CWI

Centrum voor Wiskunde en Informatica

OVERVIEW

RESEARCH ACTIVITIES

'95

Kruislaan 413, 1098 SJ Amsterdam
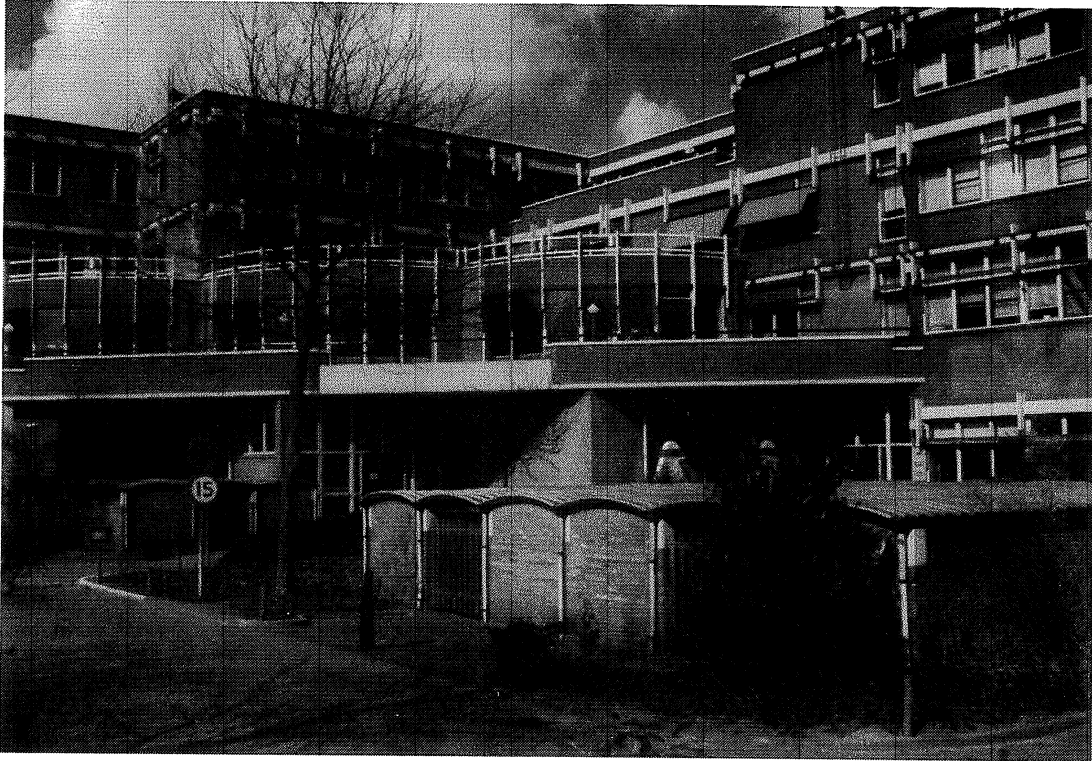P.O. Box 94079, 1090 GB Amsterdam

Photo: Sjoerd Mullender

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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PREFACE

This Overview is an extensive survey of the activities performed by the six scientific departments of CWI in 1995. It serves as a supplement to the CWI Annual Report 1995, which highlights the CWI research in 1995.

For each department the following items are addressed.

- Staff survey.
- Scientific Report.
- Organization of Conferences, Workshops, Courses, etc.

- Visits to Conferences, Workshops, Colloquia, Working Visits.
- Memberships of Committees and Other Professional Activities.
- Visitors.
- Consultancy, contract research, and relations with industry.
- Publications (papers in journals and proceedings; CWI publications; books; other publications).
- Lectures and colloquia given.
- Other relevant activities and achievements.

DEPARTMENT OF ANALYSIS, ALGEBRA AND GEOMETRY

Staff 1995

- Algebra, Combinatorics and Information Theory – AM1

  - M. Hazewinkel
  - M.C. Biemond
  - A.E. Brouwer
  - A.M. Cohen
  - S. van Dongen
  - H.J. Elbers
  - N. van den Hijligenberg
  - R.A. Hirschfeld
  - R. Hoksbergen
  - A.M.A. van Leeuwen
  - M.A.A. van Leeuwen
  - B. Lisser
  - J. de Vries
  - O.J.M. Weber

- Modelling and Analysis – AM2

  - C.J. van Duijn
  - T.W. Hantke
  - M.A. Kirkilonis
  - A.A. de Koeijer
  - Y.A. Kuznetsov
  - J. Molenaar
  - V.V. Levitin
  - B. Lisser
  - N.M. Temme
  - P.J. Oonincx
  - M. Peletier
  - J.A. Sanders
  - R. Schotting
  - R.A. Zuidwijk

- Secretary: N. Mitrovic

Main developments in the department AM in 1995

- Prof. Odo Diekmann has accepted a position as full professor at the University of Utrecht. As a result the various activities in mathematical biology and immediately related topics which took place under his supervision will gradually terminate. This affects the projects AM2.1 and AM2.2, which will end as soon as the theses and such which are involved are concluded.
- Prof. Hans van Duijn and his group joined the department in September and October of 1995 to staff project AM2.5. Prof. Van Duijn is also the new group leader of AM2.
- The proposal Wavelets (STW) has been approved and work has started in late 1995. Dr. Nico Temme is the project leader.
- Relations with CAN-RIACA. The persons involved in CAN have joined the University of Amsterdam. The institute RIACA has moved to the Technical University of Eindhoven. Cooperation with RIACA continues for the project AM2.2, in particular the development of the computer package CONTENT in the framework of DSL (Dynamical System Laboratory).
- Dr. Jan de Vries has joined the project AM1.4 (and left group AM2).

Algebra, Combinatorics and Information Theory – AM1

Staff

- Prof. dr. M. Hazewinkel
- Drs. M.C. Biemond
- Prof. dr. A.E. Brouwer
- Prof. dr. A.M. Cohen
- Ir. S. van Dongen
- Drs. H.J. Elbers
- Dr. N. van den Hijligenberg
- Prof. dr. R.A. Hirschfeld
- R. Hoksbergen
- Drs. A.M.A. van Leeuwen
- Dr. M.A.A. van Leeuwen
- Drs. B. Lisser
- Dr. J. de Vries
- Drs. O.J.M. Weber

Scientific Report

AM1.1. Hopf algebras and quantum groups

In 1995 *Nico van den Hijligenberg* worked on non-commutative geometry in collaboration with Prof. R. Martini of Twente Technological University. This resulted in a method for constructing differential calculi on quantized universal enveloping algebras which can be seen as deformations of the corresponding calculi on 'classical' universal enveloping algebras.

Astrid Scholtens (Free University of Amsterdam, thesis supervisors B. Ditters, M. Hazewinkel) put the finishing touches to her thesis. This consists of the proof that the dual of the Leibniz Hopf algebra is free polynomial and applications of this major theorem to the theory of formal groups. The actual thesis defense will be in March 1996.

Giovanna Carnovale (University of Utrecht, thesis supervisors M. Hazewinkel, Wilberd van der Kallen) investigated the algebra and Hopf algebra structure of the bialgebras which arise from multiparameter solutions of the Yang-Baxter equation. She obtained results on the structure that results when the zero divisors that can occur in these cases are divided out in suitable ways.

Michiel Hazewinkel found a new characterization of the polynomial generators of the dual of the Leibniz Hopf algebra (see above) in terms of Lyndon words.

AM1.2. Algebraic combinatorics

Marc van Leeuwen's research focussed on computational Lie theory and algebraic combinatorics. In the first area new constructions involving domino tableaux and 'pictures' in cooperation with the research groups in Paris and Marne la Vallée. In computational Lie theory algorithms from the package LIE were refined and documented using the Literate Programming Paradigm and a theoretical analysis was made of an algorithm developed by Marcel Roelofs for computing Lie algebras given by generators and relations.

AM1.3. Computer assisted mathematics and interactive books

This project consists of the much interrelated parts ACELA, MathViews, and WINST, partly joined with the department AA and AP of the CWI and the Universities of Nijmegen and Eindhoven.

André van Leeuwen and Marcel Roelofs (together with John Abbott and Andreas Strottman) worked on the OpenMath project resulting in a paper called 'Objectives of OpenMath'. Further work of André van Leeuwen concerned typing methods and systems for the computer representation of mathematical objects. A beginning has been made for an interface program between Views and the package GAP. A main part of WINST is the development of tools for making computer algebra facilities available inside proof development systems based on type theory. Several methods have been studied by Hugo Elbers to automate equational reasoning in the proof checker LEGO.

AM1.4. Chart and Web of Mathematics

This project aims (among other things, see the plan of the department AM for 1996) at the creation of tools for finding information in large databases of scientific papers. After preliminary studies, recorded in four reports of Michiel Hazewinkel (see list of publications), it has become clear that two central problems are the 'transfer problem' (transferring taxonomic information of the set of documents (for instance obtained through cocitation analysis) to the set of key terms and the problem of creating a thesaurus of standard key phrases (for mathematics). The first topic is the thesis topic of *Marc Biemond*, the second that of *Stijn van Dongen* (who joined as a Ph.D. researcher in October 1995).

On behalf of Elsevier Science Publishers an index was made of volumes 101–150 of the Journal of Theoretical Computer Science (Stijn van Dongen, Michiel Hazewinkel, and Harry Bego of TeXtract). Additional orders for similar contract research were secured late in December from Elsevier.

Thesis defenses

Master thesis: V. Kalashnikov, Crossing changes of knot diagrams and 3-topology, June 1995: supervised by M. Hazewinkel

Master thesis: Antal Jarai, Braids with intersections and R-matrices, June 1995: supervised by M. Hazewinkel.

Courses

Michiel Hazewinkel:
- Seminar Knots and braids, Master class Utrecht, January–May, 2 hours weekly. (Together with D. Siersma).
- Erasmus course, Mathematical methods of robotics. Course on Control theory; 12 hours of lectures in May, Univ. Instelling Antwerp.
- Differential geometry, 3rd year course University of Utrecht, first semester 1995/1996.

Conferences and meetings attended

Arjeh Cohen:
- May 8–12: Texel AIDA conference
- May 15–20: Sturmfels minicourse
- May 20: Baer Colloquium, Würzburg
- May 21–27: Oberwolfach, Computational Aspects of Commutative Algebra and Algebraic Geometry, organized by David Eisenbud (Waltham), Gunter Scheja (Tubingen), Frank-Olaf Schreyer (Bayreuth). Submitted title: Lie algebras (their use for commutative algebras and vice versa).
- May 28: Cocoa
- June 1: RIACA open dag
- June 5–9: Frans Oort 60 jaar
- September 1: Copenhagen OpenMath workshop
- September 5–14: 10th European Physical Society Summer School on High Performance Computing in Science, Skalsky dvur, Czech Republic
- October 6: Odense University
- 7, 8, 9 October: Copenhagen CARMA
- November 17: OU, VU, Discrete dag
- December: Santa Cruz, San Diego, Vancouver, Pasadena.

Hugo Elbers:
- Computer Science in the Netherlands, Utrecht, November 27–28.

Michiel Hazewinkel:
- AMS winter meeting, San Francisco: January 3–7.
- Working visit, Pennsylvania State Univ.: January 8–10.
- Working visit, Harvard U, MIT: January 11–13.
- KdV95, CWI and Univ. of Amsterdam, (member organizing committee): April 23–26.
- Georgian Symposium on development and conversion, Tbilisi, Georgia, (As official expert on behalf of the EEC): May 13–18.
- Working visit, Vilnius, Moscow, Kiev, 29.10–5.11.
- Working visit, LABRI, Univ de Bordeaux I: December 3–17.

Nico van den Hijligenberg:
- Algorithms in Algebra, Hotel Opduin, Texel: May 8–12.
- Workshop 'Lie groups, their representations and special functions', University Twente, Enschede: December 18–20.

Marc van Leeuwen:
- Séminaire Lotharingien / Rencontre Europees Algebraïsch Combinatoriek Netwerk, Obernai (France): 12–16 March.
- FPSAC '95, Paris (Marne la Vallée): May 29 – June 2.
- Working visit to Univ. Paris 7/Univ. Marne la Vallée, 1–14 April.
- Working visit to KTH Stockholm, 28 Nov. – 20 Dec.

Lectures and colloquia given

Arjeh Cohen:
- Februari 20: Wiskunde Colloquium Leiden, Voorstellingen van eindige groepen in algebraïsche groepen.
- March 8: Colloquium Computeralgebra in Onderwijs (S. van Gils), U Twente, slotvoordracht: Een computeralgebrapakket is nog geen eindproduct voor industrie.
- April 21: Ned. Math. Congres, Groningen, slotvoordracht: Computers: de (be)rekening gepresenteerd.
- April 26: Combin. Th. Seminar, Eindhoven: Algebraic group modules with finitely many orbits.
- May Texel, Algorithms in Algebra workshop: Algorithms for the structure determination of Lie algebras.
- May 21–27: Computational Aspects of Commutative Algebra and Algebraic Geometry, organized by David Eisenbud (Waltham), Gunter Scheja (Tubingen), Frank-Olaf Schreyer (Bayreuth), Oberwolfach: Lie algebras (their use for commutative algebras and vice versa).
- May 31: CoCoa meeting, Genua: Algorithms for the structure determination of Lie algebras.
- September 11: 10th Summer School on Computing Techniques in Physics, Skalsk y dvur, Czech Republic, September 5–14, 1995: On the structure determination of Lie algebras.

- September 27: EIDMA/Galois minicourse, Eindhoven: Grobner bases and Galois groups.
- October 4: Math. colloquium, Odense (hosted by John Perram) Computer algebra for industry.
- October 5: CARMA workshop, The technical University of Denmark, Bylund: The influence of computers on proofs.
- December 5: Math and CS Colloquium, Santa Cruz: The influence of computers on proofs.
- December 7: Vertex operator algebras seminar, Santa Cruz: Tensor categories and exceptional group representations.
- December 13: Organic Math workshop, Vancouver: The ACELA project.
- December 14: Organic Math workshop, Vancouver: Interactive proof of a finiteness theorem.
- December 15: Caltech Group Theory Seminar, Pasadena: Deligne's conjecture regarding a tensor category for the exceptional groups.

Hugo Elbers:
- 'Some basic techniques for algebraic simplification in LEGO' at the BRA-workshop 'Users and Designers of proof systems' held in INRIA, Sophia Antipolis, France, March 2–3.

Michiel Hazewinkel:
- Pennsylvania State Univ.: Colloquium lecture, Multiparameter quantum groups and multiparameter R-matrices: January 10.
- Utrecht Univ. Staff colloquium, The Wouthuysen equation: February 2.
- Univ. of Amsterdam, staff colloquium, Multiparameter quantum groups and multiparameter R-matrices: February 15.
- Nonlinear vs. linear mathematics. Opening lecture KdV course, Univ. of Amsterdam: April 19.
- Classification in mathematics, discrete metric spaces, and approximation by trees, Colloquium Lecture, Univ. of Karlsruhe, Inst. für Statistik: May 11.
- Tree — tree matrices and other combinatorial problems from taxonomy, Moscow State University: November 1.
- Multiparameter R-matrices and multiparameter quantum groups, Moscow State University: November 2.
- Tree-tree matrices and other problems from mathematical taxonomy, Colloquium LABRI, Univ. de Bordeaux I: December 15.

Nico van den Hijligenberg:
- Quantization of Lie bialgebras, Dutch national seminar on Quantum Groups titled 'A guide to Quantum Groups', University Amsterdam: February 24 and March 10.

- On the Rigidity of the Neveu-Schwarz and Ramond Lie Superalgebras, Dutch national seminar titled 'Mathematical Structures in Field Theory', University Amsterdam: March 17.
- A rigidity proof of the Virasoro algebra, AIDA workshop, Texel: May 10.
- An application of spectral sequences, Eindhoven University of Technology: November 22.
- Quantization of Differential Calculi on Universal Enveloping Algebras, workshop 'Lie groups, their representations and special functions', University Twente: December 20.

Marc van Leeuwen:
- Playing jeu de taquin with pictures. Obernai: March 14.
- Tableau algorithms and pictures, Marne la Vallée: April 13.
- On necklaces and free Lie algebras, Eindhoven: November 22.
- Strong convergence of jeu de taquin and dual equivalence, KTH Stockholm: December 6.

Organization of Conferences, Workshops, Courses, etc.

Arjeh Cohen:
- Ph.D. committees: P.J.L.M. Leyten, Complexes of local cohomology modules, 23 october (promotor J.R. Strooker) Utrecht.
- Beoordelingscommittee 6, 7 November Deelname aan de evaluatie van het CNRS programma: Medicis, Palaiseau, Frankrijk.
- Detachering Wetenschappelijke directie RIACA, Amsterdam.
- Editorship: Geometriae Dedicata.

Board Memberships:
- Chairman Board EIDMA.
- Landelijk Samenwerkingsverband Algebra en Meetkunde.
- Werkgemeenschap Discreet Nederland.
- Chairman MEGA programme committee.
- Chairman OpenMath Steering Committee.

Stijn van Dongen:
- Organization colloquium 'Language and Classification' at 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, Reidel Publ. Co., and its sub series MIA (JAPAN), MIA (USSR), MIA (Eastern Europe), 1977 ...
- Managing Editor journal: Acta Applicandae Mathematicae, Reidel Publ. Co., 1983 ...
- Co-managing Editor CWI Monographs, CWI Tracts, CWI Syllabi, North Holland Publ. Co./CWI, 1984-...
- Managing Editor translation and revision Russian Encyclopedia of Mathematics (to be published in 10 volumes), Reidel Publ. Co.
- Editor in chief journal Soviet Advances in Mathematics, Reidel Publ. Co.
- Co-managing Editor (with M. Artin, C. Procesi, M. Nagata) Handbook of Algebra (to be published in 7 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 to the former Soviet Union.
- Organizing committee KdV95.
- Member board WG, 1994–...
- Representative of WG in European Mathematical Society.
- Member Taskforce ERCIM-INTAS (now called Network Coordinating Committee).
- Chairman Scientific Steering Group ERCIM-INTAS FSU.

Marc van Leeuwen:
- Lid OR (till April '95)
- Lid commissie Alg. CWI Colloquium.
- Editor Séminaire Lotharingien de Combinatoire.

Miscellaneous

Michiel Hazewinkel refereeing and evaluation jobs:
- Villanova University, Outstanding researcher award (Woldar)
- Univ of Cyprus, Search committee (Dobroslavsky)
- NSF Applied Mathematics (Hermann)
- Univ of Notre Dame, promotion to associate professor (Rosenthal)
- Washington Univ., promotion to full professor, dep. of nuclear engineering (Ghosh)
- FFWF (Austria), research proposal (Deistler)
- Texas TEch Univ, promotion to associate professor (Wang)
- Kansas State Univ, Regents distinguished professorship (Shult)
- Georgian symposium on conversion, report on the conversion plans as expert for the Commision of the EEC (Directorates 1, 3, 12).
- NWO, visitor grant (Abdoul).
- University of Utrecht, thesis committee (Crans)
- University of Utrecht, thesis committee (Pronk)
- International Science and Technology Center, Moscow, proposals 218, 222, 333, 208, 292, 293, 368.
- Mathematische Nachrichten (Nakamura)

Michiel Hazewinkel other writings:
- WIT, Wetenschappelijke informatie technologie. Prioriteits voorstel naar NWO, 15 Febr. 1995.
- (with Jan van Eijck) Concept building from Key Phrases in Scientific Documents (Tools for information retrieval from Scientific documents). Research proposal to CWI, 21 Aug. 1995.
- Overlapping thesauri in science. (Tools for information retrieval from scientific documents). Research proposal to the 'Stichting Physica', 25 Aug. 1995.
- FIST, Finding Information In Science, research proposal to NWO/GBE, 28 Aug. 1995.
- Preface to the index of volumes 101–150 of Theoretical Computer Science, Theoretical Computer Science 150 (1995).
- (with Stijn van Dongen, Harry Bego) Index to volumes 101–150 of Theoretical Computer Science, TCS 150:2(1995).

Visitors

- Tom Banchoff, Brown University, 20 January
- Maylis Delest, Univ of Bordeaux, 14 March
- Asen Dontchev, Ann Arbor, Mich, 10.6
- Alexander Elashvili, Tbilisi, 1.6–15.6
- Jean-Marc Fedou, Univ. of Bordeaux, 14 March
- Revaz Gamkrelidze, Moscow/Karlsruhe, 19.12–20.12
- Volodya Gorunovich, Kiev, 14.8–18.8
- Henryk Gzyl, Caracas, 2.9–15.9
- V. S. Kalashnikov, 9 May
- Uno Kalujaid, Tallinn, 30.11–2.12

- Alexandras Kazbaras, Vilnius, 5.11–12.11
- Rimas Maliukevicius, Vilnius, 8.6–15.6
- Rimas Maliukevicius, Vilnius, 5.11–12.11
- Dima Malyshev, Kiev, 20–25 March
- Peter Malyshev, Kiev, 14.8–18.8
- Tadas Seibakh, Vilnius, 3.9–10.9
- Vytas Statulevicius, Vilnius, 8.6–15.6
- Vytas Statulevicius, Vilnius, 3.9–10.9

Papers in Journals and Proceedings

A. BROUWER, A. BLOKHUIS, T. SZÖNYI (1995). The number of directions determined by a function f on a finite field. *J. Comb. Th. (A)* **70**, 349–353.

A. BROUWER, J. HEMMETER, A. WOLDAR (1995). The complete list of maximal cliques of $Quad(n, q)$, q odd. *Eur. J. Combin.* **16**, 107–110.

A. BROUWER, H.A. WILBRINK (1995). Block Designs. F. BUEKENHOUT (ed.). *Handbook of Incidence Geometry*, Elsevier Amsterdam, 349–382.

A. BROUWER (1995). Toughness and spectrum of a graph. *Lin. Alg. Appl.*, 226–228 and 267–271.

A. BROUWER (1995). Variations on a theme by Weetman. *Discrete Math.* **138**, 137–145.

A. BROUWER, W.H. HAEMERS (1995). Association schemes. R. GRAHAM, M. GROETSCHEL, L. LOVÁSZ (eds.). *Handbook of Combinatorics*, 747–771.

A. BROUWER (1995). Block Designs. R. GRAHAM, M. GROETSCHEL, L. LOVÁSZ (eds.). *Handbook of Combinatorics*, 693–745.

A.M. COHEN, L. VAN GASTEL, S. VERDUYN LUNEL (1995). Computer Algebra in Industry 2, Problem Solving in Practice, Wiley, Chichester, ISBN 0-471-95529-9.

A.M. COHEN (1995). Point-line geometries associated with buildings. F. BUEKENHOUT (ed.). *Buildings and Foundations*, in Chapter 12 in the Handbook of Incidence Geometry, ISBN 0 444 88355 X, Elsevier, Amsterdam, 647–737.

A.M. COHEN, D.B. WALES (1995). Finite simple subgroups of semisimple complex Lie groups – a survey. W.M. KANTOR, L. DI MARTINO (eds.). *Groups of Lie Type and their Geometries*, LMS Lecture Notes **207**, Cambridge University Press, Cambridge, 77–96.

A.M. COHEN, D.B. WALES (1995). SL(3,3) is not a maximal subgroup of the Lie group of type. *J. Lin. Alg. and its Appl.*

A.M. COHEN, B.N. COOPERSTEIN (1995). Lie incidence systems viewed as intersections of quadrics (preprint).

A.M. COHEN, A. HOOGEWIJS, T. RECIO, L. VAN GASTEL (1995). Computer Algebra Curriculum Development in the Galois network (report).

M. HAZEWINKEL (1995). KdV95, Proc. of the conference to honour and celebrate 100 years of KdV equation. H. CAPEL, E. DE JAGER (eds). *KAP*, Amsterdam.

M. HAZEWINKEL (1995). Third Siberian school on Algebra and Analysis. L.A. BOKUT, YU.G. RESHETNYAK (eds).

M. HAZEWEINKEL (1995). Multiparameter quantum groups and multiparameter R-matrices. *Acta Appl. Math.* **41**, 57–98.

M. HAZEWINKEL (1995). TCS Subject Index Volumes 101–150. *Theoretical Computer Science* **150**, 195–313.

M. HAZEWINKEL (1995). *Linear vs. Nonlinear Mathematics with Special Emphasis on Liouville Integrable Dynamical Systems*, Text of the opening lecture of the Erasmus KdV course, Amsterdam.

N. VAN DEN HIJLIGENBERG, Y. KOTCHETKOV, G. POST (1995). Deformations of vector fields and Hamiltonian vector fields on the plane. *Math. of Comp.* **64**, 1215–1226.

N. VAN DEN HIJLIGENBERG, G.F. POST (1995). Computation by Computer of Lie Superalgebra Homology and Cohomology. *Acta Appl. Math.* **41**, 123–134.

N. VAN DEN HIJLIGENBERG, R. MARTINI (1995). Differential Hopf algebra structures on the universal enveloping algebra of a Lie algebra. *J. Math. Phys.* **36**, 3804–3814.

N. VAN DEN HIJLIGENBERG, R. MARTINI, G.F. POST (1995). Quantization of Differential Calculi on Universal Enveloping Algebras, preprint.

MARC VAN LEEUWEN (1995). The Robinson-Schensted and Schutzenberger algorithms, an elementary approach, *Electronic J. of Combinatorics*.

MARC VAN LEEUWEN (1995). Tableau algorithms defined naturally for pictures, *Discrete Math.*

CWI Reports

AM-R9501. M. HAZEWINKEL. *The Wouthuysen equation.*

AM-R9505. M. HAZEWINKEL. *Classification in mathematics, discrete metric spaces, and approximation by trees.*

AM-R9506. M. HAZEWINKEL. *Lipshits distance and hierarchical clustering.*

AM-R9507. M. HAZEWINKEL. *Tree-tree matrices and other problems from mathematical taxonomy.*

AM-R9508. M. HAZEWINKEL, V.V. KALSHNIKOV. *Counting interlacing involutions on the circle.*

AM-R9509. M. HAZEWINKEL. *Linked balanced designs are BIBD's.*

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AM-R9510. M. VAN LEEUWEN. *Literate programming in C (CWEBx manual)*.

AM-R9511. M. VAN LEEUWEN *Tableau algorithms defined naturally for pictures*.

AM-R9515. N. VAN DEN HIJLIGENBERG, R. MARTINI. *Differential Hopf algebra structures on the universal enveloping algebra of a Lie algebra*.

AM-R9518. N. VAN DEN HIJLIGENBERG, R. MARTINI. *From exponential coordinates to bicovariant differential calculi on matrix quantum groups*.

AM-R9519. N. VAN DEN HIJLIGENBERG, R. MARTINI. *A natural differential calculus on Lie bialgebras with dual of triangular type*.

Other Publications

M. HAZEWINKEL (ed.) (1995). *Handbook of Algebra* **1**, Elsevier Science Publishers.

Modelling and Analysis – AM2

Staff

- Prof. dr. ir. C.J. van Duijn
- Drs. T.W. Hantke
- Dr. M.A. Kirkilonis
- Drs. A.A. de Koeijer
- Dr. Y.A. Kuznetsov
- Dr. J. Molenaar
- Dr. V.V. Levitin
- Drs. B. Lisser
- Dr. N.M. Temme
- Ir. P.J. Oonincx
- Drs. M. Peletier
- Dr. J.A. Sanders
- R. Schotting
- Dr. R.A. Zuidwijk

Scientific Report

AM2.1. Population Dynamics and Epidemiology

Odo Diekmann, Hans Heesterbeek (GLW-DLO), Mart de Jong(ID-DLO), Mirjam Kretschmar (RIVM) and Hans Metz (RUL) gave a course on epidemic models, which was attended by 45 participants from many different fields of work. Klaus Dietz (University of Tubingen, Germany) visited CWI and gave a lecture on epidemiology and vaccination strategy in a group of households. During 5 days spread over the first half of the year the course lectures where given and exercises and computer simulations were made and discussed. During a 6th final day participants were invited to present their own work on epidemiology. Next year a book on the modelling of infectious diseases will be composed from the material provided during the course.

Preparations for a winterschool on population dynamics (to be held in Woudschoten, January 1996) were made by Odo Diekmann, Thomas Hantke and Hans Heesterbeek (GLW-DLO). The aim of the school is to give (beginning) Ph.D. students in population biology a good understanding of the way mathematics is applied to study problems in their field as well as a thorough background in relevant deterministic and stochastic mathematical techniques.

Aline de Koeijer wrote a report on modelling and analysing the 1988 seal epidemic. In collaboration with M.C.M. de Jong (ID-DLO) a model on Bovine Herpes Virus (BHV) is developed to find the (average) time untill an infected population is free from the virus. This work is still in progress. During October, November and December she attended the ecology quarter of the Special Year in Mathematical Biology at the University of Utah (USA).

Thomas Hantke extended the analysis of patch exploitation strategies of predatory mites to non-frequent invasions. He found that in such models the killer strategy is not always the best. In cooperation with Yuri A. Kuznetsov (DSL) and Victor Levitin (DSL) he used the continuation environment package CONTENT successfully to study bifurcations of predator-prey systems on patches. Together with Robert van Liere (IS) Thomas developed a toolbox for interactive invasion experiments. Biological experiments will be another application of the toolbox (joint work with Arne Janssen and Mous Sabelis, UvA, population biology).

Markus Kirkilionis continued his work on numerical continuation methods for structured population models. The theoretical work on continuation of equilibria of models with one state-at-birth is now finished and will be published soon (1996). The parallel implementation of a software package called BASE has also made much progress. Much aid came from the following collaborators: Margreet de Nool (NW) added new numerical solvers and integrated also methods implemented in FORTRAN into the package which is itself written in C. Bert Lisser was able to write a graphics interface for BASE which used techniques and software making the implementation as hardware independent as possible. We are now at a point where numerical continuation of equilibria from different example problems becomes possible. All numerical techniques are formulated inside the cumulative formulation as developed by Odo Diekmann and collaborators. Brainstorm ses-

sions on the subject continued to take place during 1995 here at the CWI. They had been attended by Ben Sommeijer (NW), Margreet Nool (NW), André de Roos (UvA-KNAW), Odo Diekmann, Bert Lisser and Thomas Hantke.

Markus Kirkilionis also organised a regular seminar on mathematical biology. Topics this year have primarily been numerical techniques for population dynamics. The seminar was attended by the members of AM2.1 and people from outside (VUA, UvA, RU Leiden).

AM2.2. Dynamical systems
Yuri Kuznetsov worked on new improved algorithms for the continuation of homoclinic bifurcations. These have been developed and implemented into HomCont v. 2.0 together with A. Champneys (Bristol,UK) and B.Sandstede (Berlin, Germany).

The first version of CONTENT, the environment for continuation and bifurcation analysis, has been finished together with Victor Levitin. It supports orbit integration, continuation of equilibria, detection and continuation of fold and Hopf bifurcations and detection of cusp, Bogdanov-Takens, and zero-Hopf bifurcations in ODEs. Interactive branch switching and hypertext graphical help system are also implemented. Experimental distribution of CONTENT has started while the work on the next version of CONTENT is in progress.

AM2.3-4. Asymptotics, Special Functions and Wavelets (N.M. Temme)
1. The book 'Special Functions: An Introduction to the Classical Functions of Mathematical Physics' is finished and will be published by Wiley early 1996.

2. With. Prof. K. Driver (South Africa) a first paper is written on non-diagonal quadratic Hermite-Padé approximations to the exponential function. Numerical investigations show the distribution of the zeros of polynomials used in the approximations. The research will be continued by using uniform asymptotic methods to obtain a precise description of the zeros distribution.

3. Research in wavelets started on the location of the zeros of the so-called Daubechies polynomials. The zeros play a role in constructing the filter coefficients of the dilation equation that defines the Daubechies orthogonal wavelets. Asymptotic methods developed earlier for the incomplete beta function can be used to obtain accurate approximations for the zeros of high degree Daubechies polynomials.

AM2.5. Nonlinear partial differential equations and applications to porous media flow
During the last part of this year the research of the porous media group focussed on the following topics:

Reactive solute transport (M. Peletier)
We continued our work on establishing the large time structure of contaminant plumes in two and three dimensional flow domains. A description was obtained in terms of self-similar variables, for which new partial differential equations were established. These equations were studied with analytical and numerical methods.

New results were obtained for models describing crystal dissolution processes in porous media. We developed a model of variational form, for which we considered travelling wave solutions. We also considered the solution of a Riemann problem (after disregarding dispersion/diffusion).

Nonlinear diffusion (C.J. van Duijn, M. Peletier)
Work continued this year on systems of diffusion equations that arise in contaminant transport in porous media. With G. Galiano at Universidad Complutense, Madrid, sufficient conditions were formulated for finite speed of propagation of the contaminant, and it was shown that the region of contamination can remain fixed for a finite time.

With D. Hilhorst from Paris-Sud the mathematical well-posedness of this problem was studied, and the convergence of general solutions to travelling wave solutions has been established. Also with D. Hilhorst and with M. Guedda from Amiens the behaviour of interfaces in salt-fresh water flow was studied in the case of varying porosity. The run-off in finite time of these interfaces has been fully characterised in terms of the porosity.

A new project has been started on the well-posedness of a system of equations that arises in the modelling of flow through a deformable porous medium. The coupling of the equations of this system has an unusual form, and there are very few theoretical results in the literature. This is done in collaboration with D. Hilhorst and M. Gutnic at Paris-Sud.

Another topic of interest is the so-called Boussinesq system, a system of equations of which one is very similar to the porous media equation. Uniqueness for this system is still an open problem, and the behaviour of solutions for large time is under investigation.

Brine transport in porous media (R. Schotting)
Two publications, dealing with similarity and Von

Mises transformation techniques, are in preparation. In collaboration with RIVM and TUD-CT we studied the consequenses of the introduction of a non-linear dispersive flux equation in models for brine transport. A joint publication is in preparation.

Stability analysis of unstable flows in porous media (C.J. van Duijn)

Embroiding on the work of an ESF postdoc we study computational aspects of a sharp interface model for density flow. We focussed on the question how to deal with heterogeneities in the permeability of the porous medium. A paper on this subject is in preparation. We also studied the stability of a diffusive zone between salt and fresh water including regional groundwater flow. Considerable effort has been put into the analysis of a model for brine transport under a salt lake. This is research in collaboration with CSIRO Australia and publications on this subject are in preparation. Another stability related subject arises in a model for the concentration of salt in an aquifer, due to the uptake of fresh water by roots of mangroves.

Multigrid simulation (J. Molenaar)

In industry the black oil model is widely used for numerical simulations. In this model it is assumed that water, oil and gas are present in the reservoir, and that gas can dissolve into the oil. We considered the possibility of applying multigrid methods for the efficient solution of the systems of equations. Good results have already been obtained for incompressible two-phase flow problems.

Polymer flooding (J. Molenaar)

Polymer flooding is an Enhanced Oil Recovery (EOR) process. Water-soluble polymer is added to the flood water to improve the mobility ratio in the flooding process. In single-phase polymer flooding experiments it is observed that polymer moves faster than water through a porous medium. This effect is incorporated in standard two-phase flow models by a constant velocity enhancement factor. We have shown that such a constant enhancement factor leads to ill-posedness of the two-phase flow equations. Moreover we proposed a saturation-dependent velocity enhancement factor, derived from percolation theory, for which this problem does not occur.

DNAPL infiltration (J. Molenaar)

Dense Non-Aqueous Liquids (DNAPL's) form a serious threat to ground water quality. DNAPL's have a density larger than that of water, therefore they tend to migrate downwards towards the bottom if aqui-

fer systems. We studied DNAPL infiltration in an aquifer with clay lenses. Due to capillary effects the DNAPL can only enter a clay lens at high enough saturations. Once it enters the clay lens it is very hard to remove. By using a vertical flow equilibrium approach we were able to derive a criterion on the maximum amount of DNAPL infiltration, such that it does not enter a clay lens.

Conferences and meetings attended

Thomas Hantke:
- Conference on dynamics of plant inhabiting mites, Gilleje, Denmark, June 24–30.
- NWO symposium on non linear systems, Amersfoort, September 15.
- Symposium Mathematical Biology, CWI, November 29.
- Course 'Infectious Diseases', CWI.
- Seminar 'Dynamics in Amsterdam', CWI/UvA.
- Seminar 'Structured Populations', CWI.

Yuri Kuznetsov:
- March 12–16: Learnshop 'Homoclinic and heteroclinic phenomena and their reduction to low-dimensional dynamics', Berlin, Germany.
- April 2–7: University of Bristol, UK, cooperation with A.R. Champneys on numerical continuation of homoclinic bifurcations.

Hans Molenaar:
- 2 November Workshop TUD Two-Phase Flow with a dynamic capillary pressure term: some numerical results.

Nico Temme:
- Exponential asymptotics, Isaac Newton Institute for Mathematical Sciences, Cambridge UK, 4 weeks in January and 1 week in June.
- ICIAM 95, Hamburg, Germany, July 3–7.
- Visit to Prof. K. Soni, University of Tennessee, Knoxville, USA, October 17–20.
- SIAM Annual Meeting, Charlotte, North Carolina, USA, October 23–26.

Courses

Yuri Kuznetsov:
- MRI Master Class course 'Dynamical Problems' at the Technical University of Twente, Enschede, September 11 – November 3.
- Third Homoclinic Workshop 'Analysis and Continuation of Homoclinic Bifurcations', CWI, June 15–16.

Ruud Schotting:
- Courses Computer Algebra (course leader and originator): Introduction to Maple (3 times) at TUD, programming in Maple at TUD.
- Course Computational Partial Differential Equations, Mathematical Institute, Leiden University.

Nico Temme:
- Contour integrals and uniform expansions, a series of 6 lectures at Isaac Newton Institute for Mathematical Sciences, Cambridge UK, January 23–27.

Lectures and colloquia given

Hans van Duijn:
- 'A free boundary problem with a cusp', Trieste, Italy: October 3.

Yuri Kuznetsov:
- 'Numerical continuation of homoclinic bifurcations of codim 1 and 2', Learnshop.
- 'Homoclinic and heteroclinic phenomena and their reduction to low-dimensional dynamics', Berlin, 13.03.95.
- 'CONTENT: The new generation continuation environment', Dynamical Systems Conference, Groningen, December 12.

Ruud Schotting:
- Visit to CSIRO Center for Environmental Mechanics, Canberra, Australia: talk given 'Non Fickian Dispersion'.
- Free Boundary Workshop, Warsaw, Poland.

Nico Temme:
- Asymptotics of Hermite-Padé polynomials associated with the exponential function, Isaac Newton Institute for Mathematical Sciences, Cambridge UK, June 21.
- Wavelets: An introduction to a new wave in mathematics and science, Knoxville TN, USA, October 18.
- Large parameter evaluation of some classical distribution functions, Charlotte NC, USA, October 25.

Rob Zuidwijk:
- Quasicomplete factorization and job scheduling, Landelijke Operatorendag in Utrecht, December 1.

Membership of Committees and Other Professional Activities

Ph.D. Committees N.M. Temme:
- J. Marée, Sudden change in second order nonlinear systems, Slow passage through bifurcation, Landbouwuniversiteit Wageningen, September 19

- P.G.A. Floris, On quantum groups, hypergroups and q-special functions, Rijksuniversiteit Leiden, December 7.

Refereeing jobs N.M. Temme:
- Mathematics of Computation (5)
- Journal of Computational and Applied Mathematics (5)
- Bulletin of the Belgian Mathematical Society: Simon Stevin
- Methods and Applications in Analysis (2)
- Acta Applicanda Mathematicae
- Journal of Mathematical Physics
- Applied Mathematics Letters
- Zeitschrift für Analysis und ihre Anwendungen
- ZAMP
- Journal of Algoritms

Advisory committees for tenure appointments N.M. Temme:
- University of Edinburgh (UK)
- University of Leeds (UK)
- University of Patras (Greece).

Nico Temme:
- Organizing committee SMC50, Jubilee congress February 1996.
- 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).

Visitors

- P.C. Abbott, Univ. of Western Australia, 15 Nov.–16 Dec.
- E. Doedel, Concordia University, Canada 11–16 June
- K.P. Hadeler, Tubingen, Duitsland, 24–25 Jan.
- Houde Han, Tsinghua University, China, 13–14 Dec.
- Willi Jaeger, Heidelberg, 20.12–21.12
- M.C. Mackey, McGill Univ. Montreal, Canada, 25–26 Jan.
- Y. Nishura, Hiroshima 18–25 June
- H.O. Walther, Giessen, Duitsland, 17–20 Jan.
- G. Wake, Massey Univ., Nieuw Zeeland, 12–14 Jan.

Papers in Journals and Proceedings

O. DIEKMANN, M. GYLLENBERG, H.R.THIEME (1995). Perturbing evolutionary systems by step responses and cumulative outputs. *Diff. Int. Equ.* **8**.

O.DIEKMANN, M.C.M. DE JONG, A.A. DE KOEIJER, P. REIJNDERS (1995). The force of infection in populations of varying size: a modelling problem. *J. Biol. Syst.* **3**.

O. DIEKMANN, S.M. MYLIUS (1995). On ESS, optimisation and the need to be specific about density dependence. *Oikos* **74**.

O. DIEKMANN, S.A. VAN GILS, S.M. VERDUYN LUNEL, H-O. WALTHER (1995). Functional-, Complex- and Nonlinear Analysis. *Applied Mathematical Sciences* **110**, Springer, New York.

O. DIEKMANN, J.A.P. HEESTERBEEK, J.A.J. METZ (1995). The legacy of Kermack and McKendrick. D. MOLLISON (ed.). *Epidemic Models: Their Structure and Relation to Data*, Publications of the Newton Institute 5, Cambridge Univ. Press.

O. DIEKMANN, M.C.M. DE JONG, J.A.P. HEESTERBEEK (1995). How does transmission of infection depend on population size?. D. MOLLISON (ed.). *Epidemic Models: Their Structure and Relation to Data*, Publications of the Newton Institute 5, Cambridge Univ. Press.

YU.A. KUZNETSOV (1995). Elements of Applied Bifurcation Theory. *Applied Mathematical Sciences* **112**, Springer-Verlag, New York, Berlin, Heidelberg.

A.R. CHAMPNEYS, YU.A. KUZNETSOV, B. SANDSTEDE (1995). A numerical toolbox for homoclinic bifurcation analysis. Applied Nonlinear Mathematics Research Report Number 1.95. University of Bristol. (to appear in *Int. J. Bifurcation & Chaos*).

YU.A. KUZNETSOV, S. MURATORI, S. RINALDI (1995). Homoclinic bifurcations in slow-fast second order systems. *Nonlinear Analysis* **25**, 747–762.

C.J. VAN DUIJN, P. DEN DECKER, R. VAN DER HOUT, L.A. PELETIER (1995). A Stefan problem in a Bridgman crystal grower. *European J. Appl. Math.* **6**, 191–199.

C.J. VAN DUIJN, M.I.J. VAN DIJKE, S.E.A.T.M. VAN DER ZEE (1995). Multi-phase flow modeling of air sparging. *Advances in Water Resources* **18**, 319–333.

C.J. VAN DUIJN, J. MOLENAAR, M.J. DE NEEF (1995). The effect of capillary forces on immiscible two-phase flow in heterogeneous porous media. *Transport in Porous Media* **21**, 71–93.

C.J. VAN DUIJN, F.J.T. FLORIS (1995). On a singular diffusion equation originating from porous media flow. *Asymptotic Analysis* **10**, 29–48.

C.J. VAN DUIJN, M.A. PELETIER (1995). Asymptotic behaviour of solutions of a nonlinear transport equation, preprint Centre for Technical Geosciences (TU Delft), pp 30, accepted for publication in Journal fur die reine und angewandte Mathematik.

C.J. VAN DUIJN, P. KNABNER, S. HENGST (1995). An analysis of crystal dissolution fronts in flows through porous media. Part I: Compatible boundary conditions. *Advances in Water Recources* **18**, 171–185.

C.J. VAN DUIJN, P.A.C. RAATS (1995). A note on horizontal redistribution with capillary hysteresis. *Water Resources Research* **31**, 231–232.

J. MOLENAAR, E.N. BIEZEN, J. BRUINING (1995). An integrated 3D model for underground coal gasifiction, SPE-30790, (presented at SPE Annual Technical Conference, Dallas, 1995).

J. MOLENAAR (1995). Adaptive multigrid applied to a bipolar transistor problem, Vol. 17, 61–83.

M. PELETIER (1994). A Supersolution of the Porous Medium Equation with Nonuniform Density. *Applied Mathematics Letters* **7**(3), 29–32.

M. PELETIER, HONGFEI ZHANG (1995). Self-similar Solutions of a Fast Diffusion Equation that do not Conserve Mass. *Differential and Integral Equations*, **8**(8), 2045–2064.

M. PELETIER, C. J. VAN DUIJN (1995). Asymptotic Behaviour of Solutions of a Nonlinear Transport Equation. to appear in *Journal für die reine und angewandte Mathematik*.

M. PELETIER, M. GUEDDA, D. HILHORST (1995). Disappearing Interfaces in Nonlinear Diffusion. to appear in *Advances in Mathematical Sciences and Applications*.

N.M. TEMME (1995). Bernoulli polynomials old and new: Generalizations and asymptotics. *CWI Quarterly* **8**, 47–66.

N.M. TEMME (1995). *Contour integrals and uniform expansions*, Lecture notes for the course Introductory lectures on Asymptotics, Exponential Asymptotics, Isaac Newton Institute, Cambridge UK, January.

N.M. TEMME, F. VITALIS, B.A. VAN TIGGELEN, A. LAGENDIJK (1995). Asymptotics of a Time Correlation Function in Multiple Recurrent Scattering of Scalar Waves. *ZAMP* **46**, 61–69.

N.M. TEMME (1995). Asymptotics of zeros of incomplete gamma functions, in Special Functions. G. ALLASIA (ed.). *Annals of Numerical Mathematics* **2**, 415–423.

CWI Reports

AM-R9502. O. DIEKMANN, A.A. DE KOEIJER, J.A.J. METZ. *On the Final Size of Epidemics within Herds.*

AM-R9503. N.M. TEMME. *Uniform Asymptotic Expansions of Integrals: A Selection of Problems,* Paper presented at the Conference in honour of Thomas Jan Stieltjes Jr. (1856–1894) October 31 – November 4, 1994, Delft University of Technology, The Netherlands.

