IBM Th.J. Watson Research Center*, Yorktown Heights, USA, March 7–16: F. Tip.
- *COMPARE Final Year Kick-Off Meeting*, Noordwijkerhout, March 14–18: T.B. Dinesh, J.J. Ganzevoort, P. Klint, A.S. Klusener.
- *CC/CAAP/ESOP*, Edinburgh, UK, April 7–14: A. van Deursen (System Demonstration ASF+SDF and ASD Tools), T.B. Dinesh, J.F.Th. Kamperman (fSDL Presentation).
- *IBM PS2 Meeting*, April 27: J.F.Th. Kamperman.
- *First International Workshop on Action Semantics*, Edinburgh, UK, April 16–20: A. van Deursen (ASD: Implementing Action Semantics Descriptions).
- *Functional Programming in the Real World*, May 16–20: J.F.Th. Kamperman (GEL—a Graph Exchange Language), H.R. Walters (Implementing tools by algebraic specification).
- *ACP '94*, Utrecht, May 16–17: A. van Deursen.
- *COMPARE Management Meeting*, Amsterdam, July 5–6: P. Klint, A.S. Klusener.
- *Teaching formal Methods*, Clinton, USA, July 29–August 6: T.B. Dinesh (Teaching formal methods using the ASF+SDF meta-environment).
- *Working visit DIKU*, Copenhagen, Denmark, July 30–August 3: F. Tip.
- *Workshop on Termination*, Utrecht, August 23: H.R. Walters.
- *PLILP '94*, Madrid, Spain, September 13–19: F. Tip (Dynamic dependence in term rewriting systems and its application to program slicing).
- *1994 Workshop of IS-CORE*, Amsterdam, September 27–30: T.B. Dinesh (Inheritance and updating in KOOL).
- *COMPARE Management Meeting*, Amsterdam, October 11–12: P. Klint, A.S. Klusener.
- *Meeting program committee TAPSOFT '95*, Aarhus, Denmark, November 25–27: P. Klint.
- *Formal Methods Europe (FME'94)*, Barcelona, October 1994: A. van Deursen (System Demonstration ASF+SDF and ASD Tools).

Memberships of Committees and Other Professional Activities

P. Klint:

- SION Scientific Advisory Board (member).
- Institute for Logic Language and Computation (ILLC) (member of the board).
- Member Programme Committee TAPSOFT '95.
- Advisor Philips Research Laboratories, Eindhoven.
- Member Review Board 'Methods and Techniques' of ABN-AMRO Bank.
- Ph.D. advisor E.A. van der Meulen, Incremental rewriting, UvA, January 7.
- Ph.D. advisor J.W.C. Koorn, Generating uniform user-interfaces for interactive programming environments, UvA, February 3.
- Ph.D. advisor A. van Deursen, Executable Language Definitions, UvA, September 29.
- Ph.D. advisor (with H.A. Partsch) N.W.P. van Diepen, Modular Algebraic Specifications and Transformational Program Development, KUN, October 12.
- Member Ph.D. committee N. Drost, UvA, Februari 10; R. Hofman, UvA, April 9; H. Korver, UvA, Juni 29; L. v.d. Voort, UvA, September 1; W.J. Fokkink, UvA, December 1.

Visitors

- T. Reps, DIKU/University of Wisconsin, January 7.

- P. Wadler, University of Glasgow, March 4 (Haskell and Two Advances in Functional Programming).
- J.-R. Abrial, Paris, April 15 (The B Method).
- J. Field, IBM Thomas J. Watson Research Center, April 23–May 1 (Semantics-Based Interactive Program Analysis: The Menagerie Project).
- M. Franz, ETH Zurich, June 17 (The Oberon Programming Language).
- M. Mohania, IIT Bombay, India, August 15 (On the Design of Distributed Deductive Databases).
- P.D. Mosses, Aarhus University, September 1994.
- M. Haaveraaen, University of Bergen, December 12 (SOPHUS - A C++ library, developed using algebraic techniques, for solving partial differential equations).

Papers in Journals and Proceedings

J.A. BERGSTRA, J. HEERING (1994). Which data types have omega-complete initial algebra specifications? *Theoretical Computer Science, 124*, 149–168.

A. VAN DEURSEN, T.B. DINESH (1994). Origin tracking for higher-order term rewriting systems. J. HEERING, K. MEINKE, B. MÖLLER, T. NIPKOW (eds.). *Higher-Order Algebra, Logic, and Term Rewriting (HOA'93)*. LNCS, Vol. 816, Springer-Verlag, 76–95.

T.B. DINESH (1994). A trying C++ experience (or why COMPARE dropped C++). *Journal of C Language Translation, 6:2*, 11–136.

T.B. DINESH (1994). Type checking revisited: Modular error handling. D.J. ANDREWS, J.F. GROOTE, C.A. MIDDLEBURG (eds). *Semantics of Specification Languages*, Workshops in Computing, Springer-Verlag, 216–231.

J. FIELD, F. TIP (1994). Dynamic dependence in term rewriting systems and its application to program slicing. M. HERMENEGILDO, J. PENJAM (eds.). *Proceedings of the Sixth International Symposium on Programming Language Implementation and Logic Programming*, LNCS, Vol. 844, Springer-Verlag, 415–431.

J. HEERING, P. KLINT, J. REKERS (1994). Lazy and incremental program generation. *ACM Transactions on Programming Languages and Systems, 16*, 1010–1023.

CWI Reports

CS-R9401 A. VAN DEURSEN. *Origin tracking in primitive recursive schemes.*

CS-R9425 A. VAN DEURSEN, T.B. DINESH. *Origin tracking for higher-order term rewriting systems.*

CS-R9435 H.R. WALTERS. *A complete term rewriting system for decimal integer arithmetic.*

CS-R9438 F. TIP. *A survey of program slicing techniques.*

CS-R9440 J.F.TH. KAMPERMAN. *GEL–A graph exchange language.*

CS-R9453 F. TIP. *Generic techniques for source-level debugging and dynamic program slicing.*

CS-R9457 T.B. DINESH. *A trying C++ experience (Why COMPARE dropped C++).*

CS-R9461 J.F.TH. KAMPERMAN, H.R. WALTERS. *Lazy rewriting on eager machinery.*

Other Publications

J.A. BERGSTRA, P. KLINT (1994). *The ToolBus, a Component Interconnection Architecture.* Programming Research Group, University of Amsterdam, Report P9408.

J.A. BERGSTRA, P. KLINT (1994). *The ToolBus Component Interconnection Architecture. Overview and First Experiences.* In Proceedings van de Tweede Landelijke Specificatie Dag, Eindhoven.

C.-T. BUHL, T.B. DINESH, J.F.TH. KAMPERMAN, H.R. WALTERS (1994). *fSDL.* COMPARE Deliverable.

A. VAN DEURSEN (1994). *Executable Language Definitions–Case Studies and Origin Tracking Techniques.* Ph.D. Thesis, University of Amsterdam.

A. VAN DEURSEN (1994). Formal methods for financial products. *Ercim News*, 8–9.

A. VAN DEURSEN, P.D. MOSSES (1994). The Action-Semantics Description tools–User's guide. P.D. MOSSES (ed.). *Proceedings of the First International Workshop on Action Semantics*, Report BRICS NS-94-1, Aarhus University, 56–60.

J. HEERING, P. KLINT (1994). Prehistory of the ASF+SDF System (1980–1984). K. APT, L. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes: a Baayen Space Odyssey*, 341–345.

J. HEERING, K. MEINKE, B. MÖLLER, T. NIPKOW (eds.) (1994). *Higher-Order Algebra, Logic, and Term Rewriting (HOA '93).* Lecture Notes in Computer Science, Vol. 816, Springer-Verlag.

J.F.TH. KAMPERMAN (1994). *A GEL Interface for the DMCP.* COMPARE Deliverable.

J.F.TH. KAMPERMAN, T.B. DINESH, H.R. WALTERS (1994). An extensible language for the generation of parallel data manipulation and control packages. PETER A. FRITZSON (ed.). *Proceedings of the Poster Session of CC '94*, Report LiTH-IDA-R-94-11, University of Linköping.

J.F.TH. KAMPERMAN, H.R. WALTERS (1994). *GEL Library.* COMPARE Deliverable.

P. KLINT (1994). Het Europese ESPRIT programma, een persoonlijk perspectief. *Informatie*, 36, 4, 253–256. Tevens in K. APT, L. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes: a Baayen Space Odyssey*, 383–390.

P. KLINT, E. VISSER (1994). *Using Filters for the Disambiguation of Context-free Grammars.* Programming Research Group, University of Amsterdam, Report P9426.

E.A. VAN DER MEULEN (1994). *Incremental Rewriting.* Ph.D. Thesis, University of Amsterdam.

H.R. WALTERS (1994). *Status Report on ASF2C.* COMPARE Deliverable CWI-0002-asf2c.

H.R. WALTERS (1994). *A Hybrid Interpreter for ARM Term Rewriting.* COMPARE Deliverable CWI-0002-arm.

Algebraic and Syntactic Methods (AP4)

Staff

- Prof. dr. J.W. Klop, group leader
- Dr. I. Bethke, postdoc, SION, part-time position 0.5, since March 1
- Drs. F. van Raamsdonk, junior researcher (OIO), SION
- Prof. dr. H.P. Barendregt, part-time research position (0.4)
- Drs. H. Elbers, junior researcher (OIO), SION, since March 1
- Dr. F.-J. de Vries, researcher, until March 1.
- Drs. C. Brovedani, visitor (until August 1).

Scientific Report

Jan Willem Klop continued his cooperation with Z.M. Ariola (Oregon) concerning cyclic lambda graphs (or, lambda calculus with explicit recursion) and equational term graph rewriting (see Papers in Journals and Proceedings). Much attention was devoted to devising a flexible system for a modular treatment, using nested systems of recursion equations.

Henk Barendregt continued and completed his work on computable processes (see CWI Reports). Together with J.W. Klop, as part of supervision of the work of H. Elbers in the project WINST, attention was devoted to the problems of enriching LEGO with term rewriting facilities.

Inge Bethke started her four years (0.5) postdoc position. After an initial orientation in infinite lambda calculus she worked in cooperation with J.W. Klop on collapsing partial combinatory algebras. A technical report is forthcoming in April 1995. Apart from developing some general theory of collapses (homomorphic images) of pca's, the main result is the construction of the extensional collapse of the pca of strongly normalizing combinators. This yields a pca which is a term model, and which cannot be extended to a total combinatory algebra.

Hugo Elbers started his work in the SION-SMC project WINST with some experiments to investigate the problems in connecting term rewriting and proof checkers (such as LEGO). A significant step forward was obtained by implementing Barendregt's suggestion to use coded expressions in order to enable LEGO to prove uniform properties (e.g. that the normal form of an expression after rewriting is semantically equal to the original expression).

Femke van Raamsdonk continued her study of the reduction theory of orthogonal higher-order rewrite systems. Completion of this work is expected in the form of a dissertation, scheduled for January 1996 (see Papers in Journals and Proceedings, and Other Publications). An important result (obtained in cooperation with V. van Oostrom) was establishing confluence for a wide class of weakly orthogonal higher-order rewrite systems (typical example second-order $\lambda\beta\eta$-calculus).

Fer-Jan de Vries concluded his work on infinitary rewriting in cooperation with J.W. Klop and our partners in ESPRIT WG Semagraph. After leaving CWI's employment (current employer: NTT Kyoto), De Vries continued this cooperation. Infinite rewriting was also developed for lambda calculus, leading to an accepted paper in RTA 95 (see Papers in Journals and Proceedings). This has resulted in several new Böhm-like models of the lambda calculus, and new descriptions of existing models.

Organisation of Conferences, Workshops, Courses, etc.

- Advanced Lambda Calculus, Masterclass, CWI, Amsterdam, October and November: H.P. Barendregt.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Informatica Colloquium*, Philips NatLab., Eindhoven, March 2: H.P. Barendregt (Computer formalized proofs).
- *First EXPRESS Workshop*, CWI, Amsterdam, March 21–23: J.W. Klop.
- *Minisymposia 30e Nederlands Mathematisch Congres*, Leiden, April 8: H.P. Barendregt (Formalizing Mathematics in type theory: Aims and Methods, invited talk).

- *LICS '94*, Paris, France, July 4–7: H.P. Barendregt (Results and Problems Related to Proof-Checking, invited talk), J.W. Klop (Cyclic Lambda Graph Rewriting), F. van Raamsdonk.
- *LFCS '94*, St. Petersburg, Russia, July 11–14: F. van Raamsdonk, (Weak Orthogonality implies confluence: the higher order case).
- *SEMAGRAPH II WG Workshop*, Norwich, UK, September 5–6: J.W. Klop (Modular term graph rewriting).
- *Advanced School on Typed Lambda Calculus and Functional Programming*, Udine, Italy, September 19–20: H. Elbers, F. van Raamsdonk.
- *Working Visit University of Edinburgh*, Edinburgh, UK, September 21: H.P. Barendregt (Computable Processes).
- CSL '94, Kazimierz, Poland, September 26: H.P. Barendregt (Computable Processes, invited talk).
- *Working visit University of Pisa*, Pisa, Italy, October 2–29: J.W. Klop.
- *Confer Workshop and Review*, London, UK, October 4–10: F. van Raamsdonk (Optimal reductions for Proof Nets).
- *Technische Universiteit Eindhoven*, Eindhoven, October 6: H.P. Barendregt (Two Level Reasoning for Lean Proof Checking, The Influence of Automath, invited talk).
- *PC meeting TAPSOFT 95*, Aarhus, Denmark, November 26–27: J.W. Klop.

Memberships of Committees and Other Professional Activities

AP4:
- Participation in ESPRIT Working Group SEMAGRAPH 6345
- Participation in ESPRIT Basic Research Action CONFER 6454

Jan Willem Klop:
- Professor in Computer Science at the Free University of Amsterdam.
- Coordinator HCM Network EXPRESS
- Scientific Secretary of Werkgemeenschap Theoretische Informatica
- Editor of Nieuwsbrief van de Werkgemeenschap Theoretische Informatica
- PC member TLCA 95
- PC member TAPSOFT 95
- Member Advisory Board of CMF (Caribbean Mathematical Foundation)
- Member Advisory Editorial Board Journal of the Egyptian Mathematical Society
- Member Ph.D. Committee F.C. van Breugel (VUA), W.J. Fokkink (UvA)
- Promotor V. van Oostrom (VUA)

H.P. Barendregt:
- Promotor J. Kuper (TUE), E. Poll TUE).
- Member Ph.D. Committee V. van Oostrom (VUA), R. Pollack (Univ. of Edinburgh), M.J. Nederhof (KUN), V.A.J. Borghuis (TUE).

Femke van Raamsdonk:
- Member organizing committee Algemeen CWI Colloquium

Visitors

- L. Ong, University of Oxford, Oxford, UK, February 22.
- M. Fernandez, University Orsay, Paris, France, April 11–16.
- A. Corradini, University of Pisa, Pisa, Italy, May 1–31.
- J.R. Kennaway, M.R. Sleep, University of East Anglia, UK, July 26–27.
- Z. Ariola, University of Eugene, Oregon, USA, July 1–31.
- P. Inverardi, University of Pisa, Pisa, Italy, August 1–5.
- D. Kesner, University Orsay, Paris, France, September 5–9.

Papers in Journals and Proceedings

Z.M. ARIOLA, J.W. KLOP (1994). Cyclic Lambda graph rewriting. *Proceedings of 9th Annual IEEE Symposium on Logic in Computer Science (LICS '94)*, IEEE, 416–425.

H.P. BARENDREGT (1994). Discriminating coded Lambda terms. K. APT, L. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey*, CWI, Amsterdam, 141–151.

J.A. BERGSTRA, J. HEERING, J.W. KLOP (1994). Object-Oriented algebraic specification; Proposal for a notation and 12 examples (with an Introductory Note). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey*, CWI, Amsterdam, 187–214.

J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.J. DE VRIES (1994). Syntactic definitions of undefined: on defining the undefined. M. HAGYIA, J.C. MITCHELL (eds.). *Proceedings of TACS '94*, Sendai, Japan, LNCS 789, Springer, 543–554.

J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.J. DE VRIES (1994). On the Adequacy of Graph Rewriting for Simulating Term Rewriting. *Transactions on Programming Languages and Systems*, 16(3):493–523.

J.W. KLOP, A. MIDDELDORP, Y. TOYAMA, R. DE VRIJER (1994). Modularity of confluence: a simplified proof. *Information Processing Letters*, 49:101–109.

F. VAN RAAMSDONK (1994). Weak orthogonality implies confluence: The higher-order case. *Proceedings of the third International Symposium on Logical Foundations of Computer Science*, LNCS 813, Springer, 379–392.

CWI Reports

CS-R9428 H.P. BARENDREGT, H. WUPPER, H. MULDER. *Computable Processes.*

CS-R9433 M. MARCHIORI. *Modularity of UN-for left-linear term rewriting systems.*

Other Publications

F. VAN RAAMSDONK (1994). *Weak Orthogonality Implies Confluence: The Higher-order Case.* Technical Report ISRL-94-5, NTT BRL, Tokyo, Japan.

Logic and Language (AP5a)

Staff

- Prof. dr. K.R. Apt, group leader, since March 1, 1987,
- Ir. J.J. Brunekreef, project member (0.4), since 1 September 1, 1994,
- S. Etalle, visitor, since November 1, 1992,
- Dr. M. Gabbrielli, visitor, since March 1, 1993,
- Dr. E. Marchiori, project member, since April 1, 1992,
- F. Teusink, Ph.D. Student (OIO), since April 1, 1992,
- M.C. Meo, visitor, February 1 - May 30, 1994.