AM-R9512. V. LEVITIN. *Computation of functions and their derivatives in CONTENT.*

AM-R9513. YU.A. KUZNETSOV, S. RINALDI. *Remarks on food chain dynamics.* (to appear in Math. Biosciences).

AM-R9514. A.A. DE KOEIJER, O. DIEKMANN, P.J.H. REIJNDERS. *A mechanistic model to describe the spread of Phocid Distemper Virus.*

AM-R9516. A.R. CHAMPNEYS, YU.A. KUZNETSOV, B. SANDSTEDE. *HomCont: An AUTO86 driver i for homoclinic bifurcation analysis. Version 2.0.*

AM-R9517. O. DIEKMANN, M.C.M. DE JONG, J.A.J. METZ. *A Deterministic Epidemic Model taking Account of Repeated Contacts between the same Individuals.*

AM-9520. O. DIEKMANN. *The Many Facets of Evolutionary Dynamics.*

AM-R9521. J. MOLENAAR. *Entropy conditions for heterogeneity induced shocks in two-phase flow problems.* (to Appear in proceedings 'International Conference on Mathematical Modeling of Flow through Porous Media).

DEPARTMENT OF OPERATIONS RESEARCH, STATISTICS, AND SYSTEM THEORY

Staff 1995

- Combinatorial Optimization and Algorithmics – BS1

  CWI funded

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

  Externally funded

  - J. Coelho de Pina
  - J.F. Geelen
  - T. Jordán
  - A. Kapoor
  - M. Laurent

- Analysis and Control of Information Flows in Networks – BS2

  - O.J. Boxma
  - J. van den Berg
  - J.W. Cohen
  - F.A. van der Duyn Schouten
  - R. Nuñez Queija

  Externally funded

  - N. Bayer
  - R.J. Boucherie
  - D.G. Down
  - A. Ermakov

  - S. Vos de Wael

- System and Control Theory – BS3

  CWI funded

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

  Externally funded

  - J.J.H. Fey
  - J. Rosenthal
  - A.A. Stoorvogel
  - P.R. de Waal
  - K.C. Wong

- Image Analysis and Spatial Stochastics – BS4

  - K.O. Dzhaparidze
  - H.J.A.M. Heijmans
  - R. Helmers
  - R. van der Horst
  - M.S. Keane
  - F.K. Potjer
  - A.G. Steenbeek
  - S.J. van Strien

  Externally funded

  - R.H.P. Janssen
  - A. Mancham
  - I.S. Molchanov

- Secretary: L.M. Schultze

Combinatorial Optimization and Algorithmics – BS1

Staff

- Prof. dr. A. Schrijver, group leader
- Dr. ir. A.M.H. Gerards, senior researcher
- Prof. dr. J.K. Lenstra, senior researcher
- A.G. Steenbeek, programmer
- Dr. J. Coelho de Pina, jr., (FAPESP)
- Drs. H. van der Holst, Ph.D. student
- Dr. J.F. Geelen, post-doctoral researcher (University of Waterloo)
- Dr. T. Jordán, post-doctoral researcher (Technical University, Budapest)
- Dr. A. Kapoor, post-doctoral researcher (Carnegie Mellon University)
- Dr. M. Laurent, visiting researcher (ENS Paris)

Scientific Report

Graphs and polyhedra.
Together with M. Conforti (Italy), A. Sebő (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.
F.B. Shepherd and A.M.H. Gerards completed a report on 't-perfect' graphs. With M. Conforti graphs with no 'odd-K_5' are investigated. As a first step a constructive characterization of a subclass has been derived. A report is under preparation. The research will be continued.

GF(4)-representable matroids.
J.F. Geelen, A.M.H. Gerards and A. Kapoor characterized the GF(4)-representable matroids in terms of forbidden minors. A report is under preparation.

Minimum-length disjoint paths.
J. Coelho de Pina finished his research on minimum-length disjoint paths, and wrote the results down in his Ph.D. Thesis, which he defended successfully in December 1995 at the University of Amsterdam.

Completion problems for matrices.
M. Laurent investigated questions related to the completion problems for positive semidefinite and Euclidean distance matrices. In particular, she obtained new necessary conditions and showed how the two problems are linked. With H-J. Bandelt (Hamburg University) and V. Chepoi (Marseille University) she studied embedding problems in the rectilinear space of given dimension. These problems have many applications in particular in statistical data analysis.

The CdV- and related invariants.
Together with L. Lovász (Yale University), H. van der Holst and A. Schrijver extended their research on the μ-invariant for graphs designed by Y. Colin de Verdière. In particular, they made progress on the conjecture of Robertson, Seymour, and Thomas on the μ-value of linklessly embedded graphs.
H. van der Holst, M. Laurent, and A. Schrijver studied a related graph invariant giving the maximum dimension of a space on the vertex set such that the positive support of any nonzero vector is connected. In this way clique sums of planar graphs are characterized. With J. Edmonds (Waterloo) an extension to oriented matroids was given.
Another invariant of Colin de Verdière, called ν, has been studied by H. van der Holst, and also a related graph invariant to this one has been considered. Extension of all these graph invariants to a larger class of objects, the rooted graphs, which contains canonically ordinary graphs, have been made.

Connectivity augmentation.
T. Jordán investigated the minimum number of arcs that should be added to a network in order to give it a connectivity of given degree. It has led to fast algorithms to make a given strongly connected directed graph 2-connected (with A. Frank) and to make a 2-connected graph 4-connected (with E. Győri), to an algorithm and characterization for successive augmentation, throughout increasing the connectivity by 1 (with E. Cheng), and to a study of the structure of crossing families (with T. Fleiner).

Bipartite edge colouring and timetabling.
A. Schrijver designed a new algorithm for finding a minimum edge colouring for bipartite graphs, with running time of order Δm, where Δ is the maximum degree and m is the number of edges. This applies to scheduling classes (the 'time-tabling problem').

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.

Moreover, with the group AP2, the problem of assigning bus platforms to autobuses in a bus station was considered, leading to an automatic system finding such an assignment.

For the Rijksuniversiteit Limburg initial investigations were done on planning the 'stages' (practical training) for 5th and 6th year medical students.

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). M. Laurent completed the first draft of the book 'Cut Polyhedra and Metrics' (with M. Deza).

Organization of Conferences, Workshops, Courses, etc.

- 'Twentieth Conference on the Mathematics of Operations Research/Sixth International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 10–12: A.M.H. Gerards, member Organizing Committee.
- 'Fifth Bellairs Workshop on Combinatorial Optimization', Holetown, St. James, Barbados, March 20–24: A.M.H. Gerards, member Organizing Committee.
- 'Twenty-First Conference on the Mathematics of Operations Research/Seventh International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 9–11, 1996: A.M.H. Gerards, member Organizing Committee.
- Fifth MPS Conference on Integer Programming and Combinatorial Optimization: J.K. Lenstra, member Program Committee.

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

- 'Twentieth Conference on the Mathematics of Operations Research/Sixth International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 10–12: A.M.H. Gerards, M. Laurent, J.K. Lenstra, A. Schrijver
- Visiting Research Scholar, Computer Science Division, University of California, Berkeley, U.S., January 17–March 11: J.K. Lenstra
- Working visit University of Padova (Italy), January 23–28: A.M.H. Gerards

- Discrete Dag, Eindhoven, January 27: H. van der Holst
- Tagung Algebraic and Geometric Combinatorics, Oberwolfach, February, 5–11: M. Laurent, A. Schrijver
- Tagung Grosse diskrete Systeme, Oberwolfach, February 26–March 4: A. Schrijver
- Working visit Computer Science Colloquium, Odense University, Denmark, March and October: T. Jordán
- 'Fifth Bellairs Workshop on Combinatorial Optimization', Holetown, St. James, Barbados, March 20–24: A.M.H. Gerards, M. Laurent, A. Schrijver
- Jubileumcongres Vereniging voor Statistiek en Operationele Research Utrecht, April 5–6: J.K. Lenstra
- Workshop on Graph Algorithms and Scheduling, Berlin, April 20–21: J.K. Lenstra
- University La Sapienza (Rome, Italy) May: M. Laurent
- Seminar on Scheduling in Computer and Manufacturing Systems Schloss Dagstuhl, May 15–19: J.K. Lenstra
- Workshop on Models and Algorithms for Planning and Scheduling Problems Wernigerode, May 22–26: J.K. Lenstra
- Workshop 'Submodular Functions', Grenoble, June 7–12: H. van der Holst
- 'First Annecy Workshop on Graph Theory', Annecy, France, June 16–23: A.M.H. Gerards
- DONET-Workshop on Combinatorial Optimization, London, June 25–30: T. Jordán, A. Schrijver
- Third Slovene International Conference in Graph Theory, Bled, Slovenia, June 25–July 1: A.M.H. Gerards, H. van der Holst
- Workshop on Combinatorial Optimization, Ankara, July 3–7: J.K. Lenstra
- 15th British Combinatorial Conference, Stirling, Scotland, July 3–7: H. van der Holst, T. Jordán
- 3rd Annual Conference on the Teaching of Computing School of Computer Applications, Dublin City University, Dublin, August 26–29: J.K. Lenstra
- 5th International Symposium on Graph Theory and Combinatorics, Marseille-Luminy, September 3–9: T. Jordán, M. Laurent, A. Schrijver
- Working visit Department of Computer Science, Yale University, New Haven, Connecticut, October: M. Laurent, A. Schrijver
- Working visit Department of Computer Science Carnegie Mellon University, Pittsburgh, October 12–13: M. Laurent, A. Schrijver
- INFORMS Meeting, New Orleans, October 29–November 1: J.K. Lenstra

- Symposium on Combinatorial Algorithms for Military Applications, Scheveningen, November 24: J.K. Lenstra

Memberships of Committees and Other Professional Activities

Ph.D. Committees
- J. Coelho de Pina (University of Amsterdam): A.M.H. Gerards, M. Laurent, J.K. Lenstra, A. Schrijver
- S.T. Fischer (University of Amsterdam): J.K. Lenstra, A. Schrijver
- K. Marcus (Université Joseph Fourier, Grenoble): M. Laurent
- J. Paulli (Aarhus Universiteit): J.K. Lenstra
- R. Peeters (KUB, Tilburg): A. Schrijver
- A. Tusera (Université Versailles - St Quentin): M. Laurent
- R.J.M. Vaessens (TU Eindhoven): J.K. Lenstra
- W.J.F. Verhaegh (TU Eindhoven): J.K. Lenstra, A. Schrijver
- M.H. van der Vlerk (Rijksuniversiteit Groningen): J.K. Lenstra
- M. Wennink (TU Eindhoven): J.K. Lenstra

Organizational Activities
- EIDMA - Euler Institute for Discrete Mathematics and Its Applications, A. Schrijver, member Bestuur
- Institute for Operations Research and the Management Sciences, J.K. Lenstra, member Council
- KNAW Akademie Raad voor de Wiskunde, J.K. Lenstra, member Bestuur
- Koninklijke Nederlandse Akademie van Wetenschappen: A. Schrijver, member Afdeling Natuurkunde
- Landelijk Netwerk Mathematische Besliskunde, A.M.H. Gerards, J.K. Lenstra, A. Schrijver, member Algemeen Bestuur
- Mathematical Programming Society, J.K. Lenstra, chairman (till August 1995), vice-chairman (from August 1995 on)
- Stichting Mathematisch Centrum, A. Schrijver, member Wetenschappelijke Raad
- Stichting Wetenschappelijk Onderzoek Verkeersveiligheid, J.K. Lenstra, member Wetenschappelijke Adviesraad
- Stieltjes Instituut voor Wiskunde, A. Schrijver, member Wetenschapscommissie
- Vereniging voor Statistiek, J.K. Lenstra, member of jury for VVS-Prize
- Visiting Committee DIKU (Informatica-Instituut van de Universiteit van Kopenhagen), J.K. Lenstra, member

- 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 Optimization, A. Schrijver, advisory 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

- Y. Colin de Verdière (Université Grenoble)
- W.J. Cook (Bell Communications Research)
- F.B. Shepherd (Centre for Discrete and Applicable Mathematics, London School of Economics, London, Unted Kingdom)
- Z. Szigeti (Mathematical Research Institute, Budapest)

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

External orders:
- Dienstregelingontwikkeling Nederlandse Spoorwegen/Railned
- Toewijzing busplatforms Nederland-Haarlem
- Stageplanning medical students Rijksuniversiteit Limburg

Graduate courses:
- Combinatorial Optimization, Combinatorial Algorithms and Graph Theory 1, EIDMA, January–March: A.M.H. Gerards, J.K. Lenstra, A. Schrijver
- ECMI Course in Combinatorial Optimization, Göteborg, June 6–9: J.K. Lenstra
- Cuts and Metrics , Department of Computer Science, Yale University, October: M. Laurent
- Disjoint Paths, Department of Computer Science, Yale University, October: A. Schrijver
- Combinatorial Optimization 1, Landelijk Netwerk Mathematische Besliskunde, November–December: A.M.H. Gerards
- Matroid Decomposition, IASI, Roma, Italy, May 8–19: A.M.H. Gerards

Papers in Journals and Proceedings

E. BALAS, J.K. LENSTRA, A. VAZACOPOULOS (1995). The one-machine problem with delayed precedence constraints and its use in job shop scheduling. *Management Science* **41**, 94–109.

C.C. DE SOUZA, M. LAURENT (1995). Some new classes of facets for the equicut polytope. *Discrete Applied Mathematics,* **62**, 167–191.

M. DEZA, V.P. GRISHUKHIN, M. LAURENT (1995). Hypermetrics in geometry of numbers. W. COOK, L. LOVÁSZ, P. SEYMOUR (eds.). *Combinatorial Optimization*, DIMACS Series in Discrete Mathematics and Theoretical Computer Science **20**, American Mathematical Society, Providence, R.I., 1–109.

A. FRANK, T. JORDÁN (1995). How to make a strongly connected digraph two-connected. E. BALAS, J. CLAUSEN (eds.). *Integer Programming and Combinatorial Optimization*, Springer Lecture Notes in Computer Science **920**, 414–425.

A.M.H. GERARDS (1995). Matching. M.O. BALL ET AL. (eds.). *Network Models*, Handbooks in Operations Research and Management Science **7**, North-Holland, Amsterdam, 135–224.

A.M.H. GERARDS (1995). On Tutte's characterization of graphic matroids—a graphic proof. *Journal of Graph Theory* **20**, 351–359.

A.M.H. GERARDS, M. LAURENT (1995). A characterization of box $\frac{1}{d}$-integral binary clutters. *Journal of Combinatorial Theory*, Series B **65**, 186–207.

M. DE GRAAF, A. SCHRIJVER (1995). Characterizing homotopy of systems of curves on a compact surface by crossing numbers. *Linear Algebra and Its Applications* **226**, 519–528.

H. VAN DER HOLST (1995). A short proof of the planarity characterization of Colin de Verdière. *Journal of Combinatorial Theory*, Series B **65**, 269–272.

H. VAN DER HOLST, M. LAURENT, A. SCHRIJVER (1995). On a minor-monotone graph invariant. *Journal of Combinatorial Theory*, Series B **65**, 291–304.

H. VAN DER HOLST, L. LOVÁSZ, A. SCHRIJVER (1995). On the invariance of Colin de Verdière's graph parameter under clique sums. *Linear Algebra and Its Applications* **226**, 509–517.

A.W.J. KOLEN, J.K. LENSTRA (1995). Combinatorics in operations research. R.L. GRAHAM, ET AL. (eds.). *Handbook of Combinatorics*, Elsevier Science, Amsterdam, 1875–1910.

M. LAURENT, S. POLJAK (1995). On a positive semidefinite relaxation of the cut polytope. *Linear Algebra and Its Applications* **223**, 439–461.

M. LAURENT, S. POLJAK (1995). One-third-integrality in the metric polytope. *Mathematical Programming* **71**, 29–50.

J.K. LENSTRA, D.B. SHMOYS (1995). Computing near-optimal schedules. P. CHRÉTIENNE, ET AL. (eds.). *Scheduling Theory and Its Applications*, Wiley, Chichester, 1–14.

A. SCHRIJVER (1995). Polyhedral combinatorics. R.L. GRAHAM ET AL. (eds.). *Handbook of Combinatorics*, Elsevier Science, Amsterdam, 1649–1704.

Books
P. CHRÉTIENNE, E.G. COFFMAN, JR., J.K. LENSTRA, Z. LIU (eds.) (1995). *Scheduling Theory and Its Applications*, Wiley, Chichester.

Analysis and Control of Information Flows in Networks – BS2

Staff .
- Prof. dr. ir. O.J. Boxma, department head and group leader
- Dr. N. Bayer, post-doc, ESPRIT; until November 1
- Dr. J. van den Berg, researcher
- Dr. R.J. Boucherie, post-doc, KNAW (0.2)
- Prof. dr. ir. J.W. Cohen, advisor

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- Dr. D.G. Down, post-doc, ERCIM; until July 1
- Prof. dr. F.A. van der Duyn Schouten, researcher (0.2 fte), KUB
- Mr. A. Ermakov, Ph.D. student (OIO), NWO
- Mr. R. Nuñez Queija, Ph.D. student (OIO)
- Mr. S. Vos de Wael, trainee (KUB); until March 15

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

Scientific Report

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

Complex variable techniques. J.W. Cohen has continued his analysis of two-dimensional random walks. In report BS-R9509 he presents the analytic solution of the asymmetrical shortest queue model with two exponential servers. He explicitly determines the generating function of the stationary joint distribution of the two queue lengths. This requires the construction of four generating functions, that are all sums of a polynomial and a meromorphic function. This representation is shown to lend itself easily to numerical computations of performance measures. Two related studies and a survey have also appeared in the period under consideration.

Negative customers and the Wiener-Hopf technique. Boucherie and Boxma have analyzed an M/G/1 queue with negative customers, in which a stochastic amount of work is removed upon the arrival of a so-called negative customer. The solution is based on the Wiener-Hopf technique. The results are also relevant for risk and inventory theory. Bayer and Boxma have also analyzed a related M/G/1 model, in which the arrival of a negative customer gives rise to the removal of *customers*; this removal can only take place at the completion of a regular service. This problem has led to the Wiener-Hopf analysis of a class of random-walks with truncation at zero and with a different step-size distribution at the boundary. In turn, this necessitated a study (by Bayer) of the identification and the properties of the Wiener-Hopf factors corresponding to a scalar generating function. Boxma and Lotov have subsequently studied a more general class of one-dimensional random walks with truncation at zero and with step-size distribution that depends on the location.

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

Cellular automata. Van den Berg and Ermakov have completed their study of a cellular automaton introduced by Coffman, Courtois, Gilbert and Piret. The problem was to show, for the infinite square grid, that each vertex changes its value only finitely many times (with probability 1). Van den Berg and Ermakov have reduced this problem to a *finite* percolation problem. In principle, the latter problem could be rigorously solved by counting all configurations on an 8 × 24 square which have certain properties, but this task is too heavy for even the most powerful computers. An interesting consequence of the above result is that, for the above cellular automaton on a *finite* part of the grid, namely, an $m \times m$ square, the expectation of the time after which no vertex changes its value any more, is at most of order $\log m$. Although the study of this particular cellular automaton has been completed, it has led to interesting, more general problems for a large class of locally mass conserving cellular automata and interacting particle systems, and, very recently, some promising progress has been made.

A symmetry problem. Besides the problems mentioned above, Ermakov has started the study of an elegant and intuitively appealing problem, posed by P.W. Kasteleyn. Consider percolation on a reflection symmetric graph. Let A and B be vertices 'on the same side of the symmetry axis', and let B' be the image of B under reflection. Is the probability of an open path from A to B always larger than or equal to that from A to B'? If this is true, some other long-standing open problem will be solved. Even if the problem can not be solved completely, it will probably lead to other, more general, useful inequalities.

Point processes. Van den Berg has completed his study on the J-function of Van Lieshout and Baddeley, which led to a paper with T. Bedford (TU Delft).

Epidemics. Van den Berg has become involved in a study, initiated by R. Schinazi (Colorado Springs) and G. Grimmett (Cambridge), of certain epidemics models. One of the results is that, for a quite large class of models, if an infection disappears with probability 1, then (except in the critical case) the probability that it lasts longer than t is exponentially bounded in t. An interesting feature of the proof is that it uses the *general* BK inequality (which was proved by Reimer in 1994; see below).

Disjoint occurrences of events. Van den Berg has spent much time on a careful study of Reimer's proof of the general Van den Berg - Kesten conjecture (which says that, for product measures, the probability that two *arbitrary* events 'occur disjointly' is smaller than or equal to the product of the two indivi-

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dual probabilities). It is believed that this inequality will have important applications in a variety of fields, like reliability, percolation and interacting particle systems (see the previous subject). Therefore, the study of this inequality, and of related conjectures which are still open, is continued. A short review paper is in preparation.

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

Maintenance policies for multicomponent systems. Preventive maintenance policies for multicomponent systems have been proposed and analysed. Special attention has been given to a class of periodic policies which have strong resemblance with 'indirect grouping' policies for multi-item inventory control models. Based on this analysis a prototype decision support system has been built for the maintenance management of traffic control systems.
Two reviews have been written of the literature on mathematical models for multicomponent maintenance management systems.

Coordination of maintenance and production. In cooperation with Shell Research Laboratories KSLA, the system effectiveness (i.e. fraction of demand that is lost) of a multicomponent production line with only buffer capacity at the output-end has been studied. Special attention has been given to the development of approximations to compute system effectiveness for the case of only corrective maintenance. The complexity and the accuracy of these approximations provide insight into the question to what extent the same type of approximations can be used to propose preventive maintenance policies.

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

Polling systems. A detailed study has been made of a model with two exponential queues and a single server 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.
An analytical approach using generating functions, as well as a power series expansion, has been used to obtain the joint queue length distribution. Boxma and Down have subsequently also solved the case of *general* service time distributions. This study has led

to an interesting theoretical problem concerning the application of Rouché's theorem in queueing theory, that was solved by Cohen and Down.
A general framework has been developed 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. Among other things, this framework has been used to analyze queues with general feedback rules and different service time distributions for customers in different loops. An interpretation is possible in which customers are removed after part of their service; this might be of interest in parallel processing.

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, which he has defended in January 1995. He and Boxma have exploited (Batch) MAP for the modeling and analysis of dependence between interarrival and service times; a paper has been accepted for publication in a forthcoming book.

Distributed systems. Esprit-BRA project QMIPS (Quantitative Modeling In Parallel Systems), in which BS2 was a partner, has been succesfully completed in October. A book in the Springer Basic Research series, containing some key studies of the project, included 3 CWI contributions.
Boxma has also written an invited survey on static optimization in queueing systems, with an emphasis on optimization problems arising in 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 has been completed. He has further investigated the numerical implementation of his theoretical results concerning Branching-Queueing networks. He has also started a study of the fixed point of compound operators that emerge in the stationary analysis of such networks. Bayer and Boucherie have undertaken a study of the space of product-form space-homogeneous Markov processes, with the motivation of analyzing single-server Branching/Queueing networks through a modified product-form model. A paper is in preparation.

ABR. Nuñez Queija has started his Ph.D. research by developing and analyzing some queueing models for an important new class of ATM traffic called Available Bit Rate (ABR). A paper is in preparation.

Organization of Conferences, Workshops, Courses, etc.

- Second IMA International Conference on Mathematical Models in Industrial Maintenance (Salford Univ., UK; April 19–21). Van der Duyn Schouten was on the scientific committee of this meeting. The conference was attended by 50 researchers from 10 countries.
- EURO-summer Institute 'OR Models of Maintenance' (Chester, UK; April 22–29). Van der Duyn Schouten was also on the scientific committee of this meeting.
- NATO Advanced Study Institute on Reliability and Maintenance of Complex Systems (Antalya, Turkey; June 12–22). 16 researchers presented a broad overview of the state-of-the-art in the mathematical modelling of multicomponent maintenance management and reliability. The conference was attended by 100 people on invitation. Van der Duyn Schouten was on the scientific and organizing committee and one of the lecturers.
- One-day seminar on queueing theory (CWI, April 25; organized by Boxma).

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

- *20th Conference on the Mathematics of Operations Research*, Lunteren, January 9–12: Bayer, Van den Berg, Boucherie, Boxma, Cohen, Down
- *ATM workshop*, Antwerpen, February 17: Boxma (lecture)
- *Conference on Applied Probability and Time Series Analysis*, Athens, March 22–26: Boxma (lecture)
- Working visit to Math. Inst. of the Hungarian Ac. Sciences, March 27 – April 8: Van den Berg (lecture)
- *ESPRIT QMIPS Workshop*, Paris, April 12–13: Boxma, Down (each one lecture)
- *Netherlands Conference on Mathematics*, Groningen, April 20–21: Van den Berg, Boxma
- *CWI National Queueing Seminar*, Amsterdam, April 25: participation by all group members, lecture by Down
- *Performance '95*, Ottawa, May 17–19: Boxma (lecture)
- Working visits to IBM Thomas J. Watson Research Center, NEC Research Center, AT&T Bell Labs, May 22–24: Boxma (3 lectures)
- *Probability meeting of the Swiss mathematical society*, June 8–10: Van den Berg (lecture)

- 23rd Conference on Stochastic Processes and their Applications, Singapore, June 19–23: Ermakov (lecture)
- Workshop Probability and Physics, Renkum, August 28 – September 1: Van den Berg and Ermakov
- *ESPRIT QMIPS Workshop*, Zaragoza, October 18–20: Bayer, Boxma (each one lecture)
- *AIO workshop LNMB*, Rotterdam, October 18–20: Nuñez Queija
- *Workshop on Probabilistic Algorithms and Algorithmic Probability*, Univ. Twente, October 31 – November 1: Van den Berg, Boxma, Nuñez Queija
- *Lunteren Stochastics conference*, November 13–15: Van den Berg, Boxma, Cohen, Ermakov
- *Eindhoven University Probability Seminar*, Eindhoven, November 29: Boxma (lecture)
- Working visit KU Leuven, December 18–19: Van den Berg
- *Spatial Stochastics Seminar, CWI*, weekly: Van den Berg (lecture), Ermakov
- *Mark Kac Seminar*, monthly: Van den Berg, Ermakov
- *Dynamical Systems Seminar, CWI and UvA*: occasionally attended by Van den Berg and Ermakov
- *Stochastics Seminar UU*, occasionally attended by Van den Berg and Ermakov
- *Stochastics Seminar TUD*, occasionally attended by Van den Berg and Ermakov
- *Courses LNMB*, attended by Nuñez Queija (fall 1995)

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 Markov Processes and Related Fields; 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 23rd 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 8th Int. Conference on Modelling Techniques and Tools for Computer Performance Evaluation (Heidelberg, September 1995)
- Member of the program committee of the 9th Int. Conference on Modelling Techniques and Tools for Computer Performance Evaluation (St Malo, June 1997)
- Member of the national committee for the ITC Seminar in Teletraffic Modelling and Measurement (PTT Research, Leidschendam, November 7–9, 1995)
- Chairman of the mathematics conference 'SMC50' (Amsterdam, February 6–7, 1996)
- Ph.D. advisor of M.B. Combé (Queueing Models with Dependence Structures, Tilburg University, January 27)
- Ph.D. advisor of R.D. van der Mei (Polling Systems and the Power-Series Algorithm, Tilburg University, April 7)
- Member of the Ph.D. committee of G.J. van Houtum (TUE, February 7)
- Member of the Ph.D. committee of J.-M. Lasgouttes (Ecole Polytechnique, Paris, March 30)
- Member of the Ph.D. committee of T.D. Cong (UvA, May 29)
- 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, Leidschendam, 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'
- Scientific coordinator of the HCM-network 'Decision Support for Maintenance Management and Quality Control'.

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

Visitors

- C. Maes (Leuven), March 5–8.
- L. Wein (MIT, Boston), April 24–27.
- K. Sigman (Columbia Univ., New York), May 8–13.
- V.V. Kalashnikov (Inst. for Systems Analysis RAS, Moscow), May 9.
- D. Reimer (Rutgers Univ.), May 10–19.
- B. Toth (Budapest), May 20–June 20.
- M. Pinedo (Columbia Univ., New York), June 19.
- V.I. Lotov (Univ. Novosibirsk, Novosibirsk), June 26–July 7.
- K. Alexander (USC), August 14–27.
- A. Gandolfi (Rome), April 21, April 25, September 5–7.
- S. Zouev (INRIA Sophia-Antipolis), September 17–27 (with BS4).
- E. Bolthausen (Zuerich), October 23–25.
- M. Menshikov (Moscow), November 20–24.
- A. Dudin (Belarussian State Univ., Minsk), December 5.

Miscellaneous

- *Consultancy:*
  (i) Direct Advertising Company (Van den Berg, Boxma, Ermakov)
  (ii) Nederland-Haarlem (Van der Duyn Schouten, Vos de Wael)
- Boxma participates in the INTAS project 'Limit theorems for stochastic discrete event systems'.

Papers in Journals and Proceedings

J. VAN DEN BERG, A. GANDOLFI (1995). A triangle inequality for covariances of binary FKG random variables. *Ann. Appl. Probab.* **5**, 322–326.

S.C. BORST, O.J. BOXMA, H. LEVY (1995). The use of service limits for efficient operation of multi-station single-medium communication systems. *IEEE Trans. Networking* **3**(5), 602–612.

O.J. BOXMA (1995). Static optimization of queueing systems. R.P. AGARWAL (ed.). *Recent Trends in Optimization Theory and Applications*, World Scientific Publ., Singapore, 1–16.

O.J. BOXMA, G.M. KOOLE, I. MITRANI (1995). A two-queue polling model with a threshold service policy. P. DOWD, E. GELENBE (eds.). *Proc. MASCOTS '95*, IEEE Computer Society Press, Los Alamitos (CA), 84–89.

O.J. BOXMA, G.M. KOOLE, I. MITRANI (1995). Polling models with threshold switching. F. BACCELLI, A. JEAN-MARIE, I. MITRANI (eds.). *Quantitative Methods in Parallel Systems*, Springer, Berlin, 129–140.

J.W. COHEN (1995). 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**, 207–237.

J.W. COHEN (1995). Two-dimensional nearest-neighbour queueing models, a review and an example. F. BACCELLI, A. JEAN-MARIE, I. MITRANI (eds.). *Quantitative Models in Parallel Systems*, Springer, Berlin.

D.G. DOWN, O.J. BOXMA (1995). A polling model with threshold switching. *Proceedings NTS-12 Conference*, Otaniemi, Espoo, Finland.

F.A. VAN DER DUYN SCHOUTEN, C.S. TAPIERO (1995). Editorial to special issue 'OR models for Maintenance Management and Quality Control'. *European Journal of Operational Research* **82**, 211–213.

F.A. VAN DER DUYN SCHOUTEN, S.G. VANNESTE (1995). Maintenance optimization of a production system with buffer capacity. *European Journal of Operational Research* **82**, 323–338.

J. JANSEN, F.A. VAN DER DUYN SCHOUTEN (1995). Maintenance optimization on parallel production units. *IMA Journal of Mathematics Applied in Business and Industry* **6**, 113–134.

CWI Reports

BS-R9505. R.J. BOUCHERIE, O.J. BOXMA. *The workload in the M/G/1 queue with work removal*; accepted for publication in *Probability in the Engineering and Informational Sciences*.

BS-R9506. O.J. BOXMA. *Static optimization of queueing systems.*

BS-R9509. J.W. COHEN. *Analysis of the asymmetrical shortest two-server queueing model.*

BS-R9519. J.W. COHEN. *On the symmetrical shortest queue and the compensation approach.*

BS-R9521. O.J. BOXMA, U. YECHIALI. *An M/G/1 queue with multiple types of feedback and gated vacations*; to appear in *Applied Probability*, eds. C.C. Heyde et al., Springer L.N. in Statistics, Springer,

Berlin, 1996.

BS-R9523. J.W. COHEN, D.G. DOWN. *On the role of Rouché's theorem in queueing analysis.*

BS-R9524. N. BAYER, E.G. COFFMAN, JR., Y. KOGAN. *An asymptotic analysis of closed queueing networks with branching populations.*

BS-R9525. N. BAYER, O.J. BOXMA. *Wiener-Hopf analysis of an M/G/1 queue with negative customers and of a related class of random walks.*

BS-R9526. J. VAN DEN BERG, A. ERMAKOV. *A new lower bound for the critical probability of site percolation on the square lattice.*

BS-R9530. O.J. BOXMA, D.G. DOWN. *Dynamic server assignment in a two-queue model.*

BS-R9537. O.J. BOXMA, V.I. LOTOV. *On a class of one-dimensional random walks.*

BS-N9502. N. BAYER. *On the identification of Wiener-Hopf factors.*

Other Publications

T. BEDFORD, J. VAN DEN BERG (1995). *A Remark on Van Lieshout and Baddeley's J-function for Point Processes*, preprint.

J. VAN DEN BERG (1995). *A Constructive Mixing Condition for 2-D Spin Systems with Random Interactions*, preprint.

O.J. BOXMA (1995). *Queueing Theory*. To appear in: Images of SMC Research 1996.

M.B. COMBÉ (1995). *Queueing Models with Dependence Structures*, Ph.D. Thesis, Tilburg University.

M.B. COMBÉ, O.J. BOXMA (1995). *BMAP modelling of a correlated queue*. G. ZOBRIST, K. BAGCHI (eds.). To appear in: The State-of-the-art in Performance Modeling and Simulation, Gordon and Breach Publishers, 1996.

System and Control Theory – BS3

Staff

- Prof. dr. ir. J.H. van Schuppen (Group leader and senior researcher. Also Director of the Systems and Control Theory Network and full Professor at University of Groningen till July 1, 1995.)
- Ir. J.J.H. Fey (Master level student (TWAIO). Funded by Eindhoven University of Technology. Since December 1, 1995)
- Drs. J.M. van den Hof (Ph.D. student (OIO).)
- Ir. A.A.F. Overkamp (Ph.D. student (OIO))
- Prof. J. Rosenthal (Visitor from University of Notre Dame. July 1, 1994 till July 1, 1995. Fun-

ded in part by CWI.)
- Dr. A.J. van der Schaft (Senior researcher. Part time 0.1. CWI funded.)
- Prof .dr. J.M. Schumacher (Senior researcher. Also, part time 0.2, full Professor at Tilburg University.)
- Dr. A.A. Stoorvogel (Senior researcher. Part time 0.1. Funded by KNAW through a fellowship and in part by CWI.)
- Dr. ir. P.R. de Waal (Post-doc. Funded by NWO through a NFI project.)
- Dr. K.C. Wong (Post-doc. Funded by ERCIM fellowship. Since September 1, 1995.)

External Funding and International Cooperation

National projects:
- Project NFI 62-354 *Performance analysis and control of distributed computer systems*. Financed by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) through the Nationale Faciliteit Informatica (NFI).
- Groot Project *Mathematical modeling of open dynamical systems*. Financed by NWO/SMC. Approved in 1995.

Projects funded by the European Commission:
- *System identification*, financed at ECU 400.000 by the European Commission through the SCIENCE program. For work visits and workshops. Project expired June 30, 1995. The Commission has approved the final report and the consolidated cost statement.
- *System identification*, financed at ECU 200.000 by the European Commission through the Human Capital and Mobility program. For post-doctoral fellowships.

Scientific Report

J.H. van Schuppen and A.A. Stoorvogel. Stoorvogel and Van Schuppen investigated the relation between H-infinity optimization, optimal stochastic control with an exponential-of-quadratic criterion, and maximum likelihood identification, and completed a paper about the subject. A parameter estimator can be derived by four methods. Later in 1995 they solved an approximation problem in terms of the divergence criterion.

The joint work of Van Schuppen with G. Picci (Padova) on the finite stochastic realization problem was continued. Together with J.M. van den Hof further results were obtained for the classification of primes in the positive matrices and in the doubly stochastic

matrices.

Control algorithms of modern technological systems are implemented by computers. Control therefore has to address the interaction of discrete or logical components and of continuous components. A system theoretic model with such interaction is called a *hybrid system*. There is a need to study modeling and control of hybrid systems. This topic attracts attention of both control theorists and computer scientists. Van Schuppen investigated models of hybrid systems, in particular the hybrid automaton model, and formulated control problems.

J.H. van Schuppen, A.A.F. Overkamp, P.R. de Waal. At the request of the Nederlandse Spoorwegen N.V., the national railway company, a model and control problems were investigated for control of railway traffic. This project is continued in 1996.

J.J.H. Fey, J.H. van Schuppen, K.C. Wong. Many industrial systems have continuous-time and discrete-event behaviour. To model, control, and simulate these systems, a hybrid process-algebra called χ is under development at the University of Eindhoven. In this three months project, control and verification of hybrid systems is studied using χ. Two industrial hybrid systems, a conveyor system and a biochemical plant for the production of ethanol, are used as examples.

J.M. van den Hof. Van den Hof studied structural identifiability from input/output observations of linear compartmental systems. The manuscript was published as a CWI report and the theoretical part was submitted for publication.

The realization of positive linear systems was elaborated further. In terms of polyhedral cones, necessary and sufficient conditions for minimality were derived and a classification of minimal realizations was investigated for a special case. Also a relation between continuous and discrete time positive linear systems was indicated. Papers about the results were submitted.

Together with Van Schuppen and G. Picci two manuscripts on the classification of prime matrices were completed, in particular prime matrices in the doubly stochastic matrices. The manuscripts appeared as CWI reports and were submitted for publication.

A.A.F. Overkamp. Overkamp continued his work on the supervisory control problem for nondeterministic systems with the use of failure semantics. A synthesis method is derived for the control problem with partial specification. Results are presented at the European Control Conference and a paper is submitted to IEEE Transactions on Automatic Control. Overkamp and Van Schuppen also worked on the

decentralized control problem for discrete event systems. A condition based on Nash equilibria is derived that characterizes the maximal solutions of the decentralized control problem. Results of this research will appear in 1996. Together with S. Lafortune, F. Lin, K. Rudie, and D. Teneketzis, Overkamp worked on the decentralized control problem with signalling during a work visit to the University of Michigan at Ann Arbor, MI, U.S.A. in July-August 1995. In this control problem the controllers can exchange information via an extra channel.

J.M. Schumacher, A.J. van der Schaft, and J. Rosenthal. Van der Schaft and Schumacher, together with J.C. Willems (Groningen), acted as main applicants in a proposal for a 'Groot Project' under the title 'Mathematical modeling of open dynamical systems', which was submitted to SMC by the Dutch Institute of Systems and Control (DISC) in May. The proposal received approval in June, and as a consequence there will be significant support from NWO available in the coming years for an intensified cooperation between RUG/IWI, UT/TW and CWI/BS3 in the area of mathematical modeling. The contribution of CWI in this project will be concerned in particular with *modeling of hybrid systems*, and the 'Groot Project' will fund one Ph.D. student to work at CWI in this area. Related activities take place in a TUE/KUB project entitled 'Dynamics under inequality constraints', which is co-supervised by Schumacher together with P.P.J. van den Bosch (TUE / Dept. of EE); this project has started with the appointment on December 1 of a Ph.D. student sponsored by the KUB/TUE joint research organization SOBU. In the meantime Van der Schaft and Schumacher have obtained first results on a modeling principle for hybrid systems that takes inspiration from physics and that avoids the assumption of strict separation between 'action sets' and 'destination sets' that is typical for many proposed formalizations of hybrid systems. The results were written up in a CWI report and submitted for publication in *Mathematics of Control, Signals, and Systems*.

Schumacher cooperated on a number of projects with Rosenthal, who stayed at CWI during his sabbatical from the University of Notre Dame. Topics included the pole placement problem by static output feedback (with J.C. Willems (RUG) and with X. Wang (Texas Tech)), a generalization of the classical Kalman controllability criterion, (with U. Helmke (Würzburg)), generalized (differential/algebraic) linear systems (with V. Lomadze (Tiflis, Georgia) and M.S. Ravi (East Carolina Univ.)), and new design methods for convolutional codes (with E.V. York (Univ. of Notre

Dame)). The work by Rosenthal and Schumacher with their co-authors resulted in four journal submissions during 1995 and a series of conference contributions.

Further work by Schumacher has included doing the final revisions of two papers with A.H.W. Geerts on impulsive behavior in multimodal systems (the papers will appear in *Automatica* in 1996) and completing two manuscripts for journal submission with J.C. Engwerda and A.J.T.M. Weeren (KUB). He has also started work on an edited volume entitled 'System Dynamics in Economic and Financial Models', to be published by Wiley. The volume, which will be co-edited by C. Heij (EUR), B. Hanzon (VU), and C. Praagman (RUG), is a spin-off of a workshop held in Oegstgeest in May/June 1995 that was co-organized by the editors. This workshop was sponsored chiefly by the European Research Network on System Identification (ERNSI) with funds from the SCIENCE program.

P.R. de Waal. De Waal and Van Schuppen investigated team problems with discrete action spaces. In analogy with team problems on continuous spaces where convexity of the cost function plays an important role in the existence and uniqueness of global optima, they introduced multimodularity of the cost function. They derived a representation of the set of person-by-person optimal strategies and necessary and sufficient conditions for the global optimality of a person-by-person optimal strategy.

De Waal also studied an admission control problem to a queue with delayed state information. Preliminary results indicate that under some conditions the optimality of threshold policies can be established. In contrast with admission control with full state information these thresholds have to be defined on a partially ordered state space. De Waal had discussions with D. Teneketzis (Ann Arbor, MI, U.S.A.) during a work visit in December 1995.

K.C. Wong. Working with Van Schuppen, Wong studied a problem in the design of communication channels in decentralized supervisory control of discrete-event systems. A paper was submitted to the Workshop on Discrete Event Systems 1996 in Edinburgh.

Organization of Conferences, Workshops, Courses, etc.

- *ERNSI Econometric Workshop 'Dynamic Models in Economics and Finance'*, Oegstgeest, May 30 – June 2, 1995. Organizers: J.C. Engwerda (KUB), B. Hanzon (VU), C. Heij (EUR), J.W. Nieuwenhuis (RUG), C. Praagman (RUG), J.M. Schuma-

cher.

- *Symposium System Identification and Modeling for Environmental Problems*, November 22, 1995, CWI. Organizers: J.M. van den Hof and J.H. van Schuppen. 44 participants.
- *15th Benelux Meeting on Systems and Control*, Mierlo, March 6–8, 1996. Main organizers: J.M. Schumacher, S. Weiland (TUE).

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

- Participation in conference 'Mathematics of Operations Research', Lunteren, January 11–12: P.R. de Waal.
- Participation in meeting for project proposal DAC-CORD, Brussels, Belgium, January 16: J.H. van Schuppen.
- Participation in lecture day 'Onzekerheid in Grondwatermodellering', Ede, January 19: J.H. van Schuppen.
- Rijksinstituut voor Volksgezondheid en Milieubeheer (National Institute for Public Health and Environmental Protection), Bilthoven, January 26, and other days during: J.M. van den Hof. Cooperation on research project with Dr. P.H.M. Janssen, and Dr. P.S.C. Heuberger.
- Work visit to Twente University, Department of Applied Mathematics, March 9: A. Overkamp. Lecture *Control of Discrete Event Systems using Failure Semantics*.
- Participation in the Benelux Meeting, Houthalen, Belgium, March 29–31: A. Overkamp, J.M. Schumacher, J. Rosenthal. Lecture by Overkamp *Marking versus Failure Semantics*. Lecture by Rosenthal *On a general realization theory*. Lectures by Schumacher *Coordination in continuously repeated games* and *Piecewise linear multimodal dynamics*.
- Participation in *IMA Conference on Environmental Modelling*, Lancaster, UK, March 29–31: J.M. van den Hof. Lecture *A test for structural identifiability of linear compartmental systems*.
- Participation in *31-ste Nederlands Mathematisch Congres*, Groningen, April 20–21: J.M. van den Hof.
- Work visit to Lund Institute of Technology, Lund, Sweden, May 3–7: J.H. van Schuppen. Lecture *System identification with information theoretic criteria*. J.H. van Schuppen was the opponent at the thesis defense of Dr. A. Hansson.
- Work visit Twente University, May 12: A. Overkamp. Lecture at the course *Dynamische Discrete Gebeurtenissen* organized by J. Schut.

- Participation in *System Theory Day*, Philips Research Laboratories, Eindhoven, May 18: A. Overkamp, J.M. Schumacher.
- Work visit Eindhoven Technical University, May 19: J.M. van den Hof. Lecture *Realization of positive linear systems*.
- Participation in *ERNSI Econometric Workshop 'Dynamic Models in Economics and Finance'*, Oegstgeest, May 30 – June 2: J.M. Schumacher.
- Participation in *4th ERNSI Workshop System Identification*, Padova, Italy, June 7–9: J.M. van den Hof and J.H. van Schuppen. Van Schuppen was chairman of two sessions, presented the TMR Project System Identification, and chaired the Meeting of the Council of Team Leaders.
- Work visit to LADSEB, Padova, Italy, June 12–30: J.M. van den Hof. Lectures *Realization of positive linear systems*, and *Structural identifiability from input-output observations of linear compartmental systems* at the Department for Electrical Engineering, University of Padova, Padova, Italy, on June 15, June 26, respectively.
- Participation in conference *Systems and Control — Perspectives on Theory and Practice*, Groningen, June 14–16: A. Overkamp, J.M. Schumacher.
- Work Visit University of Michigan, Ann Arbor (MI), USA, July 21 – August 11: A. Overkamp. Discussions with S. Lafortune, F. Lin, K. Rudie, and D. Teneketzis. Lectures *Decentralized Control of Discrete Event Systems* and *Control of Nondeterministic Discrete Event Systems using Failure Semantics and Partial Specifications*.
- Work visit to the company Railned in Utrecht, August 23: A. Overkamp, J.H. van Schuppen, P.R. de Waal. Discussion on topic of control of railway traffic.
- Work visit to Eindhoven University of Technology, Eindhoven, August 24: J.H. van Schuppen. Undergraduate thesis committee of Mr. A. van der Velde. Discussion with Prof. J.E. Rooda and Ir. J.J.H. Fey about hybrid systems.
- Participation in workshop *Control of Uncertain Systems — From the Calculus of Variations to Optimal and Robust Control*, Groningen, August 29 – September 1: J.M. Schumacher.
- Participation in the 3rd European Control Conference (ECC95), Rome, Italy, September 5–9: J.M. van den Hof, A. Overkamp. Lecture by Overkamp *Control of Nondeterministic Discrete Event Systems using Failure Semantics*. Lecture by Van den Hof *Structural identifiability of linear mamillary compartmental systems*.