Scientific Report

K.R. Apt with *R. Bol* from the University of Eindhoven published an extensive survey (62 pages long and with 174 references) on the use of negation in logic programming, which appeared in a special anniversary issued of Journal of Logic Programming.

Further, *K.R. Apt* and *M. Gabbrielli* studied the relationships between 3 different declarative semantics proposed for logic programs. They showed that for a large class of programs these semantics are isomorphic. A paper on this subject appeared in the Proceedings of the Int'l Conf. on Logic Programming (ICLP '94). This work was then extended in a joint collaboration with *M. Gabbrielli* and *D. Pedreschi* from University of Pisa to yield a comparative study of various declarative interpretations of logic and pure Prolog programs, with applications to the verification of logic programs.

K.R. Apt also wrote a survey on verification of Prolog programs. In this survey several correctness issues, like partial correctness, termination, absence of the occur-check, absence of errors in the presence of arithmetic operators, and correct treatment of negation were extensively discussed. This paper will appear in *'Specification and Validation methods for Programming languages and systems'*, E. Börger (ed.), Oxford University Press. Further, in joint work with *F. Teusink* he compared formally the use of negation in Logic Programming and in Prolog. This paper will appear in a *Meta-logics and Logic Programming*, (K.R. Apt and F. Turini, eds.), The MIT Press. Finally, in joint work with *P. van Emde Boas* and *A. Welling*, he investigated the complexity of the occur-check test. This paper will appear in the Journal of Symbolic Computation.

Ir. J.J. Brunekreef joined the group in September. He worked on an implementation of a system for transformation of logic and Prolog programs. This system is being implemented on top of the ASF+SDF system realized by AP3. It allows the user to interact with the program by means of a menu of buttons and a focus operation. A publication on this implementation will be ready in 1995.

S. Etalle continued the work on his Ph.D. thesis on unfold/fold transformations of normal logic programs. In collaboration with *A. Bossi* he introduced an applicability condition for the fold transformation, and showed that it ensures the preservation of the Fitting's semantics. The paper on this subject appeared in the Proceedings of META94, 'Fifth Workshop on Metaprogramming in Logic', F. Turini (editor).

Moreover, *S. Etalle* studied unification-free Prolog programs. He provided new simple conditions which allow us to conclude that in case of several well-known Prolog programs the unification algorithm can be replaced by iterated matching.

M. Gabbrielli , a visitor from the University of Pisa, continued part of the work on the semantics of logic programs which was done in his Ph.D. thesis. Some semantics which characterize observational properties of logic programs were investigated with *A. Bossi, G. Levi, M.C. Meo* and *M. Martelli.* Semantics compositional with respect to the union of clauses were also studied and a full abstraction result was obtained. These results were published in *Theoretical Computer Science* and in the *Journal of Logic Programming.* An application to program analysis of a semantics modeling partial answers was carried out with *R. Giacobazzi* and published in the Proceedings of the ACM Conference on Applied Computing.

Also, in his joint work with *E. Marchiori, F. de Boer* and *C. Palamidessi*, a compositional proof-system for the partial correctness of concurrent constraint programs was developed. Soundness and completeness of the method were proved with respect to a denotational semantics based on the notion of strongest postcondition. The paper on this subject appeared in the Proceedings of the 21th Annual ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages.

E. Marchiori studied a class of term properties, like *groundness* and *sharing*, which are used in static analysis of logic programs. A sound, complete and decidable logic for these properties has been introduced. A paper on this subject appeared in the Proceedings of the *4th International Conference on Algebraic and Logic Programming*.

Also, *E. Marchiori* studied how non-monotonic reasoning can be expressed in logic programming. She investigated a class of programs which behave well with respect to termination, when sld-resolution is augmented with a form of negation called *constructive negation*. The relevance of this class of programs to deal with problems in non-monotonic reasoning was illustrated. This paper has been accepted for publication in the *Journal of Logic Programming*. Moreover, she showed how a number of interesting problems in non-monotonic reasoning can be formalized by means of logic programs augmented with this form of negation. A paper on this subject appeared in the 1994 Deliverables of the COMPULOG 2 Project.

M.C. Meo studied semantics for constructive negation. Together with *A. Bossi* and *M. Frabris*, she introduced a bottom-up semantics for constructive negation and proved its soundness and completeness with respect to the three-valued completion of the program. A paper on this subject appeared in the Proceedings of the Int'l Conf. on Logic Programming (ICLP '94).

F. Teusink continued his work on a proof procedure for abductive logic programs, on which he started in 1993. He also finished his related work on a Kunen semantics for abductive logic programs. A combined paper on these two subjects appeared in the Proceedings of the *4th International Conference on Algebraic and Logic Programming*.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *POPL '94*, Portland, USA, January 16–19: E. Marchiori, M. Gabbrielli.
- *Meeting program committee LICS '94*, London, UK, February 20–21: K.R. Apt.
- *University of Padova* (host: Prof. L. Colussi), February 28–March 4, June 20–24 and October 3–7: E. Marchiori.
- *General meeting COMPULOG 2 meeting*, Cyprus, March 25–30: K.R. Apt (Proving Absence of Errors for pure Prolog programs with Arithmetic), E. Marchiori, F. Teusink (Using SLDFA-resolution with Abductive Logic Programs).
- *Int. Conf. on Logic Programming (ICLP '94)*, Genova, Italy, June 1994: M. Gabbrielli (Declarative interpretations reconsidered).
- *Workshop Int. Conf. on Logic Programming (ICLP '94)* , Genova, Italy, June 16–17: E. Marchiori (Combining Logic and Control to Chararcterize Global Invariants of Prolog Programs).
- *University of Pisa* (host: Prof. G. Levi), Pisa, Italy, July 18 – August 3: M. Gabbrielli.
- *Year 2 COMPULOG 2 meeting*,12–14 September, Leiden, K.R. Apt, E. Marchiori (Reasoning about Prolog programs: from Modes through Types to Assertions), F. Teusink.
- *Algebraic Logic Programming '94*, Madrid, Spain, September 14–16: E. Marchiori (A Logic for Variable Aliasing in Logic Programs), F. Teusink (Three-valued Completion for Abductive Logic Programs).
- *18th German Annual Conference on AI*, Saarbrücken, Germany, September 16–20: K.R. Apt (Comparing negation in logic programming and in Prolog).
- *University of Pisa* (host: Prof. Levi), Pisa, Italy, November 21–23: M. Gabbrielli.
- *META-LOPSTR'94*, Pisa, Italy, June 19–21: S. Etalle (More on Unfold/Fold Transformations of Normal Programs: preservation of Fitting's Semantics).
- *GULP-PRODE'94*, Peñiscola, Spain, September 19–22: S. Etalle (Modular Transformations of CLP programs).
- *ILPS'94*, Ithaca, N.Y. USA, November 13–17: S. Etalle.

Memberships of Committees and Other Professional Activities

AP5a:
- Member of the European Network in Computational Logic (initiated by the ESPRIT Basic Research Action 'Compulog'), since 1991.

K.R. Apt:
- Professor of Computer Science, University of Amsterdam, since 1991.
- Editorial board, Science of Computer Programming, since 1981.

- Editorial board, Informationand Computation, since 1987.
- Editorial board, Journal of Logic and Computation, since 1989.
- Editorial board, Wiley/Teubner Series in Computer Science, since 1989.
- Editorial board, Fundamenta Informaticae, since 1990.
- Editorial board, Journal of Logic Programming, since 1991.
- Editorial board, CWI Tracts, since 1992.
- Scientific Commission for Computer Science of the Belgian National Fund for Scientific Research, since 1990.
- Executive Committee of the Association for Logic Programming, since 1991.
- Program committee member, IFIP Working Conference on Programming Concepts, Methods and Calculi (PROCOMET '94), San Miniato, Italy, June 1994.
- Program committee member, Logic in Computer Science (LICS '94), Paris, France, July 1994.
- Program committee member, 4th International Conference on Algebraic and Logic Programming (ALP '94), Madrid, Spain, September 1994.
- Co-organizer of a series of lectures on 'New Developments in Programming and Specification Languages', CWI, Amsterdam, Spring 1994.
- Coordinator of the Esprit Basic Research Action 'Compulog 2', since 1992.
- Member Ph.D. committee N.J. Drost, Process Theory and Equation Solving, University of Amsterdam, February 10.
- Member Ph.D committee, Constraints and Negations in Logic Programming, C. Jonker, University of Utrecht, September 13.
- Co-organizer of 7th BENELOG – 6th Benelux Meeting on Logic Programming and PROLOG, Amsterdam, September 2.

M. Gabbrielli:

- Co-organizer of Workshop on analysis and Verification of Logic Programs, Genova, June 1994.

E. Marchiori:

- Co-organizer of 7th BENELOG – 6th Benelux Meeting on Logic Programming and PROLOG, Amsterdam, September 2.

Visitors

- Maria Chiara Meo, University of Pisa, Italy, February 1 – May 30.
- Maarten van Emden, University of Victoria, Canada, February 15 – March 15.
- Philip Wadler, University of Glasgow, March 4.
- Jean-Raymond Abrial, Paris, France, April 15.
- Dino Pedreschi, University of Pisa, Italy, September 15–16.
- Nissim Francez, Technion, Haifa, Israel, December 22–23.

Papers in Journals and Proceedings

K.R. APT, H.C. DOETS (1994). A new definition of SLDNF-resolution. *Journal of Logic Programming*, 18(2):177–190.

K.R. APT, R. BOL (1994). Logic programming and negation: a survey. *Journal of Logic Programming*, 19-20:9–71.

K.R. APT, A. PELLEGRINI (1994). On the occur-check free Prolog programs. *ACM Toplas*, 16(3):687–726.

K.R. APT, E. MARCHIORI, C. PALAMIDESSI (1994). A declarative approach for first-order built-in's of Prolog. *Applicable Algebra in Engineering, Communication and Computation*, 5(3/4):159–191.

K.R. APT, E. MARCHIORI (1994). Reasoning about prolog programs: from modes through types to assertions. *Formal Aspects of Computing*, 6(6A):743–765.

K.R. APT, M. GABBRIELLI (1994). Declarative interpretations reconsidered. P. VAN HENTENRYCK (ed.). *ICLP94*, MIT Press, 74–89.

K.R. APT, D. PEDRESCHI (1994). Modular termination proofs for logic and pure Prolog programs. G. LEVI (ed.). *Advances in Logic Programming Theory*, Oxford University Press, 183–229.

K.R. APT, E.-R. OLDEROG (1994). *Programmverifikation*. Springer-Verlag, Berlin, In German, 258 + xii pages.

A. BOSSI, M. GABBRIELLI, G. LEVI, M.C. MEO (1994). A compositional semantics for logic programs. *Theoretical Computer Science* 122(1-2): 3–47.

A. BOSSI, M. GABBRIELLI, G. LEVI, M. MARTELLI (1994). The s-semantics approach: Theory and applications. *Journal of Logic Programming*, 19–20:149–197.

A. Bossi, S. Etalle (1994). Transforming Acyclic Programs. *ACM Toplas*, 16(4):1081–1096.

A. BOSSI, S. ETALLE (1994). More on unfold/fold transformations of normal programs: preservation of Fitting's semantics. F. TURINI (ed.). *Proc. META94, 'Fifth Workshop on Metaprogramming in Logic'*.

M. GABBRIELLI, R. GIACOBAZZI (1994). Goal independency and call patterns in the analysis of Logic Programs. *Proc. ACM Symposium on Applied Computing*, ACM Press.

F.S. DE BOER, M. GABBRIELLI, E. MARCHIORI, C. PALAMIDESSI (1994). Proving concurrent constraint programs correct. *Proc. Twentyfirst Annual ACM SIGACT/SIGPLAN Symposium on Principles of Programming Languages,* POPL 94, ACM Press, 98–108.

E. MARCHIORI (1994). A logic for variable aliasing in logic programs. *Proc. 4th International Conference on Algebraic and Logic Programming,* LNCS 850, Springer-Verlag, 287–304.

F.J.M. TEUSINK (1994). Three-valued completion for abductive logic programs. GIORGIO LEVI, MARIO RODRÍGUEZ-ARTALEJO (eds.). *Proceedings of the International Conference on Algebraic and Logic Programming*, LNCS 850, Springer-Verlag, 150–167.

A. BOSSI, M. FABRIS, M.C. MEO (1994). A bottom-up semantics for constructive negation. P. VAN HENTENRYCK (ed.). *ICLP94*, MIT Press, 520–534.

CWI Reports

CS-R9402 K.R. APT, R.N. BOL. *Logic programming and negation: a survey.*

CS-R9411 K.R. APT. *Program verification and Prolog.*

CS-R9417 K.R. APT, M. GABBRIELLI. *Declarative interpretations reconsidered.*

CS-9464 K.R. APT, P. VAN EMDE BOAS, A. WELLING. *The STO problem is NP-Hard.*

CS-9468 K.R. APT, F. TEUSINK. *Comparing negation in logic programming and in Prolog.*

CS-9470 K.R. APT, M. GABBRIELLI, D. PEDRESCHI. *A closer look at declarative interpretations.*

CS-R9446 E. MARCHIORI. *A logic for variable aliasing in logic programs.*

CS-R9466 E. MARCHIORI. *Some uses of constructive negation for classical problems in non-monotonic reasoning.*

CS-R9447 A. BOSSI, S. ETALLE. *More on unfold/fold transformations of normal programs: preservation of Fitting's semantics.*

CS-R9454 S. ETALLE. *More (on) unification-free Prolog programs.*

CS-R9474 F. TEUSINK. *Three-valued completion for abductive logic programs.*

CS-R9439 A. BOSSI, M. FABRIS, M.C. MEO. *A bottom-up semantics for constructive negation.*

Other Publications

K.R. APT, A. SCHRIJVER, N. TEMME (eds.) (1994). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey*. CWI, Amsterdam, The Netherlands.

Logic and Language (AP5b)

Staff

- Prof. dr. D.J.N. van Eijck, (sub)group leader, since November 1, 1989
- D. Ben Shalom, visitor (Israel), from December 15, 1993 until June 15, 1994
- G. Cepparello, visitor (Scuola Normale, Pisa), from November 15, 1993 until March 15, 1994
- Drs. A.V. Groenink, Ph.D. Student (OIO), since November 1, 1993
- Dr. J. Jaspars, post-doc researcher, since February 1, 1994
- Drs. W. Meyer Viol, Ph.D. Student (OIO), from January 1, 1991 until December 31, 1994
- Dr. M. de Rijke, post-doc researcher, since January 1, 1994
- Prof. dr. W.C. Rounds, visitor, from August 15, 1994
- Dr. Y. Venema, post-doc researcher, from March 15 until September 1, 1994

Scientific Report

In 1994, the group as a whole has continued to explore topics on the borderline between natural language analysis and programming language analysis, including the study of incremental processing in semantics with the tools of dynamic logic, and the pursuit of connections with issues in the areas of knowledge representation and non-monotonic reasoning.

Jan van Eijck continued his work on the logic of presuppositions with a paper in *Formal Aspects of Computing*. He also worked on logics of theory extension, on representation languages for natural language meaning, and on the connection between modal logic and process theory. Also, an edited volume based on an earlier NFI workshop on 'Logic and Information Flow' appeared (jointly edited with Albert Visser).

Maarten de Rijke joined the group in January 1994. He has worked on theory and applications of modal logic; the application areas included process theory, real-time systems, semantics of natural language, grammar formalisms, and algebraic logic. In addition, De Rijke worked on logical aspects of complex systems.

During his spell at CWI as an NFI post-doc, *Yde Venema* worked on algebraic modal logic and on various aspects of dynamic logic.

Wilfried Meyer Viol has almost completed his thesis manuscript, on proof theory for term logics (instantial logic), with applications in natural language semantics.

Annius Groenink continued the work on his Ph.D. project; among other things, he is developing a framework of grammars for linear movement, using the available parser generation tools for implementation.

Jan van Eijck and *Jan Jaspars* have started work on a framework for computation semantics (sponsored by European LRE project FraCaS); they are developing tools for comparing theories of dynamic natural language semantics.

In August 1994, professor *Bill Rounds*, on sabbatical leave from the University of Michigan, joined the group as a visitor. He is working on feature logics for natural language and on applications of default logic in linguistics.

Organisation of Conferences, Workshops, Courses, etc.

- NFI Parallels Colloquium, Amsterdam, monthly through the year, until Summer 1994 (Jan van Eijck).
- NFI Workshop 'Three Days of Bisimulation', CWI, April 20–22 (Alban Ponse, Maarten de Rijke, Yde Venema).
- Seminar on Intensional Logic, Amsterdam, biweekly, January–July. (N. Alechina and M. de Rijke).
- NFI Workshop 'Logic, Structures and Syntax', CWI, Amsterdam, September 26–38 (P. Blackburn, and M. de Rijke).
- Occassional Logic Meetings, Amsterdam, monthly, October–December (N. Alechina, M. de Rijke, and Y. Venema).

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Relational Methods in Computer Science*, Dagstuhl, Germany, January 16–21: M. de Rijke (Zooming in, Zooming out).
- *LRE FRACAS project meeting*, Luxemburg, Luxemburg, January 25–26: D.J.N. van Eijck.
- *Working Visit FACCSLAB*, Cape Town, March: M. de Rijke (Dynamic Logic and Theory Change, The Logic of Peirce Algebras).
- *Workshop 'Natural Deduction and Natural Languages Semantics'*, SOAS, London, UK, March 3–5: W. Meyer Viol (Accessibility and Interpretation of Generic Proper Terms in Natural Deduction).
- *LRE FRACAS project meeting*, Stuttgart, Germany, March 15–18: D.J.N. van Eijck, J. Jaspars.
- *Working visit SRI*, Cambridge, UK, March 22–25: A.V. Groenink.
- *Logic, Language & Computation*, Stanford, USA, June 2–7: M. de Rijke (Logics of Communicating Structures).
- *Information & Orientation*, Moraga, USA, June 8–15: M. de Rijke (Zooming in, Zooming out).
- Working visit, Londen, Queen Mary and Westfield College, UK, June 16: Y. Venema (The modal logic of intervals).
- *LRE FRACAS project meeting*, Saarbrücken, Germany, June 27–30: D.J.N. van Eijck, J. Jaspars.
- *ICTL '94*, Bonn, Germany, July 11–14: M. de Rijke (Back and forth through time and events) Y. Venema (Completeness through flatness).
- *Summer School Algebraic and Category-theoretic Methods in Computer Science*, Budapest, Hungary, July: Y. Venema (course on Modal Logic and Boolean Algebra with Operators).
- *LRE FRACAS project meeting*, Saarbrücken, Germany, July 27–30: D.J.N. van Eijck.
- Working visit Imperial College, London, UK, July 31–August 7: W. Meyer Viol.
- *ESSLLI '94*, Copenhagen, Denmark, August 8–19: M. de Rijke (Combining Logics, Theories and Structures).
- *LRE FRACAS project meeting*, Cambridge, UK, September 29–October 2: D.J.N. van Eijck, J. Jaspars.
- Program Committee Meeting EACL and Working visit to Tübingen, December 12–13: B. Rounds (Partial Information and Non-monotonicity).
- Working visit University of Berlin, Berlin, Germany, 14–15 November: J. Jaspars.
- *Working visit University of Saarbrücken*, Saarbrücken, Germany, October 29–November 2: M. de Rijke.
- *ESF Conference Logic, Language and Information*, Espindio, Portugal, December 11–18: J. Jaspars.
- *NSL '94*, December: M. de Rijke (A Lindström Theorem for Modal Logic; paper presented by M. Kanazawa).

Memberships of Committees and Other Professional Activities

Jan van Eijck:

- Member of 'NWO Voorbereidingscommissie Prioriteitsprogramma Taal- en Spraaktechnologie'.
- Member of the board of the Dutch Graduate School in Logic (since July, 1993).
- Member of the Ph.D. committee of Jan Jaspars, Tilburg University (June 14).

- Promotor of the Ph.D. thesis of Kees Vermeulen, Utrecht University (with Albert Visser as co-promotor), (22 September 1994).
- Program committee member of JELIA'94, York, September 1994.
- Program committee member of CLIN'94 (Computational Linguistics in the Netherlands), Fall, 1994.
- Program committee member of the 7th European Summer School in Logic, Language and Information, August 1995, Barcelona.
- Program committee member of 7th Conference of the European Chapter of the Association for Computational Linguistics, March 1995, Dublin.
- Program committee member of the Workshop on Computational Semantics, Tilburg University, December 1994.

Maarten de Rijke:

- Editorial board, Studies in Logic, Language and Information.

Visitors

- H. Andréka (Hungary), D. Caucal (France), T. Fernando (Germany), R. Goldblatt (New Zealand), Y. Hirshfeld (Scotland), I. Hodkinson (England), M. Kwiatkowska, S. Smolka (USA), C. Stirling (Scotland), 20–22 April.
- R. Backofen (Germany), G. Bouma, C. Brew (Scotland), B. Carpenter (USA), J. Dörre (Germany), B. Keller (England), P. King (Germany), Marcus Kracht (Germany), S. Manandhar (Scotland), D. Milward (England), M. Moortgat, D. Moshier (USA), J. Nerbonne, J. Rogers (USA), I. Sag (USA), R. Treinen (Germany), J. Wedekind (Germany), 26–28 September.
- Megumi Kameyama (June) .
- Makoto Kanazawa (September).

Papers in Journals and Proceedings

J. VAN BENTHEM, J. VAN EIJCK, V. STEBLETSOVA (1994). Modal logic, transition systems and processes. *Journal of Logic and Computation*, 4:811–855.

J. VAN EIJCK (1994). Axiomatizing dynamic predicate logic with quantified dynamic logic. J. VAN EIJCK, A. VISSER (eds.). *Logic and Information Flow*, MIT Press, Cambridge Mass., 30–48.

J. VAN EIJCK (1994). The dynamics of theory extension. P. DEKKER, M. STOKHOF (eds.). *Proceedings 9th Amsterdam Colloquium*, ILLC, Amsterdam, 249–267.

J. VAN EIJCK (1994). Presupposition failure — a comedy of errors. *Formal Aspects of Computing*, 6A:766–787.

J. VAN EIJCK, G. CEPPARELLO (1994). Dynamic modal predicate logic. M. KANAZAWA, C.J. PINÓN (eds.). *Dynamics, Polarity and Quantification*, CSLI, Stanford, 251–276.

J. VAN EIJCK, A. VISSER (1994). Logic and information flow — introduction. J. VAN EIJCK, A. VISSER (eds.). *Logic and Information Flow*, MIT Press, Cambridge Mass., 1–14.

J. VAN EIJCK (1994). A natural term language. K. APT, L. SCHRIJVER, N. TEMME (eds.). *From Universal Morphisms to Megabytes: A Baayen Space Odyssey*, CWI, Amsterdam, 287-300.

P. BLACKBURN, W. MEYER VIOL (1994). Linguistics, logic and finite trees. *Bulletin of the IGPL*, volume 2, 3–31.

P. BLACKBURN, C. GARDENT, M. DE RIJKE (1994). Back and forth through time and events (Extended abstract). P. DEKKER, M. STOKHOF (eds.). *Proc. 9th Amsterdam Colloquium*, ILLC, University of Amsterdam, 161–170.

P. BLACKBURN, C. GARDENT, M. DE RIJKE (1994). Back and forth through time and events. D.M. GABBAY, H.J. OHLBACH (eds.). *Temporal Logic*, LNAI 827, Springer-Verlag, 225–337.

HOEK, W. VAN DER, J. JASPARS & E. THIJSSE (1994). Honesty in partial logic. J. DOYLE, E. SANDEWALL, P. TORASSO (eds.). *Proceedings of the Fourth International Conference on Principles of Knowledge Representation and Reasoning* (KR'94), Morgan Kaufmann, San Francisco, 583–594.

M. DE RIJKE (1994). Meeting some neighbours. J. VAN EIJCK, A. VISSER (eds.). *Logic and Information Flow*, MIT Press, 170–195.

W.C. ROUNDS, G.Q. ZHANG (1994). Domain theory meets default logic. *Journal of Logic and Computation Vol 5*, No. 1, 1–25.

CWI Reports

CS-R9412 P. BLACKBURN, W. MEYER VIOL. *Linguistics, logic and finite trees.*

CS-R9419 J. VAN BENTHEM, G. CEPPARELLO. *Tarskian variations. Dynamic parameters in classical semantics.*

CS-R9441 M. KAMEYAMA. *Indefeasible semantics and defeasible pragmatics.*

CS-R9456 M. DE RIJKE. *A Lindström theorem for modal logic.*

CS-R9462 P. BLACKBURN, M. DE RIJKE. *Zooming in, Zooming out.*

CS-R9463 P. BLACKBURN, M. DE RIJKE, Y. VENEMA. *The algebra of modal logic.*

CS-R9467 M. DE RIJKE. *The logic of Peirce algebras.*

Other Publications

J. VAN EIJCK (1994). *Presuppositions and Dynamic Logic.* Technical Report CSLI-94-186, CSLI, Stanford.

J. VAN EIJCK A. VISSER (eds.) (1994). *Logic and Information Flow*, MIT Press, Cambridge Mass.

R. COOPER, R. CROUCH, J. VAN EIJCK, C. FOX, J. VAN GENABITH, J. JASPARS, H. KAMP, M. PINKAL, M. POESIO, S. PULMAN, E. VESTRE (1994). *Harmonizing the Approaches.* FraCaS Deliverable LRE 62-051-D7, University of Edinburgh, 107 pages.

R. COOPER, R. CROUCH, J. VAN EIJCK, C. FOX, J. VAN GENABITH, J. JASPARS, H. KAMP, M. PINKAL, M. POESIO, S. PULMAN, E. VESTRE (1994). *Describing the Approaches.* FraCaS Deliverable LRE 62-051-D8, University of Edinburgh, 231 pages.

R. COOPER, R. CROUCH, J. VAN EIJCK, C. FOX, J. VAN GENABITH, J. JASPARS, H. KAMP, M. PINKAL, M. POESIO, S. PULMAN, E. VESTRE (1994). *The State of the Art in Computational Semantics: Evaluating the Descriptive Capabilities of Semantic Theories.* FraCaS Deliverable LRE 62-051-D9, University of Edinburgh, 262 pages.

R. COOPER, R. CROUCH, J. VAN EIJCK, C. FOX, J. VAN GENABITH, J. JASPARS, H. KAMP, M. PINKAL, M. POESIO, S. PULMAN, E. VESTRE (1994). *Evaluating the State of the Art.* FraCaS Deliverable LRE 62-051-D10, University of Edinburgh, 152 pages.

R. COOPER, R. CROUCH, J. VAN EIJCK, C. FOX, J. VAN GENABITH, J. JASPARS, H. KAMP, M. PINKAL, M. POESIO, S. PULMAN, E. VESTRE (1994). *The Bluffer's Guide to Computational Semantics.* Technical report, University of Edinburgh, Edinburgh, 50 pages.

R. COOPER, R. CROUCH, J. VAN EIJCK, J. VAN GENABITH, J. JASPARS, H. KAMP, M. PINKAL, M. POESIO, S. PULMAN, E. VESTRE (1994). *Rooting Semantic Phenomena in Natural Language, Part II: Progress Report on Real Data.* FraCaS Deliverable LRE 62-051-D6, University of Edinburgh, 29 pages.

J. JASPARS (1994). *Calculi for Constructive Communication.* Ph.D. Thesis, ITK, Tilburg and ILLC, Amsterdam.

DEPARTMENT OF ALGORITHMICS AND ARCHITECTURE

General Introduction

Staff Department of Algorithmics and Architecture, 1994

- AA1
  - P.M.B. Vitányi
  - H.M. Buhrman
  - H.H. Ehrenburg
  - P.D. Grünwald
  - J.-H. Hoepman
  - H.A.N. van Maanen
  - A. Panconesi
  - P.M. Papatriantafilou
  - J. Tromp
  - P.M. Riãno
  - Ph. Tsigas
- AA2
  - A.M. Bleeker
  - S.A. Brands
  - H.M. Buhrman
  - D. Chaum
  - R.J.F. Cramer
  - M.K. Franklin
  - R. Hirschfeld
  - C.J.H. van der Kolk
  - L.G.L.T. Meertens
  - L.A.M. Schoenmakers
- AA3
  - L.G.L.T. Meertens
  - E.D.G. Boeve
  - K. Clenaghan
  - M.P. Nijland
  - S. Pemberton
  - A. Takano
  - O.J.M. Weber
  - F.J. van Wingerde
  - J.B. Zwanenburg
- AA4

  M.L Kersten
  J.F.P. van den Akker
  C.A. van den Berg
  F. van Dijk
  C.A. Galindo-Legaria
  S. Heerschap
  M. Holsheimer
  M.L. Kersten
  F. Kwakkel
  J. Pellenkoft
  C.W. Quak
  A.P.J.M. Siebes
  C.J.E. Thieme
- Secretary: M. Hegt

Electronic dissemination

As of April 1993 technical reports have been distributed widely through the CWI FTP server. This channel is becoming the predominant and timely distribution means for grey literature, its use is an indication of the world interest in the results produced at CWI. In particular, since the top 5 number of copies extracted reach a more focussed and interested audience than can be expected from publishing in a workshop or international conference proceedings.

In 1994 11037 (in 1993 5319) copies of internal CWI reports where obtained from outside sources. The top 2 reports accessed in 1993 were AA/CS-R9406 (1133) and AP/CS-R9457 (1077). The detailed breakdown for the AA published reports is given on page 73. The number extracted in 1993 is presented in parenthesis. A breakdown for the AA software packages was not available, but especially Python was obtained from several hundred cites.

Department	New reports	Copies in 1994
AP	18	3851
AA	18	4232
BS	12	897
IS	2	704
NW	5	674
CST	3	569
AM	1	110

AA/CS-R9122	99 (187)	AA/CS-R9201	78 (165)
AA/CS-R9235	46 (46)	AA/CS-R9240	53 (62)
AA/CS-R9243	41 (53)	AA/CS-R9244	46 (48)
AA/CS-R9255	46 (59)	AA/CS-R9256	66 (69)
AA/CS-R9257	75 (109)	AA/CS-R9258	114 (144)
AA/CS-R9259	82 (98)	AA/CS-R9260	58 (79)
AA/CS-R9261	66 (75)	AA/CS-R9262	59 (72)
AA/CS-R9263	111 (86)	AA/CS-R9264	57 (102)
AA/CS-R9265	20 (63)	AA/CS-R9266	90 (156)
AA/CS-R9268	30	AA/CS-R9303	58 (68)
AA/CS-R9309	62 (141)	AA/CS-R9318	71 (415)
AA/CS-R9320	161 (245)	AA/CS-R9323	96 (552)
AA/CS-R9343	50 (23)	AA/CS-R9352	43 (18)
AA/CS-R9354	174	AA/CS-R9403	264
AA/CS-R9404	70	AA/CS-R9406	1133
AA/CS-R9407	30	AA/CS-R9413	47
AA/CS-R9416	46	AA/CS-R9421	47
AA/CS-R9422	33	AA/CS-R9429	209
AA/CS-R9430	131	AA/CS-R9431	12
AA/CS-R9437	19	AA/CS-R9451	35
AA/CS-R9455	93	AA/CS-R9459	11

Algorithms and Complexity (AA1)

Staff

- Prof. dr. P.M.B. Vitányi, group leader
- Dr H.M. Buhrman, postdoc (from October)
- Drs H.H. Ehrenburg, junior researcher (oio), CWI
- Drs. P.D. Grünwald, junior researcher (oio), SION
- Drs. J.-H. Hoepman, junior researcher (oio), NFI
- Drs. H.A.N. van Maanen, junior researcher (oio), SION
- Dr. A. Panconesi, ERCIM fellow (from October)
- Drs. P.M. Papatriantafilou (Univ. Patras & CTI), NUFFIC/NFI (until September)
- Dr. J. Tromp, junior researcher (postdoc), CWI/NFI (currently on leave of absence as NSERC Research Fellow at University of Waterloo)
- Drs. P.M. Riãno (Univ. Tarragona) exchange visitor (from October)
- Drs. Ph. Tsigas (Univ. Patras & CTI), NFI (until September)

Scientific Report

Vitányi (with C. Bennett, P. Gács, M. Li, and W. Zurek) extended results on information distance between finite objects for submission to a technical journal. One interpretation of this distance is as the optimal universal 'picture distance' or 'cognitive distance' which discovers all effective similarities between two pictures (or other cognitive objects). This supplies an epistimological substrate to develop a mathematical theory for the problematic notion of picture similarity in Pattern Recognition and Classification. Other results include the ultimate energy dissipation limits of computing which in turn puts fundamental limits on miniaturization of computing technologies and increase in computing power.

Vitányi with M. Li (Univ. Waterloo) published a paper introducing a new 'incompressibility' method in 'J. Combinatorial Theory, Ser. A' and a paper on statistics of block frequencies (normality properties) in finite sequences in 'Mathematical Systems Theory'.

Research (with M. Li) to have a mathematically rigorous derivation of the so-called Minimum Description Length (MDL) paradigm in statistics and machine learning from the notion of randomness tests as pioneered by P. Martin-Löf was published in a volume in the 'DIMACS Series in Discrete Mathematics and Theoretical Computer Science' by the American Math. Society.

Vitányi was invited to give a plenary talk on this subject at the 'Inductive Logic Programming Workshop' in Bad Honnef, Germany, and at the DIMACS Tutorial at the federated *Machine Learning Conference / Computational Learning Theory Conference* in New Brunswick, USA. Together with J. Kok and G. te Brake (University of Utrecht) he investigated the application of the MDL paradigm in the learning of robot arm movements by backpropagating neural networks presented at the 'European Conference on Artificial Neural Networks' in Brussels.

Vitányi and *Ehrenburg* started research in the mathematical foundations of evolutionary computing and genetic algorithms. Exploiting properties of rapid mixing Markov chains a discipline of structured evolutionary programming may develop. In the topic of Machine Learning and Multiple Computing Agents ESPRIT BRA III Working Group Nr. 8556, he was program committee chair of the second European 'EuroCOLT'—European Computational Machine Learning Conference in Barcelona, 1995.

Vitányi, Panconesi, Papatriantafilou and *Tsigas* presented research in distributed algorithms on new algorithms for wait-free self-stabilizing mutual exclusion (exclusive access of resources by concurrent processes under very strong niceness conditions and fault-tolerance); new algorithms for compressing the name-space of a system of processes using randomization techniques at the 'International Symposium on Algorithms, Architectures and Complexity' in Beijing, China.

Vitányi with Tao Jiang (McMaster University, Canada) and J. Seiferas (Rochester University, USA) resolved one of the longest-standing conjectures in theoretical machine complexity. (The basic question whether a Turing machine with two work tapes with one head each is less powerful than a Turing machine with a work tape containing two heads has been open for over a quarter century.) Using a combination of combinatorial techniques and advanced Kolmogorov complexity laws the conjecture was finally settled in the affirmative, and was presented at the '26th Annual ACM Symposium on Theory of Computation' in Canada.

Vitányi presented at PhysComp in Dallas results on interconnect length of both symmetric and random computer networks, resolving various questions raised by C. Mead (Caltech) with respect to VLSI design. Together with *J. Tromp* and M. Li (Univ. Waterloo) *Vitányi* started research on the emerging new technology of coherent quantum computation. An expert in this area, Dr. André Berthiaume (Univ. Montreal) will join the NFI project to push this type of research.