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- Participation in *First Istanbul Workshop on System Structure and Robust Control*, Istanbul, October 3–6: J.M. Schumacher. Invited 2-hour survey lecture *Geometric theory of linear systems*.
- Work visit to Department of Engineering, University of Cambridge, UK, October 23: J.M. Schumacher. Lecture *Regulation with robust stability*.
- Work visit to Control Engineering Research Centre, City University, London, October 24: J.M. Schumacher. Lecture *Modeling of multimodal systems*.
- Work visit to Philips Research Laboratories, Nat. Lab., Eindhoven, November 2: CWI delegation: J.H. van Schuppen, A. Overkamp, P.R. de Waal, K.C. Wong. Discussion with Dr. M. Steinbuch. Lecture by J.H. van Schuppen *Control of discrete event systems and of hybrid systems*.
- Participation in the ERCIM Workshop on Systems and Control, SZTAKI, Budapest, Hungary, November 6 - 8: A.A. Stoorvogel and J.H. van Schuppen. Lecture by Van Schuppen on November 6 *Research Group Systems and Control Theory*. Lecture by Van Schuppen on November 7 *System identification with information theoretic criteria*. Lecture by Stoorvogel on November 6 *Linear systems subject to saturation*.
- Participation in *ITC Seminar*, Leidschendam, November 7–9: P.R. de Waal.
- Participation in *Symposium System identification and modeling for environmental problems*, CWI Amsterdam, November 22: J.M. van den Hof, J.M. Schumacher, A.A. Stoorvogel, and J.H. van Schuppen. Lecture by Van den Hof *Structural identifiability from input-output observations of linear compartmental systems*.
- Participation in *34th IEEE Conference on Decision and Control*, New Orleans, December 13–15: P.R. de Waal.
- Work visit to University of Michigan at Ann Arbor, December 18–19: P.R. de Waal.

Memberships of Committees and Other Professional Activities

J.H. van Schuppen:

Outside appointments
- Director of the Netwerk Systeem- en Regeltheorie (Systems and Control Theory Network) till July 1.
- Professor at the University of Groningen (part time 0.3) till July 1.

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 financed by the European Commission through the SCIENCE Program, 1992–1995.
- Coordinator of the project *System identification* that is financed by the European Commission through the Human Capital and Mobility Program, 1993–1996.
- Chairman of the Steering Committee of the ERCIM Working Group Control and System Theory, since November 1995.
- Secretary of the Adviescommissie van de afdeling Besliskunde, Statistiek en Systeemtheorie (Advisory Committee of the Department of Operations Research, Statistics, and System Theory) till July 1, 1995 (since 1983).

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 Administrative Council since 1994. (EUCA = European Community Control Association).
- Member of the International Program Committee of the 1995 European Control Conference. Handled the review procedure of selected papers.
- Member of the Program Committee of the 3rd Workshop on Discrete Event Systems (WODES96).
- Member of IFAC Technical Committee on Modeling, Identification, and Signal Processing since 1994. (IFAC - International Federation of Automatic Control). Handled in 1995 the review procedure for 20 conference papers.
- Member of IFAC Technical Committee on Stochastic Systems since 1994.

Membership in research institute and graduate school
- Dutch Institute of Systems and Control (DISC), since September 1995.

J.M. Schumacher:

Outside appointments
- Professor of Mathematics (0.2), Tilburg University, since 1987

Editorial work
- Member of editorial board, SIAM Journal on Control and Optimization, since 1990
- Associate editor, Systems & Control Letters, since 1995

Ph.D. project completion

- A.J.T.M. Weeren, Tilburg University, September 22. *Coordination in hierarchical control.* Advisors M.L.J. Hautus (TUE), J.M. Schumacher. Coadvisor J.C. Engwerda (KUB)

Organizational and administrative work
- Member of the Management Team of the Dutch Institute of Systems and Control (DISC)

Program committees
- International Program Committee, IFAC Conference on System Structure and Control (Nantes, July 5–7)

Doctoral thesis committees
- Ph.D. committee M.H.P. Peeters, Tilburg University, June 9. *Ranks and structure of graphs.*
- Ph.D. advisory committee C. Simões, Department of Applied Mathematics, Twente University
- Ph.D. advisory committee F. Kraffer, Department of Applied Mathematics, Twente University

Membership of research schools
- Dutch Institute of Systems and Control (DISC)
- Center for Economic Research (CentER)

Visitors

- Prof. J. Rosenthal, July 1, 1994 – July 20, 1995. On sabbatical leave from University of Notre Dame.
- Prof. I.M.Y. Mareels, Australian National University, Canberra, Australia, January 31. Lecture *Diophantine equations in pulse train problems.*
- E.V. York (University of Notre Dame), March 13 – April 8.
- Mr. L. Gianone, SZTAKI, Budapest, Hungary, March 24. Lecture *Basis selection for identification in H_∞.*
- Prof. K. Inan, Middle East Technical University, Ankara, Turkey, April 3–7. Lecture *Reactive programming, control, and layering.*
- Prof. R.K. Boel, University of Gent, Gent, Belgium, April 24 and 25.
- Prof. N. Karcanias and Dr. J. Leventides, City University, London, United Kingdom, May 19–23. Lecture *Classification and parametrisation of degenerate compensators of feedback configurations.*
- Dr. V. Lomadze, Mathematics Institute, Academy of Sciences, Republic of Georgia, June 6–9 and June 19–23. Lecture *(Discrete-time) linear behaviours.*
- Prof. Yu. Kabanov, Central Economics and Mathematics Institute, Russian Academy of Sciences, Moscow, Russia, June 27. Lecture *On the convergence of the attainability sets for singular perturbed SDE's.*

- Prof. E. Jonckheere, University of Southern California, Los Angeles, CA, U.S.A., July 10. Lecture *SimplicialVIEW - A package for robust stability analysis.*
- Mr. D. Nesic, Australian National University, Canberra, Australia, August 28. Lecture *Output dead beat controllability for a class of odd polynomial systems: The Gröbner basis approach.*
- Dr. G.M. Koole, INRIA Sophia Antipolis, France, August 29. Lecture *On control problems with nonclassical information structure.*
- Prof. Y. Yamamoto, Kyoto University, Kyoto, Japan, September 14. Lecture *Optimal H_∞ sensitivity computations for pseudorational transfer functions.*
- Prof. K. Özçaldıran, Boğaziçi University, Istanbul, Turkey, September 25–26. Lecture *A complete classification of minimal realizations of nonsingular and strictly proper transfers under similarity transformations.*
- Prof. A.C. Antoulas, Rice University, Houston, Texas, U.S.A., October 30. Lecture *On identification for robust control.*
- Dr. K.C. Wong (ERCIM fellow), September 1, 1995 till June 1, 1996. Lecture on October 31. *Hierarchical control of discrete-event systems.*
- Prof. L. Gerencsér, SZTAKI, Hungarian Academy of Sciences, Budapest, Hungary. November 26 – December 3. Lecture on November 27 *Performance in stochastic adaptive control.*

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

Contract research
Research for the national railway company on railway traffic control.

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:

- *Coding theory*, Spring 1995. Organizers J. Rosenthal and J.M. Schumacher.
- *Positive linear systems*, Fall 1995. Organizers J.M. van den Hof and J.H. van Schuppen.

Relations with industry and public relations

- J.M. van den Hof and J.H. van Schuppen. Participation in CWI Bedrijvendag (Company Day) on October 6, 1995.
- J.M. van den Hof and J.H. van Schuppen. Participation in CWI Open Dag (Day in which the institute CWI is open to the general public) on October 9, 1995.

Doctoral students taking courses

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

Teaching of graduate course

- Organization and presentation of the course *Control of Discrete Event Systems* for the Graduate program of the System and Control Theory Network, Spring trimester, 1995. A. Overkamp and J.H. van Schuppen.

Papers in Journals and Proceedings

M.K.K. CEVIK, J.M. SCHUMACHER (1995). The regulator problem with robust stability. *Automatica* **31**, 1393–1406.

M.K.K. CEVIK, J.M. SCHUMACHER (1995). The regulator problem with robust stability. *Proc. IFAC Conference on System Structure and Control*, Nantes, July 5–7, 249–254.

J. DE DOES (1995). State-space formulas for the computation of the gap. *Int. J. Control* **62**, 737–748.

L. GERENCSÉR, Z. VÁGÓ, J.H. VAN SCHUPPEN, M. SÉTÁLÓ (1995). Performance of a minimum variance adaptive controller with noise injection. A. ISIDORI ET AL. (eds.). *Proceedings of the Third European Control Conference (ECC95)*, EUCA, 44–48.

U. HELMKE, J. ROSENTHAL, J.M. SCHUMACHER (1995). A controllability test for behavior systems. *Proc. IFAC Conference on System Structure and Control*, Nantes, July 5–7, 318–325.

J. VAN DEN HOF, M. MEIJER (1995). *Johann Bernoulli en Leonhard Euler. De leerling overvleugelt zijn meester*. J.A. VAN MAANEN (ed.). *Een complexe grootheid. Leven en werk van Johann Bernoulli*, Epsilon Uitgaven, Utrecht, 123–147.

J.M. VAN DEN HOF (1995). Structural identifiability of linear mamillary compartmental systems. A. ISIDORI ET AL. (eds.). *Proceedings of the Third European Control Conference (ECC95)*, EUCA, 1318–1323.

H.J.C. HUIJBERTS, J.H. VAN SCHUPPEN (1995). Routing control of a motorway network – A summary. A. ISIDORI ET AL. (eds.). *Proceedings of*

the Third European Control Conference (ECC95), EUCA, 781–784.

A. OVERKAMP (1995). Control of nondeterministic discrete event systems using failure semantics. A. ISIDORI ET AL. (eds.). *Proceedings of the Third European Control Conference (ECC95)*, EUCA, 2778–2783.

A. OVERKAMP, J.H. VAN SCHUPPEN (1995). Control of discrete event systems – Research at the interface of control theory and computer science, *CWI Quarterly*, **8**, 31–45.

M.S. RAVI, J. ROSENTHAL (1995). A general realization theory for higher order linear differential equations. *Systems & Control Letters* **25**, 351–360.

M.S. RAVI, J. ROSENTHAL, J.M. SCHUMACHER (1995). A realization theory for homogeneous systems: an algorithmic approach. *Proc. IFAC Conference on System Structure and Control*, Nantes, July 5–7, 183–188.

M.S. RAVI, J. ROSENTHAL, J.M. SCHUMACHER (1995). System equivalences and canonical forms from a behavioral point of view. *Proc. 34th IEEE Conf. Dec. Contr.*, New Orleans, 484–489.

M.S. RAVI, J. ROSENTHAL, X. WANG (1995). On decentralized dynamic pole placement and feedback stabilization. *IEEE Transactions on Automatic Control* AC-40, 1603–1614.

J. ROSENTHAL, J.M. SCHUMACHER, X. WANG, J.C. WILLEMS (1995). Generic eigenvalue assignment for generalized linear first-order systems using memoryless real output feedback. *Proc. 34th IEEE Conf. Dec. Contr.*, New Orleans, 492–497.

J. ROSENTHAL, J.M. SCHUMACHER, J.C. WILLEMS (1995). Generic eigenvalue assignment by memoryless real output feedback. *Systems & Control Letters* **26**, 253–260.

J. ROSENTHAL, X. WANG (1995). Eigenvalue assignment by dynamic output feedback: a new sufficiency criterion in the real case. *Proc. 34th IEEE Conf. Dec. Contr.*, New Orleans, 2710–2715.

E.V. YORK, J. ROSENTHAL, J.M. SCHUMACHER (1995). On the relationship between algebraic systems theory and coding theory: representations of codes. *Proc. 34th IEEE Conf. Dec. Contr.*, New Orleans, 3271–3276.

CWI Reports

BS-R9503. A.A.F. OVERKAMP, J.H. VAN SCHUPPEN. *Control of discrete event systems - Research at the interface of control theory and computer science.*

BS-R9508. U. HELMKE, J. ROSENTHAL, J.M. SCHUMACHER. *A controllability test for general first-order representations.*

BS-R9512. J.M. VAN DEN HOF. *Structural identifiability of linear mamillary compartmental systems.*

BS-R9513. A.A. STOORVOGEL, J.H. VAN SCHUPPEN. *System identification with information theoretic criteria.*

BS-R9514. J.M. VAN DEN HOF. *Structural identifiability from input-output observations of linear compartmental systems.*

BS-R9516. J. ROSENTHAL, X. WANG. *Output feedback pole placement with dynamic compensators.*

BS-R9522. H.J.C. HUIJBERTS, J.H. VAN SCHUPPEN. *Routing control of a motorway network.*

BS-R9529. A.J. VAN DER SCHAFT, J.M. SCHUMACHER. *The complementary-slackness class of hybrid systems.*

BS-R9532. J.M. VAN DEN HOF. *Realization of positive linear systems.*

BS-R9533. J. ROSENTHAL, J.M. SCHUMACHER, E.V. YORK. *The behavior of convolutional codes.*

BS-R9534. J. ROSENTHAL, J.M. SCHUMACHER. *Realization by inspection.*

BS-R9535. G. PICCI, J.M. VAN DEN HOF, J.H. VAN SCHUPPEN. *A partial classification of primes in the positive matrices and in the doubly stochastic matrices.*

BS-R9536. G. PICCI, J.M. VAN DEN HOF, J.H. VAN SCHUPPEN. *Primes in the doubly stochastic circulants.*

Other Publications

J.M. VAN DEN HOF (1995). *Realization of Positive Linear Systems.* Preprint, accepted for publication in *Linear Algebra and Its Applications.*

J.M. VAN DEN HOF (1995). *Structural Identifiability of Linear Compartmental Systems.* Preprint, submitted for publication to a journal.

J.M. VAN DEN HOF (1995). *Realization of Continuous-time Positive Linear Systems.* Preprint, submitted for publication to a journal.

J.M. VAN DEN HOF (1995). *Minimality of Realizations of Positive Linear Systems.* Preprint, submitted for publication to a journal.

V. LOMADZE, M.S. RAVI, J. ROSENTHAL, J.M. SCHUMACHER (1995). *Realization of Abstract Behaviors.* Extended abstract, submitted to the 1996 International Symposium on the Mathematical Theory of Networks and Systems (MTNS-96).

A. OVERKAMP (1995). *Supervisory Control Using Failure Semantics and Partial Specifications.* Preprint, submitted for publication in *IEEE Transactions on Automatic Control.*

A. OVERKAMP (1995). *The Supremal Supervisor and Partial Observations.* In preparation.

A. OVERKAMP, J.H. VAN SCHUPPEN (1995). *A Characterization of Maximal Solutions for Decentralized Discrete Event Control Systems.* Preprint, submitted for presentation at a conference.

W. SLOB, J.M. VAN DEN HOF, P.H.M. JANSSEN (1995). *Structural Identifiability of PBPK Models and Practical Consequences for Modeling Strategies and Study Designs.* Preprint, submitted for publication to a journal.

A.A. STOORVOGEL, J.H. VAN SCHUPPEN (1995). *System Identification with Information Theoretic Criteria.* Preprint, submitted for publication in the Proceedings of the NATO Advanced Study Institute 'From identification to learning'.

P.R. DE WAAL, J.H. VAN SCHUPPEN (1995). *Global and Local Optimality in Team Problems with Discrete Action Spaces.* In preparation.

A.J.T.M. WEEREN, J.M. SCHUMACHER, J.C. ENGWERDA (1995). *Asymptotic Analysis of Linear Feedback Nash Equilibria in Nonzero-sum Linear-quadratic Differential Games.* Manuscript, submitted for publication in *J. Opt. Th. Appl.*

A.J.T.M. WEEREN, J.M. SCHUMACHER, J.C. ENGWERDA (1995). *Coordination in Continuously Repeated Games.* Discussion paper no. 76, Center for Economic Research, Tilburg University, 1995.

K.C. WONG, J.H. VAN SCHUPPEN (1995). *Decentralized Supervisory Control of Discrete-event Systems with Communication.* Preprint, submitted for presentation at a conference.

Image Analysis and Spatial Stochastics – BS4

Staff

- Dr. K.O. Dzhaparidze, senior researcher
- Dr. ir. H.J.A.M. Heijmans, senior researcher
- Dr. R. Helmers, senior researcher
- R. van der Horst, programmer (0.5 fte)
- Dr. R.H.P. Janssen, Ph.D. Student (TUD, until July 1)
- Prof. dr. M.S. Keane, group leader (0.8 fte)
- Drs. A. Mancham, Ph.D. Student (NWO)
- Dr. I.S. Molchanov, post doctoral fellow (NWO, until December 1)
- Drs. F.K. Potjer, Ph.D. Student
- A.G. Steenbeek, programmer (0.5 fte)
- Prof. dr. S.J. van Strien, advisor (UvA)

Scientific Report

In 1995, research highlights in BS4 included the following items:

- Rene Janssen successfully defended his doctoral dissertation at Delft University of Technology; thesis advisors were Carel Scheffer and our own Kacha Dzhaparidze.
- Ilya Molchanov was offered a permanent position as lecturer at the University of Glasgow, and left us in December to take up his new responsibilities, thus completing an interesting period of substantial and productive research at CWI.
- An international workshop on spatial statistics, image analysis and stochastic geometry, organized by Mike Keane and Ilya Molchanov at CWI in November, generated considerable interest and participation from abroad both in the workshop and in our group's research in general.
- The two weekly seminars (see details below) are beginning to reach critical mass, with lecturers from all parts of the world. These seminars are highly important in focussing our research activities and testing our accomplishments in an international setting. In this direction, our advisor van Strien has been of considerable value.

The following short details form a summary of the individual activities and collaborations in 1995.

K. Dzhaparidze and *R.H.P. Janssen* completed their research on the problems of constructing orthogonal polynomials associated with a matrix spectral distribution function of a multiple time series. The main results of this research constitute Ch. 4 of the Ph.D. thesis by R.H.P. Janssen, Construction of Orthogonal Polynomials Associated with Time Series and Random Fields.

K. Dzhaparidze investigated convergence problems of the Abel-Goncharov interpolation series. The results obtained seem to enlarge considerably the convergence class of functions.

K. Dzhaparidze and *P. Spreij* (VU, Amsterdam) contributed to the project 'Statistical Inference for Stochastic Processes' (in persuance of the Human Capital and Mobility Programme of the EEC) by organizing a workshop at Tinbergen Institute, Amsterdam, April 5–7.

H. Heijmans continued his research on geometry-based image processing methods, and in particular, mathematical morphology. The research carried out at CWI is mainly focussed upon theoretical issues. Heijmans has finished a report dealing with the construction of morphological filters by composition. In collaboration with P. Maragos (Georgia Institute of Technology, Atlanta) he has worked on the theoretical foundations of the slope transform, the morphological counterpart of the Fourier transform. This collaboration has resulted in a report. Together with I. Molchanov, he is working on a second publication in this area. Furthermore, Heijmans is collaborating with C. Ronse (Université Louis Pasteur, Strasbourg) on the design of so-called annular filters. Most likely, their work will result in one or two reports, to appear in 1996. Finally, Heijmans is working with P.K. Ghosh (National Centre for Software Technology, Bombay, India) on applications of metric convexity to mathematical morphology.

A promising new field of research in mathematical morphology is the design of morphological operators which preserve connectivity. Such operators can be used for different purposes: filtering of images (or image sequences), segmentation, image coding, etc. The next two or three years, a substantial part of the research efforts in BS4.4–Mathematical Morphology and Image Transforms– will be directed towards connected morphological operators. The research of F.K. Potjer is now concentrated in this direction.

The research of *R. Helmers* in the general area of bootstrap resampling schemes was mainly focussed on the following topics: elementary symmetric polynomials (with A.J. van Es and M. Hušková), non-parametric regression (with M. Hušková), wild bootstrapping in finite populations (with M.H. Wegkamp) and inhomogeneous spatial Poisson processes (with R. Zitikis). Finally, with H. Putter, a joint research project concerning the double bootstrap was started.

M. Keane completed a simple and powerful derivation of a formula originally discovered without proof by Gauss; this was the subject of his presentations at Mandelbrot's 70th birthday conference and at the Royal Netherlands Academy session in October. Together with T. Hamachi of Kyushu University, the first substantial part of joint research on the structure theory of noncommutative dynamical systems has been submitted for publication, and the second part is well under way. Collaboration with Hewlett-Packard Laboratories in Bristol was continued, and this joint effort is expected to result in formal working agreements in the course of 1996; the research belongs to the area of applied dynamical systems. Finally, M. Keane has written several articles in various stages of publication and in collaboration with diverse authors

in the area of ergodic theory and dynamical systems.

A. *Mancham* finished his first year of graduate studies in October, with investigations of random shapes as a general theme. This project is being carried out in collaboration with the Daniel den Hoed clinic in Rotterdam and with Delft University of Technology, where Mancham will hold his thesis defence three years from now. The project is funded by the NWO programme Computer Intensive Methods in Stochastics, and directed by M. Keane. A. Steenbeek has assisted considerably in the necessary extensive computations performed on CAT-scans of human lungs.

I. Molchanov has given lectures in different universities throughout the Netherlands and abroad. An important part was the course for AIO-netwerk Stochastiek within Thomas Stieltjes Institute in the Fall 1995.

Molchanov and *D. Stoyan* analyzed models of random polyhedral particles and worked out statistical methods applicable to samples of particles. The corresponding paper has been accepted for the journal *Statistical Models*. Furthermore, the same authors suggested a new concept of mean figure (or mean shape for samples of images) and an applicable algorithm to compute set-valued means for samples of figures. This paper has been tentatively accepted for *Journal of Mathematical Imaging and Vision*. Further results for abstract shapes were presented by Molchanov at the conference *Current Issues in Statistical Shape Analysis* (Leeds, UK) and published in proceedings.

Keane, Mancham and *Molchanov* have been working on averaging and stochastic models of star-shaped sets in view of applications in medical imaging (images of human lungs).

Models of stationary random sets are important for statistical image analysis, where they are used to model noisy images. The most important issues here are to design image filters and to prove their optimality for a certain class of noise distributions. This is a subject of an ongoing joint project with J. Goutsias. Together with H.J.A.M. Heijmans, Molchanov suggested a new framework to morphological operations, which allows to build morphological filters in abstract non-linear spaces as soon as a family of 'evaluations' which map this space into a 'better' space is given.

Models for point processes and random sets are important for Bayesian image analysis, where they can be used as priors. M.N.M. van Lieshout and Molchanov found a new family of Markov spatial point

processes which is flexible enough to cover many practical situations. Theoretical properties of point processes in view of optimization problems and applications to telecommunication systems are the subject of an ongoing research with S. Zouev.

Statistical estimation is an important issue for models of random sets. It allows to discern principal features of the image and to fit an appropriate stochastic model. Molchanov continued his studies of statistical problems for stationary random closed sets, in particular, the Boolean model, which 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 associated point processes. This paper has been published in *Advances in Applied Probability*. Molchanov finished Lecture Notes 'Estimation of the Boolean Model Parameters' which will be submitted to *Lecture Notes in Statistics* (Springer-Verlag). 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.

Baddeley and *Molchanov* defined a new concept of averages for random closed sets based on the notion of their distance function. This concept gives a possibility to average effectively non-convex sets. Limit theorems provide an important theoretical foundation for statistical estimation. L. Heinrich and Molchanov proved a central limit theorem for a class of random measures defined for the Boolean model (and even in a more general case), which includes most of earlier results on limit theorems in statistics of the Boolean model and provides a unified approach to derive new mean value relationships, estimators and to prove the corresponding limit theorems.

Molchanov published a report 'A limit theorem for solutions of inequalities', where rather classical problems of non-parametric statistics (like density support estimation or multivariate quantiles) have been handled by techniques from the theory of random sets.

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 correspon-

ding distribution parameters are found. An earlier result of P. Hall on this subject has been considerably extended and new proof is given.

A paper devoted to the renewal theorem for random compact sets (together with E. Omey and E. Kozarovitzky) was published in December 1995 in *Advances in Applied Probability*.

Molchanov has been 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 H.J.A.M. Heijmans (CWI).

Molchanov signed a book contract with J. Wiley Scientific Publishers for a graduate text-book *Introduction to the Theory of Random Sets* which is to be completed in 1997.

Organization 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.
- Workshop Statistical Inference for Stochastic Processes, April 5–7, Tinbergen Institute, Amsterdam. Organized by K. Dzhaparidze and P. Spreij (VU, Amsterdam).
- Workshop Bootstrap Methods, July 20–September 20, Institute of Technology, Bandung. Organized by R. Helmers in collaboration with H. Putter (Amsterdam), R.K. Sembiring (Bandung) and Subanar (Yogyakarta), as part of a cooperation project 'Applied Mathematics and Computational Methods' (1995–1999) between The Netherlands and Indonesia, in which CWI is one of the Dutch cooperating Institutes.
- Lunteren conference on Stochastics, November 13–15. Organized by R. Helmers (joint with J.Th. Runnenburg (Amsterdam), W.R. van Zwet (Leiden)).
- Workshop Ergodic Theory, Churanov, Czechia, March 11–18. Organized by M. Keane and D. Volny (Prague).
- Congress CIRM Ergodic Theory, Marseille, July 2–7. Organized by M. Keane and P. Liardet (Marseille).
- Workshop Image Analysis and Spatial Stochastics, CWI, November 9–11. Organized by M. Keane, I. Molchanov, and A. Baddeley.

- Graduate course on spatial statistics for the national network Stochastics, Fall 1995, I. Molchanov.

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

- *First Brazilian Workshop on Mathematical Morphology*, Campinas, Brazil, March 7–10: H.J.A.M. Heijmans (+ invited lecture).
- Working visit (+ lecture) University of Sao Paulo, Brazil, March 6–17: H.J.A.M. Heijmans (+ lecture).
- Working visit (+ lecture) National Institute of Space Research, Sao Jose, Brazil, March 16: H.J.A.M. Heijmans (+ lecture).
- *IEEE Workshop on Nonlinear Signal and Image Processing* , Neos Marmaras, Halkidiki, Greece, June 20–22: H.J.A.M. Heijmans (+ lecture).
- Summer School *Morphological Image and Signal Processing*, Zakopane, Poland, September 27–30: H.J.A.M. Heijmans (+ 2 invited lectures), F.K. Potjer (+ lecture).
- Workshop *New Connections between Mathematics and Computer Science*, Cambridge, UK, November 20–24: H.J.A.M. Heijmans (+ invited lecture).
- Workshop on New Approximation Techniques for Statistical Inference, Ascona, Switzerland, March 20–24: R. Helmers (+ lecture).
- Lecture, Limburgs University Centre, Diepenbeek, Belgium, June 7: R. Helmers
- *SEAMS Regional Conference on Mathematical Analysis and Statistics*, Yogyakarta, Indonesia, July 10–13: R. Helmers (+ lecture).
- Workshop *Bootstrap Methods*, Institute of Technology, Bandung, Indonesia, July 20–September 20: R. Helmers (+ lectures).
- Working visit (+ lecture), Hong Kong University of Science and Technology, Hong Kong, September 1–7: R. Helmers.
- Lecture, Padjadjaran University, Bandung, Indonesia, September 9: R. Helmers.
- Lecture, North Sea Directorate, Ministry of Transport and Public Works, Rijswijk, November 2: R. Helmers.
- Curacao, Nederlandse Antillen, February 2, International Symposium on Fractals in honor of the 70th birthday of Benoit Mandelbrot: Invited lecture by M. Keane.

- Karpacz, Polen, February 11–25, Symposium 'Chaos — the interplay ...': Three invited lectures by M. Keane.
- Bremen, Germany, March 6, Visit Medical Computing Laboratory, Peitgen: Invited lecture by M. Keane.
- Bristol, UK, APril 2–7, Working visit Hewlett-Packard Laboratories and invited lecture by M. Keane.
- Grenoble, France, June 8–10, Colloquium of the Mathematics Department: Invited lecture by M. Keane.
- Utrecht, NL, June 21, Colloquium of Statistics Department: Invited lecture by M. Keane.
- Vienna, Austria, September 10–17, Working visit, Colloquium of the Mathematics Department: Invited lecture by M. Keane (+ informal lecture on 14–9 at the Schroedinger Institute).
- Cambridge, UK, October 17–27, working visit to the Isaac Newton Institute by M. Keane.
- Amsterdam, NL, October 30, Royal Netherlands Academy of Arts and Science: Lecture in regular session by M. Keane.
- Fukuoka, Japan, November 17 – December 18, working visit and Mathematics Department Colloquium: Invited lecture by M. Keane.
- Osaka, Japan, December 18–22, working visit and Mathematics Department Colloquium: Invited lecture by M. Keane.
- Workshop: *Mathematische Stochastik* and lecture 'Limit theorems for random measures associated with germ-grain models', Mathematisches Forschungsinstitut Oberwolfach, March 5–11: I. Molchanov.
- Aarhus University: minicourse 'Statistics of the Boolean model', March 19–31: I. Molchanov.
- Conference: *Current Issues in Statistical Shape Analysis*, lecture 'Abstract landmarks and their applications', University of Leeds, April 5–7: I.Molchanov.
- Workshop: *Point Processes Models, Theory and Applications*, lecture 'A CLT for a class of random measures associated with germ-grain models', Nice, May 3–5, and working visit to INRIA Sophia-Antipolis, April 23–May 2: I. Molchanov.
- *8th International Workshop on Stochastic Geometry, Stereology and Image Analysis*, lecture 'Central limit theorem for a class of random measures associated with germ-grain models', Sandbjerg Manor, August 27–31: I. Molchanov.

Memberships of Committees and Other Professional Activities

K.O. 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:
- Chairman of Algemeen CWI Colloquium Commissie.
- Editor of electronic newsletter *Morphology Digest*.
- Scientific Director of Summer School *Morphological Image and Signal Processing*, Zakopane, Poland, September 27–30.
- 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.
- Participant in cooperation project 'Applied Mathematics and Computational Methods' (1995–1999) between The Netherlands and Indonesia

M.S. Keane:
- Chairman, Scientific Committee, Stieltjes Research School. (until 1 May)
- Member of University Council, Delft University of Technology. (until 1 September)
- 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, CWI Syllabi, Dynamics and Stability of Systems, Journal of Probability and Mathematical Statistics.
- Ph.D. committee, FAN Ai Hua, Université de Paris-Sud, Orsay, France, January 16, Président de Jury.
- Ph.D. committee, Jean Mairesse, École Polytechnique, Palaiseau, France, June 7.
- Ph.D. committee, Geurt Jongbloed, TUD, October 9.

- Ph.D. committee, Rene Janssen, TUD, November 7.
- Member Commissie NWO Trends in de Wetenschap (1995).
- Member Akademieraad voor de Wiskunde.

Visitors

- P.K. Ghosh, National Centre for Software Technology, Bombay , India, December 1,1994–May 31, 1995.
- C. Ronse, Université Louis Pasteur, Strasbourg, April 24–29.
- J. Goutsias, Johns Hopkins University, Baltimore, USA, May 29–June 10.
- A. Tuzikov, Academy of Sciences, Minsk, Belarus, December 1995–September 1996.
- S.Darwis (Institute of Technology, Bandung, Indonesia), April 20–July 14.
- M. Hušková (Charles University, Prague, Czech Republic), October 1–31.
- S. Martinez, Santiago, March 3.
- R. Roy, New Delhi, March–September.
- A. Gandolfi, Rome, April 15–26.
- A. Weron, Wroclaw, April 30 – May 6.
- C.T. Sparrow, Cambridge, May 3–5.
- B. Toth, Budapest, May 20 – June 20.
- A. Hof, Pasadena, June 5–7.
- T. Hamachi, Fukuoka, July 26 – September 1.
- P. Shields, Toledo, September 15 – November 30.
- L. Heinrich, Freiberg, February 1–10.
- Visiting lecturers in the seminar Dynamics in Amsterdam: P. Veerman (Recife), L. Heinrich (Freiberg), E. Vargas (Sao Paulo), H. Nakada (Tokyo), P. Freitas (Lissabon), B. Krauskopf (Göttingen), O. Kozlovski (Amsterdam), C. Sparrow (Cambridge), M. Smorodinsky (Tel Aviv), L. Jonker (Kingston), G. Levin (Tel Aviv), H. Bruin (Erlangen), A. Quas (Cambridge), P. Shields (Toledo), Y. Yi (Atlanta), S. Hastings (Pittsburg), R. Quispel (Canberra).
- Visiting lecturers in the Spatial Stochastics Seminar: L. Heinrich (Freiberg), P. Ghosh (Bombay), D. Down (Canada), H. Putter (Amsterdam), C. Ronse (Strasbourg), A. Weron (Wroclaw), D. Reimer (Rutgers), J. Goutsias (Baltimore), A. Hof (Toronto), B. Toth (Budapest), Y. Itoh (Tokyo), V. Lotov (Novosibirsk), V. Malyshev (Paris), S. Zouev (Sophia-Antipolis), M. Zaehle (Jena), F. Spieksma (Leiden), M. Huskova (Prague), M. Menshikov (Moscow), D. Chibisov (Moscow), V. Bening (Moscow).
- Visiting lectures in the Workshop Spatial Statistics, Image Analysis and Stochastic Geometry: P. Hall (Canberra), D. Geman (Amherst), J. Besag (Seattle), H. Tjemeland (Trondheim), D.M. Titterington (Glasgow), N. Cressie (Ames), W. Kendall (Warwick), Ch. Hess (Paris), W. Weil (Karlsruhe), P. Clifford (Oxford), M. Schmitt (Fontainebleau), A. Tsybakov (Paris), M. Rudemo (Copenhagen), A. Baddeley (Perth).

Miscellaneous (Consultancy, knowledge transfer, etc.)

- RWS. A consultation project for the North Sea Directorate, Ministry of Transport and Public Works, was completed. The problem is to estimate the intensity of oil pollution in the North Sea. This project is part of CWI's research program Mathematics & the Environment (R. Helmers, R. van der Horst).
- Coopers Lybrand: Research concerning inference on rare errors is being carried out as part of an ongoing consultation project (R. Helmers, R. van der Horst)
- M.S. Keane consulted for two two-week periods 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

A.J. BADDELEY, H.J.A.M. HEIJMANS (1995). Incidence and lattice calculus with applications to stochastic geometry and image analysis. *Applicable Analysis in Engineering, Communication, and Computing* 6, 129–146.

J. GOUTSIAS, H.J.A.M. HEIJMANS, K. SIVAKUMAR (1995). Morphological operators for image sequences. *Computer Vision, Graphics and Image Processing: Image Understanding* 62, 326–346.

H.J.A.M. HEIJMANS (1995). Mathematical morphology: a modern approach in image processing based on algebra and geometry. *SIAM Review* 37, 1–36.

M. KEANE (1995). A Continued Fraction Titbit. *Fractals*.

M. KEANE, M. SMORODINSKY, B. SOLOMYAK (1995). On the morphology of γ-expansions with deleted digits. *Transactions of the American Mathematical Society* 347(3), 955–966.

M. KEANE (1995). Ergodic Theory. P. GARBAC-
ZEWSKI, M. WOLF, A. WERON (eds.). *Chaos — The
Interplay between Stochastic and Deterministic Be-
haviour*, Karpacz, Poland, 11–25 February 1995,
Lecture Notes in Physics **457**, Springer, Berlin, 179–
181.

M. KEANE (1995). The essence of the law of
large numbers. *Hayashibara Symposium on Frac-
tals and Ergodic Theory*, Ookayama, 1994, published
in 1995.

I.S. MOLCHANOV (1995). Statistics of the Boolean
model: from the estimation of means to the estima-
tion of distributions. *Adv. Appl. Prob.* **27**, 63–86.

I.S. MOLCHANOV (1995). Abstract landmarks and
their applications. K.V. MARDIA, C.A. GILL (eds.).
*Proceedings in Current Issues in Statistical Shape
Analysis*, Leeds University Press, 82–87.

I.S. MOLCHANOV (1995). On the convergence of
random processes generated by approximations of
convex compact sets. *Theory of Probability and its
Applications* **40**(3).

I.S. MOLCHANOV, E. OMEY, E. KOZAROVITZKY
(1995). An elementary renewal theorem for random
compact convex sets. *Advances in Applied Probabi-
lity.*

I.S. MOLCHANOV (1995). Set-valued estimators
for mean bodies related to Boolean models. *Statis-
tics.*

I.S. MOLCHANOV, D. STOYAN (1995). Statistics
of compact sets and random polygons. *Stochastic
Models.*

CWI Reports

BS-R9504. H.J.A.M. HEIJMANS. *Composing
morphological filters.*

BS-R9531. H.J.A.M. HEIJMANS, P. MARAGOS.
*Lattice calculus of the morphological slope trans-
form.*

BS-R9517. R. HELMERS, H. PUTTER. *Bootstrap
resampling: a survey of recent research in the
Netherlands.*

BS-R9520. R. HELMERS, M.H. WEGKAMP. *Wild
bootstrapping in finite populations with auxiliary
information.*

BS-N9501. R. HELMERS. *On estimating the in-
tensity of oil-pollution in the North Sea.*

BS-R9510. I.S. MOLCHANOV, D. STOYAN. *Statis-
tical models of random polyhedra.*

BS-R9511. D. STOYAN, I.S. MOLCHANOV. *Set-
valued means of random particles.*

BS-R9515. I.S. MOLCHANOV. *A limit theorem for
solutions of inequalities.*

BS-R9518. L. HEINRICH, I.S. MOLCHANOV. *Cen-
tral limit theorem for a class of random measures
associated with germ-grain models.*

Other Publications

H.J.A.M. HEIJMANS (1995). Mathematical morp-
hology: basic principles. *Proceedings of Summer
School on 'Morphological Image and Signal Proces-
sing'*, Zakopane, Poland.

H.J.A.M. HEIJMANS (1995). Morphological fil-
ters. *Proceedings of Summer School on 'Morpho-
logical Image and Signal Processing'*, Zakopane,
Poland.

F.K. POTJER, H.J.A.M. HEIJMANS (1995). Some
aspects of connected morphological operators. *Pro-
ceedings of Summer School on 'Morphological
Image and Signal Processing'*, Zakopane, Poland.

R. HELMERS, R. ZITIKIS (1995). *On Estimating
the Intensity Function of a Spatial Inhomogeneous
Poisson Process.* Report 270 of the Laboratory for
Research in Statistics and Probability, Carleton Uni-
versity, Ottawa, Canada.

M. HARRIS, M. KEANE (1995). *Random Coin Tos-
sing.* Report 95–33, Faculteit TWI, Delft University
of Technology.

R.H.P. JANSSEN (1995). *Construction of Ortho-
gonal Polynomials Associated with Time series and
Random Fields*, Dissertation at TUD.

M.S. KEANE (1995). Trends in de Wiskunde.
Trends in de Wetenschap, NWO, Den Haag, 53–55.

DEPARTMENT OF NUMERICAL MATHEMATICS

Staff 1995

- Discretization of Evolution Problems – NW1

  - J.G. Verwer
  - P.J. van der Houwen
  - J.G. Blom
  - W.H. Hundsdorfer
  - J. Kok
  - W.M. Lioen
  - M. van Loon
  - B.P. Sommeijer
  - E.J. Spee
  - J.J.B. de Swart
  - W.A. van der Veen

- Boundary Value Problems, Multigrid and Defect Correction – NW2

  - P.W. Hemker

  - C.T.H. Everaars
  - B. Koren
  - J. Noordmans
  - W.J.H. Stortelder
  - P.M. de Zeeuw

- Large-Scale Computing – NW3

  - H.J.J. te Riele
  - H.A. van der Vorst
  - H. Boender
  - J.G.L. Booten
  - R.-M. Elkenbracht-Huizing
  - J. Kok
  - W.M. Lioen
  - M. Nool
  - D.T. Winter

- Secretary: S. Panka-van der Wolff

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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
- Ir. M. van Loon, Ph.D. student
- Drs. E.J. Spee, Ph.D. student
- Drs. J.J.B. de Swart, Ph.D. student
- Drs.ir. W.A. van der Veen, Ph.D. student
- Drs. J. Kok, project member, seconded from NW3
- Drs. W.M. Lioen, project member, seconded from NW3

Scientific Report

In 1995 research was organized through four main projects:

Equations of fluid mechanics and related topics.
This HCM project started in 1994 and lasts until end of 1996. Seventeen research groups from Europe participate. The available budget is used mainly for long-term visitors and working and conference visits:

1. A 6-month stay of Ch. Kessler (University of Karlsruhe) was financed by this HCM budget. Dr. Kessler has assisted in a Cray-T3D pilot project on implementing a 3D atmospheric transport-chemistry solver on the T3D machine from the EFPL in Lausanne (NM-R9519). Access was obtained with support from NCF. The 3D solver, based on a prototype transport-chemistry model for regional air pollution, was earlier developed at the Cray C90 machine in 1994 in the framework of a Cray-NCF project.
2. W. Hundsdorfer has given a course on numerical advection schemes at the University of Coimbra which is one of the HCM partners.
3. A 2-month stay of Paulo Rosa (University of Coimbra) was financed by the HCM budget. At CWI he has started an investigation to numerical advection schemes for use in atmospheric transport models. The investigation will be continued at Coimbra University.
4. W. Hundsdorfer and J.G. Verwer have participated in a HCM workshop on 'Transport Problems', organized by the Coimbra research group.
5. Various conference visits by group members.

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').
The coupling of a numerical transport model with a biochemical model initiated in 1994, was continued in 1995. The research is carried out as part of the international EC/NOWESP program; financial support has been obtained via the NCF/CRAY project 'Biochemical Fluxes in Transport Models for 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 consequence 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. This algorithm was implemented on the CRAY C90 machine and experiments were reported in NM-R9503. In 1995 we also replaced the central difference discretization with upwind discretizations and we analysed various possibilities for the splitting formula. Results are reported in NM-R9516.

Parallel IVP algorithms.
This project deals with parallel Runge-Kutta and other block methods for ordinary 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 incorporation of a new iteration strategy based on triangularly implicit iteration of the nonlinear systems (NM-R9510 and NM-R9517). Furthermore, we completed the design of step-parallel iteration strategies (NM-R9507) and experiments with sparse matrix methods for use in the linear system solvers (NM-R9520). Finally, we started investigations on Runge-Kutta waveform relaxation methods (NM-R9506) and the design of parallel methods for implicit differential equations (NM-R9526).

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 exists with the Dutch Center for Climate Research (CKO) which in 1995 has been founded by IMAU, KNMI and RIVM. New co-operation with the Center for Regional and Global Environmental Research (CRGER), University of Iowa, has been established. In 1995 financial support was obtained from the RIVM for the projects EUSMOG and CIRK, from the HCM project for the 6-month visit of Ch. Kessler and the 2-month visit of Paulo Rosa, and from NCF by providing access to the Cray T3D at the EFPL in Lausanne. The research was organized through five (sub)projects:

1. *Project EUSMOG.* This is a 4-year Ph.D. project (M. van Loon) which will end March 1996. Aim has been development and implementation of numerical algorithms in an operational smog prediction model of the RIVM. The main algorithms examined concern numerical advection, local refinement and chemical kinetics solvers. All algorithms have been implemented in an existing software package of the RIVM. In 1995 a considerable part of the research time has been spent on implementation tasks and on final tests with real data (NM-R9523). More results of these tests will be published in the Ph.D. thesis of Van Loon which he will defend on the University of Amsterdam at June 17.

2. *Project CIRK.* Aim is development and implementation of numerical algorithms in a global tropospheric/stratospheric model in co-operation with the CKO. This 4-year Ph.D. project (E. Spee) started in 1994 and lasts until end of 1997. In 1995 a 2D prototype has been built which couples advection on the sphere with a methane chemistry model through operator splitting. The numerical advection is based on a flux-limited, 3rd-order upwind scheme working on a reduced (polar) grid (NM-R9508). The chemistry is solved with a special purpose, explicit ODE solver based on the 2nd-order BDF formula. This solver uses Gauss-Seidel iteration for approximately solving the implicit BDF relations (NM-R9505). The 2D prototype is currently extended to a 3D version using a hybrid pressure-sigma co-ordinate in the vertical. In co-operation with the CKO, early 1996 first runs will be made using real atmospheric and meteorological data.

3. *Cray-T3D pilot project.* See description of the HCM project 'The equations of fluid mechanics and related topics'.

4. *Benchmarking project.* Co-operation has been established with the CGRER (Center for Global and Regional Atmospheric Research) of the University of Iowa. The co-operation focuses on benchmarking special purpose stiff ODE solvers for a variety of atmospheric chemical kinetics problems. A first joint report will be published early 1996. In this report nine solvers are compared for a set of seven box models taken from real transport models. Five special purpose explicit solvers are compared to four state-of-the-art, implicit solvers from the numerical stiff ODE field. Two of them are of BDF type and two are of Runge-Kutta type. For these implicit solvers the numerical algebra overhead is reduced by using optimized sparse matrix techniques. For large atmospheric chemistry models this approach is shown to be very effective. This benchmarking project will be continued in 1996.

5. *Splitting and IMEX schemes.* A numerical stability investigation was started to 2nd-order splitting and implicit-explicit (IMEX) methods meant for integrating atmospheric transport-chemistry problems. Results will be reported early 1996.

Research consortium TASC.
Belongs to CWI's research program 'Mathematics and the Environment.

On the initiative of CWI, research groups from CWI, RIVM, RWS, TNO, TUD and WL have formed the interdisciplinary research consortium TASC (Transport Applications and Scientific Computing). The objective is to develop HPCN software for 3D transport simulation. All partners are already active in the field and involved in various joint projects. Within the framework of TASC, this co-operation will be strengthened by organizing joint symposia and workshops and by submitting joint project proposals. Three main tasks are distinguished: (I) Numerical algorithm and software development, (II) Implementation of fully integrated models, and (III) Application to real life problems. CWI and TUD will contribute mainly to task (I). RWS, RIVM, WL and TNO are end users and the application-oriented partners and will contribute mainly to tasks (II) and (III). The TASC partners CWI, TNO, TUD and WL will participate in the Dutch HPCN program (ICES support) through the project 'HPCN for Environmental Applications'. This project will start January

1996 and is planned to last 4 years. Research activities concern simulation of atmospheric air pollution and pollution in shallow water.