Ehrenburg joined the group in June. He implemented (with initial cooperation of *van Maanen*) and subsequently modified the implementation of a Genetic Programming System (called FALS) which aims at learning simple Finite Automata. In this system a preliminary step to being able to learn automata it is to be able to learn boolean functions. This work was reported at BeNelearn-94, the 4th Belgian-Dutch Conference on Machine Learning. During experimentation with a boolean function learning problem, the 6-multiplexer, which was studied before in Genetic Programming (Koza 1992), it became clear that the system performs well, even though its task is (much) more difficult than that in the original study. This is because it uses a standard basic operator set, while in the original study an operator set tailored to the problem was used.
However trying to scale up the problem, to a 11-multiplexer, resulted in poor performance. Scaling up seems to be a major problem in Genetic Programming, not only for our system. Our research has therefore concentrated on improving the Genetic Programming Paradigm. Among other things several new genetic operators were implemented, because there is no good motivation why the standardly used genetic crossover operator should be optimal. Experimental results show that other genetic operators perform as well as crossover.

Riãno visited the group from the Univ. in Tarragona (Spain). and worked on automatic rule generation from data, knowledge abstraction by heuristic search, evidential treatment of uncertainty in rule, and feasible approach to consensus of knowledge. He prepared several technical reports while at CWI.

Hoepman did research in self-stabilizing distributed algorithms which can recover from arbitrary disturbances. Together with D. Alstein (TUE), B. Olivier (Univ. Amsterdam) and P. van der Put (Utrecht Univ.) he reported on mutual exclusion in 'Comp. Sci. in The Netherlands' conference. Algorithms for self-stabilizing algorithms for ring network orientation were reported at the '8th Annual International Workshop on Distributed Algorithms'. *Hoepman, Papatriantafilou* and *Tsigas* studied algo-

rithms for self-stabilizing wait-free shared objects and submitted the paper for publication. *Hoepman, Buhrman* and J. Garay (IBM T.J. Watson Research Center, USA) studied optimal resilient protocols with respect to mobile faults (computer viruses) and submitted a paper for publication; *Hoepman, Buhrman*, J. Garay (IBM T.J. Watson Research Center, USA) and M. Moir (Univ. of Washington, USA) found solutions for the open problem of fast long-lived renaming using wait-free primitives in computer networks. He collaborated with the distributed operating systems group of S.J. Mullender (Technological University of Twente) studying technology dependence and feasible methods for obtaining improved performance algorithms on mobile radio computing networks. Finally, he organised the 'ALADDIN Distributed Algorithms Colloquium'.

Grünwald started at CWI in May. He did research on grammar inference and the use of the MDL principle for the computational learning of grammars. In the model, a learning algorithm is simply given a very large piece of text (for example, in English) and it then tries to construct a grammar that can account for that text. The model is a generalization of several other existing ones, and results of testing it on the task of word classification, which can be seen as a restricted form of grammar learning are provided. This research was reported at BeNeLearn'94, and a second paper was submitted. On nonmonotonic reasoning a paper was prepared and submitted to an AI conference on 'persistence, causation and counterfactuals'. He presented a talk on Kolmogorov complexity and the MDL principle at the University of Toulouse, and visited several conferences on grammar inference, neural networks, and machine learning.

Buhrman started at CWI in October. He completed research on complexity classes, reported in STACS, and prepared with J. Balcazar and H. Hermo (Polytechnical University of Catalunya, Barcelona) a paper on learning sequences of certain Kolmogorov complexity, accepted for EurCOLT'95 conference. Together with *J.-H. Hoepman* and others he investigated several topics in distributed algorithms, such as self-stabilization and long-lived renaming, which led to two submitted papers (see section on *Hoepman*). With respect to structural complexity aspects *Buhrman* and Torenvliet discovered the 'resource bounded injury method' and presented it in ICALP94 in Jerusalem and in Dagstuhl. Also a survey paper on structure of complete sets presented at the Structure in Complexity Theory '94 meeting in Amsterdam.

Van Maanen together with *Ehrenburg* reported on the genetic programming pilot version of FALS—Finite Automaton Learning System. This syntactically 'tree-structured' genetic programming system is intended to automatically derive circuits of flip-flops and Boolean NAND gates from specifications in BeNeLearn'94. He continued research on 'forecasting algorithms' in the sense of R. Solomonoff where he introduced a novel idea of a 'competitive information-gain' criterium for learning algorithms using the MDL principle. This may lead to a novel approach to machine learning and forecasting. Applications in automatic stochastic grammar learning from text corpora and laerning Markov chains are in preparation.

Van Maanen participated also in '35th IEEE Symposium on the Foundations of Computer Science (FOCS'94)' in Santa Fe (USA).

Panconesi continued his work on randomized algorithms for edge coloring graphs. Together with D. Dubashi of the Max-Planck-Institute in Saarbrücken he continued and published improvements in complexity of such algorithms, among others by use of the sophisticated randomized combinatorial method the 'Röddl Nibble'. They also worked on probabilistic recurrence relations. Together with Papatriantafilou, Tsigas and Vitányi, he worked on new algorithms for compressing the name-space of a system of wait-free processes using randomization techniques. In the course of this a new wait-free object was invented: a 'weak test&set' object which performs the test-and-set operation not surely but with high probability. Some of our algorithms require this new primitive. Previous complexity results were considerably improved by the method: in fact, the name space can be compressed by a polynomial algorithm to its minimum, with high probability. This paper was published in ISAAC'94. He participated in a 'Randomized Algorithms Seminar' and a 'Genetics Algorithms Seminar' at CWI.

Papatriantafilou and *Tsigas* continued their work on distributed algorithms. They participated in the ALADDIN Seminar. Apart collaborated work on wait-free renaming reported under the Panconesi heading above they worked on the following. They improved existing solutions for wait-free (extremely fault-tolerant) self-stabilizing clock synchronization by obtaining a square synchronization time where the best previous result was cubic (in number of participating processors), reported at the '4th Scandinavian Workshop on Algorithm Theory' in Aarhus (Denmark). By a sophisticated use of combinatorial color coding structures they obtained optimal lower bounds on the complexity of one-write wait-free

shared register constructions, reported at the '19th International Symposium on Mathematical Foundations of Computer Science, in Kosice, Slovenia. Joint work with *Vitányi, Hoepman*, and *Panconesi* is reported above.

Tromp continued his work on distributed algorithms machine learning. His paper (together with Ming Li of University of Waterloo, and M. Yanakakis of AT&T Research Labs) resolving the decade old question whether the greedy algorithm used by molecular biologists in determining the parent chromosome their gene sequences come from in fact obtains a chromosome which is linear in the length of the parent chromosome was accepted for publication by J. ACM. Together with P. van Emde Boas (University of Amsterdam) he published a result on associative storage modification machines (they are complete for the 2nd machine class) in a volume published by Cambridge University Press (Computer Science Series). He published several other papers and is currently on leave of absence on a prestigeous International NSERC Fellowship of the National Science Research Council of Canada to work at the University of Waterloo, Waterloo, Canada.

Organisation of Conferences, Workshops, Courses, etc.

- NFI

  The national (NFI-supported) project ALADDIN - research and education in concurrent systems - organised the ALADDIN Distributed Algorithms Seminar bi-weekly alternating between University of Utrecht and CWI; the ALADDIN Distributed Algorithms Colloquium Series (one day events) and the ALADDIN Distributed Algorithms Lecture Series. In the context of the NFI-sponsored ALADDIN project, *Vitányi* together with G. Tel from Utrecht University organised and chaired the program committee of the '8th Annual Workshop on Distributed Algorithms (WDAG'94)', held at Terschelling; and *Vitányi* with P. van Emde Boas from the University of Amsterdam organised the '9th Annual IEEE Structure in Complexity Theory Conference'. Vitányi was also program committee member for the '2nd IEEE-Texas Instruments Physics and Computation Workshop (PhysComp'94)' held in Dallas, Texas, in 1994, and various other program committees listed below. Drs. Ph. Tsigas (Univ. Patras) was ALADDIN visitor and Dr. J. Garay (IBM T.J. Watson Research, USA) was ALADDIN visiting expert.

- NWO, NUFFIC, ERCIM

  Alessandro Panconesi (Cornell Univ.) was ERCIM Fellow (8 months), Marina Papatriantafilou (Patras Univ.) was NUFFIC Exchange Fellow (1 year).

- ESPRIT

  The CWI is partner of the ESPRIT BRA III NeuroCOLT Working Group 8556 on fundamental understanding of learning and of when and how it can be implemented algorithmically. Particular classes of adaptive systems will also be studied, including neural networks with discrete and continuous activations.

  Partners are the CWI, the universities of RWTH Aachen, Universitat Pompeu Fabra, Barcelona, Technische Universität Graz, University of Helsinki, London School of Economics, University of London, Ecole Normale Supérieure de Lyon, University of Milan, Université de Mons, Royal Holloway College, University of London. A first Workshop 'EuroCOLT' was organised in December 1993 at Royal Holloway College in London. The conference was attended by 70 participants. Apart from yearly meetings, successively in London, Barcelona, Helsinki, Graz, and Amsterdam, the 2nd 'EuroCOLT' Workshop will take place in Barcelona in March 1995.

- ALADDIN Group is already mentioned above.

- IFIP

  CWI (Vitányi) is member of the IFIP Special Interest Working Group on 'Descriptional Complexity' now IFIP SIWG 14.2, and co-chair of IFIP Special Interest Working Group on 'Computational Machine Learning' IFIP SIWG 14.4.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- Dagstuhl Seminar 'Structure in Complexity Theory and Applications', Universität Saarlandes, Saarbrücken, Germany, February 13–19, P. Vitányi (Talk: Two heads are better than two tapes).
- Computer Science Department, TUE, Eindhoven, NL, March 8, J.-H. Hoepman, (Talk: Uniform Deterministic Self-Stabilizing Ring-Orientation on Odd-Length Rings).
- 'Randomized Algorithms (RAND) Workshop', Merton College, Oxford University, Oxford, UK,

March 20–25, P. Vitányi (Talk: An Introduction to Kolmogorov complexity and its applications).
- Computer Science Department, Columbia University, New York, USA, May 5–9, P. Vitányi (Talk: An Introduction to Kolmogorov complexity and its applications).
- Computer Science Department, Yale University, New Haven, USA, May 10, P. Vitányi (Talk: An Introduction to Kolmogorov complexity and its applications).
- Lab. for Computer Science, MIT, Cambridge, Mass., USA, May 11, P. Vitányi (Talk: Thermodynamics of computation and information distance).
- Computer Science Department, Brown University, Providence, RI, USA, May 12, P. Vitányi (Talk: An Introduction to Kolmogorov complexity and its applications).
- Computer Science Department, Boston University, Boston, Mass., USA, May 13–15, P. Vitányi (Talk: The Incompressibility method in Combinatorics).
- Computer Science Department, State University of New York, Buffalo, USA (host: prof. K. Regan), May 16–17, P. Vitányi (Talk: An Introduction to Kolmogorov complexity and its applications).
- Computer Science Department, University of Waterloo, Waterloo, Ontario, Canada, May 18–31, P. Vitányi (Host: prof. M. Li) (talk: Two heads are better than two tapes).
- '26th ACM Symp. Theory of Computation (STOC'94)', Montreal, Canada, May 23–25 (talk: Two heads are better than two tapes).
- 'International Summer School on Distributed Algorithms (ISSDA)', Certosa di Pontignano, Sienna, Italy, June 5–17, J.-H. Hoepman, M. Papatriantafilou, Ph. Tsigas.
- Department of Applied Mathematics and Computer Science, Technological University of Twente, Enschede (NL), June 8, P. Vitányi (Fac. Colloquium talk: An Introduction to Kolmogorov complexity and its applications).
- '9th Ann. IEEE Structures in Complexity Theory Conference', Amsterdam, NL, June 28–July 1, P. Vitányi (Local organization co-chair).
- '4th Belgian-Dutch Conference on Machine Learning (BeNeLearn'94)' Erasmus University, Rotterdam, NL, H. Ehrenburg (Talk: A Finite Automaton Learning System using Genetic Programming). P. Grünwald (Talk: Automatic Grammar Inference using MDL'), and H. van Maanen.
- Fourth Scandinavian Workshop on Algorithm Theory (SWAT'94) Aarhus University, Denmark, July 6–8, M. Papatriantafilou, Ph. Tsigas (Talk: On Self-Stabilizing Wait-Free Clock Synchronization).
- 'Machine Learning Conference', 'Computational Learning Theory Conference', Machine Learning Workshops, Rutgers University, New Brunswick, USA, 8–15 July, P. Vitányi (Tutorial talk: The minimum description length principle and randomness tests).
- Lab. for Computer Science, MIT, Cambridge, Mass, USA, July 16–21, P. Vitányi (Hosts: Dr. N. Margolus and Dr. M. Sipser), (Talk: The Incompressibility method in Combinatorics).
- 'Summer School in Data Complexity and Applications to Image Processing', Datalogisk Institut, University of Copenhagen (DIKU), Copenhagen, Denmark, August 8–13, P. Vitányi (Invited Lecture Series: Minimum description length from first principles: differences and similarities with Bayes' rule).
- '13th Annual Symposium on Principles of Distributed Computing (PODC)', Los Angeles, USA, August 14–17, J.-H. Hoepman.
- '19th International Symposium on Mathematical Foundations of Computer Science (MFCS'94) Kosice, Slovakia, August 22–26, M. Papatriantafilou, Ph. Tsigas (Talk: How a Rainbow Colouring Function Can Simulate Handshaking (A Linear One-Write Atomic Register with One Reader).
- Computer Science Labs, Academi Sineca, Beijing, China, August 15–24, P. Vitányi (Hosts: prof. M. Li and others) (Talk: Multiprocessor architectures and physical law).
- 'International Symp. on Algorithms, Architectures and Complexity (ISAAC'94)', Beijing University, Beijing, China, August 24–30, P. Vitányi (Talk: Randomized Distributed Naming).
- 'Inductive Logic Programming Workshop', GMD, Bad Honnef, Germany, September 12–14, P. Vitányi (Invited plenary talk: Minimum description length from first principles: differences and similarities with Bayes' rule).
- 'Onderzoekschool Instituut voor Programmatuurkunde en Algoritmiek (IPA)' Workshop, Ameland, NL, September 22–23, P. Vitányi, (Series tutorial talks: An Introduction to Kolmogorov complexity and its applications); September 19–23, J.H. Hoepman (Talk: Introducing: Self-Stabilization).
- '8th International Workshop on Distributed Algorithms (WDAG'94)' Terschelling, NL, September 29–October 1, P. Vitányi (program committee co-chair, local arrangements co-chair); J.-H. Hoepman (Talk: Uniform Deterministic

Self-Stabilizing Ring-Orientation on Odd-Length Rings), and H. Buhrman.
- 'Randomized Algorithms (RAND) Workshop', CNRS (Centre National de Recherche Scientifique), Paris, France, October 4–7, P. Vitányi (Talk: Minimum description length from first principles: differences and similarities with Bayes' rule).
- IBM T. J. Watson Research Center, Yorktown Heights, New York, USA, November 14–16, P. Vitányi (Hosts: Dr. J. Garay, Dr. M. Yung), (Talk: An Introduction to Kolmogorov complexity and its applications).
- '2nd IEEE Conference on Physics and Computation', Dallas, Texas, November 17–20, P. Vitányi (Talk: Multiprocessor architectures and physical law).
- '35th IEEE Symposium on the Foundations of Computer Science (FOCS'94)', Santa Fe, NM, USA, November 20–22, H. van Maanen.
- Computer Science Department, University of Waterloo, Waterloo, Ontario, Canada, November 20–December 4, P. Vitányi (Host: Prof. M. Li).
- 'CSN-94 Computing Science in The Netherlands', Jaarbeurs, Utrecht, NL, November 21–22, J.-H. Hoepman (Talk: Self-Stabilizing Mutual Exclusion on Directed Graphs), and H. Ehrenburg.
- Computer Science Department, Carleton University, Ottawa, Canada, December 5–8, P. Vitányi (Host: Prof. E. Kranakis) (Lecture Series: An Introduction to Kolmogorov complexity and its applications).

Memberships of Committees and Other Professional Activities

P.M.B. Vitányi:
- Invited plenary lecturer *4th International Workshop on Inductive Logic Programming*, Bad Honnef, Germany, September 12–14, 1994.
- Professor of Computer Science, University of Amsterdam.
- Guest Editor, 'J. Computer and System Sciences', special issue on Computational Learning Theory, 1994—.
- Editor, 'Information Processing Letters' North-Holland/Elsevier, since 1993/94.
- Editor, 'Mathematical Systems Theory,' Springer Verlags, since 1991.
- Editor, 'Parallel Processing Letters', World Scientific Publishers, Singapore, since 1991.
- Editor, 'Journal of New Generation Computer Systems', Akademie-Verlag, Berlin, since 1989.
- Editor 'Distributed Computing', Springer-Verlag, since 1987.
- Editor, 'Frontiers in Computing Systems Research', Plenum Annual Review Book Series, Plenum Press, since 1988.
- Member of the Scientific Board, 'Encyclopaedia of Mathematics', Reidel (updated and annotated translation of the Soviet 'Mathematical Encyclopaedia'.) since 1987.
- Chair Program Committee, 2nd EURO-COLT, (European Workshop on Computational Learning Theory), Barcelona, Spain, 1995.
- Program Committee, PHYSCOMP94 (IEEE Physics and Computation Conference), Dallas, Texas, 1994.
- Co-Chair Program Committee, 8th International Workshop on Distributed Algorithms, WDAG-8, Terschelling, The Netherlands, 1994.
- Local Arrangments Co-Chair, 9th Annual IEEE Structure in Complexity Theory Conference, Amsterdam, 1994.
- Program committtee, Conpar94 - VAPP VI (Concurrent and Parallel Computation 94 and Vector and Parallel Processors in Computer Science VI), Linz, Germany, September 6–8 1994.
- Program Committee, 7th European Conference on Machine Learning, Sicily, 1994.
- Project leader NFI project ALADDIN: Algorithmic Aspects of Parallel and Distributed Computing, 1992–1997.
- Amsterdam Site Manager of ESPRIT BRA III NeuroCOLT Working Group 8556: Neural and Computational Learning, 1994–1997.
- Steering Committee, International Workshop on Distributed Algorithms (WDAG), since 1990.
- Steering Committee, Annual European Conference on Computational Learning Theory (Euro-COLT).
- Member IFIP SIWG 14.2 on Descriptive Complexity and Applications, since 1991; co-chair of IFIP SIWG 14.4 on Computational Machine Learning.
- Publiciteits commissie van het Wiskundig Genootschap (Publicity Committee Dutch Mathematical Society), since 1989.
- Member Ph.D. committee P. van Haaften (UU).
- Committee of the Society for Theoretical Computer Science in The Netherlands (Werkgemeenschap Theoretische Informatica), member.
- Institute for Logic, Language, and Computation (ILLC) (member).
- Project leader various SION projects in Machine Learning and Multiple Computing Agents.