Organization of Conferences, Workshops, Courses, etc.

- *TASC Symposium 1 'Transport Algorithms and Scientific Computing'*, Feb. 24, CWI: B. Koren, CWI (A monotone, central scheme for advection and an advection scheme for source terms), M. Roemer, TNO (Results of a two-step BDF method implemented in LOTOS), J.G. Verwer, CWI (A numerical method for 3D atmospheric transport-chemistry problems).
- *TASC Symposium 2 'Transport Algorithms and Scientific Computing'*, June 9, CWI: P. Wilders, TUD (A case study of 2D miscible transport in strongly heterogeneous porous media), Ch. Kessler, University of Karlsruhe (Implementation of a 3D atmospheric dispersion model on the parallel machine Cray-T3D), M. Kirkilonis, CWI (Computing transport and growth of plankton and pollutants in the sea).
- *TASC Symposium 3 'Transport Algorithms and Scientific Computing'*, Sept. 8, CWI: B.P. Sommeijer, CWI (Time integration of a 3D transport model coupled with bio-chemical terms), E. de Goede, WL (A domain decomposition method for the shallow water equations), H.X. Lin, TUD (Parallelisation of existing flow and transport models).
- *Minisymposium 'Numerical Algorithms for Air Pollution Models'*, organized by J.G. Verwer and Z. Zlatev (NERI, Copenhagen) at ICIAM95 (International Congress on Industrial and Applied Mathematics, Hamburg, July 3–7). Speakers were Z. Zlatev, NERI, Copenhagen (Three-dimensional version of the Danish Eulerian Model), M. Jacobson, Stanford University (Application of the sparse-matrix, vectorized Gear-type code SMVGEAR in a new air pollution modeling system), O. Knoth (University of Leipzig, (Time integration of advection-diffusion-reaction equations by explicit-implicit methods), W. Hundsdorfer, CWI (Numerical modeling of global transport and chemistry), F.A. Potra, University of Iowa (On extrapolated QSSA schemes), J.G. Verwer, CWI (Algorithm and software aspects of an implicit-explicit method for 3D atmospheric transport-chemistry problems).
- *Symposium 'One Hundred Years of Runge-Kutta Methods'*, CWI, Dec. 8. Speakers were J.C. Butcher, University of Auckland (Runge-Kutta methods in the period 1963–1995), E. Hairer, Uni-

versité de Genève (On the error growth function of Runge-Kutta methods), S.P. Nørsett, Trondheim University (SIRK- and DIRK methods of Runge-Kutta type), M.N. Spijker, Leiden University (The theory of error propagation in Runge-Kutta methods), J.G. Verwer, CWI (Explicit Runge-Kutta Methods for Parabolic Partial Differential Equations). G. Wanner, Université de Genève (Runge-Kutta methods in the period 1895–1962).

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

- *Kick-off meeting MMARIE concerted action*, Leuven, Belgium, February 3: B.P. Sommeijer (Overview of CWI-contributions to 3D transport solvers).
- *SciCADE95: International Conference on Scientific Computation and Differential Equations*, Stanford University, USA, March 28–April 1: P.J. van der Houwen (Step-parallel iteration methods for solving ODE-IVPs), B.P. Sommeijer (Time integration of a 3D bio-chemical transport model), J.G. Verwer (Implicit versus explicit methods for atmospheric transport-chemistry problems).
- *Nederlands Mathematisch Congres*, Groningen, April 20–21: M. van Loon (Het oplossen van chemische vergelijkingen: een numerieke vergelijking), E.J. Spee (Koppeling van advectie en chemie in een numeriek atmosferisch model), J.J.B. de Swart (Het gebruik van ijle-matrixsolvers bij het numeriek oplossen van differentiaalvergelijkingen), W.A. van der Veen (Stap-parellelle Runge-Kutta methoden).
- *Method of Lines Workshop*, University of Kentucky, Lexington, Kentucky, USA, May 31–June 4: J.G. Verwer (Implicit-Explicit Methods for Atmospheric Transport-Chemistry Problems).
- *Seminario Matematico e Fysico di Milano*, Milan, Italy, June 7: P.J. van der Houwen (Parallel iteration methods for solving Runge-Kutta ODE and DAE equations).
- *Annual Meeting NOWESP Consortium and Workshop MMARIE*, Leuven, Belgium, June 19-21: B.P. Sommeijer (A vector/parallel method for a three-dimensional transport model coupled with bio-chemical terms).
- *Workshop on the numerical solution of ODEs*, Geiranger, Norway, June 20: P.J. van der Houwen (Smoothing techniques for stabilizing ODE methods for solving PDEs).
- *16th Biennial Conference on Numerical Analysis*, University of Dundee, Scotland, June 27-30:

P.J. van der Houwen (Three-dimensional transport in shallow water), J.J.B. de Swart (Computing method parameters for parallel implicit Runge-Kutta methods), W.A. van der Veen (Step-parallel Runge-Kutta methods).

- *ICIAM95*, University of Hamburg, July 3–7: J.G. Verwer (Algorithm and software aspects of an implicit-explicit method for 3D atmospheric transport-chemistry problems), W. Hundsdorfer (Numerical modeling of global transport and chemistry).
- *10th EUMAC Workshop*, University of Cologne, Aug. 30–Sept. 1: J.G. Verwer (Implicit-Explicit Methods for Atmospheric Transport-Chemistry Problems)
- *Working visit* FOM institute Rijnhuizen, September 12: J.G. Verwer (Numerieke Modellering van Luchtvervuiling).
- *Air Pollution 95*, Porto Carras, Greece, Sept. 26–29: M. van Loon (Fast and efficient solution methods for ozone chemistry), E.J. Spee (Coupling advection and chemistry in a global atmospheric test model).
- *CWI in Bedrijf*, CWI, Oct. 6: J.G. Verwer (Numeriek Wiskundig Milieuonderzoek op het CWI).
- *HCM Workshop*: 1º Encontro de métodos numéricos para equações de derivadas parciais, University of Coimbra, Portugal, Oct. 25–27: W. Hundsdorfer (Numerical modeling of global transport and chemistry in the troposphere), J.G. Verwer (A numerical method for 3D atmospheric transport-chemistry problems).
- *ICPAM95: International Conference on Pure and Applied Mathematics*, Sakhir Campus, University of Bahrain, Bahrain, November 18–24: P.J. van der Houwen (Solving implicit differential equations on parallel computers, November 20), B.P. Sommeijer (Time integration of a 3D bio-chemical transport model).
- *Kick-off meeting* MPR project 'The discreteness-continuity dichotomy in individual-based population dynamics using massively parallel machines', VU, Amsterdam, Dec. 15: B.P. Sommeijer (Parallel numerical integration of ODEs).

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'*

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

J.G. Verwer:
- Senior Editor *Applied Numerical Mathematics*
- Program Leader of CWI's research program *Mathematics and the Environment*
- Coordinator Research Consortium TASC
- Coordinator of the TASC project *HPCN for Environmental Applications*

Visitors

- E. Celledoni (University of Trieste, Italy) Feb. 15–May 1.
- Ch. Kessler (University of Karlsruhe), visiting post-doc, Jan.–July.
- J. Frank (University of Kansas), visiting Ph.D. student, June–Dec.
- A. Sandu (University of Iowa), Sept. 18–22.
- P. Rosa (University of Coimbra), visiting Ph.D. student, Sept.–Nov.
- R. Chan (University of Auckland), Nov. 27.
- J.C. Butcher, E. Hairer, S.P. Nørsett, M.N. Spijker and G. Wanner, on the occasion of the Symposium 'One Hundred Years of Runge-Kutta Methods', Dec. 8.
- Houde Han (Tsinghua University, Beijing, China), Dec. 13.

Papers in Journals and Proceedings

P.J. VAN DER HOUWEN, B.P. SOMMEIJER, W.A. VAN DER VEEN (1995). Parallel iteration across the

steps of high-order Runge-Kutta methods for non-stiff initial value problems. *JCAM* **60**, 309–329.

W. HUNDSDORFER, B. KOREN, M. VAN LOON, J.G. VERWER (1995). A positive finite-difference advection scheme. *J. Comput. Phys.* **117**, 35–46.

W. HUNDSDORFER, E.J. SPEE (1995). An efficient horizontal advection scheme for modelling of global transport of constituents. *Montly Weather Review*, **123**(12), 3554–3564.

W. HUNDSDORFER, J.G. VERWER (1995). A note on splitting errors for advection-reaction equations. *Appl. Numer. Math.* **18**, 191–199.

M. VAN LOON (1995). Fast and efficient solution methods for ozone chemistry. H. POWER, N. MOUSSIOPOLOS, C.A. BREBBIA (eds.). *Air Pollution III*, Computational Mechanics Publications, Southampton-Boston, 335–342.

B.P. SOMMEIJER, J. KOK (1995). Implementation and performance of the time integration of a 3D numerical transport model. *Int. J. Numer. Meth. Fluids* **21**, 349–367.

E.J. SPEE (1995). Coupling advection and chemistry in a global atmospheric test model. H. POWER, N. MOUSSIOPOLOS, C.A. BREBBIA (eds.). *Air Pollution III*, Computational Mechanics Publications, Southampton-Boston, 319–326.

J.J.B. DE SWART (1995). Efficient parallel predictor-corrector methods. *Appl. Numer. Math.* **18**, 387–396.

W.A. VAN DER VEEN (1995). Step-parallel algorithms for stiff initial value problems. *CMA* **30**, 9–23.

W.A. VAN DER VEEN, J.J.B. DE SWART, P.J. VAN DER HOUWEN (1995). Convergence aspects of step-parallel iteration of Runge-Kutta methods. *Appl. Numer. Math.* **18**, 397–411.

J.G. VERWER (1995). Explicit methods for stiff ODEs from atmospheric chemistry. *Appl. Numer. Math.* **18**, 413–430.

CWI Reports

NM-R9501. J.G. VERWER, J.G. BLOM, W.H. HUNDSDORFER. *An implicit-explicit approach for atmospheric transport-chemistry problems.*

NM-R9503. B.P. SOMMEIJER, J. KOK. *A vector/parallel method for a three-dimensional transport model coupled with biochemical terms.*

NM-R9505. J.G. VERWER, J.G. BLOM, M. VAN LOON, E.J. SPEE. *A comparison of stiff ODE solvers for atmospheric chemistry problems.*

NM-R9506. P.J. VAN DER HOUWEN, B.P. SOMMEIJER. *Iteration of Runge-Kutta methods with block triangular Jacobians.*

NM-R9507. W.A. VAN DER VEEN. *Step-parallel algorithms for stiff initial value problems.*

NM-R9508. E.J. SPEE. *Coupling advection and chemical kinetics in a global atmospheric test model.*

NM-R9509. J.G. VERWER, J.G. BLOM. *On the coupled solution of diffusion and chemistry in air pollution models.*

NM-R9510. P.J. VAN DER HOUWEN, J.J.B. DE SWART. *Triangularly implicit iteration methods for ODE-IVP solvers.*

NM-R9516. P.J. VAN DER HOUWEN, B.P. SOMMEIJER. *Splitting methods for three-dimensional transport models with interaction terms.*

NM-R9517. W. HOFFMANN, J.J.B. DE SWART. *Approximating Runge-Kutta matrices by triangular matrices.*

NM-R9519. CH. KESSLER, J.G. BLOM, J.G. VERWER. *Porting a 3D-model for the transport of reactive air pollutants to the parallel machine T3D.*

NM-R9520. J.J.B. DE SWART, J.G. BLOM. *Experiences with sparse matrix solvers in parallel ODE software.*

NM-R9523. M. VAN LOON. *Numerical smog prediction II: grid refinement and its application to the Dutch smog prediction model.*

NM-R9526. P.J. VAN DER HOUWEN, W.A. VAN DER VEEN. *Solving implicit differential equations on parallel computers.*

NM-N9501. M. VAN LOON. *Fast and efficient solution methods for ozone chemistry.*

Other Publications

P.J. VAN DER HOUWEN, K. STREHMEL, R. WEINER (eds.) (1995). Selected papers of the Seventh Conference on the Numerical Treatment of Differential Equations. *Applied Numerical Mathematics* **18**, Sept. '94, Halle, Germany, 1–430.

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 (0.3 fte)
- Ir. W.J.H. Stortelder, Ph.D. student
- Ir. J. Noordmans, Ph.D. student

Scientific Report

P.W. Hemker and *J. Noordmans* continued research on sparse-grid related algorithms for three-

dimensional problems. The work aims at the use of adaptive box-methods for sparse grids. Initiated in the framework of the BRITE-EURAM Aeronautics R&D Programme of the European Union, the purpose of this research is the efficient solution of 3D flow problems. A software package was developed for experimenting with algorithms for different possible function representations. The software was based on the BASIS3 package, developed earlier for the BRITE-EURAM project. In addition, the software was extended for discretisation of linear elliptic equations, and preparations were made to implement solution methods based on semi-coarsening. Theoretical aspects related with semi-coarsening and partially ordered sets of approximation were studied by *P.W. Hemker*. In August, a cooperation was started with *C. Pflaum* (TU München). A report on the subject is in preparation.

In the framework of the STW project 'Parameter-identificatie en model-analyse voor niet-lineaire dynamische systemen', *W.J.H. Stortelder, C.T.H. Everaars* and *P.W. Hemker*, continued the work on the interactive parameter estimation tool 'spIds'. The first edition of the user's manual was published as a CWI report. The newly developed software tool has been tested and some real life problems have been solved. An article on a problem from chemistry (in cooperation with DSM, Geleen) has been submitted for publication. Two other, more biochemically oriented papers on blood coagulation (in cooperation with Biomedical Centre, University Limburg) and fructan production by plant cells (in cooperation with the department of Chemical Engineering, Ben-Gurion University, Israel) are in preparation.

During a visit of *Prof. J.D. Pintér* (TUNS, Halifax, Canada) to CWI, global optimization problems were studied. This cooperation led to a properly working version of a global optimization routine, which can be used for parameter estimation purposes. As a consequence *J.D. Pintér* and *W.J.H. Stortelder* are preparing a paper for the Third Workshop on Global Optimization, held at Szeged, Hungary.

C.T.H. Everaars took care of new developments in the graphical user interface (GUI) of spIds. In 1995, however, he spent most of his time in the group IS2, working on the Manifold project. Possibilities of using the Manifold software for numerical problems were seriously studied. A first experiment with application to a problem in optimization was executed. Based on a previous 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, Ekaterin-

burg, Russia), who visited CWI for three weeks during the year 1994, *P.W. Hemker* continued research on singular perturbation problems. Several publications on the subject were prepared, and, together with *Prof. H.-G. Roos* (Universität Dresden) and *Prof. M. Stynes* (University College Cork) an Oberwolfach meeting 'Numerical Singular Perturbations' was organised January 22–28. Part of the joint work was also reported by Prof. Shishkin in the International Conference on Advanced Mathematics, Computations and Applications, Novosibirsk, June 20–24, 1995.

With *Prof. A.O.H. Axelsson* (KUN) a joint proposal for continued research with Russian colleagues was applied for to NWO, and the proposal was granted for continuing cooperation in the years 1996 and 1997.

During his visit as an ERCIM fellow in the summer of 1995 *Dr. A. Craig* worked on the problem of producing consistent restriction operators for multigrid methods applied to the discretisation of convection diffusion equations. It is well known that these methods can fail to work when the problem is convection dominated. It is possible to view the problem of multigrid restriction in the same light as upwinded discretisation. Using this approach, one can derive appropriate restrictions no matter what sort of discretisation was originally used. The technique has been tested on a number of trial problems and there is a body of theory (although as yet incomplete) to describe its behaviour. Preliminary results were presented at the Copper Mountain conference on Multigrid Methods in 1995, and a first paper has been written and and submitted to SIAM J. Num. Anal.

As a consequence of an Oberwolfach Meeting on 'Multilevel Methods and Applications', that was organised April 30 – May 6 by *W. Hackbusch, P.W. Hemker and G. Wittum*, it was decided that a Special Issue of the journal Applied Numerical Mathematics will be devoted to recent advances in Multigrid Methods. *P.W. Hemker*, who will act as a guest editor for the journal, started the editorial work that is involved. It is expected that the issue will appear about the end of 1996.

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), *B. Koren* continued his work on multigrid solution algorithms for the three-dimensional, steady compressible Euler equations. The work was partly done in cooperation with *P.M. de Zeeuw*. Multigrid software was written which – so far – relies on

multiple semi-coarsening (a full grid of grids) and a simple smoothing procedure (point Gauss-Seidel relaxation). The first computational results were obtained for the classical ONERA-M6 wing at transonic flight conditions. As expected, the full-grid-of-grids approach is effective (good convergence rates) but inefficient (long computing times). As a remedy, the step towards a sparse-grid approach will be made. Given the appealing distributed computing aspects of the latter approach (distribution over a cluster of workstations of the relaxation on the separate highest-level-grids), *C.T.H. Everaars*, *P.W. Hemker* and *B. Koren* discussed combining the sparse-grid Euler solver with the Manifold language compiler (see Section IS2 in this overview).

Together with *P.F.M. Michielsen* (M.Sc. student from TU Delft at KONI B.V.), *B. Koren* finished computational work on high-frequency oleodynamics (noise generation) in hydraulic shock absorbers of train bogies. The work led to the M.Sc. degree of Michielsen, a CWI report (NM-R9515), as well as a joint CWI–KONI–TU Delft presentation at the 'CWI in Bedrijf'-day. In concert with *C.R. van der Heijden*, general manager of KONI, the report was submitted for publication to the International Journal of Mechanical Sciences.

In cooperation with *C. Beets* (Institute for Marine and Atmospheric Research Utrecht), *B. Koren* finished work on an alternative discretization method for large-eddy simulation (a method with accurate, implicit subgrid-scale diffusion). A CWI report has been prepared that will be submitted for publication to the Journal of Fluid Mechanics.

In addition to the CWI Report NM-R9504, *P.M. de Zeeuw* produced results for multiple semi-coarsening techniques. As a result the paper was accepted for publication in Applied Numerical Mathematics.

He also prepared a paper on an application of Bi-CGSTAB and he started writing a survey on his research activities. This survey will be the first chapter of his Ph.D. thesis that will be defended in 1996.

Organization of Conferences, Workshops, Courses, etc.

P.W. Hemker:
- *Oberwolfach meeting 'Numerical Singular Perturbations'*, January 22–28.
- *Oberwolfach meeting 'Multilevel Methods and Applications'*, April 30–May 6.

B. Koren:
- *Symposium on behalf of the 25-year jubilee of P.W. Hemker*, CWI, February 3.

- 30^e *Werkgemeenschapscolloquium Numerieke Wiskunde*, KU Nijmegen, September 15.
- 31^e *Werkgemeenschapscolloquium Numerieke Wiskunde*, U Twente, December 1.

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

- *Working visits to KONI B.V.*, Oud-Beijerland, January 11, September 22: Koren.
- *BRITE Meeting*, Vrije Universiteit Brussel, January 20: Hemker, Koren, De Zeeuw (Feasibility study of semi-coarsening and convergence study for high-aspect-ratio cells).
- *Oberwolfach meeting 'Numerical Singular Perturbations'*, January 22–28: Hemker (A survey of feasible restriction operators).
- *Working visits to TU Delft* (on behalf of KONI-work by P.F.M. Michielsen), January 31, March 1, April 25, September 6: Koren.
- *Symposium on behalf of 25-year SMC-jubilee of P.W. Hemker*, CWI, February 3: Everaars, Hemker, Koren (Getallenstromen met kleine wrijvingsweerstand), Noordmans, Stortelder, De Zeeuw (Van grof naar fijn).
- *Milieuwiskunde-colloquium*, CWI, February 24: Koren (A monotone central scheme for advection, and an advection scheme for source terms).
- *Algemeen Wiskunde Colloquium*, Universiteit van Amsterdam, March 15: Hemker (Over numerieke benaderingen in drie dimensies).
- *Kontactgroep Numerieke Stromingsleer*, March 20: Fokker Aircraft B.V., Oude Meer. Hemker, Noordmans, De Zeeuw.
- *Seminarium* t.g.v. KSEPL-bezoek aan Thomas Stieltjes Institute for Mathematics, RU Leiden, March 31: Koren (CFD-werk van de CWI-multigridgroep).
- *31ste Nederlands Mathematisch Congres*, Groningen, April 20: Hemker.
- *Fourth Conference on Nonlinear Analysis*, Numerical Analysis and Applied Mathematics, Ovidius University, Constanza, Romania, April 26–30: Hemker (Semi-coarsening and sparse grid approximation, April 28)
- *Oberwolfach meeting 'Multilevel Methods and Applications'*, April 30–May 6: Hemker.
- *Meeting* with delegation from the SKF Engineering and Research Center B.V., Nieuwegein, May 11: Koren (Research in CWI's multigrid group), De Zeeuw.
- *Symposium on behalf of 25-year SMC-jubilee of H.J.J. te Riele*, CWI, May 16: Hemker, Koren, Stortelder, De Zeeuw.

- *Five lectures* on GMRES and its Benificial Work in Numerical Theory and in Applications, Utrecht University, May 31: De Zeeuw.
- *NW-Werkbesprekingen*, CWI: Hemker (June 7: Semi-refinement Methods), Koren (October 18: A computational method for oleo-acoustics, application to hydraulic shock absorbers), Noordmans, Stortelder, De Zeeuw (November 22: Aspects of 3D-solvers).
- *Working visit to the SKF Engineering and Research Center B.V.*, Nieuwegein, June 8: Koren, De Zeeuw.
- *BRITE Meeting*, Technical University of Denmark, Lyngby, June 9: Koren (Progress of the BRITE work at CWI), De Zeeuw.
- 30^e *Werkgemeenschapscolloquium Numerieke Wiskunde*, KU Nijmegen, September 15: Hemker, Koren.
- *Interview Visiting Committee 1995*, CWI, September 20: Hemker (Research in NW2), Koren.
- 20^e *Conferentie Numerieke Wiskunde*, Woudschoten, September 25–27: Hemker, Koren, Noordmans.
- *Wisselwerking in R&D*, CWI in Bedrijf, October 6: Hemker, Koren (stand with KONI), Michielsen from KONI (Rekenen aan geluidsproduktie in schokdempers), Noordmans, Stortelder (demonstration), De Zeeuw (demonstration with NLR).
- *Workshop 'Laplace Symphony' on numerical solvers for Laplace-like equations*, Dept. of Mathematics, University of Groningen, November 15: De Zeeuw (Solution updates at fine or coarse grids).
- 31^e *Werkgemeenschapscolloquium Numerieke Wiskunde*, U Twente, December 1: Koren, Noordmans.

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)
- Program committee Conference on Algebraic Multilevel Iteration Methods (member)
- Numerical Algorithms Group, NAG Inc. (member)

- STW Users Committee, Project 'Parameter Identification' (chair)
- Ph.D. committee J. Brandts (Univ. Utrecht, January 16) (member)
- Ph.D. committee M. Neytcheva (KUN, September 27) (member)
- Ph.D. committee Hao Lu (KUN, October 10) (member)

B. Koren:
- Secretary Werkgemeenschap Numerieke Wiskunde
- Editor *Het Nummer* (newsletter Werkgemeenschap Numerieke Wiskunde)
- Member M.Sc. committee P.F.M. Michielsen (TU Delft, May 31)

P.M. de Zeeuw:
- Member ADSARA (SARA User Committee)
- Editor *Het Nummer* (newsletter Werkgemeenschap Numerieke Wiskunde)

Visitors

- Prof. J. Pintér (Technical University of Nova Scotia, Halifax), January 6.
- Dr. P. Farrell (Kent State University, Kent, OH, USA), January 11.
- Prof. W. Hackbusch (Christian-Albrechts-Universität, Kiel) 'About the multiroostertechniek', February 3.
- Prof. P. Wesseling (TU Delft) 'De correctie van het defect van P.W. Hemker', February 3.
- Prof. H.C. Hemker (RU Limburg) 'In numero, in vitro, in vivo', February 3.
- Drs. B.T. Hemker (U Utrecht) 'Het polytome Mokken-model', February 3.
- Dr. A. Craig (University of Durham) May 1–August 31 'Domain decomposition preconditioning for the p-version finite element method', June 28.
- Dr. R. Stevenson (TU Eindhoven) 'A hierarchical basis preconditioner', June 28.
- Dr. P. Schuhmacher (GEO Partner AG, Zürich), June 30.
- Prof. J. Pintér (Technical University of Nova Scotia, Halifax), June 29–July 28.
- Dr. H. Guillard (INRIA, Sophia Antipolis, Valbonne), July 31–August 18.
- Prof. B. van Leer (University of Michigan, Ann Arbor), August 29–31. 'CFD in A^2-II', August 30.
- Dr. C. Pflaum (Technische Universität München), November 28–30.
- Dr. P. Schuhmacher (GEO Partner AG, Zürich), December 7.

Miscellaneous

P.W. Hemker:
- Consultant for Philips Research Laboratories, Eindhoven.
- Refereeing of papers for various journals, refereeing of project proposals.
- Capita selecta course *Advanced Scientific Computing* at the University of Amsterdam, on the subject *Defect Correction Methods.*

B. Koren:
- Refereeing of papers for various journals, refereeing of an STW proposal.
- Consultancy Dr. Gjesdal (Christian Michelsen Research AS, Fantoft, Norway) on defect correction solution methods for the incompressible Navier-Stokes equations
- Consultancy Dr. Ko (SKF Engineering and Research Center B.V., Nieuwegein) on a multigrid solution method for equations of elastohydrodynamic lubrication.

P.M. de Zeeuw:
- Refereeing of papers for various journals, refereeing of an STW proposal.
- Consultancy R.H.A.M. van Lieshout on the application of multigrid methods (in connection with a Master's Thesis at the Eindhoven University of Technology) and J.F.H. van Dam (TUD/NLR–AT) on grid generation techniques for flow simulations.
- Consultancy J. Heijstek and G. van Beek (NLR) on the development of 3D-multigrid methods.
- Consultancy Dr. P. Schuhmacher (GEO Partner AG, Zürich) on the applicability of multigrid methods for models of air flow over alpine topography.

W.J.H. Stortelder:
- Refereeing of a paper for the *Journal of Global Optimization.*

Papers in Journals and Proceedings

J.-A. DÉSIDÉRI, P. W. HEMKER (1995). Convergence analysis of the defect-correction iteration for hyperbolic problems. *SIAM J.Sci.Comput.* **16**, 88–118.

P. W. HEMKER, B. KOREN (1995). Defect correction and nonlinear multigrid for steady Euler equations. W. G. HABASHI (ed.). *Solution Techniques for Large-scale CFD Problems*, John Wiley & Sons, Chichester, 273–291.

P.W. HEMKER (1995). Sparse-grid finite-volume multigrid for 3D-problems. *Advances in Computational Mathematics* **4**, 83–110.

P.W. HEMKER, B. KOREN (1995). Defect correction and nonlinear multigrid for steady Euler equations. W.G. HABASHI, M.M. HAFEZ (eds.). *Computational Fluid Dynamics Techniques*, Gordon and Breach, Basel, 699–718.

P.W. HEMKER, B. KOREN, W.M. LIOEN, M. NOOL, H.T.M. VAN DER MAAREL (1995). Multigrid for steady gas dynamics problems. M. HAFEZ, K. OSHIMA (eds.). *Computational Fluid Dynamics Review 1995*, John Wiley & Sons, Chichester, 477–494.

W. HUNDSDORFER, B. KOREN, M. VAN LOON, J.G. VERWER (1995). A positive finite-difference advection scheme. *J. Comput. Phys.* **117**, 35–46.

B. KOREN (1995). Condition improvement for point relaxation in multigrid, subsonic Euler-flow computations. *Applied Numerical Mathematics* **16**, 457–469.

B. KOREN, B. VAN LEER (1995). Analysis of preconditioning and multigrid for Euler flows with low-subsonic regions. *Advances in Computational Mathematics.*, **4**, 127–144.

W. STORTELDER (1995). Parameter estimation in dynamic systems. *Proceedings of the IMACS / IFAC First International Symposium on Mathematical Modeling and Simulation in Agriculture and Bio-industries*, Free University of Brussels (ULB), pages II.C.3–1 to II.C.3–6.

H.T.M. VAN DER MAAREL, P.W. HEMKER (1995). Structured adaptive finite-volume multigrid for compressible flows. W. HACKBUSCH, G. WITTUM (eds.). *Fast Solvers for Flow Problems*, **49** of *Notes on Numerical Fluid Mechanics*, Braunschweig, Vieweg-Verlag, 14–37.

CWI Reports

NM-R9521. C.T.H. EVERAARS, P.W. HEMKER, W. STORTELDER. *Manual of splds, a software package for parameter identification in dynamical systems.*

NM-R9502. P.A. FARRELL, P.W. HEMKER, G.I. SHISHKIN. *Discrete approximations for singularly perturbed boundary value problems with parabolic layers.*

NM-R9515. B. KOREN, P.F.M. MICHIELSEN, J.W. KARS, P.WESSELING. *A computational method for oleo-acoustics, application to hydraulic shock absorbers.*

NM-R9522. J.D. PINTÉR. *LGO: An implementation of a Lipschitzian global optimization procedure, user's guide.*

NM-R9504. P.M. DE ZEEUW. *Development of semi-coarsening and sparse-grid techniques.*

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Other Publications

B. KOREN, P.M. DE ZEEUW (eds.) (1995). *Het Nummer*, **32, 33**, Stichting Mathematisch Centrum, Amsterdam.

P.A. FARRELL, P.W. HEMKER, G.I. SHISHKIN, I.V. TSELISHCHEVA (1995). A domain decomposition method for singularly perturbed boundary value problems with a local distribution of the initial conditions. *Abstracts of the International Conference on Advanced Mathematics, Computations and Applications*, Novosibirsk, p. 102.

P.W. HEMKER, G.I. SHISHKIN (1995). The use of defect correction for the solution of parabolic singular perturbation problems. *Abstracts of the International Conference on Advanced Mathematics, Computations and Applications*, Novosibirsk, 135–136.

Large-Scale Computing – NW3

In memoriam Albert Booten

On Sunday, November 12, 1995, our colleague and friend **Albert Booten** totally unexpectedly passed away: his heart failed after a sports event. Albert was only 32 years old. Since September 1994 he held a position as a postdoc in the Department of Numerical Mathematics. While his Doctor's Thesis was in Physics, he became more and more interested in Numerical Linear Algebra. He was the main researcher in the project 'Parallel computation of eigenvalues of non-Hermitian generalized eigenproblems arising in linear magnetohydrodynamics'.

Albert has worked with great enthusiasm and skill in this project and he has contributed substantially to the development of numerical algorithms for the large sparse eigenvalue problems which emerge in plasma- and astrophysics. He worked together closely with Henk van der Vorst and his group at the Mathematical Institute of Utrecht University, and with Peter Meijer from the FOM-Institute of Plasma Physics Rijnhuizen. Albert has co-authored in at least five publications and has given numerous scientific presentations at conferences, working groups and at various other occasions.

Albert was a loyal colleague and an amiable personality. He was a great sport adept. Despite his qualities as a researcher he remained modest and kept himself in the background. He had a good sense of humor, probably because his roots lie in the southern part of our country (Maastricht). When hearing a good joke, he could burst out into a Homeric laughter which was very catching for the persons around him.

We very much miss Albert. May he rest in peace.

Staff

- Dr. ir. H.J.J. te Riele, group leader
- Prof. dr. H.A. van der Vorst, advisor
- Drs. J. Kok, researcher
- Drs. W.M. Lioen, programmer
- Drs. M. Nool, programmer (0.4 fte on detachment from AM)
- D.T. Winter, programmer (0.4 fte on detachment from CST)
- Drs. H. Boender, Ph.D. student on detachment from RUL
- Dr. J.G.L. Booten, Ph.D. student since Sept. 6, 1993; researcher from Sept. 15, 1994 until Nov. 12, 1995 (see In memoriam above)
- Drs. R.-M. Elkenbracht-Huizing, Ph.D. student, NWO/RUL

Scientific Report

Introduction

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 AM2.1). In particular, J. Kok and W.M. Lioen have worked in NW1 for 75% resp. 60%, and M. Nool in AM2.1.

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

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 (RU Leiden), Dr. A.K. Lenstra (Bellcore, USA), Dr. P.L. Montgomery (San Rafael, California, USA), Dr. R.D. Silverman (Queues Enforth Development Inc., Cambridge, Massachusetts, USA), Prof. J. Buchmann (University of Saarbrücken, Germany), Prof. R.P. Brent (The Australian National University, Canberra, Australia), Prof. J. Cannon and Dr. W. Bosma (University of Sydney, Australia), Prof. G.L. Cohen (University of Technology, Sydney, Australia) and Prof. A. van der Poorten (ceNTRe for Number Theory Research, Macquarie University, Sydney, Australia)

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

NW 3.1: Parallel numerical algorithms

(a) *Parallel computation of eigenvalues of non-Hermitian generalized eigenproblems arising in linear magnetohydrodynamics (MHD)* (J.G.L. 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. In September 1995, a project proposal named *Parallel Computational Magneto-Fluid Dynamics: Nonlinear dynamics of thermonuclear, astrophysical, and geophysical plasmas and fluids* was approved by the 'Dwarsverbandcommissie Massaal Parallel Rekenen' of NWO. In this project several institutes are collaborating, including the Mathematical and Astronomical Institutes of Utrecht University, the FOM Institute for Plasmaphysics Rijnhuizen, and CWI.
The new so-called *Jacobi-Davidson method* of Sleijpen and Van der Vorst for computing the extreme eigenvalues and associated eigenvectors of a general matrix has been studied extensively. In particular, for the generalized eigenproblem $Ax = \lambda Bx$ (where the matrix B is Hermitian positive definite), the method has been implemented and tested on a Sparc workstation and on the Cray C90. Test examples were taken from problems in magnetohydrodynamics (MHD spectroscopy) with maximum matrix size of order 4800. The method is an inner-outer iteration scheme in which the inner iteration process consists of solving linear systems to some accuracy. Neither A nor B need to be factorized. One CWI report (NM-R9514) and two reports of the Universiteit Utrecht (Preprints 923 and 935) have appeared in 1995.
(b) *ERCIM PANDA project* (J. Kok, H.J.J. te Riele). In February a project proposal named *Parallel and distributed application enabling environments (PANDA)* was submitted to the Industrial Research and Technological Developments Activity of the Fourth Framework Programme of the European Commission. Purpose of this project is to build user environments for efficiently designing and re-engineering industrial and scientific applications on present and future high-performance parallel computers, and to provide a comprehensive and integrated workbench with tools to enable easy construction of these user-specific environments and to optimize existing and future simulation codes. The proposal was prepared by representatives from the

ERCIM Institutes CWI, INRIA/IRISA Rennes and GMD, Philips Research Laboratories Eindhoven, Delft University of Technology, Utrecht University, NAG (UK), Simulog(Fr.) and Institut Français du Pétrole (Fr). A coordination meeting was held in Amsterdam on January 27. Project Coordinators were Bernard Philippe (INRIA) and Herman te Riele. In April, the proposal was rejected by the EC.
(c) *ERCIM Parallel Processing Network* (H.J.J. te Riele). The ERCIM Parallel Processing Network is an informal network of ERCIM researchers interested in all aspects of parallel processing, from parallel hardware to applications. In June a project proposal named *Advancing parallel processing exploitation by interfacing applications, programming and architectures (APPEL)* was submitted to the Networks Activity of the Training and Mobility of Researchers Programme of the European Commission. Project Coordinator was Domenico Laforenza of CNR. This proposal was prepared by representatives from the ERCIM Institutes AEDIMA, CNR, CCL (the former RAL), CWI, FORTH, GMD and INESC, and finalized in a meeting in Pisa on May 10–11. The overall project was broken down into the three tasks:
1) Architectures
2) Programming models and tools
3) Technical and Scientific Applications
Task coordinators were, respectively, Antonio Gonzales (AEDIMA), Marco Vanneschi (CNR) and Herman te Riele (CWI). Unfortunately, the proposal seems to have been rejected by the EC although so far (January 1996) no formal rejection message has been received by the proposers.

NW 3.2: Computational number theory

(a) *Factorization with the Number Field Sieve (NFS)* (R.-M. Elkenbracht-Huizing, 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. Elkenbracht-Huizing finished the writing of the report 'An Implementation of the Number Field Sieve' (NM-R9511). It explains the ideas behind the CWI NFS-package which were developed partly by Montgomery, but it also gives programming tips and examples of factorizations so that the report will appeal both to researchers who are only interested in the theory of the NFS and to researchers who want to write a new or improve an existing NFS package. The report has been submitted for publication.
The CWI NFS program has been used to factor four

Most Wanted numbers in the Cunningham Table (together with Bob Silverman) and to contribute about 30% of the sieving work necessary to factor an RSA challenge number of 130 digits. The completion of the factorization of this record size number is expected early 1996. The last two steps (linear algebra and square root computation) will be carried out at CWI. Elkenbracht-Huizing started to study and implement an idea of Montgomery to use more than two polynomials in the NFS. This is expected to yield a 25% reduction of the sieving time of the algorithm in the case of three polynomials, and 33% in the case of four polynomials. An extended abstract was submitted for a presentation at the ANTS II meeting in Bordeaux in May 1996.

(b) *Experiments with the double-large-prime variation of the quadratic sieve method* (H. Boender, W.M. Lioen, P.L. Montgomery, H.J.J. te Riele). Boender finished the writing of the report 'Factoring integers with large prime variations of the quadratic sieve' (NM-R9513). It presents the results of many factorization runs with the single and double large prime variations (PMPQS and PPMPQS, respectively) of the quadratic sieve factorization method on SGI workstations, and on a Cray C90 vector-computer. Experiments on the Cray C90 show that PPMPQS beats PMPQS for numbers of more than 80 digits, and that this cross-over point goes down with the amount of available central memory. Some practical formulas are given which may help to predict the total running time of PMPQS and PPMPQS on the basis of a short test run. The report has been submitted for publication.

Boender started to analyze the problem of predicting the number of complete and the number of incomplete relations in the quadratic sieve methods. This is helpful for the optimization of the choice of the various parameters occurring in these methods. An extended abstract was submitted for a presentation at the ANTS II meeting in Bordeaux in May 1996.

(c) *Extending the Cunningham table* (P.L. Montgomery, H. Boender, R.-M. Elkenbracht-Huizing, H.J.J. te Riele, W.M. Lioen, D.T. Winter). Montgomery, Boender, Elkenbracht-Huizing and Te Riele continued to factor numbers of the form $a^n \pm 1$ ($13 \leq a < 100$) for the extended Cunningham table with the help of the ECM, NFS and MPQS factoring methods. Most of the work was carried out on 70 Indy workstations at CWI and 30 Indy workstations at Leiden University. In the first Update to this table (NM-R9419, September 1994), the factorizations were complete for $n \leq 58$ and there were no

composites numbers left smaller than 10^{86}. Now, the factorizations are complete for $n \leq 66$ and there are no composites left smaller than 10^{94}. Additional factorizations were provided by Müller, Robert Silverman, Thomas Sosnowski and Samual Wagstaff, Jr. The second Update Report, to appear early 1996, will contain about 600 new factorizations.

The original and the extended Cunningham tables have been built in in the software package MAGMA, which is being developed by a team at the University of Sydney, headed by John Cannon and Wieb Bosma.

(d) *Numerical sieve methods for number-theoretical problems* (W.M. Lioen, J. van de Lune). Lioen and Van de Lune extended Tanaka's systematic computations on Pólya's conjecture (1919)

$$L(x) = \sum_{n \leq x} (-1)^{\nu(n)} \leq 0, \quad x \geq 2,$$

where $\nu(n)$ is the number of different prime factors of n, counting multiplicity. Tanaka (1980) did systematic computations of $L(x)$ up to 10^9 and found the smallest explicit counter-example $L(906,150,257) = +1$. Lioen and Van de Lune extended the systematic computations up to 10^{12} and they found $L(x) < 0$ for $10^9 \leq x \leq 10^{12}$. (It is known that there are infinitely many x for which $L(x) > 0$.)

(e) *Amicable and related numbers* (H.J.J. te Riele). The report with many hundreds of new amicable triples announced to appear in 1995 has been delayed till 1996.

A joint report with Graeme Cohen on iterating the sum-of-divisors function was finished and submitted for publication (NM-R9525). Here, sequences of the form $n, \sigma(n), \sigma(\sigma(n)), \ldots$ are studied. Suggested by extensive experiments, several new results were proved. The results support several conjectures of Erdős et al. put forward in 1990. The original Cunningham number table was an indispensable tool for the computation of the iteration sequences.

Also jointly with Graeme Cohen, analogues of Carmichael's multiply amicable pairs, based on Euler's ϕ-function, were studied (Carmichael's pairs are defined with the help of the sum-of-divisors function). All the ϕ-amicable pairs with larger member $\leq 10^9$ were computed. Several theoretical results about the prime factor structure of these pairs were proved, and analogies with construction methods for ordinary amicable pairs were shown to exist. A joint report was finished and submitted for publication (NM-R9524).

(f) *Diophantine inequalities and continued fractions* (H.J.J. te Riele). Jointly with Richard Brent and Alf van der Poorten a comparative study was started of three known algorithms for the computation of the continued fraction of algebraic numbers (which are defined as roots of polynomials with integer coefficients). Experiments were carried out with the help of implementations in GP/PARI and MAGMA. An extended abstract has been submitted to the ANTS II meeting of May 1996 in Bordeaux.

Organization of Conferences, Workshops, Courses, etc.

- *CWI/UU Symposia on Massively Parallel Computing and Applications*
  In 1993 – 1994, CWI (Te Riele) and Utrecht University (Van der Vorst) have organized a series of bi-monthly symposia on Massively Parallel Computing and Applications. Each meeting was centered around a special topic. The Proceedings of these Symposia have appeared in November as a Special Issue of the Journal 'Applied Numerical Mathematics' (see list of Papers).
- *Course on High Performance Computing*
  In July – November H.J.J. te Riele has taught a one-semester course on High Performance Computing at the University of Technology, Sydney (UTS) in Australia. The following topics were treated: architecture, processor arithmetic, programming languages and other tools, standard mathematical software, vectorization and parallelization techniques, parallelization of selected numerical algorithms, practical experience with LAP-ACK/BLAS. Part of the course material was chosen from the NCF-book: 'Aspects of computational science—A text book on high-performance computing', Stichting Nationale Computer Faciliteiten, 's-Gravenhage, Spring 1995.
- *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 University of Amsterdam, the University of Utrecht, Delft University of Technology, the FOM Institute for Plasmaphysics Rijnhuizen, and CWI. In 1995, ten meetings took place (organized by Te Riele and Booten). The dates, speakers and their subjects were:
  on January 20:
  Albert Booten, Ingredients for Jacobi-Davidson methods to solve general eigenproblems
  Margreet Nool, Account of visit to the 'Workshop on Performance Evaluation and Benchmarking of

Parallel Systems' (University of Warwick, Coventry, 15–16 December 1994)
on February 10:
Henk van der Vorst (Utrecht University), Iterative methods for large linear eigenvalue problems
on March 3:
Peter Meijer (FOM Institute for Plasmaphysics Rijnhuizen), Parallel Magnetohydrodynamics (MHD) and the Cray-T3D
Martin van Gijzen (Utrecht University), GMRES-like methods on distributed memory computers
on March 31:
Jacques de Swart, Experiences with Sparse Matrix Solvers in Parallel ODE Software
Diederik Fokkema (Utrecht University), Accelerating Iterative Schemes (of Newton Type) for Nonlinear Equations
on May 24:
Femke Raeven (Utrecht University), Quadratic eigenproblems
Martin van Gijzen (Utrecht University), Application of the results of the previous talk to acoustic computations
on June 2:
Jitka Drkosova (Institute of Computer Science, Academy of Sciences of the Czech Republic, Prague), GMRES using Iterative Gram-Schmidt
on June 23:
Alfons G. Hoekstra (University of Amsterdam), Hierarchical methods, efficient solvers for particle simulations and beyond
on August 25:
Henk van der Vorst (Utrecht University), Preconditioning for Sparse Linear Equations
on September 8:
Jos van Dorsselaer (Utrecht University), Stability of Equilibria and Pseudospectra
Kees Dekker (Delft University of Technology), The influence of the shadow residual on the parallel performance of CG
on October 13:
Jean-François Carpraux (Utrecht University), Some software tools to control the accuracy in scientific computing
Henk van der Vorst (Utrecht University), Parallelism in CG-like methods

- *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

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Plasmaphysics Rijnhuizen, Utrecht University (the Mathematical and Astronomical Institutes) and CWI (as unofficial partner). In September 1995 NWO approved the follow-up of this pilot project by a four-year MPR project named *Parallel Computational Magneto-Fluid Dynamics: Nonlinear dynamics of thermonuclear, astrophysical, and geophysical plasmas and fluids*. CWI now is an official partner and new partners are the Computational Physics and Geodynamics Research Institutes of Utrecht University, the Institute for Marine and Atmospheric Research Utrecht, and the Computational Physics Institute of Delft University of Technology. The group met five times, namely on February 23 (FOM Rijnhuizen), April 26 (CWI), September 1 (FOM Rijnhuizen), October 11 (FOM Rijnhuizen), and December 6 (CWI). At the meeting of February 23, Albert Booten gave the presentation *The Jacobi-Davidson method for generalized MHD-eigenvalue problems*.