J.-H. Hoepman:
- Organizer ALADDIN Colloquium Series
- Organizer bi-weekly ALADDIN and CAG Seminars.

J. Tromp:

- In 1994 and 1995 postdoc at the Computer Science Dept., University of Waterloo, Waterloo, Ontario, Canada. Supported by a Canada International Fellowship of NSERC—Natural Sciences and Engineering Research Council of Canada.

Visitors

- J. Anderson (USA)
- A. Bar-Noy (USA)
- C. Crépeau (France)
- D. Dubhashi (Germany)
- J. Garay (USA)
- S. Haldar (India)
- M. Herlihy (USA)
- A. Israeli (Israel)
- S. Kutten (USA)
- M. Moir (USA)
- P. Orponen (Finland)
- A. Panconesi (Italy)
- P.M. Papatriantafilou (Greece)
- M. Ruszinkó (Hungary)
- C. Smith (USA)
- Ph. Tsigas (Greece)
- P. Wolper (Belgium)
- M. Yung (USA)

Papers in Journals and Proceedings

G. TEL, P.M.B. VITÁNYI (eds.) (1994). *Distributed Algorithms, Proc. 8th International Workshop, WDAG'94*, volume 857 of *Lecture Notes in Computer Science*. Springer-Verlag.

DICK ALSTEIN, JAAP-HENK HOEPMAN, BRYAN E. OLIVIER, PASCALE I. A. VAN DER PUT (1994). Self-stabilizing mutual exclusion on directed graphs (extended abstract). E. BACKER (ed.). *Computing Science in The Netherlands*, Utrecht, Nov. 1994. Stichting Mathematisch Centrum, Amsterdam, 42–53.

HAGERUP, TORBEN, KELLER, JÖRG (1994). Fast Parallel Permutation Algorithms. *Parallel Procesing Letters*.

KELLER, JÖRG (1994). Regular Layouts of Butterfly Network. *Integration, The VLSI Journal*, 17:3, 253–265.

KELLER, JÖRG (1994). Fast Rehashing in PRAM Emulations. *Theoretical Computer Science*.

DREFENSTEDT, REINHARD, KELLER, JÖRG, PAUL, WOLFGANG J. (1994). Applications of PRAMs in Telecommunications. *13th World Computer Congress, IFIP Congress '94*, Vol. 1, Elsevier Science Publ., 203–210.

KELLER, JÖRG, PAUL, WOLFGANG J., SCHEERER, DIETER (1994). Realization of PRAMs: Processor Design. *Proc. 8th International Workshop on Distributed Algorithms (WDAG-8)*, Lecture Notes in Computer Science, Vol. 857, 17–27.

J.-H. HOEPMAN (1994). Uniform Deterministic Self-Stabilizing Ring-Orientation on Odd-Length Ring. *Proc. 8th International Workshop on Distributed Algorithms (WDAG-8)*, Lecture Notes in Computer Science, Vol. 857, 265–279.

H. BUHRMAN, J. KADIN, T. THIERAUF (1994). On functions computable with nonadaptive queries to np. U. SCHOENING (ed.). *Proc. Structure in Complexity Theory, 9th annual conference*, IEEE computer society press, 43–52.

H. BUHRMAN, P. ORPONEN (1994). Random strings make hard instances. U. SCHOENING (ed.). *Proc. Structure in Complexity Theory, 9th annual conference*, IEEE computer society press, Amsterdam, 217–223.

H. BUHRMAN, L. TORENVLIET (1994). On the cutting edge of relativization: The resource bounded injury method. S. ABITEBOUL, E. SHAMIR (eds.). *Proc. ICALP 94, Lecture Notes in Computer Science 820*, Springer-Verlag, 263–273.

H. BUHRMAN, L. TORENVLIET (1994). On the structure of complete sets. U. SCHOENING (ed.). *Proc. Structure in Complexity Theory, 9th annual conference*, IEEE computer society press, 118–133. (Invited)

T. JIANG, J. SEIFERAS, P.M.B. VITÁNYI (1994). Two heads are better than two tapes. *Proc. 26th ACM Symp. Theory of Comput.*, 668–675.

M. LI, P.M.B. VITÁNYI (1994). Inductive reasoning. E.S. RISTAD (ed.). *Language Computations; Proc. DIMACS Workshop on Human Language, March 20-22, 1992*, volume 17 of *DIMACS Series in Discrete Mathematics and Theoretical Computer Science*, American Math. Society, 127–148.

M. LI, P.M.B. VITÁNYI (1994). Kolmogorov complexity arguments in combinatorics. *J. Comb. Theory, Ser. A*, 66(2), (Erratum, *Ibid.*, 69(1995), 183.), 226–236.

M. LI, P.M.B. VITÁNYI (1994). Statistical properties of finite sequences with high Kolmogorov complexity. *Math. Systems Theory*, 27, 365–376.

A. PANCONESI, M. PAPATRIANTAFILOU, P. TSIGAS, P. VITÁNYI (1994). Randomized wait-free distributed naming. *Proc. Fifth Annual International Symposium on Algorithms and Computation*, volume 834 of *Springer Lecture Notes in Computer Science*, 83–91.

M. PAPATRIANTAFILOU, P. TSIGAS (1994). Self-

Stabilizing Wait-Free Clock Synchronization. *4th Scandinavian Workshop on Algorithm Theory (SWAT'94)*, Lecture Notes in Computer Science Vol. 824, Springer-Verlag, 267–277.

M. PAPATRIANTAFILOU, P. TSIGAS (1994). How a Rainbow Coloring Function Can Simulate Wait-Free Handshaking. *Proceedings of the 19th International Symposium on Mathematical Foundations of Computer Science (MFCS'94)*, Lecture Notes in Computer Science Vol. 841, Springer-Verlag, 546–555.

G. TE BRAKE, J.N. KOK, P.M.B. VITÁNYI (1994). Model selection for neural networks: comparing mdl and nic. *Proc. European Symposium on Artificial Neural Networks.*

P.M.B. VITÁNYI (1994). Multiprocessor architectures and physical law. *Proc. 2nd IEEE Workshop on Physics and Computation, PhysComp'94*, 24–29.

P.M.B. VITÁNYI (1994). Randomness. A. SCHRIJVER, N. TEMME, K. APT (eds.). *From Universal Morphisms to Megabytes: a Baayen space Odyssey*, CWI, Amsterdam, 627–642.

J. TROMP (1994). On Update-Last Schemes. *Parallel Processing Letters.*

A. ISRAELI, A. SHAHAM, A. SHIRAZI (1994). Linear-time snapshot protocols for unbalanced systems. *Mathematical System Theory.*

P. GRÜNWALD (1994). Grammar Inference using the MDL Principle. *Proceedings 4th Belgian-Dutch Conference on Machine Learning (BeNeLearn).*

H.-H. EHRENBURG, H.A.N. VAN MAANEN (1994). A Finite Automaton Learning System using Genetic Programming. *Proceedings of the 4th Belgian-Dutch Conference on Machine Learning (BeNeLearn'94).*

CWI Reports

CS-R9410 H.A.N. VAN MAANEN. *Axioms for Aleph 0 categorical orderings.*

CS-R9418 TAO JIANG, J.L. SEIFERAS, P.M.B. VITÁNYI. *Two heads are better than two tapes.*

CS-R9421 M. PAPATRIANTAFILOU, P. TSIGAS. *Self-stabilizing wait-free clock synchronization.*

CS-R9422 A. PANCONESI, M. PAPATRIANTAFILOU, P. TSIGAS, P.M.B. VITÁNYI. *Randomized wait-free naming.*

CS-R9423 J.-H. HOEPMAN. *Uniform deterministic self-stabilizing ring-orientation on add-length rings.*

CS-R9437 M. PAPATRIANTAFILOU, P. TSIGAS. *How a rainbow coloring function can simulate wait-free handshaking.*

CS-R9458 H.H. EHRENBURG, H.A.N. VAN MAANEN. *A finite automaton learning system using genetic programming.*

CS-R9469 D. RIAÑO. *Knowledge abstraction using heuristic search, I: A specialization approach.*

CS-R9472 D. RIAÑO. *One incursion in the non-supervised generation of concepts.*

Other Publications

KELLER, JÖRG, WALLE, THOMAS (1994). A Note on Implementing Combining Networks, Universität des Saarlandes, FB 14 Informatik, SFB-Report, 11/1994.

HAGERUP, TORBEN, KELLER, JÖRG (1994). Fast Parallel Permutation Algorithms, Universität des Saarlandes, FB 14 Informatik, SFB-Report 2/1994.

H. BUHRMAN (1994). Using simple Algebraic properties to prove upper bounds, with an application to distributed computing. *AMCoT94*, Madras, India.

Cryptography (AA2)

Staff

- Drs. A.M. Bleeker (junior reseacher (oio), SION)
- Drs. S.A. Brands (junior reseacher (oio))
- Dr. H.M. Buhrman (postdoc, from October 1)
- Dr. D. Chaum (advisor, CAFE)
- Drs. R.J.F. Cramer (project member, CAFE)
- M.K. Franklin Ph.D. (visitor, from January 24 till June 15)
- R. Hirschfeld MSc. (project leader CAFE, resp. group leader)
- C.J.H. van der Kolk (adm. manager, CAFE)
- Prof. L.G.L.T. Meertens (project leader)
- Dr. ir. L.A.M. Schoenmakers (scientific researcher CAFE)

Scientific Report

The group has continued research in its traditional core areas of secure computation, digital signatures, and electronic communication, payment, and credentials. At the same time it has expanded its scope to include work on verification of cryptographic protocols and secure distributed computation, and is beginning to look into cryptographic issues related to complexity theory and quantum computing. The group also devotes considerable effort to the practical realization and implementation of its theoretical ideas; the ESPRIT project CAFE (Conditional Access For Europe) is designing and constructing an electronic payment system based on some of the protocols developed in the group.

Annette Bleeker completed the first year of her Ph.D. studies; her main activity was research into

formal description and verification of cryptographic protocols, and into modifications of existing approaches in this area. She has worked closely with Lambert Meertens on this topic.

Stefan Brands has continued his Ph.D. work on electronic cash protocols and has presented a number of conference papers on the topic. He has also done related work on secret-key certificates and electronic cash on the Internet, and completed some earlier work on pseudo-randomness.

Harry Buhrman has worked primarily on structural complexity theory as a member of the AA1 group, but has turned some attention to cryptographic aspects as part of the joint research project on Cryptography, Learning, and Randomness.

David Chaum has served as an advisor to the group primarily in his role as chairman of the CAFE project.

Ronald Cramer and *Berry Schoenmakers* have worked primarily on the cryptographic protocol development for the CAFE project. They have also worked together on digital signatures, proofs of knowledge and witness hiding (with Ivan Damgaard), and electronic voting (with Matthew Franklin). Schoenmakers has also extended earlier work on series parallel graphs.

Matthew Franklin worked on secure distributed computation, a general framework for balancing cooperation and mistrust among independent agents, as well as on signatures and on voting.

Rafael Hirschfeld has served as technical director of the CAFE project, coordinating the research and development of the several workpackages that make up the project. He has also continued his research on both theoretical and systems aspects of electronic money, and on complexity-theoretic aspects of cryptography.

Hans van der Kolk is responsible for the administrative coordination of the CAFE project.

Organisation of Conferences, Workshops, Courses, etc.

- The Cryptography Working Group, organized by Hirschfeld (formerly by Brands), meets bimonthly to present results in all areas of cryptography. The Working Group is national in scope and has participation from throughout The Netherlands.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- European Information Technology Conference Exhibition, Brussels, BE: Hirschfeld, van der Kolk.
- Eurocrypt '94, Perugia, IT: Bleeker, Cramer, Franklin, Hirschfeld, Schoenmakers.
- Crypto '94, Santa Barbara, CA: Cramer, Hirschfeld, Schoenmakers.
- ALCOM Complexity Theory Workshop, Barcelona, ES: Hirschfeld.
- Plastic Cards Conference, London, GB: Hirschfeld.
- First Smart Card Research and Advanced Application Conference, Lille, FR: Brands.
- Smart Card Technology Opportunities Seminar, Dublin, IE: Hirschfeld.
- CAFE General Meeting, Aarhus, DK: Chaum, Cramer, Hirschfeld, van der Kolk, Schoenmakers.
- CAFE General Meeting, Frankfurt, DE: Chaum, Hirschfeld, van der Kolk.
- CAFE General Meeting, Munich, DE: Chaum, Cramer, Hirschfeld, van der Kolk, Schoenmakers.
- CAFE Secure Protocols Workpackage Meeting, Trondheim, NO: Cramer, Schoenmakers.
- CAFE Secure Protocols Workpackage Meeting, Leuven, BE: Schoenmakers.
- CAFE Secure Protocols Workpackage Meeting, Hildesheim, DE: Schoenmakers.
- CAFE Executive Committee Meeting, Paris, FR: Chaum, Hirschfeld, van der Kolk.
- CAFE SIG meeting, London, GB: Hirschfeld.
- CAFE review, Leuven/Brussels, BE: Chaum, Hirschfeld, van der Kolk.
- CAFE mini review, Paris, FR: Chaum, Hirschfeld, van der Kolk.
- CAFE working visit to European Commission, Brussels, BE: Chaum.
- CAFE working visit to Siemens, Munich, DE: Hirschfeld.
- CAFE working visit to European Commission, Brussels, BE: Hirschfeld, van der Kolk.
- CAFE working visit to Gemplus, Paris, FR: Chaum, Hirschfeld.
- CAFE working visit to Banksys, Brussels, BE: Hirschfeld.
- CAFE working visit to European Commission, Brussels, BE: Chaum, Hirschfeld.
- CAFE working visit to Cardware, London, GB: Hirschfeld.
- CAFE working visit to United States Postal Service, Washington, US: Hirschfeld.
- CAFE working visit to GIS, Cambridge, GB: Hirschfeld.
- CAFE working visit to IBM, Zurich, CH: Hirschfeld.
- Working visit to European Commission, Brussels, BE: Hirschfeld.

Memberships of Committees and Other Professional Activities

- In 1994, CWI became a member of the National Chipcard Platform. A representative from the group will be selected to attend and provide input to the technical meetings.
- Hirschfeld is a representative to two task forces of the Special Interest Group for Multicurrency Electronic Wallets (SIGMEW). He represents CAFE, which is a liaison member. David Chaum is also convenor of one of the task forces as a representative of DigiCash, which is a full member.
- Most of the researchers in the group are members of the International Association for Cryptologic Research.

Visitors

- Gilles Brassard, Université de Montreal, CA.
- Johannes Buchmann, Universität des Saarlandes, DE.
- Claude Crepeau, Ecole Normale Supérieure, FR.
- Matthew Franklin, AT&T Bell Laboratories, US.
- Klaus Kiefer, Universität des Saarlandes, DE.

Papers in Journals and Proceedings

R. CRAMER, B. SCHOENMAKERS, I. DAMGAARD (1994). Proofs of partial knowledge and simplified design of witness hiding protocols. *Crypto '94*, Santa Barbara, Springer-Verlag LNCS, Vol. 839, 174–187.

S. BRANDS (1994). Off-line cash transfer by smart cards. *Proceedings of First Smart Card Research and Advanced Application Conference*, Lille, France, 101–117.

M. FRANKLIN, M. YUNG (1994). The blinding of weak signatures. *Proceedings of Eurocrypt '94*, Perugia, Italy.

CWI Reports

CS-R9413 R.J.F. CRAMER, I.B. DAMGAARD, L.A.M. SCHOENMAKERS. *Proofs of partial knowledge and simplified design of witness hiding protocols.*

CS-R9436 M. FRANKLIN, M. YUNG. *Privacy from partial broadcast.*

CS-R9455 S. BRANDS. *Off-line cash transfer by smart cards.*

Other Publications

R. HIRSCHFELD (1994). Addressing the problems of developing and implementing an international pre-payment system, presented at Plastic Cards Conference, London, England.

R. HIRSCHFELD (1994). A security architecture for payment systems, presented at Smart Card Technology Opportunities Seminar, Dublin, Ireland.

R. CARTER, R. HIRSCHFELD, C. STANFORD (1994). Electronic payments in ECU, presented at the 1994 European Finance Convention and ECU Week, Frankfurt, Germany.

R. CRAMER, I. DAMGAARD (1994). *Secure Signature Schemes based on Interactive Protocols,* Basic Research in Computer Science (BRICS Report Series) RS-9429, Aarhus University, Denmark.