- *Symposium 'Te Riele 25'*
  To celebrate Herman te Riele's 25-th anniversary as CWI-employee on May 1, a Symposium was organized by Kok and Van der Houwen on May 16. After an opening word by the director of CWI (G. van Oortmerssen) and a retrospective talk by the head of the Department of Numerical Mathematics (P.J. van der Houwen), the following speakers gave the following contributions:
  Henk van der Vorst (Utrecht University), *Moeilijke sommetjes*
  Rob Tijdeman (Leiden University), *Hoe gaat het met Catalan?*
  Richard Brent (Canberra, Australia), *Some real-variable conditions equivalent to the Riemann Hypothesis*
  Peter Montgomery (San Rafael, California, USA), *Progress in factoring over the last 25 years*
  Walter Lioen (CWI), *Grootschalige getallenvrienden*

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

- *ERCIM PANDA project meeting*, Amsterdam, January 27: P.J. van der Houwen, J. Kok, H.J.J. te Riele, H.A. van der Vorst.
- *Kloosterman Lectures door H.W. Lenstra, Jr.*, Leiden University, February 9 and 17; March 3, 17, 24, and 31; April 7: H. Boender, R.-M. Elkenbracht-Huizing, W.M. Lioen, H.J.J. te Riele.
- *CWI Cryptography Working Group*, March 14: H. Boender, R.-M. Elkenbracht-Huizing (Experiments with the Number Field Sieve), W.M. Lioen,

H.J.J. te Riele.
- *Getaltheorie Seminarium*, Leiden University, March 17: H. Boender, R.-M. Elkenbracht-Huizing (Extracting the square root in the Number Field Sieve), W.M. Lioen, H.J.J. te Riele.
- *Eenendertigste Nederlands Mathematisch Congres*, Universiteit van Groningen, April 20–21: H. Boender, R.-M. Elkenbracht-Huizing (Experimenten met de Number Field Sieve), J. Kok, H.J.J. te Riele (Berekeningen van kettingbreuken op een supercomputer).
- *Symposium ter gelegenheid van de vijftigste verjaardag en het vijfentwintigjarige dienstverband van Peter van Emde Boas*, UvA, April 28,: J. Kok, M. Nool, H.J.J. te Riele.
- *High Performance Computing Colloquium*, RU Leiden, May 4: H.J.J. te Riele.
- *ERCIM APPEL project meeting*, Pisa, May 10–11: H.J.J. te Riele.
- *Number Theory Day*, Leiden, May 19: H. Boender, R.-M. Elkenbracht-Huizing, W.M. Lioen, P.L. Montgomery (The search for two cubics for GNFS), H.J.J. te Riele:
- *Symposium GMRES and its beneficial work in numerical theory and in applications*, Utrecht, May 31: J.G.L. Booten, J. Blom (Which Krylov method should one use in a general PDE solver?), H.J.J. te Riele, P.M. de Zeeuw.
- *SGI meeting on HPCN market, supercomputing products and trends*, De Meern, June 12: D.T. Winter.
- *Algebraic Eigenproblem Day*, Utrecht, June 15: J.G.L. Booten.
- *ICIAM 95*, Hamburg, July 3–7: J.G.L. Booten (Jacobi-Davidson methods for generalized MHD-eigenvalue problems).
- *HPC Colloquium*, Leiden, September 7: J.G.L. Booten (The Jacobi-Davidson method for large-scale generalized eigenvalue problems).
- *Working visits to:*
  the School of Mathematical Sciences of the University of Technology, Sydney (UTS);
  the ceNTRe of Number Theory Research of Macquarie University, Sydney; and
  the School of Mathematics and Statistics of the University of Sydney,
  Sydney, Australia, July 27–November 1: H.J.J. te Riele (lectures on: Continued fractions, September 4, Macquarie University; Amicable Numbers, September 14, UTS and September 25, Macquarie University).
- *Working visit to Bellcore Laboratories*, Morristown, NJ, USA, October 1–31: H. Boender.

- *Working visit to the Universität des Saarlandes*, Saarbrücken, October 5–6: R.-M. Elkenbracht-Huizing (Experiments with the Number Field Sieve).
- *Amsterdam Simulation Club*, University of Amsterdam, October 13: M. Nool.
- *Symposium 'Eigenwaarden in modellering'*, Philips Natuurkundig Laboratorium Eindhoven, November 10: J.G.L. Booten (Posterpresentatie: Gegeneraliseerde eigenwaardeproblemen).
- *Working visit to the Computer Sciences Laboratory and the School of Mathematical Sciences of the Australian National University*, Canberra, Australia, November 2–18: H.J.J. te Riele (Computing continued fractions of algebraic numbers, November 13; Sieve methods for factoring large numbers, November 15; High performance numerical computing, November 17).
- *Symposium 'Models of physiologically structured populations'*, CWI, November 29: M. Nool.
- *Twaalfde Supercomputer Gebruikersdag*, Vrije Universiteit Amsterdam, December 1: W.M. Lioen, M. Nool, H.J.J. te Riele.
- *Kick-off Meeting of the MPR Cluster on 'Biologic Dynamic Systems'*, Free University Amsterdam, December 15: M. Nool.

Memberships of Committees and Other Professional Activities

H.J.J. te Riele:
- Coordinator (together with B. Philippe of IN-RIA/IRISA) of ERCIM project proposal 'Parallel and Distributed Applications Enabling Environments (PANDA)' for the Fourth Framework Programme of the European Commission
- Technical and scientific applications—task coordinator of ERCIM project proposal 'Advancing parallel processing exploitation by interfacing applications, programming and architectures (APPEL)' for the Training and Mobility of Researchers Programme (TMR) of the European Commission.
- Editor of *Nieuw Archief voor Wiskunde* (Section Expository Papers)
- Referee of papers for various scientific journals
- 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*
- Deputy member of the *CWI – Bibliotheekcommissie* (July–November)
W.M. Lioen:
- Brandwacht/persluchtmaskerdrager

Visitors

- T. Denny (Fachbereich Informatik, Universität des Saarlandes, Saarbrücken, Germany), May 8–10 (Solving large sparse systems of linear equations over finite prime fields).
- P.L. Montgomery (San Rafael, California, USA), May 12–21. (see Symposium 'Te Riele 25').
- R.P. Brent (The Australian National University, Canberra, Australia), May 15–18 (see Symposium 'Te Riele 25').
- K. Koyama (NTT Communication Science Laboratories, Kyoto, Japan), May 29.
- S.S. Wagstaff, Jr. (Dept. of Computer Science, Purdue University, West-Lafayette, In, USA), June 6–7 (48 More solutions of Martin Davis's quaternary quartic equation).
- Jane Cullum (Dept. of Computer Science, University of Maryland, and IBM T.J. Watson Research Center, Yorktown Heights, USA), June 14 (Peaks, plateaus, and other relationships between Krylov methods for solving $Ax = b$).
- J.-M. Couveignes (Ecole Normale Supérieure, Paris, France), November 30.

Papers in Journals and Proceedings

A. STEWART, M. NOOL, H.J.J. TE RIELE, D.T. WINTER (1995). An investigation of data reuse on the Cray S-MP system 500, *Supercomputer* XI-1, nr. 59, 1994/1995.

P.L. MONTGOMERY (1995). A block Lanczos algorithm for finding dependencies over GF(2). LOUIS C. GUILLOU, JEAN-JACQUES QUISQUATER (eds.). *Advances in Cryptology – EUROCRYPT '95*, (Proc Int. Conf. on the Theory and Application of Cryptographic Techniques, Saint-Malo, France, May 1995), Springer-Verlag, Berlin, 106–120.

H.J.J. TE RIELE, H.A. VAN DER VORST (eds.). (1995). Special Issue on Massively Parallel Computing and Applications. *Applied Numerical Mathematics* 19, 1–171.

P.W. HEMKER, B. KOREN, W.M. LIOEN, M. NOOL, H.T.M. VAN DER MAAREL (1995). Multigrid for Steady Gas Dynamics Problems. M. HAFEZ, K. OSHIMA (eds.). *Computational Fluid Dynamics Review 1995*, Wiley, 477–494.

CWI Reports

NM-R9511. R.-M. HUIZING. *An implementation of the number field sieve.*

NM-R9512. H.J.J. TE RIELE. *A new method for finding amicable pairs.*

NM-R9513. H. BOENDER, H.J.J. TE RIELE. *Factoring integers with large prime variations of the quadratic sieve.*

NM-R9514. J.G.L. BOOTEN, D. FOKKEMA, G.L.G. SLEIJPEN, H.A. VAN DER VORST. *Jacobi-Davidson methods for generalized MHD-eigenproblems.*

NM-R9518. W.M. LIOEN. *On the diagonal approximation of full matrices.*

NM-R9524. G.L. COHEN, H.J.J. TE RIELE. *On ϕ-amicable pairs,* (with appendix).

NM-R9525. G.L. COHEN, H.J.J. TE RIELE. *Iterating the sum-of-divisors function.*

Other Publications

G.L.G. SLEIJPEN, J.G.L. BOOTEN, D.R. FOKKEMA, H.A. VAN DER VORST (1995). Jacobi-Davidson type methods for generalized eigenproblems and polynomial eigenproblems: Part I, Universiteit Utrecht, Department of Mathematics, Preprint nr. 923.

J.G.L. BOOTEN, H. VAN DER VORST (1995). Cracking large-scale eigenvalue problems, Universiteit Utrecht, Department of Mathematics, Preprint nr. 935.

DEPARTMENT OF SOFTWARE TECHNOLOGY

Staff 1995

- Computational Models – AP1

  - J.W. de Bakker
  - P. Di Gianantonio
  - B.P.F. Jacobs
  - C.H.M. van Kemenade
  - J.J.M.M. Rutten
  - D. Turi
  - M. van Wezel
  - H. Wiklicky

- Concurrency and Real-Time Systems – AP2

  - F.W. Vaandrager
  - D.J.B. Bosscher
  - W.O.D. Griffioen
  - A.S. Klusener (joint AP2/AP3)
  - J. Romijn
  - J.G. Springintveld

- Extensible Programming Environments – AP3

  - P. Klint
  - T.B. Dinesh
  - J. Heering
  - J. Kamperman
  - S. Klusener (joint AP2/AP3)
  - D. Naidich
  - F. Tip
  - H.R. Walters

- Algebraic and Syntactic Methods – AP4

  - J.W. Klop
  - G. Barthe
  - I. Bethke
  - H.J. Elbers
  - M. Marchiori
  - F. van Raamsdonk

- Logic and Language – AP5a

  - K.R. Apt
  - A. Bracciali
  - J.J. Brunekreef
  - S. Etalle
  - M. Gabbrielli
  - E. Marchiori
  - A. Schaerf
  - F. Teusink

- Logic and Language – AP5b

  - D.J.N. van Eijck
  - P.J.E. Dekker
  - S. van Dongen (joint AM1)
  - A.V. Groenink
  - J. Jaspars
  - W.P.M. Meyer Viol
  - M. de Rijke
  - W.C. Rounds

- Secretary: J.J. Bruné-Streefkerk

Computational Models – AP1

Staff

- Prof. dr. J.W. de Bakker, department head and group leader
- Dr. P. Di Gianantonio, Eurofocs fellow (from March 23 till September 23)
- Dr. B.P.F. Jacobs, post-doc
- Drs. C.H.M. van Kemenade, Ph.D. student
- Dr. J.J.M.M. Rutten, researcher
- Drs. D. Turi, Ph.D. student
- Drs. M. van Wezel, (TEG, from February 15)
- Dr. H. Wiklicky, visitor (Austria) (till July 1)

Scientific Report

De Bakker completed the work on the preparation of a comprehensive textbook/monograph entitled Control Flow Semantics, describing more than a decade of 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 published by MIT Press and appear April 1996.

As 28th language, De Bakker investigated the semantics of unguarded recursion. For a long time, the comparative semantics of this notion, especially when based on metric tools, has remained elusive, but now a full treatment seems in sight.

Rutten has continued the work on transition systems and coalgebras (partly in the context of the SION project 'Non-well-founded sets and programming language semantics'). In particular, a calculus of transition systems has been developed, with as main ingredients coalgebras, homomorphisms and bisimulations, along the lines of universal algebra. As an 'exercise in coalgebra', special attention has been paid, in joint work with B.P.F. Jacobs, to the example of the co-inductive natural numbers. Some basic definitions (addition) and proofs (addition is commutative) have been given using coinduction. A start has been made with the application of coalgebra to probabilistic transition systems and programming languages (joint work with E. de Vink, Free University of Amsterdam).

Rutten has continued his work on generalized (ultra)metric domain theory, based on the work of F. Lawvere on generalized metric spaces. A number of basic results has been established, notably the solution of recursive domain equations (unifying the standard order-theoretic and metric approaches). In joint work with M. Bonsangue (Free University of Amsterdam) and F. van Breugel (McGill University), further results have been obtained on completion, topology, and powerdomains for generalized metric spaces. In all constructions, the metric Yoneda embedding turns out a crucial tool. As a first application, domains for quantitative simulation and bisimulation have been defined.

Jacobs has been employed by the NWO 'HOOP' project on 'Higher Order Object-Oriented Processes'. His work has concentrated on the semantics of object-oriented concepts, starting from the notion of a co-algebra. This is the formal dual of an algebra. Co-algebras are especially useful in describing state-based dynamical systems (like objects). For example, using these coalgebras a semantical explanation has been given of inheritance, dual to the explanation of parametrization in algebraic specification. Present and future research concentrates on the use of these coalgebras in studying other dynamical systems (including continuous and hybrid systems). Such systems may be organized in suitable categories of processes, having structure familiar from process theory (like renaming, composition, replication and feedback).

Turi has been writing his thesis *Functorial Operational Semantics and its denotational dual* where a general theory linking operational and denotational semantics is introduced. An operational semantics is functorial when it is a suitable categorical *lifting* of the *syntax*. The basic property is that it always coinduces a denotational semantics and the main theorem is that this is always *adequate* wrt the operational one. Dually, every functorial denotational semantics (a suitable lifting of the *behaviour*) induces an equivalent functorial operational semantics. *Basic process algebra* (denotationally) and *GSOS* (operationally) are shown to be functorial. (This work has been started during Daniele Turi's visit to LFCS, Edinburgh.)

Di Gianantonio Pietro Di Gianantonio has visited the CWI from March to September 1995 working on two subjects, namely real numbers computability and the problem of full abstraction for non-deterministic programming languages. For the latter subject he has carried forth his study of new semantic structures consisting of cpos enriched with extra order relations, establishing some connections with the recent work on generalized ultrametric spaces by Marcello

Bonsangue, Franck van Breugel, and Jan Rutten. For the former subject, ie real numbers computability, he has worked on a new form of digit notation for real numbers, consisting in a binary notation having the golden ratio as base. (See 'Publications'.)

Wiklicky The main focus was on the continuation and conclusion of the research project 'A Calculus for Neural Networks', and in particular the investigation of existing connections between neural networks, dynamical systems and discrete structures, like proofs in (linear) logic.

Whereas computational processes – sequential as well as concurrent ones – usually are investigated in theoretical computer science within the framework of (mathematical) logic and/or discrete mathematics (both in semantics on one and in complexity theory on the other side) one sometimes – especially in the context of evolutionary programming and neural networks – is also interested in additional, continuous aspects of (computational) processes, like stability, similarity or optimality. This makes it necessary to establish a connection between discrete and continuous process concepts.

The particular approach towards comparing and integrating both frameworks was based on a functional analytical model of algorithms. Operator algebras, in particular especially well behaved ones like C*-algebras, provide a general framework for investigations concerning computational processes – both from a logical point of view as well as seen in evolutionary computing. Such algebras are not only of relevance in several mathematical disciplines dealing with dynamic processes, but also play an important role within logic or semantic models, like Girard's Geometry of Interaction.

Van Kemenade has continued his work on evolutionary Air Traffic Flow management (ATFM) and multi-parent recombination operators. The ATFM research is joint work with with J.N. Kok (Leiden University) and J.M. van den Akker (National Aerospace Laboratories NLR). The research involved in multi-parent recombination operators is joint work with A.E. Eiben and J.N. Kok (Leiden University). Further research involved application of principles from evolution to (un)constrained numerical optimization problems, which resulted in the development of the Cluster Evolution Strategies.

Van Wezel started his work on applications of neural networks and genetic algorithms. Projects were carried out for Nijenrode University, KLM-cargo, Rijkswaterstaat, TVA developments, and TNO health and prevention. For each project, a report was written.

As preparation for a Ph.D. project, literature studies were conducted in the fields of combinatorial optimization, multivariate data analysis, and mathematical statistics.

Organization of Conferences, Workshops, Courses, etc.

- The CWI was 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 was Rutten. The sixth workshop of MASK was organized by the University of Pisa and took place in Alghero, Italy.

  Rutten has been co-organizer of a special session on topology and computer science of the International Summer Conference on Topology and its Applications, August 1995, Portland, Maine.
- 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), prof. dr. J.N. Kok (RUL), 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

- *Working visit LFCS*, Edinburgh, UK (prof. G. Plotkin): D. Turi, till April 30.
- *CLICS-TYPES, Workshop on Categories and Type Theory*, Goteborg, Sweden, January 8–11: B.P.F. Jacobs (Two invited talks: Fibrations in Logic and Type Theory and Aspects of Co-algebras).
- *First Nordic Workshop on Genetic Algorithms*, Vaasa, Finland, January 9–13: C.H.M. van Kemenade ((An evolutionary approach to time constrained routing problems).
- *Working visit BRICS*, Aarhus, Denmark, January 16–February 15: B.P.F. Jacobs.
- *Austrian Research Institute for AI*, Vienna, Austria, January 27: H. Wiklicky (Elemente einer analytischen Algorithmik: Operatoren, Algebren und (neuronale) Netzwerke).
- *Review ESPRIT Basic Research Action Coordination*, London, UK, February 3: J.W. de Bakker.
- *Working visit LITP*, Paris, France (prof. M. Nivat), March 6–8: M. Bonsangue, J.J.M.M. Rutten (Elements of generalized ultrametric domain theory).

- *Mathematical Foundations of Program Semantics '95*, New Orleans, USA, March 29–April 1: B.P.F. Jacobs (Subtypes and bounded Quantification from a fibred Perspective), J.J.M.M. Rutten.
- *Seminar on Object-orientation and Persistence*, Dagstuhl, Germany, April 3–7: B.P.F. Jacobs, J.J.M.M. Rutten.
- *British Colloquium on Theoretical Computer Science*, Swansea, UK, April 3: J.W. de Bakker (The three dimensions of semantics).
- *European Science and Technology Assembly*, Brussels, Belgium, April 5, 6 and October 17: J.W. de Bakker.
- *STRICT*, Berlin, Germany, May 10–12: J.W. de Bakker (The three dimensions of semantics).
- *IMU meeting*, Paris, France, May 12–14: J.W. de Bakker.
- *Peripatetic Seminar on sheaves and logic*, Genua, Italy, May 13–14, B.P.F. Jacobs, J.J.M.M. Rutten (The Yoneda Lemma in generalized ultrametric domain theory).
- *Sixth MASK workshop*, Alghero, Italy, May 17–19: J.W. de Bakker, M. Bonsangue (Generalized ultrametric spaces: completion and topology), F. van Breugel (From branching to linear metric domain (and back)), P. Di Gianantonio (Enriched CPO's for nondeterminism), B.P.F. Jacobs (Objects and classes, co-algebraically), J.J.M.M. Rutten, D. Turi (Functiorial operational semantics and its denotational dual).
- *Workshop on Logic, Domains and Programming Languages*, Darmstadt, Germany, May 25–27: P. Di Gianantonio.
- *Seventh Dutch Conference on Artificial Intelligence*, Rotterdam, June 22–23: C.H.M. van Kemenade ((Multi-Parent Recombination to overcome Premature Convergence in Genetic Algorithms).
- *AMAST '95*, Montreal, Canada, July 3–7: B.P.F. Jacobs (Mongruences and cofree coalgebras).
- *Working visit University of Calgary*, Galgary, Canada, July: B.P.F. Jacobs.
- *Working Visit McGill University*, Montreal, Canada (dr. C. Hermida and dr. F. van Breugel), July 10–14: B.P.F. Jacobs.
- *Summer Conference on General Topology and Applications*, Portland, Maine, USA, August 8–12: J.J.M.M. Rutten (Generalized ultrametric domain theory: completion, topology, powerdomains).
- *Working Visit McGill University*, Montreal, Canada (prof. P. Panangaden and dr. F. van Breugel), August 14–16: J.J.M.M. Rutten (Generalized ultrametric domain theory).
- *Workshop on Computability and Complexity in Analysis*, Hagen, Germany, August 19–20: P. Di Gianantonio.
- *Fifth Belgian-Dutch Conference on Machine Learning*, Brussels, Belgium, September 15, C.H.M. van Kemenade ((A Two-level Evolution Strategy: balancing global and local search).
- *City University London*, London, UK October 2: H. Wicklicky.
- *Peripatetic seminar on sheaves and logic* Edinburgh, UK, October 7–8: B.P.F. Jacobs (Inheritance and co-free constructions).
- *World Wide Web Consortium Europe*, Founding Meeting, Paris, France, November 1–2: J.W. de Bakker.

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 Section Informatics, 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 IFIP Working Group 2.2 on Formal Description of Programming Concepts
- Local organizer, IFIP Working Group 2.2 Meeting on Formal Description of Programming Concepts
- Board member IPA, Dutch Graduate School Institute for Programming and Algorithmics
- Member SION Beoordelingscommissie Onderzoeksvoorstellen
- Project leader SION project HOOP: Higher Order and Object-Oriented Processes
- Site leader, EU Human Capital and Mobility Network/Fellowships to Institutes project EUROFOCS
- Program committee member, section Topology and Computer Science, International Summer Conference on Topology and its Applications, University of Maine, August 10–13

- Reviewer EU Basic Research Action Coordination
- Referee EU ESPRIT Long Term Research proposals
- Member Ph.D. Committee, M. van Hulst, UU

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)
- Member of the editorial board of Elseviers 'Electronic Notes in Theoretical Computer Science'.
- Member of the programme committee of CONCUR'96
- Board member of the 'NVTI' (Dutch Association of Theoretical Computer Science)

Papers in Journals and Proceedings

F. ALESSI, P. BALDAN, G. BELLÉ, J.J.M.M. RUTTEN (1995). Solutions of functorial and non-functorial metric domain equations. *Proceedings of the Eleventh Conference on the Mathematical Foundations of Programming Semantics*, ENTCS, 1, Elsevier.

B. BACK, G. OOSTEROM, K. SERE, M. VAN WEZEL (1995). Intelligent Information Systems within Business: Bankruptcy Predictions Using Neural Networks. *Proceedings of the European Conference on Information Systems*, Athens, Greece.

B. BACK, K. SERE, M. VAN WEZEL (1995). Bankruptcy Prediction (Choosing the Best Set of Bankruptcy Predictors). J.T. ALANDER (ed.). *Proceedings of the Nordic Workshop on Genetic Algorithms '95*, University of Vaasa, Finland, 285–296.

M. BONSANGUE, B.P.F. JACOBS, J. KOK (1995). Duality beyond sober spaces: topological spaces and observation frames. *Theor. Comp. Sci.* **151**(1), 79–124.

P. DI GIANANTONIO, F. HONSELL, G. PLOTKIN, Countable non-determinism and the lambda-calculus. *Nordic Journal of Computing*, 2, 126–145.

A.E. EIBEN, C.H.M. VAN KEMENADE, J.N. KOK (1995). Orgy in the Computer: Multi-Parent Reproduction in Genetic Algorithms. F. MORAN, A. MORENO, J.J. MERELO, P.CHACON (eds.). *Proceedings of the Third European Conference on Artificial Life (LNAI 929)*, Springer-Verlag, Berlin Heidelberg, 934–945.

C. HERMIDA, B.P.F. JACOBS (1995). An algebraic view of structural induction. L. PACHOLSKI, J. TIURYN (eds.). *Computer Science Logic 1994*, Springer LNCS 933, Berlin, 412–426.

C. HERMIDA, B.P.F. JACOBS (1995). Induction and coinduction via subset types and quotient types. P. DYBJER, R. POLLACK (eds.). *Informal Proceedings of the Joint CLICS-TYPES Workshop on Categories and Type Theory, Prog. Meth. Group*, Report 85, Goteborg Univ. and Chalmers Univ. of Techn.

B.P.F. JACOBS (1995). Subtypes and bounded quantification from a fibred perspective. *Electr. Notes in Theor. Comp. Sci.* **1**.

B.P.F. JACOBS (1995). Mongruences and cofree coalgebras. V.S. ALAGAR, M. NIVAT (eds.). *Algebraic Methods and Software Technology*, Springer LNCS 936, Berlin, 245–260.

B.P.F. JACOBS (1995). Parameters and Parametrization in Specification using distributive categories. *Fund. Inform.* **24**(3), 209–250.

B.P.F. JACOBS (1995). Bisimulation and Apartness in Coalgebraic specification. P. DYBJER, R. POLLACK (eds.). *Informal Proceedings of the Joint CLICS-TYPES Workshop on Categories and Type Theory*, Prog. Meth. Group, Report 85, Goteborg Univ. and Chalmers Univ. of Techn.

J.J.M.M. RUTTEN (1995). A calculus of transition systems (towards universal coalgebra), Modal Logic and Process Algebra, a bisimulation perspective. A. PONSE, M. DE RIJKE, Y. VENEMA (eds.). *CSLI Lecture Notes No. 53*, CSLI Publications, Stanford, 231–256.

C.H.M. VAN KEMENADE, C.F.W. HENDRIKS, H.H. HESSELINK, J.N. KOK (1995). Evolutionary computation in Air Traffic Control Planning. S. FORREST (ed.). *Proceedings of the Sixth International Conference on Genetic Algorithms*, Morgan Kaufmann, San Francisco, California, 611–616.

C.H.M. VAN KEMENADE, J.N. KOK (1995). Time Constrained Routing. J.T. ALANDER (ed.). *Proceedings of the First Nordic Workshop on Genetic Algorithms*, University of Vaasa, Finland, 107–121.

C.H.M. VAN KEMENADE, A.E. EIBEN (1996). Multi-Parent Recombination to overcome Premature Convergence in Genetic Algorithms. J.C. BIOCH, Y.-H TAN (eds.). *Proceedings of the Seventh Dutch Conference on Artificial Intelligence*, Erasmus University, Rotterdam, The Netherlands, 137–146.

C.H.M. VAN KEMENADE, J.N. KOK, A.E. EIBEN (1995). Controlling the Convergence of Genetic Algorithms by Tuning the Disruptiveness of Recombination Operators. *Proceedings of the Second IEEE conference on Evolutionary Computation*, IEEE Service Center, Piscataway, NJ, 345–351.

C.H.M. VAN KEMENADE (1995). A Two-level Evolution Strategy: balancing global and local search. C. DECAESTECKER, T. VAN DE MERCKT

(eds.). *Proceedings of the Fifth Belgian-Dutch Conference on Machine Learning (TR/IRIDIA/95-16)*, Université Libre de Bruxelles, Belgium, 49–60.

E. RORIJE, M.C. VAN WEZEL, W.J.G.M. PEIJNENBURG (1995). On the use of backpropagation neural networks in modeling environmental degradation. *SAR & QSAR in Environmental Research* 4(4).

M.C. VAN WEZEL, W. BAETS (1995). Predicting Market Responses with a Neural Network: the Case of Fast Moving Consumer Goods. *Marketing Intelligence and Planning* 13(7).

CWI Reports

CS-R9503. J.J.M.M. RUTTEN, *A calculus of transition systems (towards universal coalgebra)*.

CS-R9507. J.J.M.M. RUTTEN. *Elements of generalized ultrametric domain theory*.

CS-R9536. B.P.F. JACOBS. *Objects and classes, coalgebraically*.

CS-R9547. C.H.M. VAN KEMENADE, J.N. KOK. *An evolutionary approach to time constrained routing problems*.

CS-R9548. A.E. EIBEN, C.H.M. VAN KEMENADE, J.N. KOK. *Orgy in the computer: multi-parent reproduction in genetic algorithms*.

CS-R9549. C.H.M. VAN KEMENADE, J.N. KOK. *Multi-parent recombination to overcome premature convergence in genetic algorithms*.

CS-R9550. C.H.M. VAN KEMENADE, C.F.W. HENDRIKS, H.H. HENSELINK, J.N. KOK. *Evolutionary computation in air traffic control planning*.

CS-R9558. C.H.M. VAN KEMENADE, J.N. KOK, A.E. EIBEN. *Raising GA performance by simultaneous tuning of selective pressure and recombination discruptiveness*.

CS-R9559. C.H.M. VAN KEMENADE. *A two-level evolution strategy balancing global and local search*.

CS-R9560. M.M. BONSANGUE, F. VAN BREUGEL, J.J.M.M. RUTTEN. *Generalized ultrametric spaces: completion, topology, and powerdomains via the Yoneda embedding*.

CS-R9564. B.P.F. JACOBS. *Inheritance and Cofree Constructions*.

Other Publications

J.W. DE BAKKER, F. VAN BREUGEL (1995). *Metric Semantics for Second Order Communication*. Technical Report SOCS-95-4, School of Computer Science, McGill University, July.

P. GASTIN, J.J.M.M. RUTTEN editors of a special issue of *Theoretical Computer Science* dedicated to the first International workshop on 'Topology and Completion in Semantics' 151(1).

Visitors

- F.C. van Breugel, McGill University, Montreal, Canada, May 7–13.
- E. Best, University of Hildesheim, Hildesheim, Germany, D. Bjoerner, University of the United Nations, Macau, E. Boerger, University of Pisa, Pisa, Italy, M. Broy, Technical University, Munich, Germany, R. Gorrieri, University of Bologna, Bologna, Italy, P.E. Lauer, McMaster University, Hamilton, Canada, E.J. Neuhold, GMD, Darmstadt, Germany, E.-R. Olderog, University of Oldenburg, Oldenburg, Germany, June 12–14.
- M. Baldamus, TU Berlin, Germany, July 16–19.
- U. Montanari, University of Pisa, Pisa, Italy, October 10.
- L. Pooyan, TU Berlin, Germany, December 11–14.

Concurrency and Real-Time Systems – AP2

Staff

- Dr. F.W. Vaandrager, group leader
- Drs. D.J.B. Bosscher, Ph.D. student
- Drs. W.O.D. Griffioen, Ph.D. student
- Dr. A.S. Klusener, project member
- Drs. J.M.T. Romijn, Ph.D. student (from August 1)
- Dr. J.G. Springintveld, post-doc (from July 1)

Scientific Report

Frits Vaandrager continued his cooperation with Prof. Nancy Lynch (MIT). Work was done to revise two papers: 'Forward and backward simulations Part II: Timing-based systems' and 'Action transducers and timed automata', which have been accepted for publication in *Information and Computation* and *Formal Aspects of Computing*, respectively. Also, Vaandrager and Lynch collaborated with Dr. Roberto Segala (Bologna) and H.B. Weinberg (MIT) on a paper about hybrid I/O automata. In this paper, which has been presented during an invited talk at the DIMACS Workshop on Verification and Control of Hybrid Systems, New Brunswick, NJ, USA, a new automaton model is introduced that is capable of describing both continuous and discrete behavior. The model, which extends the timed I/O automaton model of Lynch et al and the phase transition system models of Manna, Maler and Pnueli, allows communication among components using both shared variables and shared actions. Currently, the results

of this paper are being applied at MIT in a number of projects in the areas of personal rapid transit and intelligent vehicle highway systems.

Together with Jan Springintveld, a start was made with the development of a testing theory for timed automata in the style of Alur and Dill, analogous to the testing theory for finite automata that has been proposed by Kohavi, Chow and others. An initial study led to the conclusion that in order to develop such a timed testing theory, it is essential to be able to minimize timed automata. Unfortunately this is not possible for timed automata as proposed by Alur and Dill. Therefore, the research currently aims at the definition of a variant of the model of Alur and Dill which (modulo strong bisimulation semantics) is equally expressive as the original model but in which for each automaton an equivalent minimal automaton can be constructed.

The research with Dr. Rob van Glabbeek (Stanford) on splitting of actions that was initiated in 1987 was taken up again and has now finally been completed. In the resulting paper it is established that durational and structural aspects of actions can in general not be modeled in interleaving semantics, even when a time-consuming action is represented by a pair of instantaneous events denoting its start and finish. By means of a series of counterexamples it is shown that, for any n, it makes a difference whether actions are split in n or in $n + 1$ parts.

During an invited talk at the CONCUR conference in Philadelphia, Vaandrager discussed a verification within the I/O automaton model of a simple distributed summation algorithm due to Segall. New in this correctness proof is the use of prophecy variables to prove correctness of a program transformation.

Doeko Bosscher has been working on three projects. Until about March he has been writing a (theoretical) paper on linearization of μCRL specifications and meanwhile implementing the technique in the ASF+SDF system. After that he and Griffioen have studied and solved the question of decidability of regularity of context-free processes to the affirmative. Lastly, he has solved the decidability of definability of regular processes in BPA with iteration.

David Griffioen did work on the formal verification of the Philips Audio Control Protocol using a tool for first order logic with quantification and data, the Larch Prover. This tool is a so called 'proof assistant' which means that it can check the correctness of a given proof. Due to the large amount of arithmetic with real numbers this verification amounted to a lot of work.

Based on this experience attention is directed to a completely automatic verification of this protocol by a tool. Griffioen has visited Prof. K. Larsen of Aalborg University to learn to handle the Uppaal tool. This is a model checker for timed automata. A version of the Audio Control Protocol has been verified using Uppaal. In this version there are two senders instead of one. This causes bus collisions which cause an additional level of complexity. Griffioen also worked together with D. Bosscher on the question whether it is decidable if a Basic Process Algebra proces is regular (with respect to strong bisimulation). This question could be answered affirmatively. In addition work has been done to compare different methods to analyse protocols by applying I/O automata methods on the Bakery Protocol which had already been verified in process algebra.

Judi Romijn works in the context of the Philips/SMC Project 'Specification, Testing and Verification of Software for Technical Applications'. She has started to work on the standard verification problem which has been formulated by Manfred Broy and Leslie Lamport. This example has been verified in the context of the I/O automata model. This problem appeared to give rise to some observations on liveness and fairness issues in the I/O automata model. Together with Frits Vaandrager this problem was dealt with.

Jan Springintveld. Together with Vaandrager the development has been started of a testing theory for Alur-Dill style timed automata, analogous to the testing theory that has been developed for finite state automata by Kohavi, Chow and others.

From an initial study of the literature it became apparent that it is technically essential to be able to minimize the automata. However, this operation cannot be defined for the Alur-Dill model. Therefore, a variant of this model has been developed in which every automaton can be minimalized and which is (modulo strong (timed) bisimulation) precisely as expressive as the Alur-Dill model. A report will appear soon.

Together with Groote (UU) a proof strategy has been developed for efficient verification of communication protocols. This resulted in a report which has been submitted.

Steven Klusener is mentioned in the report of AP3.

Organization of Conferences, Workshops, Courses, etc.

- *Final Meeting BRA CONCUR2*, CWI, Amsterdam, March 21–23: F.W. Vaandrager, D.J.B. Bosscher

and W.O.D. Griffioen (organiszation).

- *IPA Course 'Program Verification for the Working Computer Scientist'*, Egmond aan Zee and Amsterdam, October 16–18: F.W. Vaandrager and W.O.D. Griffioen (organization).
- *IPA Workshop 'Using Theorem Provers to Formalize Correctness Proofs of Programs'*, CWI, Amsterdam, October 19–20: F.W. Vaandrager and W.O.D. Griffioen (organization).

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

- *CSI-Colloquium, Computing Science Institute Nijmegen*, KUN, January 30: F.W. Vaandrager (Ontwikkeling van de Technisch Gerichte Informatica).
- *BRA Concur2 Meeting*, Cannes, France, March 30: F.W. Vaandrager (Verification of a distributed summmation algorithm).
- *Colloquium Graduate School of Systems and Control*, Utrecht, May 1: F.W. Vaandrager (Linear hybrid systems).
- *Second European Workshop on Real-Time and Hybrid Systems*, Grenoble, France, May 31 – June 2: F.W. Vaandrager (Linear hybrid systems, invited lecture).
- *Meeting of IFIP WG 2.2*, CWI, Amsterdam, June 13–17: F.W. Vaandrager (Linear hybrid systems).
- *Workshop HCM Network EXPRESS*, Tarquinia, Italy, June 21–24: F.W. Vaandrager (Action transducers and timed automata).
- *Sixth International Conference on Concurrency Theory (CONCUR'95)*, Philadelphia, Pennsylvania, USA, August 21–24: F.W. Vaandrager (Verification of a distributed summation algorithm, invited lecture).
- *Working visit Massachusetss Institute of Technology* (prof. Lynch), Cambridge, USA, August 25–31: F.W. Vaandrager.
- *IPA Course 'Program Verification for the Working Computer Scientist'*, Egmond aan Zee and Amsterdam, October 16–18: F.W. Vaandrager (The I/O automaton model, tutorial).
- *DIMACS Workshop on Verification and Control of Hybrid Systems*, New Brunswick, New Jersey, USA, October 22–25: F.W. Vaandrager (Hybrid I/O automata, invited lecture).
- *ITT Colloquium*, CSI, KUN, Nijmegen, December 6: F.W. Vaandrager (Live I/O automata).
- *IPA introductieweek*, Egmond aan Zee. Themes: 'Program Verification for the Working Computer Scientist' and 'Using Theorem Provers/Proof Checkers to Formalize Correctness Proofs of Programs' October 16–20: Judi Romijn.

- *Colloquium* TU Twente, Faculteit Informatica, groep Formele Methoden and Tools, December 15: Judi Romijn (A Note on Fairness in I/O Automata).
- *Workshop on Higher-Order Algebra, Logic and Term Rewriting (HOA '95)* Paderborn, Germany, September 22: Jan Springintveld (Third-Order Matching in the Polymorphic Lambda Calculus).
- *Nederlandse Test Conferentie*, KPN Research, Leidschendam, The Netherlands, December 12: Jan Springintveld (Towards Testing Real-Time Systems)
- *IFIP WG 6.1 International Workshop on Protocol Test Systems (IWPTS '95)*, Evry, France, September 4–6: Jan Springintveld.
- *Computer Science Logic*, Paderborn, Germany, September 23–29: Jan Springintveld.
- *IPA terugkomdagen*, Ameland, The Netherlands, March 9–10: W.O.D. Griffioen (Proof-checking of I/O-automata proofs).
- *Concur2 meeting*, Cannes, France, March 30: W.O.D. Griffioen (Proof-checking of I/O-automata proofs).
- *Section Applied Logic, Department of Philosophy*, Utrecht, The Netherlands, May 23: W.O.D. Griffioen (Using LP for protocol verification + Demo).
- *Computing Science in the Netherlands*, Jaarbeurs, Utrecht, The Netherlands, November 27: W.O.D. Griffioen (The Bakery Protocol).
- *TACAS'95*, Aalborg, Denmark, May 19–20: D.J.B. Bosscher (Linearisation of μCRL specifications).
- *Summerschool Distributed Computing*, Siena, Italy, September 20–28: D.J.B. Bosscher, W.O.D. Griffioen.
- *Final meeting CONCUR2*, Amsterdam, The Netherlands, October 9–10: D.J.B. Bosscher.

Membership of Committees and Other Professional Activities

AP2:

- 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)
- SION Project 612-33-001. 'Classifying Proof Techniques for Propositional Logic'. Together with Technical University Delft, Department of Technical Mathematics and Computer Science, (1 August 1995 – 1 August 1999)
- SION Project 612-316-125. 'Checking Verifications of Concurrent Systems with Type Theory Tools'. Together with Utrecht University, Department of Philosophy, (16/6/1994 – 16/6/1998)

F.W. Vaandrager:

- Associate professor (Universitair Hoofddocent) at the University of Amsterdam (until April 1995)
- Full professor at the University of Nijmegen (starting from December 1995)
- Scientific manager ESPRIT Basic Research Action no. 7166, Calculi and Algebras of Concurrency: Extensions, Tools and Applications (CONCUR2).
- Coordinator (together with J.W. Klop) of HCM cooperation network EXPRESS
- Member Programme Committee AMAST'95
- Member Programme Committee TACAS'96
- Moderator of CONCURRENCY email forum (`concurrency@cwi.nl`). Active forum focusing on concurrency theory, with a subscription list of about 650, including approximately 25 subsidiary lists
- Board member Dutch Graduate School *Institute for Programming Research and Algorithmics*
- Member Dutch Graduate School in Logic
- Member IFIP Working Group 2.2 on Formal Description of Programming Concepts
- Member European Research Action on Verification and Validation Methods for Formal Descriptions (COST Project 247)
- Member Working Group Embedded Software, Ministerie van Economische Zaken

W.O.D. Griffioen:

- Member Dutch Graduate School *Institute for Programming Research and Algorithms*

J. Springintveld:

- Member Dutch Graduate School *Institute for Programming Research and Algorithmics*

J.M.T. Romijn:

- Member Dutch Graduate School *Institute for Programming Research and Algorithmics*

D.J.B. Bosscher:

- Member Dutch Graduate School in Logic

Papers in Journals and Proceedings

J. SPRINGINTVELD (1995). Third-Order Matching in the Polymorphic Lambda Calculus. *Proceedings*

Workshop on Higher-Order Algebra, Logic and Term Rewriting (HOA '95), Paderborn, Germany (accepted to final proceedings, which will appear as LNCS volume).

N.A. LYNCH, F.W. VAANDRAGER (1995). Forward and backward simulations Part I: Untimed systems. *Information and Computation* 121(2), 214–233.

R. DE NICOLA, F.W. VAANDRAGER (1995). Three logics for branching bisimulation. *Journal of the ACM* 42(2), 458–487.

F.W. VAANDRAGER (1995). Verification of a distributed summation algorithm. I. LEE, S.A. SMOLKA (eds.). *Proceedings 6th International Conference on Concurrency Theory (CONCUR'95)*, Philadelphia, PA, USA, LNCS 962, Springer-Verlag, 190–203.

D.J.B. BOSSCHER, W.O.D. GRIFFIOEN (1995). Een Philips-protocol correct bewezen. *Informatie* 37(6), 379–384.

W.O.D. GRIFFIOEN, H.P. KORVER (1995). The bakery protocol: A comparative case-study in formal verification (abstract). *Proceedings of CSN'95*, Stichting Mathematisch Centrum, 109–121.

D.J.B. BOSSCHER, A. PONSE (1995). Translating a Process Algebra with Symbolic Data Values to Linear Format. UFFE H. ENGBERG ET AL (eds.). *Proceedings of TACAS 95*, BRICS Notes Series, NS-95-2, 119–130.

CWI Reports

CS-R9502. C. BONINI, W.J. FOKKINK, A. LESCH. *A reference model for teleconferencing systems.*

CS-R9505. F.W. VAANDRAGER. *Verification of a distributed summation algorithms.*

CS-R9508. W.J. FOKKINK, R.J. VAN GLABBEEK. *Ntyft/ntyxt rules reduce to ntree rules.*

CS-R9542. W.J. FOKKINK, A.S. KLUSENER. *An effective axiomatization for real time ACP.*

CS-R9553. R.J. VAN GLABBEEK, F.W. VAANDRAGER. *The difference between splitting in n and $n+1$.*

CS-R9566. J.F. GROOTE, J. SPRINGINTVELD. *Focus Points and Convergent Process Operators. A proof strategy for protocol verification.*

CS-R9569. W.O.D. GRIFFIOEN, H.P. KORVER. *The bakery protocol: A comparative case-study in formal verification.*

CS-R9570. W.O.D. GRIFFIOEN. *Proof-checking an audio control protocol with LP.*

CS-R9578. N.A. LYNCH, R. SEGALA, F.W. VAANDRAGER, H.B. WEINBERG. *Hybrid I/O automata.*

CS-R9579. J.M.T. ROMIJN, F.W. VAANDRAGER. *A note on fairness in I/O automata.*

Other Publications

J.F. GROOTE, J. SPRINGINTVELD (1995). *Focus Points and Convergent Process Operators. A proof strategy for protocol verification*, Logic Group Preprint Series, no. 142, Department of Philosophy, Utrecht University, Utrecht.

J.F. GROOTE, J. SPRINGINTVELD (1995). Towards Testing Real-Time Systems. *Handout Nederlandse Test Conferentie, KPN Research*, Leidschendam, The Netherlands.

Visitors

- R. van Glabbeek, University of Stanford, USA, March 20–22.
- Y. Gurevich, USA, September 9.

Extensible Programming Environments – AP3

Staff

- Dr. T.B. Dinesh, project member (supported by SION)
- J. Heering, senior researcher
- Drs. J. Kamperman, project member
- Dr. A.S. Klusener (joint AP2/AP3), acquisition
- Prof. dr. P. Klint, group leader
- Dr. D. Naidich, project member (from October 1, supported by NWO)
- Dr. F. Tip, project member (until March 1)
- Dr. H.R. Walters, senior researcher (supported by SION)

Scientific Report

The group is involved in the design, implementation, and promotion of the ASF+SDF system for interactive language development and incremental programming environment generation. The system, which was developed in cooperation with INRIA Sophia-Antipolis and other partners in the ESPRIT GIPE and GIPE II projects, incrementally generates an interactive environment for the language being developed, so the latter can be used immediately. It is primarily a development tool for application languages. The system is distributed to commercial and academic customers by the Connexité company in Sophia-Antipolis as well as by CWI itself.

With the final review meeting in Amsterdam in April, the ESPRIT COMPARE project (Compiler Generation for Parallel machines—ESPRIT Project 5399) was concluded. Its end was further marked by F. Tip defending his Ph.D. thesis on generic debugging and software maintenance tools, work he did as a member of COMPARE in cooperation with J. Field and G. Ramalingam (IBM T.J. Watson Research Center). He accepted a position at the Watson Research Center.

In response to the needs expressed by several large Dutch banks, the emphasis in the group's work has been shifting towards the development of tools for system renovation, reverse engineering and software maintenance, and their incorporation in the ASF+SDF system. The above-mentioned work of Tip falls in this area and further work was done by T.B. Dinesh and J. Heering in cooperation with J.A. Bergstra (UvA) and J. Field (IBM T.J. Watson Research Center) in AP3.2 (see below). Furthermore, in cooperation with G. Wijers (ID-RESEARCH), P. Klint prepared the Resolver project, which was accepted and will be funded by Senter (Ministry of Economic Affairs), ABN-AMRO, and the ROC-CADE Group. Resolver will focus on the renovation of software for financial and banking applications. In 1995 a start was made with a literature study. The project proper will start in January 1996.

AP 3.1 – Implementation, maintenance, and promotion of the ASF+SDF system

The ASF+SDF system is being restructured using the ToolBus interconnection architecture under development by P. Klint in cooperation with J.A. Bergstra (University of Amsterdam). The ToolBus-based version of the system will be much more easily extendible than the current version, which is necessary in view of the software maintenance tools we want to add to it. The first version of the ToolBus was used in a variety of case studies. Based on this experience, a redesign of the ToolBus was completed resulting in the Discrete Time ToolBus.