Constructive Algorithmics (AA3)

Staff

- Prof. L.G.L.T. Meertens (group leader)
- Ir. E.D.G. Boeve (junior researcher (oio), NFI until March 16)
- K. Clenaghan, B.Sc. (visitor (UK) until July 27)
- M.P. Nijland (trainee, ACM from April 5 until October 5)
- S. Pemberton (senior researcher)
- A. Takano (visitor (Japan) until August 16)
- Ir. O.J.M. Weber (junior researcher (oio), STW)
- F.J. van Wingerde (trainee until July 15)
- J.B. Zwanenburg (trainee from April 5 until July 1)

Scientific Report

The work of the AA3 project group comprises fundamental and strategic research.

The more fundamental research concerns calculi for program construction. The group participated in the activities of the NFI-sponsored STOP project, involving close cooperation with the Universities of Utrecht, Eindhoven and Nijmegen.

The strategic research focusses on issues of interoperable systems. Here, the group participated in the NFI-sponsored project 'Systematic Design of User-Interfaces', as well as in the STW-sponsored Acela project (in cooperation with CWI department AM and Eindhoven University), which aims at the development of an interactive book on Lie Algebras. The SION-sponsored MathViews project is embedded in the Acela efforts. The Views System, a prototype application environment developed earlier by the group, was used both as a model and as a research tool. Further development of the functionality of the Views System was done in cooperation with the Software Technology Group at Utrecht University.

Eddy Boeve. The work was performed within the STW project 'Systematic Design of User-Interfaces'. In the context of the design of a generic editor based on the TAXATA user model of Views, algorithms for generalised pasting of (not necessarily textual) document elements into structured documents were designed.

Kieran Clenaghan. Visiting on sabbatical leave from the University of Glasgow, Clenaghan worked on algebra for algorithm calculation, with particular interest in path problems in graphs, and the solution of linear equations over semirings and related structures. Dynamic algebra was used to unify and simplify two different approaches. A technical report on these results will appear in 1995.

Lambert Meertens. Meertens developed a course on the use of category theory for program calculation, which was taught at Utrecht University. A relational characterisation for 'maintainers' (methods invoked to maintain a two-way constraint between linked documents when either of the documents is modified) was extended to incorporate 'normalisation requirements' (such as being sorted) imposed on the documents involved. For the Acela project Meertens inventoried, together with Cohen (TUE), the capabilities of active documents, compared to more classical static documents, and examined the additional value they can offer to the readers of a book, in particular when concerned with an advanced mathematical topic. A paper on this was accepted for publication.

Marcel Nijland. Funded by ACM, this work investigated the design of on-line electronic journals, with the aim of reducing the negative properties of reading journals online. This included designing a structure for such a journal, and implementing a pilot issue, using the SIGCHI Bulletin, Vol. 26, No. 3, July 1994 as material.

Steven Pemberton. The work, performed partly within the Acela project, focussed on architectural and user interface issues of systems for electronic publishing, in particular for interactive books, for data structuring, presentation and its abstraction from pure content issues, data delivery, including integration with the World Wide Web, and interoperability.

Akihiko Takano. An automatic program transformation for eliminating intermediate data structures from programs was investigated on the basis of calculational theory, based on the adoption of hylomorphisms as a canonical representation of programs and using their calculational properties. Earlier results were improved by the introduction of a mild generalisation of the notion of hylomorphism, together with an appeal to a 'Free Theorem' in the sense of Wadler. In cooperation with Erik Meijer (University Utrecht), these results were embedded in the category CPO/ and applied to examples in the functional programming language Gopher. A joint paper on the technique was submitted to FPCA'95.

Olaf Weber. The work, performed within the Acela project, concentrated on the study of the desirable functionality for interactive books in general, and those concerning mathematical subject matter specifically. In this initial phase of the research, the emphasis was on literature study and presentation issues.

F.J. van Wingerde. The design and implementation of an extended version of STDWIN, a portable multi-platform window-management package developed at CWI, was completed. An unusual approach was the use of ETAG to evaluate the interface of the program library (as seen from the programmer's point of view).

Jack Zwanenburg. This work initiated study on architectural solutions to the problems associated with receiving massive amounts of email: what can be done to relieve the position when users receive thousands of emails per day.

Organisation of Conferences, Workshops, Courses, etc.

- EWHCI Special Interest Group, CHI '94, Boston, April 24–28
- Electronic Publishing Workshop, 1st International World Wide Web Conference, Geneva, May 25-27
- EWHCI '94, St. Petersburg, Russia, August 2–6.
- International Workshop on WWW Design Issues, Amsterdam, November 29–December 1.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- IFIP WG 2.1 meeting, Renkum, January 10–14: L.G.L.T. Meertens (Incremental Optimum-Fit Line Breaking).
- Colloquium Computing Science Institute, Nijmegen, March 24: L.G.L.T. Meertens (Wiring).
- CHI '94, Boston, April 24–28: Steven Pemberton (EWHCI Special Interest Group).
- NLUUG Conference on Networks: Ede, May 18: Steven Pemberton.
- 1st International World Wide Web Conference, Geneva, May 25–27: Steven Pemberton (Electronic Publishing Workshop).
- LICS'94, Paris, July 3–8: A. Takano.
- Working visit to DIKU, Copenhagen Univ. (Prof. Neil Jones, Prof. Turchin, Dr. Glueck), July 13–19: A. Takano.

- CHI '95 Working visit, Denver, July 15–17: Steven Pemberton.
- SIGCHI Working visit, Orlando, July 28–31: Steven Pemberton.
- IPA Summerschool, Ameland, September 22: L.G.L.T. Meertens (Calculational Derivation of Programs).
- Working visit to ACM, New York, December 8–11: Steven Pemberton.

Memberships of Committees and Other Professional Activities

E.D.G. Boeve:
- Logistics Co-chair, EWHCI '94 Conference.
- Logistics Co-chair, EWHCI '95 Conference.
- Advisor, Ingres Users Group.

L.G.L.T. Meertens
- Member IFIP Working Group 2.1 on Algorithmic Languages and Calculi.
- Member of the NFI (National Computer Science Facility) Committee.
- Project leader in the national NFI project STOP (Specification and Transformation of Programs).
- Project leader in the national NFI project Systematic Design of User Interfaces.
- Project leader in the SION project MathViews and the STW project Acela.
- Member Program Committee ICCL'94, Toulouse, France (1994).
- Member Program Committee PROCOMET'94, San Miniato, Italy (1994).
- Member Program Committee Third International Conference on the Mathematics of Program Construction, Kloster Irsee, Germany (1995).
- Member Ph.D. committee N.W.P. van Diepen, Modular Algebraic Specifications and Transformational Program Development, October 12 (KUN).
- Member Ph.D. committee M.C. Pennings, Incremental Attribute Evaluators, November 25 (UU).

S. Pemberton:
- Editor-in-chief ACM SIGCHI Bulletin, [Volume 26, Nos 1-4, 1994].
- Logistics co-chair, EWHCI '94.
- Logistics co-chair, EWHCI '95.
- Student Volunteers Chair, CHI '95.
- Workshops and Special Interest Groups Chair, CHI '96.
- Member ACM SIGCHI Executive Committee.
- Member NNI (Dutch Standards Authority) Software Ergonomy Committee.
- Member Program Committee DAGS '95, Boston.
- Chair, W4G (European World Wide Web Working Group).
- Ph.D. Supervisor E. Boeve.

Awards

- S. Pemberton, ACM Recognition of Service Award.

Papers in Journals and Proceedings

S. PEMBERTON (1994). The People of the World Iix. *SIGCHI Bulletin,* Vol 26, No 2.

S. PEMBERTON (1994). A Word of Encouragement. *SIGCHI Bulletin,* Vol 26, No 3.

S. PEMBERTON (1994). Let Us Coniecture. *SIGCHI Bulletin,* Vol 26, No 4.

Databases (AA4)

Staff

- Prof. Dr. M.L Kersten (department head and group leader)
- Drs. J.F.P. van den Akker (junior researcher (oio))
- Dr. C.A. van den Berg (scientific researcher MADE till January 1, 1995)
- Drs. F. van Dijk (programmer, MADE)
- Dr. C.A. Galindo-Legaria (ERCIM-fellow, till March 1)
- S. Heerschap (trainee, from April 1 till August 1)
- Ir. M. Holsheimer (TEG, from January 16; project member, from January 16)
- Ing. F. Kwakkel (project member, Pythagoras)
- Ir. J. Pellenkoft (junior researcher (oio))
- Drs. C.W. Quak (project member, from June 16 till December 16)
- Dr. A.P.J.M. Siebes (project leader, MADE)
- Drs. C.J.E. Thieme (junior researcher (oio), NFI, till August 1)

Scientific Report

Object-oriented database platforms. Effective exploitation of distributed platforms for database management requires better solutions for load balancing to improve response time in a loosely coupled system; dynamic query optimization to exploit data- and processing skew, techniques for database browsing, and adaptive storage structures.

The analytical model and small-scale experimentation of *van den Berg* were condensed in his Ph.D. thesis. The architectural model and analytical results have been published in the 'Journal of Systems and Software' and a well-received book on 'Advances in Query Processing'. *Kersten* and *van den Berg* continued their work on dynamic query optimization by developing their experimentation platform, *Monet.*

Monet is a database kernel developed to experiment with implementation techniques for novel application domains on parallel and distributed processing platforms. Its salient features include: a fully decomposed storage scheme (binary model), adaptive indexing to speed-up query processing, inter-operator parallelism, implicitly by looking for facilities to delegate as much as possible or to advise the lower level OS-primitives on the intended behavior, extensibility and portability.

Heerschap was hired as a trainee to exercise the system in the context of database support for World-Wide-Web. It clearly demonstrated the effectiveness of system architecture to cope with the requirements of novel application domains. The Monet system has matured to become a full-fledged database engine, which runs under Solaris and IRIX. The architecture successfully exploits the parallel processing opportunities on our SGI multi-processor. Its performance and its functionality has proved to become an important factor in the data mining and GIS projects discussed below.

Query optimization. Galindo-Legario continued his research on query optimization of outer-join operations. A paper has been published in SIGMOD 1994. *Galindo, Pellenkoft* and *Kersten* continued their cooperation by focusing on the problem of selecting efficiently valid-query evaluation plans from a large space. Several reports have been produced and the key algorithm has been presented at the Conference on Very Large Databases. Results obtained by *Kersten* and *M. de Boer* were presented at the Int. Conference on Data Engineering.

Geographical Information Systems. Mid-1994 a national project on Geograpical Information Systems, sponsored by SION was started. It involves a cooperation between University of Twente, CWI, University of Amsterdam, and University of Eindhoven. *Kersten* and *P. Boncz (UvA)* extended the Monet database server to support the requirements posed by this new application domain. In particular, the system supports user-defined types and search accelerators. By the end of 1994 the functionality was sufficient to embark upon a quest to implement the Sequioa benchmark, a large test case for GIS.

Database design theory. The growing expressiveness of new datamodels increases the need of well-founded design tools which allow a database designer to analyse her design to assess its correctness. Currently, two topics in this area are studied: *Schema integration* and *Active databases.*

One of the critical stages in the design of a database is the integration of the different user-views into one coherent schema. In the context of the NFI ISDF project (with UT, TUE, RUL, RULimburg), this subproject studies the notion of equivalence of classes in different hierarchies. In 1994 *Siebes* and *Thieme* continued their work in this area. The main result has been the formalisation of the underlying type-theory and the extensions this offered to previous results. Moreover, *Thieme* finished his Ph.D. thesis based on this work and the graduation takes place in 1995.

An active database system is characterised by a set of active objects, i.e., event-condition-action pairs, which describe actions to be taken upon encountering an event in a particular database state. *Siebes* and *van den Akker* continued the theoretical research track that was set out by *Siebes* and *van de Voort* in previous years. The proof that almost all properties are undecidable in all but the most simple systems is the main result reached in 1993. Subsequently, the attention has been shifted to the design of an *autonomous data model.* The first results on this track will appear early 1995.

Database applications. The group balances the theoretical and architectural studies with database applications. In 1993 we started a new project on data mining.

Data mining. Databases contain much more information than that what can be found using conventional query-languages. An example of such 'hidden' information is the set of risk-profiles that can be derived from an insurance database. The discovery of such higher order information is commonly called data mining.

The emphasis in 1994 of *Holsheimer* and *Kersten* has been on the design and implementation of a data mining system called *Data Surveyor.* This tool is built on top of the Monet database server, developed by the database research group.

Data Surveyor has been used by *Holsheimer* and *Siebes* in a number of pilot studies in data mining for industrial partners. Informing industry of the wide applicability of data mining has continued to be a major concern in 1994.

In a more theoretical track, *Siebes* has started the development of a framework for data mining and studied the validity of inferences made in this framework.

Finally, collaboration with data mining research groups at the University of Helsinki (*prof. Mannila*) and GMD (*dr. Klösgen*) has been initiated.

A performance assessment toolkit. The increasing number of advanced database management systems offered on the market requires tools to quickly as-

sess their performance and to assure their quality. Performance measurement involves running a set of representative work loads, such as benchmarks, and quality assurance, which involves extensive testing. The Software Testpilot developed in the context of ESPRIT-III project Pythagoras greatly simplifies both jobs by enabling a compact specification of the workload search space, a flexible mechanism to interact with a system under study, and a fast algorithm to explore the performance bottlenecks or software instabilities.

Kwakkel and *Kersten* further developed the system according to the project workplan. Effort was spent on the documentation of the system, several benchmarks were implemented, and a demonstration video was produced. During the year, focus shifted towards detailed design and analysis of the internal algorithms.

Van den Berg and *Kwakkel* have established a cooperation with the ING-bank to apply the technology in a real-world setting and to effectuate knowledge transfer. The project has been graded as amongst the best European projects, which lead to an invitation to demonstrate the results through a CD-ROM publication of the CEC.

Organisation of Conferences, Workshops, Courses, etc.

- Pythagoras. CWI is prime contractor of the ESPRIT-III project Pythagoras. Its day-to-management is lead by M.L. Kersten. Several working meetings have been organized and substantial effort has been invested in reporting the project's progress towards the CEC.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- ERCIM workshop on Databases, Univ. Barcelona, Spain, November 1–4, van den Akker.
- Conf. Phil. Logic, Gent, Belgium, December 15, van den Akker, 'QML: A paraconsistent default logic with multiple levels'.
- HCPN conference, Munich, April 16–20, van den Berg, 'Project proposal'.
- ICL, Manchester (host. P. Broughton), July 4–7, van den Berg and Kwakkel, 'Software Testpilot and Goldrush'.
- ICLP Conference, Sancta Margaritha, Italy, June 11–16, Holsheimer 'A database interface for complex objects'.
- KDD'94 workshop, Seattle, USA, July 31–August 2, Holsheimer, 'Architectural support for Data Mining'.
- University of Helsinki, Finland, (host. prof. Manilla), November 20–December 2, Holsheimer 'Datamining algorithms'.
- ICL, Manchester, January 10–11, Kersten, 'Pythagoras project meeting'.
- 10th Int. Conf on Data Engineering and Int. Workshop on Active Database, Houston, USA, February 12–19, Kersten, 'Browsing optimization techniques'.
- Dagstuhl Seminar 'Active database systems', Univ. Saarlandes, Saarbrucken, March 20–25, Kersten, 'Active behavior in Monet'.
- EDS, Paris, June 14–16, Kersten, Kwakkel, 'Pythagoras Review Meeting', Pellenkoft 'Fast Randomized Join Order Selection-Why use Transformations'.
- IFIP 6.2 working group, Beaune, June 15–17, Kersten 'Semi-automonous performance assessment'.
- ERCIM executive meeting, GMD Bonn, September 18, Kersten.
- ERCIM executive meeting and ERCIM database workshop, Univ. di Barcelona, Spain, November 1–4, Kersten.
- RAPS workshop on HPCN, Toulouse, France, October 19–10, Kersten, 'Benchmarks for Database Systems'.
- DG 3, Brussels, December 12–13, Kersten, 'The HCPN infrastructure project'.
- Herriot-Watt Univ., April 18–19, Kersten and Kwakkel, 'Pythagoras project meeting'.
- Pythagoras project meeting, Paris, October 27–28, Kersten and Pellenkoft.
- Int. conf. on Very Large Database, Santiago del Chili, Chili, September 10–19, Galindo and Pellenkoft, 'Fast Randomized Join Order Selection-Why Use Transformations'.
- AAAAI 94 & KDD'94 Workshop, Seattle, USA, July 29–August 5, Siebes 'Homogeneous discoveries contain no supprises'.
- Eurostat, DG-3 Luxemburg, November 23–26, Siebes, 'Datamining project proposals'.
- CSN,94, Utrecht, van den Akker, Thieme and Pellenkoft.
- ERCIM workshop on Databases, Univ. Barcelona, Spain, November 1–4, Thieme, 'Schema integration based on structure and behavior'.

Memberships of Committees and Other Professional Activities

M.L. Kersten:

- Professor of Computer Science, University of Amsterdam.

- Project coordinator CEC project 7091, Pythagoras.
- Project leader SION project Starfish: SION aandachtsgebied.
- Reviewer ESPRIT main-stream project European Declarative System.
- Member CEC evaluation committee ESPRIT-III, HPCN applications.
- Member executive committee ERCIM.
- European coordinator VLDB 1996.
- Member program committee COMAD94, India.
- Member program committee CSN'94, Nederland.
- Member program committee Intl. Workshop on Optimization in Databases.
- Member program committee PARLE-94.
- Member program committee Int. Workshop Rules in Database 1995.
- Member program committee VLDB 1996.
- Tutorial coordinator EDBT 96.
- Member Beoordelingscommissie Onderzoek SION 1995–1996.
- Rijksgecommitteerde HIO 'Oost-Nederland'.
- Member Programmaraad PAO-Informatica.

A.P.J.M. Siebes:

- Projectleader NFI project ISDF.

M. Holsheimer:

- Member database club NGI.

Visitors

- Dr. C.A. Galindo-Legaria, Mexico, January 1–February 25.
- MsC. Z. Navarro-Villicaña , Mexico, January 15–February 25.
- Prof. dr. H. Manilla, Univ. of Helsinki, February 23–25.
- Dr. P. Valduriez , INRIA Rocquencourt, February 24–26.
- Prof. dr. K. Dittrich, Univ. Zurich, Suisse, August 31–Sepember 2.
- Dr. C.A. Galindo-Legaria, Sintef Norway, September 7–23.
- Prof. dr. H. Manilla, Univ. of Helsinki, November 3–4.
- Dr. W. Klösgen, GMD, November 3–4.

Papers in Journals and Proceedings

C. GALINDO, A. PELLENKOFT, M.L. KERSTEN (1994). Fast, Randomized Join-Order Selection - Why Use Transformations? *20th Int. Conf. on Very Large Databases,* 1994, Chili.

M. HOLSHEIMER, M.L. KERSTEN (1994). Architectural support Database mining. *Int. Workshop on Knowledge Discovery in Database (KDD'94),* Seattle, 217–228.

C.A. VAN DEN BERG, M.L. KERSTEN (1994). Analysis of a dynamic query optimization technique for multi-join queries. *Journal of Systems and Software,* Vol 27, Nr 3, 233–243.

C.A. VAN DEN BERG, M.L. KERSTEN (1994). An analysis of a dynamic query optimisation scheme for different data distributions. J. FREYTAG, D. MAIER, G. VOSSEN (eds.). *Advances in Query Processing,* Morgan-Kaufmann, 449–470.

M.L. KERSTEN, M. DE BOER (1994). Query Optimization Strategies for Browsing Sessions. *Proc. IEEE Int. Conf. on Data Engineering 1994,* Houston.

M. HOLSHEIMER, R.A. DE BY, H. AÏT-KACI (1994). A database interface for complex objects. *Proceedings of the 11th International Conference on Logic Programming.*

JOHAN VAN DEN AKKER, YAO HUA TAN (1994). QML: A Paraconsistent Default Logic with Multiple Levels. *Proceedings of The XI Brazilian Symposium on Artificial Intelligence,* Fortaleza, Brazil, 101–114.

J. PELLENKOFT, C.A. GALINDO-LEGARIA, M.L. KERSTEN (1994). Fast, Randomized Join-order and Join-Method Selection Combined with Transformation Based Optimization. *From Universal Morphisms to Megabytes: A Baayen Space Odyssey,* CWI, Amsterdam, 469–484.

C. THIEME, A. SIEBES (1994). An Approach to Schema Integration Based on Transformations and Behaviour. *Proceedings 6th Int. Conference, CAiSE'94,* Utrecht, The Netherlands, 297–310.

A. SIEBES (1994). Data Mining, Exploratory Data Analysis on Very Large Databases. *From Universal Morphisms to Megabytes: A Baayen Space Odyssey,* CWI, Amsterdam, 535–558.

A. SIEBES (1994). Homogeneous discoveries contain no surprises: Inferring risk-profiles from large databases. *Int. Workshop on Knowledge Discovery in Database (KDD'94),* Seattle, 97–108.

C.J.E. THIEME, A.P.J.M. SIEBES (1994). Schema integration based on structure and behavior. *ERCIM workshop on Databases,* Univ. Barcelona, Spain, November 1–4.

CWI Reports

CS-R9403 C.J.E. THIEME, A.P.J.M. SIEBES. *An approach to schema integration based on transformations and behaviour.*

CS-R9404 C. GALINDO-LEGARIA. *Outerjoins as disjunctions.*

CS-R9406 M. HOLSHEIMER, A.P.J.M. SIEBES. *Datamining - The search for knowledge in databases.*

CS-R9407 M.L. KERSTEN, C.A. VAN DEN BERG, A.P.J.M. SIEBES, C.J.E. THIEME, M.H. VAN DER VOORT. *The Goblin database programming language.*

CS-R9416 C. GALINDO-LEGARIA, J. PELLENKOFT, M.L. KERSTEN. *Fast, randomized join-order selection - Why use transformations?*

CS-R9429 M. HOLSHEIMER, M.L. KERSTEN. *Architectural support for data mining.*

CS-R9430 A.P.J.M. SIEBES. *Homogeneous discoveries contain no surprises: Inferring risk-profiles from large databases.*

CS-R9431 C.A. GALINDO-LEGARIA, J. PELLENKOFT, M.L. KERSTEN. *Uniformly-distributed random generation of join orders.*

CS-R9432 C.A. GALINDO-LEGARIA, J. PELLENKOFT, M.L. KERSTEN. *Cost distributions of search spaces in query optimization.*

CS-R9451 C.J.E. THIEME, A.P.J.M. SIEBES. *Type equivalence, subtyping, and type transformations in object-oriented databases.*

CS-R9459 J. PELLENKOFT, C.A. GALINDO-LEGARIA, M.L. KERSTEN. *The impact of catalogs and join algorithms on probabilistic query optimization.*

Other Publications

C.A. VAN DEN BERG (1994). *Dynamic Query Processing in a Parallel Object- Oriented Databse System.* Ph.D. Thesis, Twente University.

M.H. VAN DER VOORT (1994). *A Design Theory for Database Triggers.* Ph.D. Thesis, University of Amsterdam.

F. KWAKKEL (1994). *AS3AP Module for the Software Testpilot.* Pythagoras Project Deliveral Report, May.

F. KWAKKEL (1994). *Wisconsin Module for the Software Testpilot.* Pythagoras Project Deliveral Report, March.

F. KWAKKEL (1994). *DBMS Test Pilot Version 2.* Pythagoras Project Deliveral Report, May.

F. KWAKKEL, M.L. KERSTEN (1994). *Software Testpilot Demonstration Video.* Pythagoras Project Deliverable, September.

F. KWAKKEL (1994). *Architecture Documentation of the Software Testpilot Implementation.* Pythagoras Project Deliverable, November.

DEPARTMENT OF INTERACTIVE SYSTEMS

General Introduction

Staff Department of Interactive Systems, 1994

- IS1

  - A.A.M. Kuijk
  - E.H. Blake
  - I. Diaz de Etura
  - S. Haritakis
  - R. van Liere
  - P.C. Marais
  - J.D. Mulder
  - J. van de Poll
  - T. van Rij
  - J.J. van Wijk
  - C.A. Wüthrich
  - M. in 't Veld

- IS2

  - F. Arbab
  - C.L. Blom
  - F.J. Burger
  - P.A.J. Bouvry
  - M.A. Guravage
  - I. Herman
  - R.H.M.C. Kelleners
  - D. Soede
  - P. Spilling
  - R.C. Veltkamp

- IS3

  - P.J.W. ten Hagen
  - P.A. Griffin
  - M. Haindl
  - F.C. Heeman
  - I. Herman
  - J.E.A. van Hintum
  - H. Noot
  - G.J. Reynolds

- Secretary: M. Hegt

Computer Graphics and Visualization (IS1)

Staff

- A.A.M. Kuijk (group leader)
- E.H. Blake Ph.D. (visitor, from May 16 till July 6)
- I. Diaz de Etura (trainee, till November 5)
- S. Haritakis B.Sc. (trainee, from June 1 till December 1)
- R. van Liere (researcher)
- P.C. Marais (visitor, from June 20 till September 20)
- J.D. Mulder (junior researcher (oio))
- J. van de Poll (trainee, from September 1)
- T. van Rij (researcher)
- J.J. van Wijk (project leader)
- C.A. Wüthrich (ERCIM fellow, till March 1)
- M. in 't Veld (trainee, till April 1)

Scientific Report

Computer Graphics. In the aftercourse of the STW funded project CWI 79.1249 we completed a prototype Difference Engine (a fast rasterizing engine for computer graphics and image reconstruction). The board-level implementation has been done by colleagues from the electronics lab of the FWI (faculty of mathematics and computer science of the University of Amsterdam). A.A.M. Kuijk assisted them by providing facilities for testing the state of the prototype hardware. In the last quarter of the year it was found that a final version would require some lay-out adjustments. This modified version will be ready in the first half of 1995.
For a study on adaptive rendering T. van Rij implemented an environment (first parts in C++ now converted to Eiffel) to test a rule-based system (ADMIRE). This rule-based system serves to optimize the performance of interactive graphics applications by dynamically selecting rendering algorithms, data structures and level of detail on a per-object basis. I. Diaz de Etura implemented a Motif based user interface for this test environment.

Image Coding. Research on image analysis by P.C. Marais, E.H. Blake and A.A.M. Kuijk has concentrated on spline-wavelet transforms. Decoding of multi-resolution image representations based on these transforms has been analyzed — in particular the reconstruction on a Difference Engine-like architecture. Meanwhile S. Haritakis did some research on codebook vector quantization methods.

Computational Steering. The goal of the computational steering project is to study methods and techniques that will allow for interactive control of simulations: the researcher can change parameters while the simulation continuously produces results which, in turn, are visualized. In 1994 work has continued on the the design and development of a novel technique, in which a user can incrementally build an interactive graphical interface to an ongoing simulation. A complete environment has been developed which has been applied to several practical applications.

A number of research topics were addressed in 1994:

- 3D presentation.
- visualization systems design.
- generative data visualization.

A joint SION project proposal with TUD and VU on computational steering and feature recognition has been granted.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Sisal Workshop*, Amsterdam, May 25–27: E.H. Blake.
- *5th EG Scientific Visualization Workshop*, Rostock, May 30–June 1: J.J. van Wijk and J. Mulder (Spatial Audio in Graphical Applications).
- *Seminar: Principles of Library Design*, Amsterdam, June 2–3: I.Diaz de Etura, T. van Rij.
- *5th Eurographics Workshop on Rendering*, Darmstadt, June 13–15: A.A.M. Kuijk.
- *SIGGRAPH 94*, Orlando, July–August: R. van Liere.
- *9th Eurographics Workshop on Graphics Hardware*, SINTEF, Oslo, September 12–13: A.A.M. Kuijk (own work: 'Experience with a Difference Engine for Graphics' and 'Imagine — The Image Engine' for Arcobel Graphics b.v., The Netherlands).
- *Eurographics'94*, Oslo, September 12–16: J.J. van Wijk.
- *Eurographics'94*, Oslo, September 12–16: A.A.M. Kuijk.
- *ERCIM workshop*, Barcelona, October 31 – November 4: I. Diaz de Etura.
- *ICIP-94 — IEEE International Conference on Image Processing*, Austin, November 13–16: A.A.M. Kuijk (Spline Wavelet Image Synthesis on a Difference Engine).

Memberships of Committees and Other Professional Activities

A.A.M. Kuijk:
- Member Programme Committee Eurographics Workshop on Graphics Hardware
- Member VISTAN Working group

R. van Liere:
- ACM Transactions on Graphics Reviewer
- Computer Graphics Forum Reviewer
- EG 94 Conference Reviewer
- Member VISTAN Working group

J.J. van Wijk:
- Member Executive Committee Eurographics

Visitors

- E.H. Blake
- I. Diaz de Etura
- P.C. Marais
- C.A. Wüthrich

Papers in Journals and Proceedings

A.A.M. KUIJK, E.H. BLAKE, E.H. STEFFENS (1994). Experience with a Difference Engine for Graphics. *Proceeding of the 9th Eurographics Workshop on Graphics Hardware*, Eurographics Technical Report Series, editor W. Strasser, Oslo, Norway, September 12–13, 36–47.

R. VAN LIERE, J. VAN WIJK (1994). Visualization of Mulit-Dimensional Scalar Functions Using HyperSlice. *CWI Quarterly* Volume 7, Number 2, 147–158.

P.C. MARAIS, E.H. BLAKE, A.A.M. KUIJK (1994). Adaptive Spline-Wavelet Image Ecoding and Real-Time Synthesis. *Proceedings of ICIP-94 — IEEE International Conference on Image Processing*, Volume III, November 13–16, 1994, Austin Texas, 368–372.

J. MULDER (1994). Spatial Audio in Graphical Applications. M. GÖBEL, H. MÜLLER, B. URBAN (eds.). *Visualization in Scientific Computing*, Springer-Verlag Wien New York, ISBN 3-211-82633-5.

CWI Reports

CS-R9414 C.A. WÜTHRICH. *Line segment rasterization in n-dimensional space.*

CS-R9426 T. VAN RIJ. *Object space versus image space - A comparison of image synthesis algorithms.*

CS-R9427 T. VAN RIJ. *Antialiasing and shading, an implementation.*

CS-R9434 J.D. MULDER, E.H. DOOIJES. *Spatial audio in graphical applications.*

CS-R9448 J.J. VAN WIJK, R. VAN LIERE. *An environment for computational steering.*

CS-R9449 J.J. VAN WIJK, R. VAN LIERE. *Hyperslice visualization of scalar functions of many variables.*

CS-R9450 J.J. VAN WIJK, R. VAN LIERE. *Visualization of multi-dimensional scalar functions using hyperslice.*

Interaction and Parallelism (IS2)

Staff

- Dr. ir. F. Arbab (group leader)
- Drs. C.L. Blom (programmer)
- F.J. Burger (programmer)
- P.A.J. Bouvry Ph.D. (post-doc, NFI, from October 16)
- Drs. M.A. Guravage (researcher, from October 1)
- Dr. I. Herman (researcher, resp. project member MADE)
- Ir. R.H.M.C. Kelleners (junior researcher (oio), SION, from July 1)
- Drs. D. Soede (scientific researcher, till March 1)
- Ir. P. Spilling (scientific researcher, NFI, till June 16)
- Dr. R.C. Veltkamp (scientific researcher, NFI)

Scientific Report

Implementation of the Manifold language compiler, its run-time system, and support utilities continued in 1994. Some of the components of this implementation are of more general interest. We made the DTh package and the build utility available as a piece of software independent of the Manifold system.

DTh is a package that provides support for threads (preemptively scheduled light-weight processes) and monitors contained in various tasks (normal operating system level processes) running on a heterogeneous, distributed computing environment. In his Masters project, a student in a German university used the DTh package to re-implement an image encoding algorithm and obtained favourable results. Several other research groups have expressed their interest in using DTh.

We organized an international tutorial workshop with the Sisal team from the Lawrence-Livermore National Laboratory in May 1994 at CWI. Combining Sisal for fine-grain parallelism and Manifold for medium- and large-grain parallelism and distribution

seems an interesting prospect for large applications in High Performance Computing.

A SION proposal to support the work of R. Veltkamp on 'Constraint-based Graphics' in IS2 was granted in October 1994. The work on this project started in November and is complementary to the previous work on constraint systems carried out in this group.

Organisation of Conferences, Workshops, Courses, etc.

- Sisal Workshop, May 25–27 1994, Amsterdam

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- OMI Conference, Eindhoven, January 27: F. Arbab.
- 4th Eurographics Object-Oriented Graphics Workshop, Sintra, Portugal, May 9–11: R.C. Veltkamp.
- ERCIM PPN Workshop, Heraklion, June 8–10: F. Arbab.
- University of Erlangen, Germany, July 1: R.C. Veltkamp.
- SIGGRAPH, Orlando, Florida, July 25–29: R.C. Veltkamp.
- Eurographics'94, Oslo, Norway, September 12–16: R.C. Veltkamp.
- ERCIM PPN Steering Committee, Barcelona, November 2–4: F. Arbab.
- Esprit Fourth Framework Information Day, Brussels, December 12: F. Arbab.

Memberships of Committees and Other Professional Activities

F. Arbab:

- Editorial Board Member, COMPUTERS & GRAPHICS, An International Journal

R.C. Veltkamp:

- Editorial Board Member, CWI Quarterly

Visitors

- Hans Martin Werner, January 24–25.
  Kim Yates, Lawrence-Livermore National Laboratory, California, May 23–27.
- Patrick Miller, Lawrence-Livermore National Laboratory, California, May 23–27.

Papers in Journals and Proceedings

F. ARBAB AND I. HERMAN (1994). Manifold. *Future Generation Computer Systems,* vol. 10, no. 2&3, 273–277, June.

W. WESSELINK, R.C. VELTKAMP (1994). Interactive Variational Curve Design. *Proceedings Computer Science in The Netherlands '94,* ISBN 90-6196449-0, 318–331.

R.C. VELTKAMP, E. H.BLAKE (1994). Event-based.constraints: coordinate.satisfaction → object.solution. *Proceedings 4th Eurographics Workshop on Object-Oriented Graphics,* Sintra, Portugal, May 9–11, 251–262.

Other Publications (including software packages and documentation)

Software:

ARBAB. mc: the Manifold language compiler.

ARBAB. DTh: a package for building applications with distributed threads.

ARBAB. build: a utility for building distributed and parallel applications.

ARBAB. mlink: the Manifold linker.

ARBAB. decoy: a utility to produce fake Manifold modules.

ARBAB. config: a utility for run-time configuration of distributed applications.

BLOM. Manifold interface library for atomic manners and internal atomic processes.

BURGER. the Manifold run-time system modules.

VELTKAMP. 2Smurve: 2D smooth curve modeling.

VELTKAMP. 3Smurve: 3D smooth curve modeling.

VELTKAMP. Covas: constrained variational surface modeling.

Documentation:

ARBAB. DTh: a package for building applications with distributed threads.

ARBAB. build: a utility for building distributed and parallel applications.

ARBAB. mlink: the Manifold linker.

ARBAB. decoy: a utility to produce fake Manifold modules.

ARBAB. config: a utility for run-time configuration of distributed applications.

ARBAB. Manifold interface library for atomic manners and compliant atomic processes

Books:

VELTKAMP. 'Closed Object Boundaries from Scattered Points,' Lecture Notes in Computer Science 885, Springer-Verlag, 1994, ISBN 3-540-58808-6.