AP3.2 – Generation of tools for program analysis and optimization from formal language definitions, and their integration into the ASF+SDF system

(a) (Bergstra/Dinesh/Field/Heering/Naidich—supported in part by SION project *Generic Tools for Program Analysis and Optimization*) The logical enrichment of the lazy store component of PIM, an algebraic 'machine' for imperative languages, and its implementation were finished. The implementation uses Knuth-Bendix completion and has reached the limits of what current completion systems such as RRL, TIP, and LP can do. Further progress requires

associative unification, but even without it the power of the enriched PIM is already considerable.

Mechanical verification of the PIM enrichment taxed the capabilities of the SPIKE and TIP provers, although verification by hand is straightforward. D. Naidich, who joined the project in October on an NWO visitor's grant, implemented the SPIKE system in ASF+SDF in order to be able to control the proof strategy of the system. He also started working on a survey of inductive theorem proving.

(b) (Kamperman/Walters—supported in part by SION project *Generic Tools for Program Analysis and Optimization*) A new, higher-capacity, version of the ASF2C compiler was finished. It incorporates various improvements to the Abstract Rewriting Machine (ARM), which is used as an intermediate level by the compiler. The machines currently supported are SGI/IRIX, Sun4/SunOS, Sun4/Solaris, IBM SP1/AIX, HP-UX, 486 PC/LINUX, and 68K/MacOS. A preprocessor for the elimination of associative matching was finished. A lot of time was spent on documenting the compiler and the principles used in it.

(c) Dinesh is working with S. Üsküdarli (University of Amsterdam) on building a meta-environment for visual languages, based on the ASF+SDF Meta-Environment. The intention is to generate visual language environments based on visual algebraic specifications. With respect to this, a constraint based language VODL was developed to help construct 'visual lexicals', and its utility in building a visual algebraic specification environment (VASE) was studied.

AP3.3 – Implementation of term rewriting on the IBM SP1 parallel computer

(Kamperman) The Abstract Rewriting Machine and the GEL Graph Exchange Library were moved to the IBM SP1 machine under the AIX system—see AP3.2(b).

AP3.4 – Industrial Contracts

(a) (Klint) The Resolver software renovation proposal was accepted (see above).
(b) (A.S. Klusener with S.F.M. van Vlijmen (Department of Applied Logic, UU), and L. Schrijver and F. van der Duyn Schouten (BS)) Two projects were carried out for Nederland Haarlem, one of the largest Dutch companies in the field of traffic control systems. The project A.S. Klusener was especially involved in was the development of a dynamic regulation system prototype for a bus station. He imple-

mented the prototype in Perl and TCL/TK, internally connected by the ToolBus (see AP3.1).
(c) (Klusener—*Upgrade RISLA*) RISLA is a high-level specification language for financial products. It was developed in 1992 by A. van Deursen (at that time a member of AP3) jointly with CAP Volmac and MeesPierson. RISLA is a language to be used by financial experts to shorten the time-to-market of new products. In the summer, CAP Volmac and MeesPierson granted CWI a 20 person-months fl 192.000 order to upgrade RISLA by adding modularization to it as well as a query language (RISQUEST) for building modularized RISLA specifications on the basis of a graphically presented question/answer session. This project taxed the capabilities of the current version of the ASF+SDF system, but it could not have been successful without it.
(d) (Walters) A small project was carried out for PTT Telecom in the field of specification languages.

Organization of Conferences, Workshops, Courses, etc.

- T.B. Dinesh and J.F.Th. Kamperman (with M.G.J. van den Brand (UvA), A. van Deursen (TUE) and E. Visser (UvA))organized the ASF+SDF '95 Workshop (Amsterdam, May 11–12).
- P. Klint was a member of the organizing committee of the Ministry of Economic Affairs Conference on the Strategic Meaning of Software (May 31, 1995).
- P. Klint and J.W. Klop (AP4) continued the organization of the monthly VIP colloquium.

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

- *Working visit Carnegie Mellon University*, Pittsburgh, USA, January 19–20: F. Tip.
- *POPL '95*, San Francisco, USA, January 22–25: F. Tip.
- *Amsterdams Logica Colloquium*, Amsterdam, February 3, P. Klint (The Discrete Time ToolBus).
- *BCTCS 11*, Swansea, UK, April 2–5: J. Heering (Invited talk: Algebraic specifications and proofs by induction).
- *RTA '95*, Kaiserslautern, Germany, April 4–7: J.F.Th. Kamperman (Lazy rewriting and eager machinery), H.R. Walters (Rewrite systems for integer arithmetic).
- *ESPRIT/COMPARE Final Review Meeting*, Amsterdam, April 11–12: P. Klint, A.S. Klusener.
- *Guest lecture*, TUE, April: J.F.Th. Kamperman, H.R. Walters (Implementatie van termherschrijfsystemen).

- *ESPRIT/SAGA Project Preparation Meeting*, Swansea, UK, April 25–28: J. Heering.
- *ASF+SDF '95*, Amsterdam, May 11–12: T.B. Dinesh (Injection misdemeanors), J. Heering (Invited talk: An algebraic machine for imperative programs), P. Klint (Invited talk: The evolution of implementation techniques in the ASF+SDF meta-environment), J.F.Th. Kamperman (The new ASF compiler: an exercise in self-applicability), H.R. Walters.
- *Guest lecture*, TUE, May 16: T.B. Dinesh (Using origin tracking to generate error reporters for typecheckers).
- *TAPSOFT '95*, Aarhus, Denmark, May 22–26: F. Tip (Generic techniques for source-level debugging and dynamic program slicing).
- *5th Eurographics Workshop on Programming Paradigms in Graphics (Eurographics '95)*, Maastricht, September 2–3: T.B. Dinesh (Visual Object Definition Language).
- *TeReSe Colloquium*, September, J.F.Th. Kamperman (Minimal term rewriting systems).
- *ADT '95*, Oslo, Norway, September 19–25: T.B. Dinesh (Implementation of PIM—a logic for imperative languages), J.F.Th. Kamperman (Minimal term rewriting), H.R. Walters (A model for I/O in equational languages with don't care non-determinism).
- *HOA '95*, Paderborn, Germany, September 21–23: J. Heering.
- *Novi Conference on Development Tools*, November 14, P. Klint (Invited talk: Systeemrenovatie: nachtmerrie of droom?).

Memberships of Committees and Other Professional Activities

J. Heering:
- Member Programme Committee HOA '95.

P. Klint:
- Member Programme Committee TAPSOFT '95, ESOP '96.
- President European Association for Programming Languages and Systems (EAPLS).
- Ph.D. advisor F. Tip, *Generation of Program Analysis Tools*, UvA, March 17.
- Ph.D. advisor (with F.E.J. Kruseman Aretz) B.W. Watson, *Taxonomies and Toolkits of Regular Language Algorithms*, TUE, September 15.
- Member Ph.D. committee J. Brunekreef, UvA, February 17; M. Aben, UvA, February 23; S. Etalle, UvA, June 7; G. Veltink, UvA, June 9; J. van Wamel, UvA, September 15; J. Verheul, TUD, Dec.

Papers in Journals and Proceedings

J.A. BERGSTRA, J. HEERING (1995). Homomorphism preserving algebraic specifications. *Information and Computation* **119**, 119–123.

J.A. BERGSTRA, P. KLINT (1995). Een architectuur voor componentkoppeling: de eerste ervaringen met de ToolBus. *Informatie* **37**(6), 370–378.

T.B. DINESH, S. ÜSKÜDARLI (1995). Towards a visual programming environment generator for algebraic specifications. *Proceedings VL'95, IEEE Symposium Visual Languages*, Darmstad, Germany.

T.B. DINESH, S. ÜSKÜDARLI (1995). Visual Object Definition Language. *Proceedings of the Fifth Eurographics workshop on Programming Paradigms in Graphics (Eurographics '95)*, CWI, Amsterdam, 109–124.

J. FIELD, G. RAMALINGAM, F. TIP (1995). Parametric program slicing. *Conference Record of the Twenty-Second ACM Symposium on Principles of Programming Languages*, ACM.

J.F.TH. KAMPERMAN, H.R. WALTERS (1995). Lazy rewriting and eager machinery. J. HSIANG (ed.). *Rewriting Techniques and Applications (RTA '95)*, Lecture Notes in Computer Science **914**, Springer-Verlag, 147–162.

F. TIP (1995). Generic techniques for source-level debugging and dynamic program slicing. P.D. MOSSES ET AL. (eds.). *TAPSOFT '95: Theory and Practice of Software Development*, Lecture Notes in Computer Science **915**, Springer-Verlag.

F. TIP (1995). A survey of program slicing techniques. *Journal of Programming Languages* **3**, 121–189.

H.R. WALTERS, H. ZANTEMA (1995). Rewrite systems for integer arithmetic. J. HSIANG (ed.). *Rewriting Techniques and Applications (RTA '95)*, Lecture Notes in Computer Science **914**, Springer-Verlag, 324–338.

CWI Reports

CS-R9572. H.R. WALTERS, J.F.TH. KAMPERMAN. *A model for I/O in equational languages with don't care non-determinism.*

CS-R9573. H.R. WALTERS, J.F.TH. KAMPERMAN. *Minimal term rewriting systems.*

CS-R9575. H.R. WALTERS, J.F.TH. KAMPERMAN, T.B. DINESH. *An extensible language for the generation of parallel data manipulation and control packages.*

CS-R9576. H.R. WALTERS, H. ZANTEMA. *Rewrite systems for integer arithmetic.*

Other Publications

J.A. BERGSTRA, T.B. DINESH, J. FIELD, J. HEE-RING (1995). *A complete transformational toolkit for compilers*, Report RC 20342, IBM T.J. Watson Research Center, Yorktown Heights.

J.A. BERGSTRA, P. KLINT (1995). *The Discrete Time ToolBus*, Report P9502, Programming Research Group, University of Amsterdam.

M.G.J. VAN DEN BRAND, A. VAN DEURSEN, T.B. DINESH, J.F.TH. KAMPERMAN, E. VISSER (eds.) (1995). *Proceedings ASF+SDF '95: a Workshop on Generating Tools from Algebraic Specifications*, Report P9504, Programming Research Group, University of Amsterdam.

A. VAN DEURSEN, F. TIP (1995). *The role of origin tracking in the Compare project*, COMPARE Deliverable.

T.B. DINESH, J.F.TH. KAMPERMAN, S. KLUSENER, H.R. WALTERS (1995). *The ASF+SDF specification of the flattening procedure in fSDL*, COMPARE Deliverable.

T.B. DINESH. (1995). Injection misdemeanors. *Proceedings ASF+SDF '95*.

J. HEERING, P. KLINT (1995). The prehistory of ASF+SDF. *Proceedings ASF+SDF '95*.

J.F.TH. KAMPERMAN EN H.R. WALTERS (1995). The new ASF compiler—an exercise in self-applicability. *Proceedings ASF+SDF '95*.

P. KLINT (1995). The evolution of implementation techniques in the ASF+SDF meta-environment. *Proceedings ASF+SDF '95*.

P. KLINT (1995). Over de rampzalige complexiteit van software mag niet gesproken worden. *Automatisering Gids*.

P. KLINT (1995). From line numbers to origins. E.H.L. AARTS ET AL. (eds.). *Simplex Sigillum Veri, Een Liber Amicorum voor Prof. dr. F.E.J. Kruseman Aretz*, Technical University Eindhoven, 215–230.

D. NAIDICH, T.B. DINESH (1995). Specifying an automated induction proof procedure in ASF+SDF. PROCEEDINGS ASF+SDF '95.

F. TIP (1995). *Generation of Program Analysis Tools*, Ph.D. Thesis, University of Amsterdam.

Visitors

- J. Field, IBM T.J. Watson Research Centre, New York, USA, March 15–22.

- D. Naidich, University of Iowa/Kiev, March 11–12 and October 15 – October 1996 (NWO grant).

Algebraic and Syntactic Methods – AP4

Staff

- Prof. dr. J.W. Klop, group leader
- Dr. G. Barthe, post-doc (from October 1), SMC/LAW
- Dr. I. Bethke, post-doc, SION, part-time position 0.5
- Drs. F. van Raamsdonk, Ph.D. student, SION
- Drs. H.J. Elbers, Ph.D. student, SION
- M. Marchiori, guest researcher (from October 6)

Scientific Report

Jan Willem Klop continued the cooperation with Z.M. Ariola (Univ. of Oregon), who was a guest researcher during the summer, on the subject of term graph rewriting. Some older work of last year was finalized. Another activity of Klop concerns writing a book on term rewriting, together with co-editors R.C. de Vrijer (VUA), M. Bezem (UU), and various chapter contributors. Van Raamsdonk and Klop have been involved this year for the last time in BRA Confer; this ESPRIT project ended in October (a prolongation as working group is attemped at present). The project was during its three year extension a continuous source of stimulation for both the work on term graph rewriting and higher-order rewriting.

Gilles Barthe has started his two year post-doc assignment in the framework of the WINST project. Initial work concerned theoretical foundations of theorem proving activities, notably on the 'two-level approach' and on congruence types. Also he is participating in the daily supervision of the Ph.D. work of Elbers.

Inge Bethke has completed together with J.W. Klop a report on homorphisms of partial combinatory algebras. This work has been presented at HOA 95 and will appear in the proceedings. In cooperation with R.C. de Vrijer (VUA) this study was continued, yielding a criterion for completability of partial combinatory algebras. A report about this will appear in the proceedings of LICS 96. Furthermore, an introductory chapter on lambda calculus in a forthcoming book on term rewriting systems (see J.W. Klop) was completed.

Hugo Elbers continued his Ph.D. work in the framework of the project WINST. The main goal of research for the WINST project is the development of tools for making Computer Algebra facilities

available inside proof development systems based on type theory. Several methods have been studied to automate equational reasoning in the proof checker LEGO. An experiment in which the Computer Algebra System Maple has been used as an oracle for producing verifiable succinct proofs for the primality of prime numbers has been carried out.

Massimo Marchiori started a second stay in our department as a guest researcher, for half a year. He continued to work on modularity of properties in term rewriting, in the abstract setting of a theory of 'vaccins'.

Femke van Raamsdonk continued her study of higher-order rewriting, working towards completion of a dissertation scheduled to appear spring 1996. In cooperation with Paula Severi (TUE) new proofs for some classical theorems such as finite developments and strong normalization for simply typed lambda calculus were given.

Organization of Conferences, Workshops, Courses, etc.

- J.W. Klop organized a symposium day of the NVTI (Nederlandse Vereniging voor Theoretische Informatica), on March 17, Utrecht.
- J.W. Klop is organizing together with P. Klint the CWI Colloquium VIP (Vragen uit de Informatica Praktijk).

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

- *BRA Workshop on Users and Designers of Proof Systems*, Antibes, France, March 2–3: H.J. Elbers (Some basic techniques for algebraic simplification in LEGO).
- *Promotion J. Barros*, Oxford, UK, March 21: J.W. Klop (external examiner).
- *Confer Workshop*, Paris, France, April 10–12: F. van Raamsdonk.
- *2nd Internatinal Workshop on Termination*, La Bresse, France, May 29–31: F. van Raamsdonk (On normalisation in lambda calculus).
- *HOA '95*, Paderborn, Germany, September 20–23: I. Bethke (Collapsing partial combinatory algebras), J.W. Klop, F. van Raamsdonk (Normalising strategies).
- *CSL '95*, Paderborn, Germany, September 24–29: J.W. Klop (Ten topics in term rewriting).
- *Final review meeting BRA CONFER*, Munich, Germany, October 10–14: J.W. Klop (Term graph rewriting).
- *CSN '95*, Utrecht, November 27–28: H.J. Elbers.

Memberships of Committees and Other Professional Activities

Jan Willem Klop:
- Professor in Computer Science at the Free University of Amsterdam
- Coordinator HCM Network EXPRESS
- Scientific Secretary of Nederlandse Vereniging voor Theoretische Informatica (NVTI)
- Editor of NVTI nieuwsbrief
- PC member CSN '95
- PC member SEGRAGRA workshop (Volterra, August '95)
- Member Advisory Editorial Board Journal of the Egyptian Mathematical Society
- Member Ph.D. Committee S. Etalle (UvA)
- External examiner J. Barros (University of Oxford)

Femke van Raamsdonk:
- Member organizing committee Algemeen CWI Colloquium

Papers in Journals and Proceedings

J.A. BERGSTRA, I. BETHKE, P. RODENBURG (1995). A propositional logic with 4 values: time, false, divergent and meaningless. *Journal of Applied Non-Classical Logics* 5(2), 199–217.

J.A. BERGSTRA, J.W. KLOP (1995). The algebra of recursively defined processes and the algebra of regular processes. A. PONSE, C. VERHOEF, S.F.M. VAN VLIJMEN (eds.). *Algebra of Communicating Processes*, Utrecht 1994, Workshops in Computing, Springer-Verlag, 1–25.

N. DERSHOWITZ, J.-P. JOUANNAUD, J.W. KLOP (1995). Problems in rewriting III. JIEH HSIANG, (ed.). *Proc. of 6th Intern. Conf. RTA-95*, Kaiserslautern, LNCS 914, Springer-Verlag, 457–471.

J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.-J. DE VRIES (1995). Infinitary lambda calculi and Bohm models. JIEH HSIANG, (ed.). *Proc. of 6th Intern. Conf. RTA-95*, Kaiserslautern, April 1995, Springer LNCS 914, 257–270.

J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.-J. DE VRIES (1995). From finite to infinite lambda calculi. *Bulletin of the section of Logic* 24(1), Univ. of Lodz, Dept. of Logic (Special issue containing abstracts of papers delivered at Workshop on non-standard logics and logical aspects of Computer science, Kanazawa, Japan, Dec. 5–8. 1994, editor Hiroakira Ono), 13–20.

J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.-J. DE VRIES (1995). Transfinite reductions in Orthogonal

Term rewriting Systems. *Inf. and Comp.* **119**(1), 18–38.

M. MARCHIORI (1995). Modularity of Completeness Revisited. J. HSIANG (ed.). *Proceedings of the Sixth International Conference on Rewriting Techniques and Applications*, LNCS 914, Springer-Verlag, 2–10.

M. MARCHIORI (1995). The functional side of logic programming. S.L. PEYTON JONES (ed.). *Proceedings of the ACM International Conference on Functional Programming Languages and Computer Architecture*, ACM Press, 55–65.

M. SCHMIDT-SCHAUSS, M. MARCHIORI, S.E. PANITZ (1995). Modular Termination of r-Consistent and Left-Linear Term Rewriting Systems. *Theoretical Computer Science* **149**(2), 361–374.

CWI Reports

CS-R9501. V. VAN OOSTROM, F. VAN RAAMSDONK. *Weak orthogonality implies confluence: the higher-order case.*

CS-R9529. I. BETHKE, J.W. KLOP. *Collapsing partial combinatory algebras.*

CS-R9535. J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.-J. DE VRIES. *Infinitary lambda calculus.*

CS-R9544. I. BETHKE, J.W. KLOP, R. DE VRIJER. *Completing partial combinatory algebras with unique head-normal forms.*

CS-R9545. F. VAN RAAMSDONK, P. SEVERI. *On normalisation.*

CS-R9552. Z.M. ARIOLA, J.W. KLOP. *Equational term graph rewriting.*

Other Publications

Z.M. ARIOLA, J.W. KLOP (1995). *Equational Term Graph Rewriting* IR-391, Vrije Universiteit Amsterdam, Fac. der Wiskunde en Informatica.

N. DERSHOWITZ, J.-P. JOUANNAUD, J.W. KLOP (1995). *Problems in Rewriting III*, IR-380, Vrije Universiteit Amsterdam, Fac. der Wiskunde en Informatica.

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

F. VAN RAAMSDONK, P. SEVERI (1995). *On Normalisation*, Computing Science Report 95/20, Eindhoven University of Technology.

Visitors

• Ian Mackie, Imperial College/Ecole Polytechnique, January 9–12.
• A. Middeldorp, University of Tsukuba, Japan,

March 5–7.
• F.-J. de Vries, NTT Research Labs, Kyoto, Japan, March 5–11.
• T. Hoare, University of Oxford, Oxford, UK, March 20–23.
• T. Lengauer, GMD, Bonn, Germany, March 20–22.
• N.G. de Bruijn, Eindhoven, March 31.
• Y. Toyama, JAIST, Japan, April 3–4.
• S. Hirokawa, University of Kyushu, Japan, May 11–12.
• Z.M. Ariola, University of Oregon, USA, July 1–31.
• R. Verma, INRIA, Rocquencourt, France, August 5–7.

Logic and Language – AP5a

Staff

• Prof. dr. K.R. Apt, group leader, since March 1, 1987
• A. Bracciali, guest student, from April 1 till September 1
• Dr. ir. J. J. Brunekreef, project member (0.4), till March 1
• Dr. S. Etalle, visitor, till April 1
• Dr. M. Gabbrielli, visitor, till March 1
• Dr. E. Marchiori, project member (0.5 from August 1)
• Dr. A. Schaerf, researcher, from July 10
• Drs. F. Teusink, Ph.D. student.

Scientific Report

K.R. Apt studied verification of parallel logic programs and foundations of logic programming with meta-variables. In another paper he advocated the use of arrays and bounded quantification in logic programming and constraint logic programing. Finally, he worked on his forthcoming book on logic programming and Prolog. The book will be published in 1996 by Prentice Hall.

A. Bracciali, a guest student (supported by the Erasmus programme) studied the extensions of logic programming that make it possible to express mutual exclusion and coordination by means of delay declarations and atomic unification.

J.J. Brunekreef continued his work 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 and allows the user to interact with the program by means of a menu of buttons and a focus operation. A publication on this implementation describes the design decisions and explains in detail the use of the system.

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S. Etalle, an ERCIM fellow, has continued his study on the correctness of some transformation operations for Logic and Constraint Logic Programs. Part of this work has been carried out in cooperation with M. Gabbrielli; this part was focused on the definition of applicability conditions for the Unfold, Fold and Replacement operations in the context of modular CLP. Further work was done in the direction of defining a transformation system for terminating pure prolog programs.

M. Gabbrielli, a visitor from the University of Pisa, supported by the HCM EUROFOCS project, worked on transformations of constraint logic programs and on semantic aspects of logic languages with delay declarations. Moreover he studied an extension of concurrent constraint programming which allows to model real-time aspects.

E. Marchiori (until July 31 employed by the BRA Esprit Project 'Compulog 2') worked on the termination of normal logic programs and of constraint logic programs. Moreover, in another paper, she introduced a new dataflow semantics for constraint logic programs, that was used to develop a parallel asynchronous execution model, and to define proof methods for run-time properties. Finally, she investigated compositional proof methods for proving termination and deadlock-freedom of logic programs with dynamic scheduling.
As of August 1 she has been working in the SION project 'Computational Intelligence for Constraint Logic Programming' and employed 50% at CWI and 50% at the University of Leiden (Prof. dr. J.N. Kok). Her current work deals with the integration of genetic and constraint programming.

A. Schaerf an ERCIM fellow, worked on the solution of various scheduling problems using constraint logic programming techniques. He also worked on timetabling problems using both constraint logic programming and local search techniques.

F. Teusink who works in the SION project 'Computational Aspects of Non-Monotonic Reasoning', finalized his work on abductive logic programming. He also worked jointly with Elena Marchiori on compositional proof methods for proving termination and deadlock-freedom of logic programs with dynamic scheduling. In the last quarter, he worked together with Sandro Etalle on modular logic programs.

As of January 1, 1996, the AP5 project will be transferred to the Department of Interactive Systems (IS) where it will become the IS4 project 'Logic Programming and Computational Linguistics'.

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

- *Compulog II Meeting*, Albufeira, Portugal, April 10–13: K.R. Apt, E. Marchiori (A Practical Methodology for Proving Termination of General Logic Programs), F. Teusink (Comparing negation in logic programming and in Prolog).
- *Working visit University of Pisa*, Pisa, Italy, April 30–May 27: K.R. Apt (5 lectures on 'Verification of Prolog Programs'.)
- *FMTA '95*, Warsaw, Poland, May 29–June 1: K.R. Apt (Declarative programming in Prolog).
- *CCP '95*, Venezia, Italy, May 29–31: E. Marchiori.
- *Working visit University of Venezia*, Italy (Prof. Cocco), June 1,: E. Marchiori (On Termination of Constraint Logic Programs).
- *LPNMR '95*, Lexington, USA, June 25–29: K.R. Apt.
- *Working visit IBM*, Hawthorne, USA, (dr. J. Jaffar), June 29–30: K.R. Apt.
- *AMAST '95*, Montreal, Canada, July 2–7: K.R. Apt (Verification of Logic Programs with Delay Declarations).
- *Mathematics of Program Construction '95*, Kloster Irsee, Germany, July 17–21: K.R. Apt (Arrays, Bounded Quantification and Iteration in Logic and Constraint Logic Programming).
- *ESSLLI '95 Summerschool*, Barcelona, Spain, August 14–25: F. Teusink.
- *IJCAI '95*, Montreal, Canada, August 19–25: E. Marchiori (A Methodology for Proving Termination of General Logic Programs).
- *1st Intl. Conf. on the Practice and Theory of Automated Timetabling (ICPTAT '95)*, Edinburgh, UK, August 29 – September 1: A. Schaerf (Local search techniques for high school timetabling).
- *GULP-PRODE '95*, Vietri, Italy, September 11–14: E. Marchiori (Arrays, Bounded Quantification and Iteration in Logic and Constraint Logic Programming (for K.R. Apt)).
- *PLILP '95*, Utrecht, September 20–22: E. Marchiori (A Dataflow Semantics for Constraint Logic Programs).
- *Final Compulog II Meeting*, CWI, Amsterdam, September 25–27: K.R. Apt (CWI's work on verification of logic programs with delay declarations), E. Marchiori, F. Teusink.
- *BENELOG '95*, Gent, Belgium, September 29: E. Marchiori, F. Teusink (Dynamic Scheduling: Deadlock Freedom Analysis).

- *International Logic Programming Symposium,* Portland, USA, December 4–7: F. Teusink (Proving termination of logic programs with delay declarations).

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, *Information and 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.
- Program committee member, 3rd Logic Programming and Non-Monotonic Reasoning Conference Lexington, USA, June 1995.
- Program committee member, International Logic Programming Symposium 1995 (ILPS '95), Portland, USA, December 1995.
- Invited speaker, Formal Specifications: Foundations, Methods, Tools and Applications (FMTA'95), Konstancin, Poland, June 1995.
- Invited speaker, Fourth International Conference on Algebraic Methodology and Software Technology, (AMAST'95), Montreal, Canada, July 1995.
- Invited speaker, Mathematics of Program Construction (MPC '95), Kloster Irsee, Germany, July 1995.
- Invited speaker, GULP-PRODE Joint Conference on Declarative Programming, Marina di Vietri – Salerno, Italy, September 1995.
- Coordinator of the Esprit Basic Research Action *Compulog 2,* 1992–1995.
- Member Ph.D. committee, Jacob Brunekreef, *On Modular Algebraic Protocol Specification,* February 17.

- Member Ph.D. committee, Erik Aarts *Investigations in Logic, Language, and Computation,* December 4.
- Co-organizer of 7th BENELOG – 7th Benelux Meeting on Logic Programming and PROLOG, Gent, Belgium. September 29.

Papers in Journals and Proceedings

K. R. APT (1995). Program verification and Prolog. E. Börger (ed.). *Specification and Validation methods for Programming languages and systems,* Oxford University Press., 55–95.

K.R. APT, P. VAN EMDE BOAS, A. WELLING (1994). The STO problem is NP-Hard. *Journal of Symbolic Computation,* 18, 489–495. (Appeared only in 1995.)

K.R. APT, F. TEUSINK (1995). Comparing negation in logic programming and in Prolog. K.R. APT, F. TURINI (eds.). *Meta-logics and Logic Programming,* The MIT Press, Cambridge, Massachussets, 111–133.

K.R. APT, I. LUITJES (1995). Verification of logic programs with delay declarations. V.S. ALAGAR, M. NIVAT (eds.). *Proceedings of the Fourth International Conference on Algebraic Methodology and Software Technology, (AMAST'95),* Lecture Notes in Computer Science 936, Springer-Verlag, Berlin, 66–90. (Invited Lecture.)

A. BOSSI, N. COCCO, S. ETALLE (1995). Transformation of Left Terminating Programs: the Reordering Problem. M. PROIETTI (ed.). *LOPSTR95 – Fifth International Workshop on Logic Program Synthesis and Transformation,* LNCS, Springer-Verlag.

F.S. DE BOER, M. GABBRIELLI (1995). Modeling Real-time in Concurrent Constraint Programming. J. LLOYD (ed.). *Proc. Int'l Logic Programming Symposium,* ILPS'95, The MIT Press.

L. COLUSSI, E. MARCHIORI, M. MARCHIORI (1995). A Dataflow Semantics for Constraint Logic Programs. *Proc. 7th International Symposium on Programming Languages,* Implementations, Logics and Programs (PLILP'95), 431–448.

L. COLUSSI, E. MARCHIORI, M. MARCHIORI (1995). On Termination of Constraint Logic Programs. *Proc. International Conference on Principles and Practice of Constraint Programming (CP'95),* 431–448.

S. ETALLE, M. GABBRIELLI (1995). A Transformation System for Modular CLP Programs. L. STERLING (ed.). *Proc. Twelfth Int'l Conf. on Logic Programming,* ICLP 95, The MIT Press, Cambridge, Mass., 681–695.

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S. ETALLE, M. GABBRIELLI (1995). The Replacement Operation for CLP modules. *Proc. ACM SIGPLAN Symposium on Partial Evaluation and Semantics-Based Program Manipulation*, PEPM '95, ACM Press, 168–177.

M. FALASCHI, M. GABBRIELLI, K. MARRIOTT, C. PALAMIDESSI (1995). Confluence and concurrent constraint programming. *Proc. Fourth Int'l Conf. on Algebraic Methodology and Software Technology*, AMAST 95, **936** of Lecture Notes in Computer Science, Springer-Verlag, Berlin.

M. GABBRIELLI, M.G. DORE, G. LEVI (1995). Observable semantics for Constraint Logic Programs. *Journal of Logic and Computation* 5(2), 133–171.

M. GABBRIELLI, G. LEVI, M.C. MEO (1995). Observable Behaviors and Equivalences of Logic Programs. *Information and Computation* 122(1), 1–29.

E. MARCHIORI (1995). A Methodology for Proving Termination of General Logic Programs. *Proc. 14th International Joint Conference on Artificial Intelligence (IJCAI'95)*, 356–367.

K. MARRIOTT, M. FALASCHI, M. GABBRIELLI, C. PALAMIDESSI (1995). A simple semantics for logic programming languages with delay. R. KOTAGIRI (ed.). *Proc. Eighteenth Australian Computer Science Conf., Australian Computer Science Comm.* 17(1), 356–363.

E. MARCHIORI, F. TEUSINK (1995). Proving termination of logic programs with delay declarations. J. LLOYD (ed.). *Proceedings of the International Logic Programming Symposium*, MIT Press.

A. SCHAERF, M. SCHAERF (1995). Local search techniques for high school timetabling. *Proc. of the 1st Intl. Conf. on the Practice and Theory of Automated Timetabling*, 313–323.

A. SCHAERF, Y. SHOHAM, M. TENNENHOLTZ (1995). Adaptive load balancing: a study in multi-agent learning. *Journal of Artificial Intelligence Research* 2, 475–500.

CWI Reports

CS-R9515. S. ETALLE, M. GABBRIELLI. *Transformations of CLP modules.*

CS-R9540. E. MARCHIORI. *A methodology for proving termination of general logic programs.*

CS-R9543. K.R. APT. *Arrays, bounded quantification and iteration in logic and constraint logic programming.*

CS-R9567. A. SCHAERF. *A survey of automated timetabling.*

Other Publications

K.R. APT, F. TURINI (eds.) (1995). *Meta-logics and Logic Programming.* The MIT Press, Cambridge, Massachussets.

K.R. APT, R. BEN-ELIYAHU (1995). *Meta-variables in logic programming, or in praise of ambivalent syntax,* University of Amsterdam, Technical Report, CT-95-06.

J. BRUNEKREEF (1995). *Translog, an Interactive Tool for Transformation of Logic Programs,* University of Amsterdam, Technical Report, P9512.

S. ETALLE (1995). *Transformation and Analysis of (Constraint) Logic Programs,* Ph.D. Thesis, University of Amsterdam.

Logic and Language – AP5b

Staff

- Prof. dr. D.J.N. van Eijck, (sub)group leader
- Dr. P.J.E. Dekker, post-doc researcher, from October 2
- Drs. A.V. Groenink, Ph.D. student
- Dr. J. Jaspars, post-doc researcher
- Dr. W.P.M. Meyer Viol, Ph.D. student
- Dr. M. de Rijke, post-doc researcher
- Prof. dr. W.C. Rounds, visitor, until July 1
- Ir. S. van Dongen, Ph.D. student, jointly with AM, from October 1

Scientific Report

In 1995, the group as a whole has continued to work on 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 worked on connections between the logic of presuppositions and the logic of information updating, on generalized quantifier theory, and on systems for reasoning with underspecified formal languages.

Maarten de Rijke continued his work 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.

Wilfried Meyer Viol finished his Ph.D. thesis on instantial logic, and defended it successfully on June 20, 1995, at the University of Utrecht (promotores: Jan van Eijck and Johan van Benthem).

Annius Groenink continued the work on his Ph.D. project; he is further exploring a hierarchy of grammar formalisms based on linear movement.
Jan van Eijck and *Jan Jaspars* have continued their work on a framework for computation semantics (sponsored by European LRE project FraCaS). *Jaspars* has developed tools for comparing theories of dynamic natural language semantics. Van Eijck and Jaspars have worked on developing a logic for reasoning with underspecified representations.

Paul Dekker has joined the FraCaS effort in October, contributing a paper on event semantics to the FraCaS deliverables.

Stijn van Dongen has started his work on Classification of Keywords in Mathematical Abstracts, a joint project with Department AM (Michiel Hazewinkel).

Professor *Bill Rounds*, on sabbatical leave from the University of Michigan until July 1, has worked on feature logics for natural language and on applications of default logic in linguistics.

Organization of Conferences, Workshops, Courses, etc.

- Occassional Logic Meetings, Amsterdam, occasionally (N. Alechina, M. de Rijke, and Y. Venema).
- CWI Colloquium on Language and Classification, biweekly (Stijn van Dongen).

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

- *FRACAS Midterm Review*, Edinburgh, UK, January 14–20: D.J.N. van Eijck (How to Ambiguate a Logical Language), J. Jaspars.
- *ACL '95*, Dublin, Ireland, March 28–31: A.V. Groenink (Literal movement grammars), W.C. Rounds.
- *FRACAS Meeting*, Stuttgart, Germany, April 2–5: D.J.N. van Eijck, J. Jaspars.
- *Working visit Imperial College*, London, UK, April 9–13: W.P.M. Meyer Viol.
- *Working visit University of Sussex and Cambridge*, Sussex/Cambridge, UK (prof. D. Weir and Dr. S.G. Pulman), May 19–26: A.V. Groenink (Literal Movement Grammar).
- *LSLI-LU Workshop*, Stanford, USA, May 26–June 1: J. Jaspars (Preferences in dynamic logics).

- *Working visit SRI*, Menlo Park, USA, May 26–June 1: J. Jaspars.
- *Epistemic Logic, Partial Logic and Dynamic Logic*, Montreal, Canada, June 9–12: D.J.N. van Eijck (Making Things Happen), J. Jaspars (Partiality and discourse).
- *AMAST '95*, Montreal, Canada, July 3–7: M. de Rijke (Completeness results for two-sorted metric temporal logics).
- *FRACAS Project Meeting*, Saarbrücken, Germany, July 10–12: D.J.N. van Eijck (Learning from Paradox), J. Jaspars.
- *Seventh European Summer School in Logic, Language and Information*, Barcelona, Spain, August 14–25: D.J.N. van Eijck (Formal Forays into Language, Reasoning with Ambiguous Languages), A.V. Groenink, J. Jaspars, M. de Rijke (Advanced Modal Logic).
- *OZSL School Days*, Putten, October 4–6: D.J.N. van Eijck (Discourse Representation and Memory Management).
- *FRACAS Project Meeting*, Cambridge, UK, October 15–18: D.J.N. van Eijck, J. Jaspars.
- *Mathematics of Language 4*, Philadelphia, USA, October 26–28: A.V. Groenink (An elegant operational formation for the polynomial-time recognizable languages).
- *Computational Linguistics Group of Paris VII*, Jussieu, Paris, France, November 1–30: D.J.N. van Eijck (Semantique et Language Naturelle, Representation de Discours et Semantique Dynamique, Comment Assembler les Composants d'un Discours?).
- *CTL Colloquium, Utrecht*, December 12,: D.J.N. van Eijck (Dynamic Reasoning Without Variables).

Memberships of Committees and Other Professional Activities

Jan van Eijck:
- Member of the board of the Dutch Graduate School in Logic (since July, 1993)
- Coordinator of NFI project NF 102/62-356 ('Structural and Semantic Parallels in Natural Languages and Programming Languages'), funded by the Netherlands Organization for Scientific Research (N.W.O.)
- Member of the FRACAS LRE Consortium (other partners: R. Cooper, Edinburgh, H. Kamp, Stuttgart and M. Pinkal, Saarbrücken)
- Visiting professor 'Université Paris VII, UFR Linguistique — TALANA', November 1995

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- Promotor of Wilfried Meyer Viol, Utrecht University (with Johan van Benthem as second promotor), (June 20, 1995)
- Member of the Ph.D. committee of Erik Aarts, Utrecht University (December 4, 1995)
- Member of the Ph.D. committee of Willem Groeneveld, University of Amsterdam (November, 1995)
- Member of the Ph.D. committee of Emiel Krahmer, Tilburg University (November, 1995)
- Program committee member of JELIA'96, Evora, Portugal, September/October 1996
- 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

Maarten de Rijke:
- Editorial board, Studies in Logic, Language and Information

Papers in Journals and Proceedings

J. VAN EIJCK, F.-J. DE VRIES (1995). Reasoning about update logic. *Journal of Philosophical Logic* **24**, 19–45.

J. VAN EIJCK, N. FRANCEZ (1995). Verb-phrase ellipsis in dynamic semantics. M. MASUCH, L. POLOS (eds.). *Applied Logic: How, What and Why?*, Kluwer, Dordrecht, 29–60.

P. BLACKBURN, C. GARDENT, M. DE RIJKE (1995). Rich ontologies for tense and aspect. J. SELIGMAN, D. WESTERSTAHL (eds.). *Logic, Language and Computation*, CSLI Publications.

P. BLACKBURN, M. DE RIJKE (1995). Logical aspects of complex structures. J. SELIGMAN, D. WESTERSTAHL (eds.). *Logic, Language and Computation*. CSLI Publications.

A.V. GROENINK (1995). A Simple Uniform Semantics for Concatenation-based Grammar. *Proceedings of the TWLT10/AMiLP meeting, University of Twente.*

A.V. GROENINK (1995). An Elegant Grammatical Formalism for the Polynomial-time recognisable Languages. Extended abstract of paper presented at the *fourth Mathematics of Language workshop (MOL4)*, Univ. of Pennsylvania.

A.V. GROENINK (1995). Formal Mechanisms for Left Extraposition in Dutch. *Proceedings of the 5th CLIN (Computational Linguistics In the Netherlands) meeting*, November 1994, Enschede.

A.V. GROENINK (1995). Literal Movement Grammars. *Proceedings of the 7th EACL Conference,*

University College, Dublin.

W. VAN DER HOEK, M. DE RIJKE (1995). Counting objects. *Journal of Logic and Computation*, **5**, 325–345.

A. MONTANARI, M. DE RIJKE (1995). Completeness results for two-sorted metric temporal logics. V.S. ALAGAR, M. NIVAT (eds.). *Proc. 4th International Conference on Algebraic Methodology and Software Technology, AMAST '95*, Springer, 385–399.

M. DE RIJKE (1995). A Lindström theorem for modal logic. A. PONSE, M. DE RIJKE, Y. VENEMA (eds.). *Modal Logic and Process Algebra*, CSLI Publications.

M. DE RIJKE (1995). The logic of Peirce algebras. *Journal of Logic, Language and Information.*

M. DE RIJKE, Y. VENEMA (1995). Sahlqvist's theorem for Boolean algebras with operators. *Studia Logica*, **54** 61–78.

CWI Reports

CS-R9511. J. JASPARS. *Partial up and down logic.*

CS-R9512. W. VAN DER HOEK, J. JASPARS, E. THIJSSE. *Honesty in partial logic.*

CS-R9519. M. DE RIJKE. *Modal model theory.*

CS-R9533. P. BLACKBURN, M. DE RIJKE. *Why combine logics?*

CS-R9546. D.J.N. VAN EIJCK. *Presuppositions and information updating.*

CS-R9551. W.C. ROUNDS, G.Q. ZHANG. *Suggestions for a non-monotonic feature logic.*

CS-R9561. P. BLACKBURN, M. DE RIJKE, Y. VENEMA. *Relational methods in logic, language and information.*

CS-R9562. M. DE RIJKE. *A modal characterization of Peirce algebras.*

CS-R9563. P. BLACKBURN, W.P.M. MEYER-VIOL, M. DE RIJKE. *A proof system for finite trees.*

CS-R9574. H. HERRE, J. JASPARS, G. WAGNER. *Partial logics with two kinds of negation as a foundation for knowledge-based reasoning.*

CS-R9577. A. MONTANARI, M. DE RIJKE,. *Two-sorted metric temporal logics.*

Other Publications

L. CSIRMAZ, D.M. GABBAY, M. DE RIJKE (eds.) (1995). *Logic Colloquium '92*, Studies in Logic, Language and Information, CSLI Publications, Stanford.

J. VAN DER DOES, J. VAN EIJCK (1995). Basic quantifier theory. Technical Report LP-95-08, ILLC.

To appear in J. VAN DER DOES J. VAN EIJCK (eds.). *Quantifiers,* Logic, and Language, CSLI, Stanford.

W.P.M. MEYER VIOL (1995). *Instantial Logic*, Ph.D. thesis, OTS, Utrecht and ILLC, Amsterdam.

A. PONSE, M. DE RIJKE, Y. VENEMA (eds.) (1995). *Modal Logic and Process Algebra*, CSLI Publications, Stanford.

Visitors

- H. Wansing, Leipzig, Germany, February 23–26.
- G. Cepparello, Scuola Normale, Pisa, Italy, March 5–12.
- M. Kohlhase, University of Saarland, Germany, March 7–April 17.
- N. Kurtonina, Moscow, July 1–August 31.
- E. Krahmer, Tilburg, December 18–21.

DEPARTMENT OF ALGORITHMICS AND ARCHITECTURE

Staff 1995

- Algorithms and Complexity – AA1

  - P.M.B. Vitányi
  - A. Berthiaume
  - H. M. Buhrman
  - H.H. Ehrenburg
  - P.D. Grünwald
  - J.H. Hoepman
  - H.A.N. van Maanen
  - B. Terhal
  - J. Tromp

- Cryptology – AA2

  - A.M. Bleeker
  - S.A. Brands
  - H.M. Buhrman
  - D. Chaum
  - R.J.F. Cramer
  - R. Hirschfeld
  - C.J.H. van der Kolk
  - L.A.M. Schoenmakers

- Interoperable Multimedia Systems – AA3

  - L.G.L.T. Meertens
  - D.C.A. Bulterman
  - L. Hardman
  - A.J. Jansen
  - K.S. Mullender
  - J.R. van Ossenbruggen
  - S. Pemberton
  - G. van Rossum
  - M.E. Schutler
  - M. Theodoridou
  - O.J.M. Weber

- Databases – AA4

  - M.L Kersten
  - J.F.P. van den Akker
  - R. Choenni
  - F. van Dijk
  - M.C.A. van de Graaf
  - M. Holsheimer
  - A.R. van Hulzen
  - L. Keuss
  - F. Kwakkel
  - J. Pellenkoft
  - A.P.J.M. Siebes
  - H. Sprangers
  - C. del Val Merino

- 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 gray 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. (Thanks to R. van Liere for providing this information)

In 1995 14760 (1994:11037, 1993:5319) copies of internal CWI reports where obtained from outside sources. The top 2 reports accessed in 1995 were AA/CS-R9406 (1538) and AA/CS-R9429 (651). The detailed breakdown for the AA published reports is given below. A breakdown for the AA software packages was not available, but especially Python was obtained from several hundred sites.

Department	Reports	Copies in 1994
AP	88	3673
AA	73	6868
BS	68	1608
IS	18	736
NW	37	885
CST	3	416
AM	24	574

Report	No.	Report	No.
AA/CS-R9571	4	AA/CS-R9557	14
AA/CS-R9556	53	AA/CS-R9555	50
AA/CS-R9544	21	AA/CS-R9541	35
AA/CS-R9540	12	AA/CS-R9539	54
AA/CS-R9534	53	AA/CS-R9531	310
AA/CS-R9530	44	AA/CS-R9529	42
AA/CS-R9527	35	AA/CS-R9526	46
AA/CS-R9525	27	AA/CS-R9524	26
AA/CS-R9523	46	AA/CS-R9522	70
AA/CS-R9521	204	AA/CS-R9519	35
AA/CS-R9518	35	AA/CS-R9514	55
AA/CS-R9513	61	AA/CS-R9510	110
AA/CS-R9509	78	AA/CS-R9506	122
AA/CS-R9504	63	AA/CS-R9501	4
AA/CS-R9459	41	AA/CS-R9458	87
AA/CS-R9455	235	AA/CS-R9451	84
AA/CS-R9437	33	AA/CS-R9432	43
AA/CS-R9431	32	AA/CS-R9430	343
AA/CS-R9429	651	AA/CS-R9423	61
AA/CS-R9422	24	AA/CS-R9421	62
AA/CS-R9416	27	AA/CS-R9413	36
AA/CS-R9407	48	AA/CS-R9406	1538
AA/CS-R9404	35	AA/CS-R9403	63
AA/CS-R9354	216	AA/CS-R9352	25
AA/CS-R9343	57	AA/CS-R9323	112
AA/CS-R9320	95	AA/CS-R9319	28
AA/CS-R9318	67	AA/CS-R9309	32
AA/CS-R9303	59	AA/CS-R9268	32
AA/CS-R9266	59	AA/CS-R9265	47
AA/CS-R9264	76	AA/CS-R9263	78
AA/CS-R9262	40	AA/CS-R9261	48
AA/CS-R9260	42	AA/CS-R9259	43
AA/CS-R9258	137	AA/CS-R9257	66
AA/CS-R9256	67	AA/CS-R9255	52
AA/CS-R9244	56	AA/CS-R9243	32
AA/CS-R9240	25	AA/CS-R9235	27
AA/CS-R9201	45	AA/CS-R9122	53

Algorithms and Complexity – AA1

Staff

- Prof. dr. P.M.B. Vitányi, group leader
- Dr. H.M. Buhrman, postdoc, NFI
- Dr. A. Berthiaume, postdoc (from March), NFI
- 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
- Drs. B. Terhal, (from September), UvA
- Dr. J. Tromp, junior researcher (postdoc), CWI/NFI (currently on leave of absence as NSERC Research Fellow at University of Waterloo)

Scientific Report

The project works at algorithmic methods and complexity analysis. Specific subjects are computational learning, computational linguistics, network algorithms, evolutionary algorithms, formal aspects of AI, structural complexity theory, descriptive complexity and applied complexity theory. Considerations are with respect to both sequential and parallel computation and quantum computing.