.BOUVRY, P. 'Placement de taches sur ordinateurs MIMD a memoire distribuée,' PhD dissertation, Institut National Polytechnique de Grenoble, October 1994.

Interaction and Multimedia (IS3)

Staff

- Drs. P.J.W. ten Hagen (head of department, group leader, project leader MADE)
- Ms. P.A. Griffin M.Sc. (project leader FERSA)
- Dr. M. Haindl (project member MADE)
- Drs. F.C. Heeman (project member MADE)
- Dr. I. Herman (senior researcher MADE)
- Drs. J.E.A. van Hintum (Ph.D. student MADE)
- Drs. H. Noot (programmer FERSA, MADE)
- G.J. Reynolds Ph.D. (project member MADE)

Scientific Report

Multimedia Fundamentals. The experience gained in the MADE project with the advanced MADE object model was used to produce a first draft for the proposed international standard for Multimedia presentation programming. IS3 (I. Herman) was the editor for the first two parts of this standard i.e. Fundamentals and Object model for PREMO. Considerable contributions were made to the third part of PREMO for Modelling and Interaction. Intensive cooperation also exists with the Multimedia Systems Services group of the IMA (Interactive Multimedia Association)- consortium. In the MADE project itself the definitive versions of the MADE object model were delivered, with full documentation.

Multimedia Systems. Full attention was paid this year to the integration of media functionality towards real Multimedia. To this end a media composition object system together with composition editor was designed and prototyped. Also generic online help functions were designed which can be added on all target platforms. (e.g. UNIX and WINDOWS NT). Finally a sophisticated facility for Interaction with composite media objects was designed and delivered.

Multimedia Applications. The performer driven lipsynch facial animation tool was implemented and delivered at the industrial partner, together with a complete usermanual.

Organisation of Conferences, Workshops, Courses, etc.

- EUROGRAPHICS 95 is organised by CWI: several preparatory meetings were set up for this purpose, in Amsterdam, Oslo and Maastricht.
- PREMO Rapporteur group meeting was held at CWI from march 7 to 11: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.
- SISAL course, May 25-27: I. Herman. F. Arbab.

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- The MADE project:
  The MADE project team members have had many working visits, both at CWI and at partners places. Especially during the integration and rescheduling phase visits were held several times a month. Meeting places were at Bull, Paris, ESI, Paris, INRIA, Sophia Antipolos, FAO, Stuttgart, EU, Brussels. In September there was a project review meeting in Oslo at NR. Eight visits were at CWI, Amsterdam. The people involved were P. ten Hagen, I. Herman, G.J. Reynolds, F. Heeman, M.M. de Ruiter, M. Haindl and C. van de Berg.
- ESPRIT preparatory meeting for the fourth framework multimedia programme, Brussels, January 12: P.J.W. ten Hagen.
- PREMO workshop at RAL, Abingdon, UK; organised by ERCIM CG Network of the EU HCM programme: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.
- EUROGRAPHICS Executives meeting and IPC meeting for EG94, Oslo Norway: P.J.W. ten Hagen, I. Herman.
- Object Oriented techniques for PREMO, workshop held at SINTRA, Portugal, May 4–6:
  by ERCIM CGN of EU HCM programma: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.
- HCM CGN Steering Committee meeting, May 8, Sintra, Portugal: P.J.W. ten Hagen.
- EUROGRAPHICS workshop on O–O techniques in Graphics, May 9–11, Sintra, Portugal: P.J.W. ten Hagen.
- EUROGRAPHICS Seminar on Multimedia, Graz, Austria, June 6–8: F.C. Heeman.
- ISO/IEC JTC1/SC24 meeting in Bordeaux, France June 13- 24: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.
- MHEG Workshop, Berlin, Germany, August 25–26: P.J.W. ten Hagen.
- ISO/IEC JTC1 Multimedia Symposium, Nice, France, September 12–13: P.J.W. ten Hagen.
- EUROGRAPHICS 94 conference Oslo, Norway, September 12–16: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.
- PREMO Rapporteur Group Meeting, Arlie, USA, October 10–15: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.

- ERCIM CGN HCM meeting on formal specifications of PREMO, Barcelona, Spain, November 2–4: P.J.W. ten Hagen, I. Herman, G.J. Reynolds.
- Review Meeting of ESPRIT project OMHEGA, Brussels, Begium, November 23–24: as external reviewer, P.J.W. ten Hagen.
- ESPRIT Information day Brussels, Belgium, December 13: P.J.W. ten Hagen, I. Herman.
- LLCC'94; Lifelike Computer Characters Conference, Sponsored by Microsoft, MIT, AT&T, Salt Lake City, Utah, USA, October: P.A. Griffin.
- FERSA was presented in October, by P.A. Griffin, at: AT&T Bell Laboratories, Visual Communications Research Dept., Holmdel N.J.;
  New York University, Interactive Telecommunications Program, Thisch School of The Arts New York, N.Y.;
  University of Pennsylvania, Computer Science Dept., Pittsburg Pennsylvania.

Memberships of Committees and Other Professional Activities

P.J.W. ten Hagen:
- Fellow of the EUROGRAPHICS
- Member of the Executive Committee of EUROGRAPHICS
- Program Committee member of EUROGRAPHICS 94 and 95
- Chairman of the Organising Committee of EUROGRAPHICS 95 in Maastricht
- Co-Chair of the ERCIM computer Graphics workshop series
- Member of the European Steering Committee for Computer Graphics
- Member of IFIP W.G. 5.2 on CAD
- Member of IFIP W.G. 5.10 on Computer Graphics
- Project leader for CWI of ESPRIT project MADE
- Project Leader of the ERCIM Computer Graphics Network of the EU HCM Program
- Chairman of ISO/IEC JTC1/SC24 WG5 on Multimedia
- Liaison for SC24 to IMA
- Liaison for SC24 to OMG
- Member of the Advisory Committee on Mathematics and Computer Science of the Dutch Aerospace Laboratory
- Member of the Advisory Committee of the 'Post Hoger Technisch Onderwijs School' in Amsterdam

Papers in Journals and Proceedings

M. HAINDL, S. SIMBEROVA, (1994). An Adaptive Image Line Reconstruction Method. *Proceedings of the 12th IAPR Int. Conf. on Pattern Recognition vol. III,* Jerusalem, IEEE Press., 153–155.

D.A. DUCE, D.J. DUKE, P.J.W. TEN HAGEN, G.J. REYNOLDS (1994). PREMO - an initial approach to a formal definition. *Computer Graphics Forum,* Vol. 13, No. 3 (Eurographics'94 Issue).

I. HERMAN, G.S. CARSON, J. DAVY, P.J.W. TEN HAGEN, D.A. DUCE, W.T. HEWITT, K. KANSY, B.J. LURVEY, R. PUK, G.J. REYNOLDS, H. STENZEL (1994). Premo: an ISO standard for a presentation environment for multimedia objects. D. FERRARI (ed.). *Proceedings of the Second ACM International Conference on Multimedia (MM'94),* San Francisco, CA.

H. STENZEL, G.S. CARSON, I. HERMAN, K. KANSY (1994). Premo — An Architecture for presentation of multimedia objects in an open environment. W. HERZNER, F. KAPPE (eds.). *Proceedings of the 1st Eurographics Symposium on Multimedia,* Graz, Springer Verlag.

F.C. HEEMAN, I. HERMAN, G.J. REYNOLDS (1994). Interaction Objects in the MADE Multimedia Environment. W. HERZNER, F. KAPPE (eds.). *Proceedings of the 1st Eurographics Symposium on Multimedia,* Graz, Springer Verlag.

J. DAVY, I. HERMAN, G.J. REYNOLDS (1994). MADE, an environment for object–oriented multimedia support. *Multimedia et Normalisation de la Télématique à la Télévision Numérique,* Colloque International, Paris.

I. HERMAN, G.J. REYNOLDS, J. DAVY (1994). MADE: A Multimedia application development environment. *Proceedings of the IEEE International Conference on Multimedia Computing and Systems (ICMCS'94),* Boston, IEEE CS Press, Los Alamitos.

I. HERMAN, G.J. REYNOLDS, J. DAVY (1994). MADE: A Multimedia application development environment. *CWI Quarterly,* Vol. 7, No. 1.

Delivered Software & Documentation

ESPRIT Project 6307 (MADE), Constraint Objects T/COO/P.1, Final release with Documentation (H. van Hintum).

ESPRIT Project 6307 (MADE), Help Object, T/HEO/P.1 and U/GHE/P.0, Final release, Documentation (M. Haindl, B. de Ruiter).

ESPRIT Project 6307 (MADE), Help Browser, U/GHE/S.1 and U/GHE/P.0, Final Specification and Intermediate release (M. Haindl, B. de Ruiter).

ESPRIT Project 6307 (MADE), mC++ Compiler, T/MOM, Final release (B. de Ruiter).

ESPRIT Project 6307 (MADE), Object Monitoring, T/OBM/P.0, Intermediate release, Documenta-

tion (M. Haindl, B. de Ruiter).

ESPRIT Project 6307 (MADE), Composition Utilities, U/CU/S.1 and U/CU/P.0, Final Specification and Intermediate software release (F. Heeman, G.J. Reynolds).

ESPRIT Project 6307 (MADE), Tcl/Tk Interface, Final Release (I. Herman).

ESPRIT Project 6307 (MADE), Input Model and Sensor specification (G.J. Reynolds and F. Heeman).

FERSA User manual, final version, by P. Griffin and H. Noot.

FERSA software toolkit, final version, by P. Griffin and H. Noot.

DEPARTMENT OF COMPUTER SYSTEMS AND TELEMATICS

General Introduction

Staff Department of Computer Systems and Telematics, 1994

- CS1

  - D.C.A. Bulterman
  - L. Hardman
  - A.J. Jansen
  - K.S. Mullender
  - G. van Rossum
  - M. Theodoridou

  Secretary: J.J. Bruné-Streefkerk

External Funding

National Projects:

- *ACUTE*, ATM pilot project under SURFnet-4 (CS1 and CS2)
- *MICE Consortium*, National Coordinator (funded via SURFnet) (CS1)

Projects funded by the Commission of the European Communities:

- Scientific Trans-European Network (STEN), funded under the RACE programme, for CS1

External Cooperation:

- Department of Computer Science, Brown University, Providence RI (USA)
- US National Institute of Standards and Technology (NIST), Gaithersburg MD (USA)
- FORTH, Greece

Multimedia Kernel Systems (CS1)

Staff

- Dr. D.C.A. Bulterman, group leader and department head
- Drs. L. Hardman, senior researcher
- A.J. Jansen, programmer
- Drs. K.S. Mullender, programmer
- Drs. G. van Rossum, senior researcher
- Drs. M. Theodoridou, visiting researcher

Scientific Report

The *Multimedia Kernel Systems* group (CS1) has as its focus the study of specifications that can be used to describe and implement distributed multimedia documents containing complex synchronization and resource constraints. To date, the group has developed a prototype authoring and playback system that is used as a testbed for the capture and implementation of document specifications. The work of the group has been published widely and presented at a series of leading conferences within the multimedia research community. During 1994, the work of the group was presented at five conferences and appeared in three journal articles/book chapters. In addition, the group participated in a number of external projects, funded by the European Commission, academic networking sources within The Netherlands and international exchange programs funded by the US Government. While the productivity of the group has exceeded its modest size, it is expected that considerable effort will be devoted in 1995 to increasing the research staff size of the group via participation in external projects.

During the first half of the year *Bulterman* continued and concluded his visit as visiting professor within the department of computer science at Brown University in Providence, RI (USA). During this time, he continued his research into distributed support for multimedia systems and he completed several articles and conferences papers. During his time in the USA, he also served as guest editor of the CWI Quarterly's special issue on Multimedia. Bulterman serves as editorial board member of the journal Multimedia Tools and Applications and as associate program committee chair of ACM Multimedia 95. He is also on the program committee of the International Conference on Multimedia Modelling.

Hardman continued her research on hypermedia modelling during 1994. She (along with other members of the project) published an article in Communications of the ACM on her work on the Amsterdam Hypermedia Model extensions to the Dexter model and she contributed to the ECHT '94 European Hypertext and the ACM Multimedia '94 conferences. She spent part of 1994 as an ERCIM visitor at GMD's IPIS laboratory in Darmstadt and also made short-term scientific visits to the United States. During 1994, she was a member of the ECHT program committee and a board member of the Werkgemeenschap Informatiewetenschap.

In addition to his activities in implementing the CMIFed authoring environment, *Van Rossum* also further refined and distributed his Python high-level programming language. Python enjoys considerable following on both sides of the Atlantic Ocean, with the majority of users coming from the United States. In the Fall of 1994, Van Rossum was invited to be a guest researcher at the US National Institute of Standards and Technology (NIST); the purpose of this trip was to explore methods for further deploying and supporting Python.

During 1994, both *Jansen* and *Mullender* provided programming support that enabled the development and the extension of the CMIFed authoring system. In addition, Mullender devoted a significant portion of his effort towards support of the CWI workstation infrastructure. Jansen, as part of his work on multimedia communication, also played a visible national role in providing expertise and advice on Internet-based video conferencing.

In October, *Theodoridou* arrived as a visiting ERCIM researcher from FORTH. She will participate in a user evaluation of the CMIFed authoring environment and will work with our group on defining functionality within the authoring environment to support multi-platform multimedia document development. She will remain with the group until May, 1995.

At the end of 1994, it was formally decided to move the research activities of the CS1 group out of the department of Computer Systems and Telematics (CST) into the department of Architecture and Algorithms (AA), effective January 1, 1995.

Organisation of Conferences, Workshops, Courses, etc.

- ECHT '94, European Conference on Hypertext, Edinburgh, UK, September; L. Hardman, member program committee and reviewer, and D.C.A. Bulterman, reviewer.
- ACM Multimedia '94, San Francisco, CA, USA, October 17–20; D.C.A. Bulterman, reviewer (Na-

mur), and prof. W. Rounds (visitor AP5).

Visits to Conferences, Workshops, Colloquia, etc., Working Visits

- *Working Visit (+ Lectures)*, Department of Computer Science, Brown University, Providence, RI (USA): D.C.A. Bulterman (January–July), L. Hardman (February), G. van Rossum (March).
- *AAAI Symposium on Intelligent Multi-Media Multi-Modal Systems*, Stanford University, March: D.C.A. Bulterman.
- *Working Visit (+ lecture)*, University of Massachusetts/Lowel, Lowel, MA (USA) April 1994.
- *Working Visit (+ 2 Lectures)*, GMD IPSI, Darmstadt, Germany, April: L. Hardman.
- *Invited Lecture*, Symposium on Multimedia and Hypermedia, Technical University, Helsinki, March: D.C.A. Bulterman.
- *National Institute of Standards and Technology (NIST)*, Gaithersburg, MD (USA), working visit, July 20: D.C.A. Bulterman.
- *ECHT '94*, European Conference on Hypertext, Edinburgh, UK, September: L. Hardman.
- *ACM Multimedia '94*, San Francisco, CA, USA, October 17–20: D.C.A. Bulterman and L. Hardman.
- *National Institute of Standards and Technology (NIST)*, Gaithersburg, MD (USA), working visit, October 30 – December 4: G. van Rossum.
- *Stinfon 94*, annual conference of the Stichting Informatiewetenschap, KU Brabant, December 16: L. Hardman and D.C.A. Bulterman.

Memberships of Committees and Other Professional Activities

Organisational Activities
- Vereniging Werkgemeenschap Informatiewetenschap: L. Hardman, lid bestuur.

Editorial Activities
- Multimedia Tools and Applications, D.C.A. Bulterman, member Editorial Board.

Visitors

- Jacqueline Hogg, Aldus Ltd., June 20–24.
- Shinji Shimojo, University of Osaka, Japan, October.
- Maria Theodoridou, FORTH (Greece), October–December.

Papers in Journals and Proceedings

L. HARDMAN, D.C.A. BULTERMAN, G. VAN ROSSUM (1994). The Amsterdam Hypermedia Model: Adding Time and Context to the Dexter Model. *Communications of the ACM 37 (2)*, February, 50–62.

D.C.A. BULTERMAN (1994). Managing the Adaptive Processing of Distributed Multimedia Information. *CWI Quarterly 7(1)*, March, 3–26.

L. HARDMAN, D.C.A. BULTERMAN (1994). Authoring Hypermedia: Problems and Prospects. *CWI Quarterly 7(1)*, March, 47–66.

D.C.A. BULTERMAN (1994). Supporting Adaptive Multimedia. *Proceedings of the AAAI Symposium on Multi-Modal Multi-Media Systems*, Stanford University, Palo Alto CA (USA) March 21–23, 108–114.

L. HARDMAN (1994). Authoring Hypermedia for Fluctuating Resource Usage. *Proceedings of the Stinfon 94 conference*, Tilburg, December.

Other Publications

D.C.A. BULTERMAN, D.T. WINTER (1994). A Distributed Approach to Retrieving JPEG Pictures in Portable Hypermedia Documents. R.I. DAMPER, W. HALL AND J.W. RICHARDS (eds.). *Multimedia Technologies and Future Applications*, Pentech Press, London, 107–117.

D.C.A. BULTERMAN (1994). CWI's Experiments with High-Speed Communication: Life Near the Fast Lane. *ERCIM News*, October.

L. HARDMAN (1994). *Experiences in Authoring Hypermedia: Creating Better Presentations* (preprint).

D.C.A. BULTERMAN, L. HARDMAN (1994). *Embedded Video and Hypermedia: Application, User and Adaptive Control* (preprint).

Systems and Network Services (CS2) and User Services (CS3)

CS2 and CS3 involve research support activities associated with the information technology infrastructure at CWI. For a summary of these efforts, please see CWI's *Annual Report 1994.*