Multiple Computing Agents & Machine Learning

MCA: *Vitányi* investigated mathematical foundations of evolutionary computing and genetic algorithms. Exploiting properties of rapid mixing Markov chains a discipline of structured evolutionary programming is identified which guaranties provable global optimization in polynomial time with probability almost one. A paper was submitted to a FOGA'96.

Ehrenburg continued work on Genetic Programming. More particular we studied the representation of a population of trees by a Directed Acyclic Graph and the advantages and new possibilities of this representation. Advantages are that Genetic Programming can be much more efficient both in the use of time and space. We found new ways of evaluating a population, which improve on existing methods of evaluation. One of the new possibilities offered by a DAG representation is that it becomes feasible to efficiently gather important statistical information regarding the evolution of a population, existing representation methods can not efficiently gather this information. An other new possibility is the efficient implementation of more specific genetic operators than the commonly used Crossover. The genetic operator Combine, for example, accurately combines two similar trees into one.

An implementation of the methods described above was written and successfully tested. Experiments showed that time and space usage are indeed much decreased by the use of a Directed Acyclic Graph.

New genetic operators where implemented and results of experiments with these genetic operators showed improved performance of Genetic Programming. Results can be found in 'Improved DAG handling in GP' submitted to Genetic Programming 1996 Conference this paper is also available at the NeuroColt ftp site.

Grünwald designed a very simple recurrent neural network that is able to recognize a simple context sensitive formal language. As it has frequently been claimed that the representational power of recurrent neural networks does not go beyond that of finite-state automata, this result seemed to us important enough to spend some time analyzing the exact behaviour of the network. This analysis has by now been almost completed. It turns out that the behaviour of the network originates from the fact that we use the standard logistic activation function in a clever way.

ML: In the topic of Machine Learning and Multiple Computing Agents ESPRIT BRA III Working Group Nr. 8556, *Vitányi* was program committee chair of the second European 'EuroCOLT'–European Computational Machine Learning Conference in Barcelona, 1995.

In the last few decades a computational approach to machine learning has emerged based on paradigms from recursion theory and the theory of computation. Such ideas include learning in the limit, learning by enumeration, and probably approximately correct (pac) learning. These models usually are not suitable in practical situations. In contrast, statistics based inference methods have enjoyed a long and distinguished career. Currently, Bayesian reasoning in various forms, minimum message length (MML) and minimum description length (MDL), are widely applied approaches. They are the tools to use with particular machine learning praxis such as simulated annealing, genetic algorithms, genetic programming, artificial neural networks, and the like. These statistical inference methods select the hypothesis which minimizes the sum of the length of the description of the hypothesis (also called 'model') and the length of the description of the data relative to the hypothesis. It appears to us that the future of computational machine learning will include combinations of the approaches above coupled with guaranties with respect to used time and memory resources. Computational learning theory will move closer to practice and the application of the principles such as MDL require further justification.

In a contribution to jubilee LNCS Vol 1000 of Springer-Verlag *Vitányi* (co-author M. Li) surveyed some of the actors in the relation between theory and praxis in computational machine learning, focussed on explaining for the first time similarities and differences between the 'minimum description length' principle (a prior-free approach which is widely applied in practice) and Bayesian reasoning in statistical inference and learning. We justify MDL via the Bayesian approach, and give a comparison between pac learning and MDL learning of decision trees.

Grünwald investigated the Minimum Description Length Principle so as to be able to a) apply it in more sophisticated contexts than word classification and/or b) be able to prove some theorems about (bounds/guarantees on) its performance in some learning algorithms that are commonly used for more complicated grammar inference problems and for protein modeling and DNA/RNA sequence modeling. We found that these modeling problems are very similar in nature to grammar inference problems. (one wants to analyse sequences of words vs. sequences of base pairs or amino acids). We have improved upon results obtained in 1994 about the automatic classification of words in grammatical categories. While in 1994, we only used the Minimum Description Length Principle in a somewhat rudimentary way, we now make use of its full power. Thus we have been able to come up with much better experimental results and with a clear 'stopping' criterion. This criterion indicates at what point during its execution our algorithm has found an optimal classification and thus should not try any further. Our results will be published in January 1996 as a chapter in the ' Symbolic, connectionist, and statistical approaches to learning for natural language processing' by Stefan Wermter, Ellen Riloff, Gabriele Scheler (Editors), in the Springer Verlag LNAI Series.

Vitányi (co-author *M. Li (Univ. Waterloo, Canada)*) enriched formal language theory with Kolmogorov complexity arguments leading to results which obviate so-called pumping lemmas and simplify or establish several old and new results, and appeared in SIAM J. Comput.

Van Maanen considered the possibilities of extensions to the Minimum Description Length (MDL) framework to a theory about learning statistical causal relationships. In general statistical models are used to evaluate likely consequences of future actions. The MDL principle states that the model (from a predetermined possibly non-parametric class) that describes the past data most efficiently is the best predictor. We hope to prove that this principle is correct in the very general sense that, for all systems that use an optimal strategy to choose actions on the basis of predictions, there is no algo-

rithm that yields infinitely more gain in the worst case than an arbitrary algorithm that adheres to the MDL principle. An account of why these statistical notions model learning in the sense of knowledge acquisition in a very fundamental way was presented as a talk at the University of Groningen.

He continued research on 'forecasting algorithms' in the sense of R. Solomonoff where he introduced a novel idea of a 'competetive 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. Computational learning issues necessitate a fundamental inquiry in the nature of randomness of individual objects and the relation to compressibility of effective descriptions. *Vitányi* wrote a comprehensive treatment of the notion and its history of 'randomness' of individual objects and infinite sequences in mathematics and physics in the 20th century for an Italian encyclopaedia ('Storia del Secolo XX'). *Vitányi*'s co-author *M. Li* of the University of Waterloo received the 1996 E.W.R. Steacie Memorial Fellowship awarded by the Natural Sciences and Engineering Research Council of Canada (NSERC), some of Canada's most prestigious research awards. The citation states ' Dr. Li, now a professor at the University of Waterloo, is playing a key role in developing and demonstrating the power of Kolmogorov complexity. His book (co-authored with Paul Vitányi), An Introduction to Kolmogorov Complexity and Its Applications, was the first comprehensive book in this field. It is used to teach graduate seminar courses all over the world; various parts of the book have been translated into Chinese, Japanese and Russian. Drs. Li and Vitányi's work has changed the status of Kolmogorov complexity – from elegant idea to versatile tool for concrete investigations.'

Buhrman and *J. Balcazar, M. Hermo (UPC, Barcelona)* considered the Computation Learning Model where one tries to learn a concept through membership and equivalence queries to a teacher. We study the concepts that have easy descriptions (i.e. low Kolmogorov Complexity). Results concerning Learnability are published in 'Learnability of Kolmogorov-Easy Circuit Expressions Via Queries', EUROCOLT'95. More results and a characterizations of the learnability in a Complexity Theoretical notion have been obtained and can be found in the manuscript 'Characterizing the Learnability of Kolmogorov Easy Circuit', which can be found in the NEUROCOLT ftp directory.

Algorithms and Complexity

Buhrman and *E. Mayordomo (UPC Barcelona)* studied the notion of resource bounded measure. We made a connection between resource bounded measure, instance complexity and resource bounded Kolmogorov complexity. We showed among other things that the lower cone and upper cone of the set of resource bounded Kolmogorov strings has p-measure 0. See 'An excursion to the Kolmogorov Random Strings' STRUCTURES'95. We also gave a new definition of resource bounded measure in terms of Compressibility, a nation akin to Kolmogorov Complexity. This new notion enables us to prove new results concerning resource bounded measure. Results can be found in 'Compressibility and Resource Bounded Measure', accepted for publication in STACS'96.

Buhrman and *L. Fortnow (Univ. Chicago), L. Torenvliet (Univ. Amsterdam)* others investigated the program initiated in the Thesis 'Resource Bounded Reductions', by *Buhrman*. We studied the internal structure of complete sets. The idea is to separate complexity classes by looking at certain structural properties. We proposed to study the notion auto-reducibility, that in a certain way points some kind of redundancy in computation. We show that this is the correct notion to look at. We prove that all complete sets for PSPACE are autoreducible and that this is not the case for EXSPACE. Hence a solution for this question for EXPTIME will solve (either way) a big open problem in Complexity Theory (either P $<>$ SPACE or P $<>$ LOGSPACE). As an advantage we show that our results do not relativize. This work can be found in 'Using Autoreducibility to Separate Complexity Classes', FOCS'95. We will try to settle this question for EXP in the next year when Lance Fortnow will have his sabbatical in Amsterdam.

Buhrman and *M. Hermo (UPC Barcelona)* considered the (im)possibility of NP having very sparse Complete sets in 'On the Sparse Set Conjecture for Sets with Low Density' STACS'95. *Buhrman* and others partially solved an open problem by Papadimitriou. Is the problem whether a graph has a Unique Optimal Clique complete for theta-2. We show that this is probably not the case since this would imply the existence of proof systems for NP that can be easily generated. We have derandomized a construction of Sipser, concerning the CD complexity of strings in an easy recognizable set. Our results are close to optimal. They can be found in the Manuscript 'Distinguishing Complexity and Sym-

metry of Information'. Concerning complexity of algorithms *Vitányi* was/is program committee member of FCT'95 in Dresden, ICALP'96 in Paderborn, COCOON'97 in Shanghai.

Distributed Computing

Buhrman, Hoepman and *J. Garay (IBM T.J. Watson Research), M. Moir (University of Washington, Seattle)* considered the problem of Renaming. We constructed the first long-lived algorithm that renames to a name space of $O(k^2)$, whose time complexity is polynomial in k (and independent of the number of processes). This Algorithm can be found in 'Long-Lived Renaming Made Fast' PODC'95. Furthermore concerning synchronous fault tolerant communication models, *Buhrman, Hoepman* and *J. Garay (IBM T.J. Watson Research)* continued work on the model where the faults (malicious agents) are allowed to move through the network. We studied the Byzantine Agreement problem and showed optimal bounds on the number of faults and how fast they move through the network. These results can be found in 'Optimal Resiliency against Mobile Faults' FTCS'95.

Hoepman (together with *M. Papatriantafilou, P. Tsigas (MPI, Saarbrücken)* started unifying the processor-failure (wait-free) and memory-failure (self-stabilization) approach to fault-tolerant distributed computing, that are usually considered seperately. This yielded highly fault-tolerant protocols that implement wait-free self-stabilizing shared memory objects. These results are reported in 'Self-Stabilization of Wait-Free Shared Memory Objects' WDAG'95.

Buhrman, Hoepman and Vitányi obtained many new results solving open problems concerning optimal size of compact routing tables using the novel tool of applying Kolmogorov Complexity to Distributed Algorithms. The notion of Kolmogorov complexity gives a nice and new handle on obtaining new results in this area of distributed computing. It seems that this approach is fruitful and that many applications lay waiting for us. Results concerning routing can be found in 'Optimal Routing Tables', which was accepted for publication at PODC'96. As an offspring to this approach we recovered a new definition of Random Graphs, Kolmogorov Random Graphs, that has a right to be studied in its own. Results have been obtained and differences and similarities with other models of Random Graphs are bundled in a forthcoming paper entitled 'Kolmogorov Random Graphs'.

Hoepman partially completed his Ph.D. The-

sis 'Communication, Synchronization, and Fault-Tolerance' which he will defend in June 1996. Last we began investigations into the problem of generating a minimum spanning tree in a communication network. This work will be continued when Juan Garay (IBM) will visit our group for 6 months.

Tromp continued his work on distributed algorithms machine learning. His paper (together with *M. Li* of University of Waterloo, and *M. Yanakakis* of AT&T Research Labs *T. Jiang* of University of Washington Seattle, and *A. Blum*) 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 appeared in J. ACM. Another paper by *Tromp, Vitányi* and *M. Li* resolving the difficult and error-prone problem of how to construct concurrent wait-free variables (for asynchronous interprocess communication) was accepted for publication in J. ACM. *Tromp* published several other papers and was 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.

Physics and Computation & Quantum Computing

Physics of Computation: *Vitányi* wrote two invited papers and gave two invited plenary lectures (for WADS'95 co-authored with *M. Li* of the University of Waterloo, and MFCS'95) which dealt with physical aspects of computation such as unavoidable interconnect length in Euclidean embeddings of parallel computer architectures. For most archtectures the volume taken by wires will drown the volume taken by processing elements, both for regular small diameter networks and for random networks. The problem of unavoidable heat dissipation in computing is the single most influential factor which in the short term will halt further progress in miniaturization and therefore in increase of computing power. One way to overcome this problem is by so-called 'reversible computing' which in principle can be implemented completely dissipation-free. Research was started in the direction of coherent quantum computing, a promising radically new approach to parallel computing which—if realized—will overcome both the interconnect problem and the heat dissipation problem, and moreover will perform way beyond the possibilities of classical high performance parallel computing. Further work on reversible computing and reversible simulation of irreversible computations, and several

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lower bounds on energy dissipation in real computation were derived as well as time and space versus heat dissipation tradeoffs will be reported in the IEEE Computational Complexity Conference and in the Proc. Royal Soc. London, Ser. A. *Vitányi* is program committee member of PhysComp'96 in Boston. He was also invited plenary speaker at the final ESPRIT ALTEC Project Conference in Prague 1995.

Quantum Computing: The goal of this pilot project is to establish theoretical and practical principles to develop physically realizations of coherent quantum computers, and to develop theory and applications of reversible unitary algorithms for such machines which improve the capabilities of machines based on classical physics (by an exponential factor). Quantum coherent computation is a new field of research that has attracted an increasing number of computer scientists and physicists over the last 10 years. In the last year evidence has arisen that the proposed coherent quantum computers may be intrinsically much faster than classical computing devices, thus making their technological development of great economic interest. Coherent quantum computers have also a theoretical interest, as their study has contributed open problems and may contribute to solving standing open problems in computation theory. Exploring the possibilities of a quantum computer is anticipated to shed new light on aspects of quantummechanics, thus increasing our understanding of quantum phenomena.

The project has no counterpart in the Netherlands. The Algorithms and Complexity group at CWI cooperates with the Theoretical Physics Department and the Computer Science and Logic Department of the University of Amsterdam.

Berthiaume (Aladdin-NFI Fellow) won NSERC's (Natural Sciences and Engineering Research Council of Canada) national doctoral prize competition. Those selected are judged to have completed the most outstanding doctoral research in Canada last year. The citation says that 'Dr. Berthiaume is working in the forefront field of 'quantum' computing. His doctoral research has increased the likelihood that such a computer may eventually be built.' He gave a popular weekly seminar on Quantum Computing at CWI in the first half of 1995 introducing the topic in the Netherlands and creating a growing interest (NRC O&W Supplement January 4, 1996). Moreover, he wrote the first comprehensive survey of this new area to appear in 'Complexity Theory Retrospective II' editors: Lane Hemaspaandra and Alan L. Selman, Springer-Verlag.

During the ISI workshop on Quantum Computing in Turin, discussions with C. Macchiavello (Oxford) and D. Aharonov (Technion) made possible the generalization of results in A. Berthiaume's Ph.D. thesis. More specifically, the symmetrization technique proposed by Deutsch to stabilize quantum computation subject to errors is efficient even with respect to the number of bits in the quantum computer. However, the error model is still unrealistic and it is still unknown how the method performs on more realistic error models.

Terhal investigated quantum computing feasibility of hard combinatorial optimization problems. More physical problems considered include statistical models of low-dimensional classical spin glasses. Research will focus on the relation between the computational complexity of these systems in relation to their statistical properties. Quantum dots were identified as candidate physical systems for implementation of quantum logic gates, from which quantum computers can be build. Double quantum dots in an oscillating electric field are suitable to represent a qubit.

At the second international meeting on Quantum Computing at ISI Turin the Netherlands were represented for the first time *Berthiaume, Terhal, Vitányi.*

Organization of Conferences, Workshops, Courses, etc.

- NFI The national (NFI-supported) project ALADDIN – research and education in concurrent systems – organized 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. Dr. J. Garay (IBM T.J. Watson Research, USA) was ALADDIN visiting expert. *Vitányi* was invited plenary speaker at Aladdin related subjects at both WADS'95 and MFCS'95.
- INTAS *Vitányi* submitted together with *V. Uspensky* of Moscow University a proposal 'Kolmogorov complexity and Forecasting' to INTAS.
- 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. *Vitányi* is work area manager of two out of three work areas. In machine learning theory *Vitányi* is invited tutorial speaker

at the ISIS'96 conference and invited plenary speaker at the ALT'96 conference, both in Australia.

- 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 organized 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 took place in Barcelona in March 1995 with *Vitányi* as program committee chair.
- 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 cochair of IFIP Special Interest Working Group on 'Computational Machine Learning' IFIP SIWG 14.4.

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

- Computer Science Department, Universität Ulm, Ulm, Duitsland, 20–28 February, (U. Schöning, T. Thierauf): H. Buhrman (Talk: Proof-Systems, Relativizations and the Exponential Hierarchy).
- ESPRIT ALTEC Conference, Prague, Czech Republic, 4–10 March: P. Vitányi(Invited Plenary Talk: Multiprocessor architectures and physical law).
- STACS Conference, University of Munich, Munich, Germany, 2–4 March: H. Buhrman.
- ESPRIT NeuroCOLT Project Meeting, Barcelona, Spain, 10–12 March: P. Vitányi (work area manager, CWI site manager). H. Buhrman, P. Grünwald, H. Ehrenburg (9–12 March): J. van Maanen (members CWI site).
- EuroCOLT Computational Machine Learning Conference, Barcelona, Spain, 13–16 March: P. Vitányi (program committee chair). H. Buhrman (Talk: Learnability of Kolmogorov-Easy Circuit Expressions Via Queries): P. Grünwald, H. Ehrenburg, J. van Maanen.
- NeuroCOLT Query Learning Workshop, Royal Holloway College, University of London, 17–22 March: P. Vitányi (Talk: Learning Simple Concepts under Simple Distributions). P. Grünwald (Talk: The MDL Principle and Grammar Learning from Text Corpora): J. van Maanen.

- Accolade '95: a conference on logic and its applications, Amsterdam, 24 March: P. Grünwald (Talk: Persistence, Causation and Counterfactuals).
- Informatik, Technische Universität Berlin, Berlin, Germany, 5 May: H. Buhrman (Talk: Using Autoreducibility to Separate Complexity Classes).
- DEC Palo Alto Research Center, Palo Alto, California (L. Lamport), 26–28 May: P. Vitányi (visit).
- Max Planck Institut für Informatik, Saarbrücken, Germany, May 28 – June 3, (P. Tsigas and M. Papatriantafilou): J.H. Hoepman (Talk: Long-lived renaming made fast).
- 1995 ACM Symposium on Theory of Computing, Las Vegas, 29 May – 1 June: P. Vitányi.
- Computer Science Department, University of California, San Diego (W. Savitch) 2–7 June: P. Vitányi (Talk: Physics and the new computation)
- Dutch Conference on Artificial Intelligence 1995 (NAIC'95), Erasmus University, Rotterdam, 22–23 June: P. Grünwald (Talk: A New Causal Theory of Action).
- Computer Science Department, University of Chicago, Chicago, 23–28 June: (L. Fortnow), H. Buhrman (Talk: Proof-Systems, Relativizations and the Exponential Hierarchy).
- IEEE Annual Structures in Complexity Theory, Minneapolis, Minesota, 19–22 June: H. Buhrman (Talk: An excursion to the Kolmogorov Random Strings).
- Computer Science Department, University of Chicago, Chicago, 2–9 July: (S. Kurtz), A. Berthiaume.
- ISI Quantum Computation Workshop, Turin, ISI Institute at Villa Gualino, 25 June – 9 July: B. Terhal; 25–30 June: A. Berthiaume (Talk); 2–8 July: P. Vitányi.
- Genetic Programming Workshop at Int. Conference on Machine Learning, Tahoe City, California, 8–12 July: H. Ehrenburg (Talk: Finding the Combine Operator).
- Stanford University, Stanford, California, 13–14 July (J. Koza): H. Ehrenburg (Talk: Finding the Combine Operator).
- Genetic Programming Workshop at Int. Conference on Genetic Algorithms, Pittsburgh University, Pittsburgh, Pennsylvania, 15–19 July: H. Ehrenburg, (Talk: Finding the Combine Operator)
- Computer Science Department, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 17–18 July (M. Martin): H. Ehrenburg.
- Computer Science Department, Boston University, 1–4 August (S. Homer): H. Buhrman.

- Workshop in Complexity Theory, University of Southern Maine, Freeport, Maine, 6–11 August: H. Buhrman (Talk: Using Autoreducibility to Separate Complexity Classes).
- Computer Science Department, McGill University, Montreal, 17–18 August (D. Therien and P. McKenzie): H. Buhrman.
- Computer Science Department, University of Waterloo, Waterloo, Canada, 30 July – 15 August (M. Li): P. Vitányi (Talk: Compact Routing Tables).
- International Joint Conference in Artificial Intelligence, IJCAI'95, Montreal, Canada, 19 – 26 August: P. Grünwald.
- Fourth Workshop on Algorithms and Data Structures (WADS'95), Kingston, Ont., Canada, August 16–18: P. Vitányi (Invited Plenary Talk: Incompressibility Arguments in Physics).
- Computer Science Department, University of Chicago, 18–20 August: H. Buhrman.
- Annual ACM Conference on Principles of Distributed Computing (PODC'95), 20–23 August: H. Buhrman, J.H. Hoepman (Talk: Long-lived renaming made fast).
- IBM T.J. Watson Research Center, Yorktown Heights, NY, 24–25 August (J. Garay): H. Buhrman (Talk: Optimal Routing Tables), J.H. Hoepman (Talk: Self-Stabilization of shared memory objects).
- Annual IEEE Conference on Foundations of Computer Science, Milwaukee, WI, USA, 22–25 August: H. Buhrman (Talk: Using Autoreducibility to Separate Complexity Classes).
- 20th International Symposium on Mathematical Foundations of Computer Science (MFCS'95), Prague, Czech Republic, August 28 – September 1: P. Vitányi (Invited Plenary Talk: Physics and the new computation).
- Annual International Workshop on Distributed Algorithms (WDAG'95), Le Mont Saint Michel, France, 13–15 September: J.H. Hoepman (Talk: Self-Stabilization of Wait-Free Shared Memory Objects).
- Neural Network School & Workshop, Universitaet Würzburg, Würzburg, Germany, 12–17 October: H. Ehrenburg.
- Dagstuhl Seminar 'Real Complexity and Applications', Universität Saarlandes, Saarbrücken, Germany, 6–10 November: P. Vitányi (Talk: Real Computation and Kolmogorov Complexity).
- Philosophie Department, University of Groningen, Groningen, 15 November: J. van Maanen (Talk: Filosofische Aspecten van Machinaal Leren).
- Computer Science Department, Université de Montréal, 12 December (Gilles Brassard): A.

Berthiaume (Talk: Comment exorciser le fantôme de Newton).

Memberships of Committees and Other Professional Activities

P.M.B. Vitányi:

- Invited plenary lecturer *4th bi-annual Workshop on Algorithms and Data Structures (WADS'95)* Kingston, Ontario, Canada.
- Invited plenary lecturer *20th International Symposium on Mathematical Foundations of Computer Science (MFCS'95)*, Prague, Czech Republic.
- Invited plenary lecturer *ESPRIT ALTEC Project Workshop*, Prague, Czech Republic.
- Invited speaker, Computer Science Seminar, University of California, San Diego, USA.
- Invited speaker *International Computing Research Seminar*, University of Waterloo, Canada.
- Invited speaker, Real Complexity and Applications Workshop, Dagstuhl Castle, Saarbrüken, Germany.
- Professor of Computer Science, Universiteit van Amsterdam.
- Guest Editor, 'J. Computer and System Sciences', special issue on Computational Learning Theory, 1994—.
- Editor 'Distributed Computing', Springer-Verlag, since 1987.
- Editor, 'Mathematical Systems Theory,' Springer Verlags, since 1991.
- Editor, 'Information Processing Letters' North-Holland/Elsevier, since 1993/94.
- Editor, 'Parallel Processing Letters', World Scientific Publishers, Singapore, since 1991.
- Editor, 'Journal of New Generation Computer Systems', Akademie-Verlag, Berlin, since 1989.
- 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.
- Program Committee, Third Annual International Computing and Combinatorics Conference (COCOON'97), Shanghai, China, August 1997.
- Program Committee, conference on Information, Statistics and Induction in Science (ISIS), Melbourne, Australia, 20–23 August, 1996.
- Program Committee, PHYSCOMP96 (IEEE Physics and Computation Conference), Boston, Mass., 1996.

- Program Committee, International Conference on Algorithms, Languages, and Programming, Paderborn (ICALP), Germany, 1996.
- Program Committee, Fundamentals of Computation Theory (FCT), August 1995, Dresden, Germany.
- Chair Program Committee, 2nd EURO-COLT, (European Workshop on Computational Learning Theory), Barcelona, Spain, 1995.
- 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 14.5 on Computational Machine Learning.
- Publiciteits commissie van het Wiskundig Genootschap (Publicity Committee Dutch Mathematical Society), since 1989.
- Ph.D. Committee D. Alstein, Technological University Eindhoven, 1995 (member).
- Ph.D. Supervisor in 1995 of B. Terhal, R. Cramer, H.H. Ehrenburg, P. Grünwald, B. Olivier, J.-H. Hoepman, J. van Maanen, University of Amsterdam.
- Committee of the Society for Theoretical Computer Science in the Netherlands (Nederlandse Vereniging voor Theoretische Informatica (NVTI)) member.
- Dutch Institute for Logic, Language, and Computation (ILLC) (member).
- Dutch Institute for Programming and Algorithmics (IPA) (member).
- Onderzoekschool Logica (OzL) (member).
- Project leader various SION projects in Machine Learning, Multiple Computing Agents, Cryptography and Randomness.

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

Papers in Journals and Proceedings

A. BERTHIAUME (1995). Quantum Computation Revue. LANE HEMASPAANDRA, ALAN L. SELMAN (eds.). *Complexity Theory Retrospective II*, Springer-Verlag, to appear.

H. BUHRMAN, E. MAYORDOMO (1995). An excursion to the Kolmogorov Random Strings. *STRUCTURES'95. (10th IEEE Conference on Structure In Complexity Theory)*, Minneapolis, MN, IEEE Comp. Soc. Press. (Invited for special issue for STRUCTURES'95 in J. Computer and System Sciences).

J. BALCAZAR, H. BUHRMAN, M. HERMO (1995). Learnability of Kolmogorov-Easy Circuit Expressions Via Queries. P. VITÁNYI (ed.). *Proc. EURO-COLT'95 (2nd European Conference on Learning Theory)*, Lecture Notes in Artificial Intelligence, 904, Springer-Verlag, Heidelberg, 112-124.

H. BUHRMAN, M. HERMO (1995). On the Sparse Set Conjecture for Sets with Low Density. *Proc. STACS'95 (Symposium on Theoretical Aspects of Computer Science 1995)*, Lecture Notes in Computer Science, Springer-Verlag, Heidelberg.

H. BUHRMAN, L. FORTNOW, L. TORENVLIET (1995). Using Autoreducibility to Separate Complexity Classes. Proc. FOCS'95 (36th IEEE Symposium on Foundations of Computer Science), IEEE Comp. Soc. Press.

H. BUHRMAN, J.A. GARAY, J.-H. HOEPMAN (1995). Optimal Resiliency against Mobile Faults. *Proc. FTCS'95 (25th International Symposium on Fault Taulerant Computing)*, Pasadena, CA.

H. BUHRMAN, J.H. HOEPMAN, P.M.B. VITÁNYI (1995). Optimal routing tables. *Proc. 15th ACM Symp. on Principles of Distributed Computing*, to appear.

H. BUHRMAN, J.A. GARAY, J.-H. HOEPMAN, M. MOIR (1995). Long-Lived Renaming Made Fast. *Proc. POCD'95 (14th ACM Symposium on Principles of Distributed Computing)*, ACM Press.

H. BUHRMAN, P. ORPONEN (1995). Random strings make hard instances. *J. Computer and System Sciences*, to appear.

H. BUHRMAN, E. HEMASPAANDRA, L. LONGPRE (1995). Sparse Reduces Conjunctively to Tally. *SIAM J. Computing* 24(4), 673–681.

M. LI, P.M.B. VITÁNYI (1995). Computational Machine Learning in Theory and Praxis. J. VAN LEEUWEN (ed.). *Computer Science Today*, Lecture Notes in Computer Science, 1000, Springer-Verlag, Heidelberg, 518–535.

M. LI, J. TROMP, P.M.B. VITÁNYI (1995). How to

share concurrent wait-free variables. *J. Assoc. Comp. Mach.*, to appear.

M. LI, P.M.B. VITÁNYI (1995). Reversible simulation of irreversible computation. *Proc. 11th IEEE Conference on Computational Complexity*, to appear.

M. LI, P.M.B. VITÁNYI (1995). Reversibility and adiabatic computation: trading time and space for energy. *Proc. Royal Society of London, Series A*, to appear.

M. LI, P.M.B. VITÁNYI (1995). A new approach to formal language theory by Kolmogorov complexity. *SIAM J. Comput.* **24**(2), 398–410.

M. LI, P.M.B. VITÁNYI (1995). Kolmogorov complexity arguments in Combinatorics, *J. Comb. Th., Series A* **66**(2), 1994, 226–236. Correction, *Ibid.* **69**, p. 183.

P. GRÜNWALD, B. GAUME, M. BOUAJJANI (1995). Persistence, Causation and Counterfactuals. *Proc. Accolade '95: a conference on logic and its applications*, Amsterdam, the Netherlands 24th of March 1995. (proceedings appeared August 1995)

P. GRÜNWALD, B. GAUME, M. BOUAJJANI (1995). A New Causal Theory of Action. *Proc. NAIC-95 (= 7th Dutch Conference on Artificial Intelligence)*, Rotterdam, the Netherlands.

P. GRÜNWALD (1995). A Minimum Description Length Approach to Grammar Inference. *Proc. IJCAI-95 Workshop on New Approaches to Learning for Natural Language Processing*, Montreal, Canada.

P. GRÜNWALD (1995). A Minimum Description Length Approach to Grammar Inference. S. WERMTER, E. RILOFF, G. SCHELER (eds.). *Symbolic, connectionist, and statistical approaches to learning for natural language processing*, Lecture Notes in Artificial Intelligence, Springer-Verlag, Heidelberg, to appear.

P.M.B. VITÁNYI (1995). Physics and the New Computation, Prague. *Proc. 20th Int. Symp. Math. Foundations of Computer Science, MFCS'95*, Lecture Notes in Computer Science, Vol. 969, Springer-Verlag, Heidelberg, 106–128. (Invited paper)

P.M.B. VITÁNYI (1995). Randomness. In: 'Matematica, Logica, Informatica' Volume 12 of the **Storia del XX Secolo**, to be published by the *Instituto della Enciclopedia Italiana*.

P.M.B. VITÁNYI, M. LI (1995). Algorithmic arguments in physics of computation. *Proc. 4th Workshop on Algorithms and Data Structures*, Kingston, Ontario. Lecture Notes in Computer Science, Vol 955, Springer-Verlag, Heidelberg, 315–333. (Invited paper)

P.M.B. VITÁNYI (ed.) (1995). *Proc. 2nd European Conference on Computational Learning Theory, EuroCOLT'95*, Lecture Notes in Artificial Intelligence (A subseries of Lecture Notes in Computer Science), Volume 904, Springer-Verlag, Heidelberg.

P.M.B. VITÁNYI (1995). Randomness. *CWI Quarterly* **8**(1), 67–82.

CWI Reports

CS-R9513. D. ALSTEIN, J.H. HOEPMAN, B.E. OLIVIER, P.I.A. VAN DER PUT. *Self-stabilizing mutual exclusion on directed graphs.*

CS-R9514. J.H. HOEPMAN, M. PAPATRIANTAFILOU, P. TSIGAS. *Towards self-stabilizing wait-free shared memory objects.*

CS-N9501. H.A.N. VAN MAANEN. *Filosofische aspecten van machinaal leren.*

Other Publications

A. BERTHIAUME (1995). *L'ordinateur Quantique: Complexite et Stabilisation des Calculs*, Ph.D. thesis. Dept. d'informatique et de recherche operationelle, Universite de Montreal.

A. BERTHIAUME (1996). *Quantum Computation Mini Course*, Lecture notes for Basic Research in Computer Science (BRICS), University of Aarhus. NS-96-1.

H. EHRENBURG (1995). *Improved DAG handling in GP*, available at the NeuroColt ftp site.

P. GRÜNWALD (1995). *Grammar Inference and the Minimum Description Length Principle*, Neurocolt Technical Report no. NC-TR-94-015, appeared as such: March 1995.

Visitors

- J. Balcazar (UPC, Barcelona)
- André Berthiaume (Univ. Montreal, Canada)
- N. Cesa-Bianchi (Univ. Milan, Italy)
- J. Garay (IBM T.J. Watson Research, Yorktown Heights, N.Y., USA)
- F. Gegout (Ecole Normale Supérieure, Lyon, France)
- F. Gruau (Stanford University, Stanford, USA)
- L. Hemaspaandra (Rochester University, NY, USA)
- Chris Lynch (INRIA & CRIN, Nancy, France)
- M. Martin (Carnegie Mellon University, Pittsburgh, USA)

Cryptology – AA2

Staff

- Drs. A.M. Bleeker (Ph.D. student, SION)
- Drs. S.A. Brands (Ph.D. student)
- Dr. D. Chaum (advisor, CAFE)
- Drs. R.J.F. Cramer (project member, CAFE)
- R. Hirschfeld MSc. (project leader CAFE, resp. group leader)
- C.J.H. van der Kolk (adm. manager, CAFE)
- Dr. ir. L.A.M. Schoenmakers (sen. researcher CAFE)

Scientific Report

The group has continued research in its traditional core areas of secure computation and communication, digital signatures, and digital payment and credentials. It also made progress in the area of verification of cryptographic protocols. The group devotes considerable effort to the practical realization and implementation of its theoretical ideas; the ESPRIT project CAFE (Conditional Access For Europe) has designed, implemented, and tested an electronic payment system based on protocols developed in the group, and the ACTS project SEMPER (Secure Electronic MarketPlace for EuRope), which was launched in 1995, is developing mechanisms for payments and other market functions in high-speed computer networks.

Annette Bleeker has worked on verification of security protocols, developing a logic–based on the earlier studied BAN formalism–that has at the same time a clear and sound semantics. The result can detect a certain category of protocol design failures. This logic can be used to bring the notions of time and probability into the formalism.

Stefan Brands has continued his work on electronic cash protocols as well as investigating a number of other security topics.

David Chaum has served as an advisor to the group primarily in his role as chairman of the CAFE project.

Ronald Cramer worked on the cryptographic protocols for the CAFE project, and continued research in a variety of directions. With Damgaard (Aarhus University and BRICS) and Pedersen (Cryptomathic) he worked on the design and analysis of secure and efficient digital signatures, under cryptographic assumptions as weak as possible, or as efficient as possible under a specific assumption. With Schoenmakers, Franklin (AT&T) and Yung (IBM), he worked on the design and analysis of secure and practical secret ballot election schemes. This research has led to the most efficient and secure scheme in this area so far. Based on earlier work (partial proofs), Cramer and Damgaard (Aarhus University and BRICS) have arrived at monotone function closure results for classes languages of languages that admit certain zero-knowledge proof systems. Next, they have built on the same primitive and constructed a general ZK proof system for any NP-language, with linear communication complexity. This can be thought of as optimal in the asymptotic point of view. Finally, they studied the practical problem of designing an efficient identification scheme that is secure against impersonation and man-in-the-middle attacks. The latter kind of attack seemed to be an inherent threat in any identification scheme. They have identified a technique and a setting where those natural security requirements are met after all.

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 was responsible for the administrative coordination of the CAFE project. In addition to protocol development work for CAFE, Berry Schoenmakers completed a technical report on a new linear-time algorithm for recognizing series-parallel graphs (or partial 2-trees for that matter). He also completed a technical report presenting a clean and efficient privacy protecting off-line payment system. The system was actually developed in the summer of 1994 and first presented in the CAFE project. This system has advantages over the similar system presented later by Brands, in particular its ability to withstand so-called parallel attacks, with no loss in performance. Schoenmakers found basic problems in a paper he refereed for the journal IPL, and proposed a way to overcome them, which may lead to co-authorship of a revised paper. Together with Katoen (Twente University), he completed a paper on 'Systolic Arrays for the Recognition of Permutation-Invariant Segments'. Joint work with Cramer, Franklin (AT&T), and Yung (IBM) resulted in a paper on cryptographic protocols for secret-ballot elections, which constitutes a major advance as it achieves an improvement in performance from quadratic to linear, as well as making secret-ballot elections much simpler to understand and handle.

This is due to the use of the efficient '1-out-of-2 proof' technique developed with Cramer and Damgaard (Aarhus University). Future work will address even more versatile protocols for elections.

Organization of Conferences, Workshops, Courses, etc.

- The Cryptography Working Group, organized by Hirschfeld in 1995, met bimonthly to present results in all areas of cryptography. The Working Group is national in scope and has participation from throughout the Netherlands. In 1996, the working group will be organized by Cramer.
- A conference on 'Electronic Consumer Payment Systems: The Next Generation', sponsored by the CAFE project, was organized in 1995 to take place at the end of January 1996. The conference featured speakers from leading financial, commercial, and governmental institutions involved with electronic payments.
- A workshop as part of the HCM project 'Digital Identification and Authentication' (DIA), which is coordinated by CWI, was organized to take place in Saarbrücken, Germany at the beginning of February 1996. This workshop included presentations from team members throughout the DIA network.

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

- Eurocrypt '95 Conference, St. Malo, FR: Brands, Cramer, Hirschfeld, Schoenmakers.
- Crypto '95 Conference, Santa Barbara, US: Cramer, Hirschfeld, Schoenmakers.
- Internet Security Symposium, San Diego, US: Brands.
- Smart Card '95 Conference, London, GB: Hirschfeld.
- Asian Smart Card Summit, Singapore: Hirschfeld.
- Federal Smart Card Users Group Meeting at CardTech/SecurTech Conference, Washington, US: Hirschfeld.
- Cryptography Workshop '95, Luminy, FR: Hirschfeld.
- ESCAT '95 Conference, Helsinki, FI: Chaum.
- Smart Card Club meeting at Cartes '95 Conference: Paris, FR: Hirschfeld.
- CAFE General Meeting, Paris, FR: Chaum, Cramer, vd Kolk, Schoenmakers.
- CAFE General Meeting, Trondheim, NO: Chaum, Cramer, Hirschfeld, vd Kolk, Schoenmakers.

- CAFE General Meeting, Hildesheim, DE: Cramer, Chaum, Hirschfeld, vd Kolk, Schoenmakers.
- CAFE General Meeting, Brussels, BE: Cramer, Hirschfeld, vd Kolk.
- CAFE review, Brussels, BE: Chaum, Hirschfeld, vd Kolk.
- CAFE review, Brussels, BE: Chaum, Hirschfeld, vd Kolk.
- CAFE sponsor meeting, London, GB: Hirschfeld.
- CAFE sponsor meeting, Athens, GR, Hirschfeld.
- CAFE sponsor meeting, Milan, IT: Hirschfeld.
- SIGMEW General Assembly, London, GB: Hirschfeld.
- SIGMEW Task Force 1 meeting, Paris, FR: Hirschfeld.
- SIGMEW General Assembly, Brussels, BE: Hirschfeld.
- DIA management committee meeting, Salerno, IT: Hirschfeld.
- SEMPER proposal meeting, Zurich, CH: Hirschfeld.
- SEMPER General Meeting, Athens, GR: Hirschfeld.
- SEMPER General Meeting, Munich, DE: Hirschfeld, Salvail.
- Working visit to Aarhus University: Cramer.
- Working visit to MIT, Cambridge, MA: Brands.
- Working visit to KPN, Leidschendam, NL: Hirschfeld.
- CAFE working visit to Siemens, Munich, DE: Hirschfeld.
- CAFE working visit to SEPT, Caen, FR: Hirschfeld.
- 7 CAFE working visits to European Commission, Brussels, BE: Hirschfeld.
- 3 CAFE working visits to European Commission, Brussels, BE: vd Kolk.
- 2 CAFE working visits to European Commission, Brussels, BE: Schoenmakers.
- 2 CAFE/VALUE working visits to Brussels, BE: vd Kolk.
- CAFE/VALUE working visit to London, GB: vd Kolk.

Memberships of Committees and Other Professional Activities

- CWI is a member of the National Chipcard Platform. In 1995, CWI was not active in the NCP, but Cramer was selected as the representative from the group to attend and provide input to the technical meetings.
- Hirschfeld is the deputy chairman of one of the task forces of the Special Interest Group for Multicurrency Electronic Wallets (SIGMEW).

- Brands served on the program committees of the Eurocrypt '96 and CARDIS '96 conferences.
- Most of the researchers in the group are members of the International Association for Cryptologic Research.

Visitors

- Antoon Bosselaers, Katholieke Universiteit Leuven, BE
- Claude Crepeau, Université de Montreal, CA
- Matthew Franklin, AT&T Bell Laboratories, US
- Jeroen vd Graaf, Université de Montreal, CA
- Sigrid Guergens, GMD, DE
- Eric Laffont, Gemplus, FR
- Torben Pedersen, Aarhus Univerity, DK
- Rene Peralta, JAIST, JP and University of Wisconsin at Milwaukee, US
- Kazue Sako, NEC, JP
- Louis Salvail, Université de Montreal, CA
- Victor Shoup, Universität des Saarlandes, De
- Jacques Stern, Ecole Normale Supérieure, FR

Papers in Journals and Proceedings

S. BRANDS, R. GILL (1995). Cryptography, statistics and pseudo-randomness, Probability and Mathematical Statistics, special issue in memoriam of Neyman.

R. CRAMER, I. DAMGAARD (1995). Secure Signature Schemes based on Interactive Protocols. *Crypto '95* 963, Santa Barbara, CA, Springer-Verlag, LNCS, 297–310.

R. HIRSCHFELD (1995). The CAFE trial on the European Commission premises. *Proceedings of Smart Card '95*, London, England, (supplemental).

CWI Reports

CS-R9504. L.A.M. SCHOENMAKERS. *A new algorithm for the recognition of series parallel graphs.*

CS-R9506. S.A. BRANDS. *Off-line electronic cash based on secret-key certificates.*

CS-R9509. S.A. BRANDS. *Restrictive blinding of secret-key certificates.*

CS-R9510. S.A. BRANDS. *Secret-key certificates.*

CS-R9519. S.A. BRANDS. *A note on parallel executions of restrictive blind issuing protocols for secret-key certificates.*

CS-R9522. L.A.M. SCHOENMAKERS. *An efficient electronic payment systems withstanding parallel attacks.*

CS-R9523. S.A. BRANDS. *Restrictive blind issuing of secret-key certificates in parallel mode.*

CS-R9529. R.J.F. CRAMER, T.P. PEDERSEN. *Efficient and provable security amplifications.*

CS-R9530. R.J.F. CRAMER. *On shared randomness and the size of secure signatures.*

CS-R9534. S.A. BRANDS. *More on restrictive blind issuing of secret-key certificates in parallel mode.*

CS-R9555. S.A. BRANDS. *Secret-key certificates* (continued).

CS-R9557. R.J.F. CRAMER. *New generation of secure and practical RSA-based signatures.*

CS-R9571. R.J.F. CRAMER, M. FRANKLIN, L.A.M. SCHOENMAKERS, M. YUNG. *Multi-authority secret-ballot elections with linear work.*

Other Publications

J.-P. KATOEN, B. SCHOENMAKERS (1995). *Systolic Arrays for the Recognition of Permutation-Invariant Segments*, Technical Report 95–27, Technical University of Twente, July 1995. To appear in Science of Computer Programming.

BRANDS, CRAMER (1995). Hirschfeld have each given a number of invited presentations at various international colloquia and seminars.

Interoperable Multimedia Systems – AA3

Staff

- Dr. D.C.A. Bulterman, Group leader
- Prof. L.G.L.T. Meertens, Group leader
- H.L. Hardman, M.Sc., Sen. Researcher
- A.J. Jansen, Programmer
- Drs. K.S. Mullender, Programmer
- Drs. J.R. van Ossenbruggen (trainee, till May 1)
- S. Pemberton, Sen. Researcher
- Drs. G. van Rossum, Sen. Researcher
- M.E. Schutler (trainee, 13 March–June 10)
- M. Theodoridou, M.Sc., Visiting Researcher
- Ir. O.J.M. Weber (STW)

Scientific Report

Interoperability of independently-developed multimedia applications is a research area of theoretic, strategic and pragmatic relevance. The central research issue of the Interoperable Multimedia Systems group is to develop formalisms and tools that support the concept of interoperability in its broadest sense. The research issues include the development of mechanisms that support abstract modelling, authoring, and runtime implementation of multimedia applications at the systems and user levels. The applications

studied cover a broad spectrum of concerns, but all share a need for presentation on heterogeneous environments and a requirement for long life-cycles to recover the high costs of multimedia data definition. The core problems include the development of document activity specification that can be used as the basis for transportable applications, the development of protocol rules for adaptive communication of multimedia data, and distributed resource allocation algorithms.

During 1995, the group participated in the following national and international research projects: ACELA (NL/STW) on the construction of interactive books, conducted within the project AA-3.1 Interactive Books (Meertens, Pemberton, Weber); CHAMELEON (EU/Esprit-IV) on the development of multimedia authoring systems for adaptive documents, conducted within AA-3.2 Multimedia Authoring Environments (Bulterman, Hardman, van Rossum, Jansen, Mullender, Theodoridou); and SEMPER (EU/ACTS), on multimedia support within secure electronic marketplaces and STEN (EU/Race) on ATM support for International Scientific Networks, conducted within AA-3.3 Distributed Multimedia Applications (Bulterman, Mullender).

Dick Bulterman. Together with Lambert Meertens, Bulterman directed the AA-3 group as it shifted a significant amount of its focus to multimedia activity. During this year, he published several papers (alone and together with Lynda Hardman) on various aspects of multimedia systems design and authoring. He successfully submitted funding proposals on three EU projects and he served as associate program chair and associate editor for a variety of leading conferences and journals during the year. He participated in the EU's CHAMELEON, SEMPER and STEN projects during the year.

Lynda Hardman. Ms. Hardman continued work on her dissertation in the area of hypermedia information models. She published several papers on various aspects of hypermedia authoring and on hyper-structured document design. She was a frequent presenter at conferences and workshops in conjunction with the activities of AA-3.2. She contributed significantly to the STEM project proposal, which was accepted for funding under the EU Telematics program starting in January 1996. She participated in the CHAMELEON project during the year.

Jack Jansen. Jansen contributed to the CMI-Fed/CHAMELEON runtime environments. He also worked on multi-platform support for CMIFed, specifically on the Macintosh port of this environment. His CMIFed work focussed on issues of scheduling

the runtime execution of multimedia data fragments. He was also involved in OR activities at CWI. He participated in the CHAMELEON project during the year.

Lambert Meertens. Together with Frans Rietman (Ph.D. student, UU) Meertens developed calculational techniques for deriving distributed programs from high-level specifications. He was invited to give a lecture series on program construction by calculation at ESSLII'95, Barcelona. For work together with Annette Bleeker, see AA2, Cryptology. Together with Steven Pemberton and Olaf Weber he performed mainly 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. Among the issues investigated were the design of a library of interactive presentation primitives, a simplified method to describe the structure of interactive electronic documents, and the design of style sheets for HTML documents.

Sjoerd Mullender. Mullender worked on implementation aspects of the CMIFed runtime environment. In particular, he worked on a uniform thread-based window interface and on support for media drivers within CMIF. He also contributed to the SEMPER project in AA-3.3, providing expertise on systems architecture and applications design and to the STEN project (also in AA-3.3), developing a test suite for ATM protocols (together with P. Beertema of CST).

Jaco van Ossenbruggen. As a visitor from the Free University of Amsterdam, Van Ossenbruggen worked in AA-3.2 on formalizing the CMIF and AHM models. Together with Hardman and Bulterman, he developed a Z-based AHM description and a HyTime translation of the CMIF/AHM document structure.

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.

Guido van Rossum. Van Rossum worked on developing and supporting the Python VHLL, which he invented at CWI. He also contributed to the development of the CMIFed multimedia environment in AA-3.2. Van Rossum spent most of the time at CNRI in Reston, VA (USA) during the year.

Maria Theodoridou. Ms. Theodoridou worked on various aspects of the CMIFed authoring environment in AA-3.2. Specifically, she worked to develop a number of applications that demonstrated the features of this system. She developed a multiplatform application for CD-ROM entitled Pictures at a Mondrian Exhibition together with composer David Little, based on a musical piece of the same name, which is scheduled for production in early 1996.

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.

Organization of Conferences, Workshops, Courses, etc.

S. Pemberton:
- 2nd International W4G Workshop on WWW Authoring and Integration tools. Held at INRIA, Rocquencourt, Paris, France, February 8–10, 1995
- HCI on the Web Workshop, Darmstadt, Germany, 10 April
- W4G BoF, Darmstadt Germany, 11 April
- CHI '95, Denver, Colorado, USA, 9–11 May 1995
- 3rd International W4G Workshop on searching and active documents. Held at VTT Helsinki, Finland, 5–7 June 1995
- EWHCI '95 Moscow, July 4–8, 1995
- World Wide Web Consortium Stylesheets Workshop, Paris, France, 6–7 November
- 4th International W4G Workshop on Design and Electronic Publishing Abingdon (near Oxford), England, 20–22 November 1995.

Visits to Conferences, Working Groups, Colloquia, etc.

D.C.A. Bulterman:
- GMD, Darmstadt, February 20; (SEMPER proposal preparation)
- STEN Workshop on Scientific ATM Networking, Madeira, March 20–22; On the Quality of Service of Long-Haul ATM Networks)
- European Commission, Brussels, March 30 and May 5; (STEN project review)
- IBM ZRL, Zürich, April 28 and May 26; (SEMPER proposal preparation)
- IEEE Conference on Multimedia, Washington D.C., May 16; (Workshop on Multimedia Synchronization)
- Cyncos CSO, Paris, June 6; (CHAMELEON proposal preparation)
- Xerox PARC, Palo Alto CA, June 8; (ACM MM '96 Program Committee meeting)
- IBM La Gaude, Nice, July 11–12; (SEMPER Kick-Off meeting)
- IBM Network Systems Center, Heidelberg, November 7; (SEMPER Synchronization workshop)
- CCLRC/RAL, London, December 13; (CHAMELEON Kick-Off meeting)
- FOGRA, Munich, December 18; (SEMPER quarterly meeting)

L. Hardman:
- MILIA, Cannes, January 12–13; (Panel: Roadblocks on the Information Highway)
- Sustainable Telematics for Environment Management, Brussels February 27 and July 7; (proposal preparation)
- ERCIM Workshop on Digital Libraries, Pisa, May 9;
- City University, London, June 22; (THEMA proposal preparation)
- International Workshop on Multimodal Multimedia Interfaces, Edinburgh, July 13–14; (Modelling the Multimedia Development Process)
- DFKI, Saarbrücken, October 12; (Document Model Issues for Hypermedia)
- ACM Multimedia '95, San Francisco, November 11–13; (Workshop on Effective Abstractions in Multimedia)
- Schloß Dagstuhl Seminar, near Turkismuhle, October 16–20; (Document Model Issues for Hypermedia)
- IEE Workshop on Authoring and Application of Hypermedia-Based User-Interfaces, London, November 14; (Multimedia Authoring Paradigms)

L.G.L.T. Meertens:
- IFIP WG 2.1 meeting, Hong Kong, January 9–13
- MPC '95, Kloster Irsee, Germany, July 17–21: L.G.L.T. Meertens
- ESSLLI'95, Barcelona, August 13–26: L.G.L.T. Meertens (Program construction by calculation)
- IFIP WG 2.1 meeting, Schloß Reisensburg, Germany, October 23–27: (A Relational Calculus for Distributed Processes; A Derivation of the Alternating Bit Protocol).

S. Pemberton:
- 2nd International W4G Workshop on WWW Authoring and Integration tools. Rocquencourt, February 8–10
- Electronic Community Workshop, Nashville, February 25

- ACM SIG Editors Workshop, Nashville, February 26
- World Wide Web Consortium European Meeting, Brussels, April 7
- 3rd International World Wide Web Conference, Darmstadt, April 10–13
- CHI '95, Denver, May 9–11
- HCI on the Web Special Interest Group Meeting, Denver, May 10
- ACM SIGCHI EC Meeting, Denver, May 12–14
- Working Visit to Apple Computer Inc. Cupertino, May 23; (Application Environments)
- 3rd International W4G Workshop on searching and active documents, VTT Helsinki, June 5–7
- Constraints working group meeting, Delft, July 13
- ACM SIGCHI EC Meeting, Detroit, August 25–27
- CHI 97 training meeting, New York, August 28–30
- CHI 97 organisational meeting, Atlanta, August 31 – September 1
- ERCIM/World Wide Web Consortium meeting, Paris, September 21
- World Wide Web Consortium, Paris, November 2–3
- World Wide Web Consortium Stylesheets Workshop, Paris, November 6–7; (Chair)
- 4th International W4G Workshop on Design and Electronic Publishing, Abingdon (near Oxford), England, November 20–22
- NLUUG Autumn Conference, Ede, November 23; (The Design of Electronic Publications)
- Working visit to ACM, New York, December 8
- ACM SIGCHI EC Meeting, New York, December 9–11
- 4th International World Wide Web Conference, Boston, December 12–14
- Stylesheets for HTML BoF, Boston, December 12; (Chair)

Committee Memberships and Other Professional Activities

D.C.A. Bulterman:
- Technical director, ESPRIT-IV CHAMELEON
- CWI project leader, ATCS SEMPER project
- Editorial board, Multimedia Systems Journal (ACM/Springer)
- Editorial board, Multimedia Tools and Applications Journal (Kluwer)
- Program committee, ACM Multimedia '95 (San Francisco; associate chair)
- Program committee, Multimedia Modelling '95 (Singapore)

- Member, SION Stuurgroep Multimedia
- Referee: ACM TOIS, IEEE Multimedia

L. Hardman:
- Proposal reviewer, EPSRC (UK)
- Program committee, International Workshop on Hypermedia Design, IWHD '95, Montpelier, France
- Reviewer: ACM Hypertext '96, IEEE MM magazine, J. Info Processing and Management, CACM
- Video reviewer, CHI '96

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
- Member of the Visiting Committee for Computer Science University Education in The Netherlands 1995/1996
- Project leader in the national NFI project STOP (Specification and Transformation of Programs)
- Project leader in the SION project MathViews and the STW project Acela
- Member Program Committee Third International Conference on the Mathematics of Program Construction, Kloster Irsee, Germany (1995)
- Member Program Committee IFIP TC2 Working Conference on Algorithmic Languages and Calculi, Strasbourg (1997)
- Member Ph.D. committee R.T. Udink, Program refinement in Unity-like environments, September 15 (UU)
- Ph.D. advisor F. Rietman, A Relational Calculus for the Design of Distributed Algorithms, September 27 (UU)
- Member Ph.D. committee I.S.W.B. Prasetya, Mechanically Supported Design of Self-stabilizing Algorithms, October 9 (UU)

S. Pemberton:
- Editor-in-chief ACM SIGCHI Bulletin, [Volume 26, Nos 1–4, 1994]
- Logistics co-chair, EWHCI'95
- Student Volunteers Chair, CHI '95
- Workshops and Special Interest Groups Chair, CHI '95
- 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)
- *Acela* project manager
- Advisor to Amsterdam and Haarlem Chamber of Commerce on WWW issues.

Visitors

- Prof. dr. J. Buford (U. Mass/Lowell) [Bulterman]
- E. Gudes (Ben-Gurion University of the Negev, Israel) [Mullender]
- Prof. dr. W. Grosky (Wayne State Univ.) [Hardman]
- Dr. A. Rezk (Eurclid) [Bulterman]
- Rodney Fuller; lecture: Finding and Visualizing Semantic Links within Email [Pemberton]

Papers in Journals and Proceedings

D.C.A. BULTERMAN (1995). Embedded Video in Hypermedia Documents: Supporting Integration and Adaptive Control. *TOIS* 13(4), 440–470.

D.C.A. BULTERMAN, L. HARDMAN (1995). Multimedia Authoring Tools: State of the Art and Research Challenges. JAN VAN LEEUWEN (ed.). *Computer Science Today: Recent Trends and Developments*, Springer Lecture Notes in Computer Science 1000, 575–591.

L. HARDMAN, G. VAN ROSSUM, A. VAN BOLHUIS (1995). An Interactive Multimedia Management Game. *Journal of Intelligent Systems* 5(2-4), 139–150.

D.C.A. BULTERMAN, L. HARDMAN (1995). Using the Amsterdam Hypermedia Model for Abstracting Presentation Behavior. *Procs. of Effective Abstractions in Multimedia*, ACM Multimedia '95 workshop, 4 November.

D.C.A. BULTERMAN, L. HARDMAN (1995). Authoring Support for Durable Interactive Multimedia Presentations. *State of The Art Report in Eurographics '95*, Maastricht, The Netherlands.

D.C.A. BULTERMAN, L. HARDMAN (1995). Towards the Generation of Hypermedia Structure. *Proc. of First International Workshop on Intelligence and Multimodality in Multimedia Interfaces*, Edinburgh, UK.

L. HARDMAN (1995). Experiences in Authoring Hypermedia: Creating Better Presentations. W. SCHULER, J. HANNEMANN, N. STREITZ (eds.). *Designing User Interfaces for Hypermedia*, Springer.

S. PEMBERTON (1995). No Such Number, No Such Zone. *SIGCHI Bulletin* 27(1).

R. FULLER, S. PEMBERTON (1995). Deconstructing TOG. *SIGCHI Bulletin* 27(2).

S. PEMBERTON (1995). Gbldgk - Steven Pemberton. *SIGCHI Bulletin* 27(2).

S. PEMBERTON (1995). Things that Stay Us form the Swift Completion of Our Appointed Tasks. *SIGCHI Bulletin* 27(3).

S. PEMBERTON (1995). Metaphorically Speaking. *SIGCHI Bulletin* 27(3).

CWI Reports

CS-R9518. K. CLENAGHAN. *Calculational graph algorithmics: reconciling two approaches with dynamic algebra.*

CS-R9524. G. VAN ROSSUM. *Python library reference.*

CS-R9525. G. VAN ROSSUM. *Python reference manual.*

CS-R9526. G. VAN ROSSUM. *Python tutorial.*

CS-R9527. G. VAN ROSSUM. *Extending and embedding the Python interpreter.*

CS-R9541. K.S. MULLENDER. *X Python reference manual.*

Other Publications

D.C.A. BULTERMAN, P. BEERTEMA, K.S. MULLENDER (1995). Adaptive Quality-of-Service Support in Heterogeneous Networks: Results of a Trans-European Experiment, CEC RACE project STEN (1003) *ABC Newsletter* 8.

S. PEMBERTON (1995). Grammar Analysis with ABC, *ABC Newsletter* 8.

S. PEMBERTON (1995). Eight Queens, More or Less, *ABC Newsletter* 8.

S. PEMBERTON (1995). General-Purpose Database, *ABC Newsletter* 8.

Databases – AA4

Staff

- Prof. dr. M.L Kersten, department head and group leader
- Drs. J.F.P. van den Akker (Ph.D. student)
- Dr.ir. R. Choenni (postdoc, from July 1 1995)
- Drs. F. van Dijk (programmer, MADE)
- M.C.A. van de Graaf (trainee, 1 Januari – 1 September)
- Ir. M. Holsheimer (proj. member, till 1 September)
- A.R. van Hulzen (trainee, March 16–16 June)
- L. Keuss (trainee, 1 February–1 June)
- Ing. F. Kwakkel (proj. member, Pythagoras, till 1 December)
- Ir. J. Pellenkoft (Ph.D. student)

- Dr. A.P.J.M. Siebes (project leader)
- Drs. H. Sprangers (visitor, from 16 October)
- C. del Val Merino (trainee, 1 February – 1 September)

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.

Monet is a database kernel developed in our group 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.

Developments in 1995 have been concentrated on the realization of a module extension facility to the database system, its consolidation and dissemination to key partners working on data mining and geographical information systems. Furthermore, the kernel has been extended by *Kersten* to enable experimentation with database triggers. The results of this investigation have been published at an international forum. With *Boncz* (UvA) an overview of the system architecture has been produced and published at the international BIWITT'95 conference.

Two HIO trainees have ported the database system to the IBM SP/1. The results of this experiment demonstrated the maturity of the system software and prepares the route for the full scale development of an MPP version of the Monet kernel. Such a version is a prerequisite to experiment with the already designed algorithms for dynamic and randomized query optimization.

Query optimization. Galindo, Pellenkoft and *Kersten* continued their cooperation by focussing on the problem of selecting efficiently valid-query evaluation plans from a large space. The theory for uniformly distributed random generation of plans has been presented at the International Conference on Database Theory, Prague. *Pellenkoft* has spent three months in the US at the Microsoft team responsible for the development of their new query optimizer.

Geographical Information Systems. As of mid-1994 a national project on Geographical 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. In 1995 we have developed and published results on a large-scale GIS benchmark to demonstrate the approach taken.

Active Databases. 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 1994 and was published in 1995. Subsequently, the attention has been shifted to the design of a *data model for autonomous objects*. In 1995 a data model was formulated as a foundation for an active, object database programming language, DEGAS. It will serve as a basis for research into design of active object-based information systems. The implementation of a prototype DEGAS system started late in 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 1995 of *Holsheimer* has been on further development 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 1995.

In a more theoretical track, *Siebes* has continued the development of a framework for data mining which resulted in an inductive query language called *Data Surveying*.

The intensive contacts of the data mining project with industry has led to the foundation of the spin-off company *Data Distilleries* that will commercialise *Data Surveyor.*

Finally, collaboration with data mining research groups at the University of Helsinki (*prof. Mannila*) and GMD (*dr. Klösgen*) has resulted in the (granted) ESPRIT project KESO.

A performance assessment toolkit. The ESPRIT-III project Pythagoras came to an end with high marks for the results achieved. The software delivered has been documented extensively and it has been used in various of our other projects to improve experimentation.

Carel v.d. Berg and *Kwakkel* set up 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.

The successor project, called Mercury, has started per December and aims at further extending the use of the Software Testpilot as a means to control and predict the performance of database technology. As of end of 1995 *Kwakkel* decided to join Data Distilleries, which delayed the evident Ph.D. track based on the result obtained.

Physical Database Design. Since July 1, 1995, Choenni joined the database research group. In anticipation of the start of the ESPRIT-IV project KESO, work initiated at Univ. Twente and GAK have been finalized. In particular, several papers on physical database design for relational and object-oriented databases have been published.

Organization 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 substancial effort has been invested in reporting the project's progress towards the CEC
- Kersten, organizer and chairmen of the 'Seminar on Datawarehousing' in cooperation with Euroforum, November 1995, Amsterdam
- KESO. CWI is prime contractor of the ESPRIT-IV project KESO. Its day-to-management is lead by A. Siebes. Several working meetings have been organized and substantial effort has been invested in reporting the project's progress towards the CEC

- J.F.P. van den Akker organized the Autumn 1995 Dutch Database Workshop, held on November 14th, 1995 at CWI
- HPCN project preperation meeting (C. Skelton), Jan. 16, Manchester: Kersten, Siebes
- Pythagoras project meeting (P. Broughton), Jan. 17, Manchester: M. Kersten
- Parallel Application Center (C. Uphil) and Univ. of Southampton, Jan. 18, M. Kersten, 'The software testpilot experience'
- Magnum project meeting, Amsterdam, Feb. 14: Kersten
- ERCIM executive committee meeting, Oporto, Feb. 20: Kersten
- ETH Zurich (J-G. Schek), Feb. 22: Kersten 'The software testpilot experience'
- University of Zurich (K. Dittrich), Feb. 23: Kersten
- Review meeting Copernicus project, Sztaki, Budapest, Feb. 27: Kersten
- HPCN project preparation CEC Brussel (T. vd Pyl): March 14: Kersten
- AIO-week Informatiesystemen, Arnhem, March 20–24: Van den Akker
- PAO lecture Data Mining, Utrecht, April 6: Holsheimer, Siebes (lecturers)
- PAO lecture Data Mining, Utrecht, April 12: Holsheimer, Siebes (lecturers)
- Spring 1995 Dutch Database Workshop, TU Eindhoven, April 25: Pellenkoft, Van den Akker ('Autonomous objects in Databases')
- Datamining meeting Philips Nederland (Everaars), Eindhoven, April 26: Kersten, Siebes
- MLnet Familiarization workshop on Statistics, Machine Learning, and Knowledge Discovery in Databases: Siebes ('On the inseparability of data mining and statistics')
- Pythagoras project meeting, Edingburgh, April 27: Kersten, Kwakkel
- Review Epoch project, München, May 16: Kersten
- Datamining meeting Philips Consumer Electronics, Eindhoven, May 31: Kersten, Siebes
- Direct Marketing Seminar (IIR), Amsterdam, June 14: Siebes ('Data Mining: Schatgraven in Databases')
- KESO negotiation meeting, July 10, Luxemburg: Siebes
- First International Conference on Knowledge Discovery and Data Mining, August 20–21, Montreal, Canada: Holsheimer ('A perspective on databases and data mining'), Siebes ('Data Surveying: Foundations of an Inductive Query Language')

- ERCIM executive committee meeting, Heraklion, Sept 1: Kersten
- Eurographics Workshop on Programming Paradigms in Graphics, Maastricht, September 2–3: Van den Akker ('Applying an Advanced Data Model to Graphic Constraint Handling')
- Esprit workshop, September 9–10, Eurostat, Luxembourg: Siebes (Knowledge Extraction for Statistical Offices).
- Conference on Very Large Databases, Zurich, Sept. 13–15: Kersten
- Int. Workshop on Rules in Databases '95, Sept. 25–27, Athens, Greece: Kersten
- DMSA congres, Maastricht, October 2–4: Siebes ('Direkt Marketing and Databases')
- ERCIM executive meeting, Paris, Oct. 9–10: Kersten
- 2BIS lezing, Twente University, November 3: Siebes ('An introduction to data mining')
- ERCIM executive and directors meeting, Sztaki, Budapest, Nov. 8–10: Kersten
- New Trends and Technologies in Statistics, November 19–22, Bonn: Siebes ('Data mining for Statistical Offices')
- PAO Course Data Mining, Amsterdam, November 21–22: Siebes (lecturer)
- Seminar Datawarehousing, Amsterdam, Nov. 28: Kersten 'The datawarehouse concepts'
- KESO preperation meeting, December 11, GMD Bonn: Siebes ('The KESO architecture')
- HPCN meeting on project strategies, Brussels, Dec. 12: Kersten
- Review meeting Copernicus project, Smolenice, Slovenia, Dec. 13: Kersten

Membership of Committees and Other Professional Activities

M.L. Kersten:
- Professor of Computer Science, University of Amsterdam
- Project coordinator CEC project 7091, Pythagoras
- Member editorial board 'The VLDB Journal'
- Member editorial board 'Distributed and Parallel Databases'
- Project leader SION project Starfish: SION aandachtsgebied
- Reviewer ESPRIT HPCN proposals
- Reviewer ESPRIT Copernicus project
- Member IFIP working group 2.6
- Member CEC evaluation committee ESPRIT-III, HPCN applications
- Member executive committee ERCIM
- Member program committee Int. Workshop Rules in Database 1995

- Member program committee Int. Workshop on Image Databases and Multi Media Search 96
- European coordinator VLDB 1996
- Member program committee VLDB 1996
- Tutorial coordinator EDBT 96
- Member Beoordelingscommissie Onderzoek SION 1995–1996
- Rijksgecommitteerde HIO 'Oost-Nederland'
- Co-founder of Data Distilleries

A.P.J.M. Siebes:
- Co-promotor C.J.E. Thieme, May 23
- Member of the program commitee of the MLnet familiarization workshop on Statistics, Machine Learning and Knowledge Discovery in Databases
- Member of the program commitee of the First International Conference on Knowledge Discovery and Data Mining (KDD-95).

M. Holsheimer:
- Member database club NGI
- Co-founder of Data Distilleries

Visitors

- Andres [Kersten]
- Mannila/Klösgen [Siebes]
- Saltor [Thieme]
- Skelton [Siebes]
- Theodoridou [Kersten]

Papers in Journals and Proceedings

J.F.P. VAN DEN AKKER, A.P.J.M. SIEBES (1995). Applying an Advanced Data Model to Graphic Constraint Handling. *Proceedings of the 5th Eurographics Workshop on Programming Paradigms in Graphics*, Maastricht, The Netherlands.

F. ANDRES, F. KWAKKEL, M.L. KERSTEN (1995). Calibration of a DBMS using the Software Testpilot. *CISMOD95*, New Deli.

P.A. BONCZ, M.L. KERSTEN (1995). Monet: An Impressionist Sketch Of An Advanced Database System. *BIWIT '95*, Spain, 240–251.

R. CHOENNI, H. WAGTERVELD, H.M. BLANKEN, S.C. CHANG (1995). A. MIN TJOA, N. REVELL (eds.). *TOPYDE: A Tool for Physical Database Design*, DEXA '95 6th Int. Conf. on Database and Expert Systems Applications, London, United Kingdom, Springer-Verlag, Lectures Notes in Computer Science 978, 502–511.

M. VAN DE GRAAF, M.L. KERSTEN (1995). Cooperative Systems Supported by Active Database Technology. *8th ERCIM Database Research Workshop*

on Database Issues and Infrastructure in Cooperative Information Systems, Trondheim, Norway.

M. HOLSHEIMER, M.L. KERSTEN, H. MANNILA (1995). A perspective on databases and data mining. Proc. Knowledge Discovery in Database '95 (KDD95), Montreal, Canada.

C.A. GALINDO LEGARIA, J. PELLENKOFT, M.L. KERSTEN (1995). Uniformly-distributed random generation of join orders. International Conference on Database Theory, Prague.

M.L. KERSTEN (1995). An Active Component for a Parallel Database Kernel. T. SELLIS (ed.). Proceedings Rules in Databases '95, Springer-Verlag, 277–291.

A.P.J.M. SIEBES (1995). On the inseparability of data mining and statistics. Proceedings of the ML-net familiarization workshop on Statistics, Machine Learning and Knowledge Discovery in Databases, Crete, Greece.

A.P.J.M. SIEBES (1995). Data Surveying: Foundations of an Inductive Query Language. Proceedings of the First International Conference on Knowledge Discovery and Databases, Montreal, Canada.

A.P.J.M. SIEBES (1995). Knowledge Extraction for Statistical Offices. Proceedings of the Eurostat Conference on New Trends and Technologies in Statistics, Bonn, Germany.

C.J.E. THIEME, A.P.J.M. SIEBES (1995). Guiding schema integration by behavioural information. To be published in Information Systems.

CWI Reports

CS-R9521. M.L. KERSTEN, M. HOLSHEIMER. On the symbiosis of a data mining environment and a DBMS.

CS-R9531. M. HOLSHEIMER, M.L. KERSTEN, H. MANNILA, H. TOIVONEN. A perspective on databases and data mining.

CS-R9539. J.F.P. VAN DEN AKKER, A.P.J.M. SIEBES. A data model for autonomous objects.

CS-R9556. A.P.J.M. SIEBES, J.F.P. VAN DEN AKKER, M.H. VAN DER VOORT. (Un)decidability results for trigger design theories.

CS-R9568. P.A. BONCZ, F. KWAKKEL, M.L. KERSTEN. High performance support for OO traversals in Monet.

Other Publications

C. THIEME (1995). Schema Integration Based on Structure and Behaviour, Ph.D. Thesis, Universiteit van Amsterdam.

F. KWAKKEL (1995). Architecture Documentation of the Software Testpilot Implementation, Pythagoras Project Deliverable.

R. CHOENNI, H. WAGTERVELD (1995). Complexiteit grote database groeit ontwerper boven het hoofd. Automatisering Gids, jaargang 29, week 33/34, 1995, Ten Hagen & Stam Uitgevers, Den Haag.

M. HOLSHEIMER, A.P.J.M. SIEBES (1995). Data Mining. Handboek Database Systemen, Array Publications, 8440, 1–24.

DEPARTMENT OF INTERACTIVE SYSTEMS

Staff 1995

- Computer Graphics and Visualization – 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
  - M. in 't Veld
  - J.J. van Wijk
  - C.A. Wüthrich

- Interaction and Parallelism – IS2

  - F. Arbab
  - C.L. Blom

  - F.J. Burger
  - P.A.J. Bouvry
  - C.T.H. Everaars
  - M.A. Guravage
  - R.H.M.C. Kelleners
  - G.A. Papadopoulos
  - R.C. Veltkamp

- Interaction and Multimedia – IS3

  - P.J.W. ten Hagen
  - M. Haindl
  - F.C. Heeman
  - I. Herman
  - H. Noot
  - G.J. Reynolds
  - M.M. de Ruiter

- Secretary: M. Hegt (until September)
                J.J. Bruné (from September)

Computer Graphics and Visualization – IS1

Staff

- Drs. A.A.M. Kuijk (group leader)
- Prof. dr. E.H. Blake
- I. Diaz de Etura
- S. Haritakis
- Ir. R. van Liere (researcher)
- Dr. P.C. Marais
- J.D. Mulder (Ph.D. student)
- J. van de Poll
- Drs. T. van Rij (researcher)
- M. in 't Veld
- Dr. J.J. van Wijk (project leader)
- Dr. C.A. Wüthrich

Scientific Report

Computer Graphics. In this year, 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). The project ended with a successful demonstration for an international group of system engineers.

ADMIRE is a rule-based system that serves to optimize the performance of graphics applications by dynamically selecting rendering algorithms, data structures and level of detail on a per-object basis. The system was reimplemented in C++ because an implementation in the object oriented language EIFFEL turned out to be too slow. Together with Marisa de Diego an animation system based on actors was implemented. A graphics user interface was implemented based on FORMS. The first static rules that serve to select the appropriate rendering algorithm and level of detail were put in and analysed.

Image Coding. In this year research on image coding concentrated on characteristics of quadratic and cubic spline-wavelet transforms. Decoding of multi-resolution image representations based on these transforms has been analysed. Some characteristics of architectures for image reconstruction were studied.

Computational Steering. The goal of the computational steering project is to study methods and techniques that allow for interactive control of simulations. The techniques are incorperated into the Computational Steering Environment. Particular emphasis is placed in applying new techniques to

industrial problems.
A number of research topics were addressed in 1995:

- 3D presentation, interaction and viewing.
- visualization environments for high performance computing.
- high level input and control.

J.D. Mulder continued work on 3D presentation, interaction and viewing. The work involves research and develop of novel interaction techniques which allow users to specify visualizations in intuitive ways. R. van Liere and J.J. van Wijk continued work on distributed visualization systems. This work involves applying computational steering to practical high performance computing problems. This has lead to a joint HPCN project proposal with ACE, Arcobel, CAP-Volmac and FEL-TNO on high performance visualization, which has been granted.
K. Shahroudi and J.J. van Wijk started work on the SION funded project. The goal of this work is to research high level input techniques for interactive scientific visualization.

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

- *TOOLS EUROPE 1995*, Versailles, March 6–10: T. v. Rij.
- *EIFFEL Workshop*, Paris, March 8: T. van Rij (Using Eiffel to Adaptively Render 3 Dimensional Images).
- *ProRISC & IEEE Benelux Workshop on Circuits, Systems and Signal Processing*, Mierlo, March 23–24: A.A.M. Kuijk (Efficient Vector Quantization Using the Human Visual System Characteristics) and (Wavelet-based Image Encoding and Real-Time Reconstruction on a VLSI Difference Engine for Image Generation).
- *Eurographics Workshop: Implicit Surfaces '95*, Grenoble, April 18–19: A.A.M. Kuijk.
- *6th EG Scientific Visualization Workshop*, Chia, Italy, May 3–5: J.J. van Wijk and J.D. Mulder.
- *Software in Nederland: Motor voor nieuwe producten en diensten?*, Eindhoven, May 31: A.A.M. Kuijk.
- *10th Eurographics Workshop on Computer Graphics Hardware*, Maastricht, August 28–29: A.A.M. Kuijk (A VLSI Difference Engine for Image Generation).
- *Eurographics '95*, Maastricht, August 28–September 1: T. van Rij, J.D. Mulder, K. Shahroudi and J.J. van Wijk.

- *Eurographics'95*, Maastricht, August 30–September 1: A.A.M. Kuijk.
- *Visualization'95*, Atlanta, October 27–November 4: J.D. Mulder.

Courses
ASCI course on Scientific Visualization, Delft, May 29–June 2: R. van Liere.

Consultancy
SKF, Nieuwegein, November 13–December 1: R. van Liere.

Memberships of Committees and Other Professional Activities

A.A.M. Kuijk:
- Member Programme Committee Eurographics Workshop on Graphics Hardware
- Member Programme Committee International Workshop on Implicit Surfaces

R. van Liere:
- ACM Transactions on Graphics Reviewer
- Computer Graphics Forum Reviewer
- Member VISTAN Working group

J.J. van Wijk:
- Member Executive Committee Eurographics
- Chairman Eurographics Working Group on Visualization in Scientific Computing
- Computer Graphics Forum Reviewer
- Eurographics'95 Reviewer
- SIGGRAPH'95 Reviewer
- IEEE Transactions on Visualization and Computer Graphics Reviewer
- Member VISTAN Working group

Papers in Journals and Proceedings

T. VAN RIJ, A.A.M. KUIJK (1995). Using Eiffel to adaptively render 3 dimensional images. *EIFFEL Workshop Paris, March 8*.

T. VAN RIJ, A.A.M. KUIJK (1995). Using Eiffel to adaptively render 3 dimensional images. *Eiffel Outlook* 4(5).

S.M. HARITAKIS, A.A.M. KUIJK (1995). Efficient vector quantization using the human visual system characteristics. *ProRISC/IEEE workshop on Circuits, Systems and Signal Processing*, Mierlo, March 23–24.

P.C. MARAIS, E.H. BLAKE, A.A.M. KUIJK (1995). Wavelet-based image encoding and real-time reconstruction on a VLSI difference engine for image generation. *ProRISC/IEEE workshop on Circuits, Systems and Signal Processing*, Mierlo, March 23–24.

J.D. MULDER, J.J. VAN WIJK (1995). Logging in a Computational Steering Environment. R. SCATENI, J.J. VAN WIJK, P. ZANARINI (eds.). *Visualization in Scientific Computing '95 , Proceedings EG'95 Workshop on Visualization in Scientific Computing*, Chia, Italy, 118–125.

J.D. MULDER, J.J. VAN WIJK (1995). 3D Computational Steering with Parametrized Geometric Objects, *IEEE Visualization '95 , Atlanta, USA*, 304–311.

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)
- Drs. C.T.H. Everaars (programmer, 0.7 fte)
- Drs. M.A. Guravage (researcher, till August)
- Ir. R.H.M.C. Kelleners (Ph.D. student, SION)
- Dr. G.A. Papadopoulos (ERCIM Fellow, from July 1st)
- Dr. R.C. Veltkamp (post-doc, SION, till September)

Scientific Report

Implementation of the Manifold language compiler, its run-time system, and support utilities continued in 1995. By the end of 1995, the implementation of the basic Manifold system was complete. Maintenance and enhancement of the basic system, as well as the development of additional utilities and programming libraries and support tools still continue.

We began to use the Manifold system to run real examples. *C.T.H. Everaars* was dispatched from NW2 to spend 0.7 fte his time in IS2 in order to learn Manifold and study the suitability of Manifold for numerical applications. He worked on several examples and his results were very promising. Researchers in NW2 and in other groups were encouraged by these results to start and experiment with Manifold for their applications.

Dr. Papadopoulos (University of Cyprus) spent six months of his ERCIM fellowship in our group working on Manifold. Together with him, we worked on several papers on coordination models and languages and he evaluated the applicability of Manifold for soft real-time applications. We plan to continue our collaboration and finish our joint papers in 1996.

We contributed to the submission of two HPCN proposals which were accepted. The work on these projects will start in 1996. Our partners in these projects include NLR and Delft Hydraulics.

M.A. Guravage developed the Manifold interface library for external atomic processes. This software is not yet integrated with the rest of the Manifold software, due to his early departure.

The first prototype implementation of the Visifold visual programming environment for Manifold was done by *P.A.J. Bouvry*. This work proceeded at a slower pace than planned, due to early departure of M.A. Guravage. His position is now vacant.

The work of *R.C. Veltkamp* on "Constraint-based Graphics" in IS2 was stopped due to his early departure. His position is now vacant. *R.H.M.C. Kelleners* is making progress with his research on "Constraints in Object Orientation" for his Ph.D.

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*, September

Organization of Conferences, Workshops, Courses, etc.

- F. Arbab: PARCO Program Committee
- F. Arbab: Eurographics Programming Paradigms for Graphics Program Committee
- R.C. Veltkamp: Eurographics Programming Paradigms for Graphics Program Co-chair

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

- F. Arbab: Eurographics 95, August 28–September 1, Maastricht
- F. Arbab: Eurographics Programming Paradigms for Graphics, September 2–3, Maastricht
- F. Arbab: PARCO, September 19–22, Gent
- C.L. Blom: Eurographics 95, August 28–September 1, Maastricht
- P.A.J. Bouvry: Journées du SEH 95, Paris, January
- P.A.J. Bouvry: ECCO VIII, Eight European Chapter on Combinatorial Optimization, Poznan (Poland), May
- P.A.J. Bouvry: Scheduling in Computer and Manifacturing Systems, Dagstuhl (Germany), May

- P.A.J. Bouvry: Eurographics 95, August 28–September 1, Maastricht
- R.C. Veltkamp: Eurographics 95, August 28–September 1, Maastricht
- R.C. Veltkamp: Eurographics Programming Paradigms for Graphics, September 2–3, Maastricht

Papers in Journals and Proceedings

P. BOUVRY, D. TRYSTRAM (1995). Placement de taches sur ordinateurs paralleles a mémoire distribuée. Journées du SEH 95, Paris, France.

J. BLAZEWICZ, P. BOUVRY, D. TRYSTRAM, R. WALKOWIAK (1995). An efficient tabu search for the mapping problem. *ECCO VIII, Eight European Chapter on Combinatorial Optimization*, Poznan, Poland.

P. BOUVRY (1995). Mapping Undirected Task Graphs on DMPC. *Scheduling in Computer and Manifacturing Systems*, Dagstuhl, Germany.

P. BOUVRY, J. CHASSIN, D. TRYSTRAM (1995). Efficient Solutions for mapping parallel programs, Europar 95, Stockholm, Sweden.

CWI Reports

CS-R9565. F. ARBAB. *Coordination of massively concurrent activities.*

Other Publications (including software packages and documentation)

R. SCATENI, J.J. VAN WIJK, P. ZANARINI (1995). Visualization in *Scientific Computing '95*, Springer Computer Science.
Software:

F. ARBAB. *mc: the Manifold language compiler.*

F. ARBAB. *DTh: a package for building applications with distributed threads.*

F. ARBAB. *build: a utility for building distributed and parallel applications.*

F. ARBAB. *mlink: the Manifold linker.*

F. ARBAB. *decoy: a utility to produce fake Manifold modules.*

F. ARBAB. *config: a utility for run-time configuration of distributed applications.*

C.L. BLOM. *Manifold interface library for atomic manners and internal atomic processes.*

C.L. BLOM. *Manifold Builin Library.*

F.J. BURGER. *the Manifold run-time system modules Guravage Manifold interface library for external atomic processes.*

R.C. VELTKAMP. *2Smurve: 2D smooth curve modeling.*

R.C. VELTKAMP. *3Smurve: 3D smooth curve modeling.*

R.C. VELTKAMP. *Covas: constrained variational surface modeling.*

Documentation:

F. ARBAB. *DTh: a package for building applications with distributed threads.*

F. ARBAB. *build: a utility for building distributed and parallel applications.*

F. ARBAB. *mlink: the Manifold linker.*

F. ARBAB. *decoy: a utility to produce fake Manifold modules.*

F. ARBAB. *config: a utility for run-time configuration of distributed applications.*

F. ARBAB. *Manifold interface library for atomic manners and compliant atomic processes.*

F. ARBAB. *Manifold Reference Manual – preliminary version.*

Visitors

- Dr. G.A. Papadopoulos, University of Cyprus, July 1–December 31
- Dr. Franciszek Seredynski, Polish Academy of Sciences, September 15–18

Interaction and Multimedia – IS3

Staff

- Drs. P.J.W. ten Hagen (head of department, group leader, project leader MADE)
- Dr. M. Haindl (project member MADE)
- Drs. F.C. Heeman (project member MADE)
- Dr. I. Herman (senior researcher and Workpackage Manager MADE)
- Drs. J.E.A. van Hintum (Ph.D. student MADE)
- Drs. H. Noot (programmer MADE)
- Dr. G.J. Reynolds (project member MADE)
- Drs. M.M. de Ruiter (programmer MADE)

Scientific Report

Multimedia Fundamentals. Attention shifted to the Modelling and Interaction components of PREMO. IS3 continued to make major contributions. Many were produced as position papers prepared at several workshops of the EU HCM project ERCIM Computer Graphics Network under task 2. After the ISO meeting in Airlie (USA), IS3 (I. Herman) became co-editor of PREMO Part IV about Multimedia Systems Services. Together with the co-editor Dr. J. van Loo (Sun) a compatible version was prepared.

This version will also become the accepted standard for the IMA consortium of over 300 companies.

Multimedia Systems. The MADE project was extended by six months until the end of 1995. IS3 took over several task of Bull who had to partially withdraw. As a result IS3 became the sole designer and implementer of the integration functionality of MADE, being the technologically most advanced part. This work was succesfully completed with a very positive technical review by the EU. CWI succeeded in finding an industrial partner who will bring the entire MADE result to the market (world wide), on behalf of the entire consortium.

Organization of Conferences, Workshops, Courses, etc.

- EUROGRAPHICS 95 was organised by CWI, with the following persons involved: P.J.W. ten Hagen, conference co chair and chairman G. Reynolds, tutorials chairman; R. Veltkamp, state of the art reports and panels chairman; H. Nieland, slide and video competition; F. Snijders, secretary organising committee. The conference took place from August 28 until September 1.
- PREMO Workshop at CWI, March 20–24, organised by P.J.W. ten Hagen, I. Herman and G. Reynolds.
- ISO/IEC JTC1/SC24/WG6 meeting in Ottawa, Canada, July 12–13 organised by P.J.W. ten Hagen.

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

- The MADE project: The MADE project team members have had many working visits, both at CWI and at partners places. Especially during the takeover of Bull Tasks by CWI visiting frequency was high. Meeting places were at Bull or ESI, Paris, British Aerospace, UK, Nr, Oslo, Norway, and at the EU in Brussels. As part of the marketing of MADE visits were also made to Gallium Ottawa and Sun, California.
- The ERCIM Computer Graphics Network. Several workshops were organised under Task2 of this EU HCM network. P.J.W. ten Hagen as chiar of task two coorganised workshops in Manchester, UK, January 24–27 on PREMO components with CWI participation of P.J.W. ten Hagen, I. Herman and G. Reynolds. In Amsterdam, March 20–23, with the same perticipants from CWI, on Modelling and Interaction. In Abingdon, UK, on April 24–25, on Constraints in Multimedia. in Toulouse, France, on June 5–8, on Time and Synchronisation

in Multimedia. In Amsterdam, on September 14–15, on Sound Components for PREMO.

- The ISO Rapporteur Group on PREMO had three technical meetings, one of which was chaired by P.J.W. ten Hagen. IS3 made considerable contributions to these meetings. The participants were P.J.W. ten Hagen, I. Herman and G. Reynolds. The meetings were: in Bonn, Germany, on February 13–17. In Ottawa, Canada, on July 5–12. In Chester, UK, on October 2–6.
- The steering committee if the ERCIM CG Network of the EU HCM programme held two meetings were P.J.W. ten Hagen participated on January 26, in Manchester, and on June 7 in Toulouse.
- National Conference on Software for Industry in Eindhoven on May 31: P.J.W. ten Hagen paticipated in the preparatory meetings, formulating position papers.
- IMA meeting in Boston, USA on June 1–2: P.J.W. ten Hagen participated as ISO liaison officer.
- ESPRIT OMHEGA project review meeting, Brussels June 8–9: P.J.W. ten Hagen.
- ISO/IEC JTC1/SC24 meeting in Ottawa, Canada, July 13–14: P.J.W.ten Hagen, I Herman.
- EG95 conference, Maastricht, August 28–September 1: P.J.W. ten Hagen, I. Herman. G. Reynolds, M. Haindl, J.E.A. van Hintum, H. Noot, M.M. de Ruiter.
- EU 5th Framework preparation by NWO, Den Haag on September 13: P.J.W.ten Hagen.
- Working Visits to Industry
  P.J.W. ten Hagen payed working visits to industry: Finsiel, Brussels on January 18 (with I. Herman). Elsevier, on January 20. IRDETO on February 9. UNISYS on March 15. XELION on March 22. Fokker Space & Systems on April 7. SKF Research on May 11. Gallium, Ottawa, on July 12, with I. Herman, also on November 23. ACE on August 23. Philips Research on November 1. BARCO, Belgium on November 9. SUN Microsystems, USA on November 27.
- Working Visits to Academia, P.J.W. ten Hagen, H. van Hintum and R. Veltkamp visited TUE (Prof. D. Hammer and Dr. C. van Overveld) on June 15. P.J.W. ten Hagen and P. Griffin visited TUD, Dr. J. Gerbrands and Ir. M. Reynders, on February 6. P.J.W. ten Hagen and F. Arbab visited Hydrolics Labs in Delft on March 7 (Dr. A. Mynett). P.J.W. ten Hagen and R. van Liere visited Prof. J. Encarnaçao at FhG-IGD in Darmstadt, Germany, on December 14.

Memberships of Committees and Other Professional Activities

P.J.W. ten Hagen:
- Fellow of EUROGRAPHICS
- Member of the Executive Committee of EUROGRAPHICS.
- Program committee member of EG 95, and 96 annual conference.
- Chairman of the organising committee of the EG95 annual conference.
- Member of the Eurpean Steering Committee for Computer Graphics.
- Co-chair of the ERCIM CGN worksop series.
- Member of IFIP W.G. 5.2 on CAD.
- Member of IFIP W.G. 5.10 on Computer Graphics.
- Project leader of ESPRIT MADE for CWI.
- Chairman of ISO/IEC JTC1/SC24 WG6 on Multimedia.
- Liaison for ISO to IMA.
- Liaison for ISO to OMG.
- Member of the advisory subcommittee for mathematics and computer science of the Dutch Aerospace Laboratory.
- Member of the advisory board of the 'Post Hogere Technisch Onderwijs' school in Amsterdam.

Papers in Journals and Proceedings

F. ARBAB, I. HERMAN, G.J. REYNOLDS (1993). An Object Model for Multimedia Programming. *Computer Graphics Forum (Eurographics'93 Conference Issue)* 12. Also CS-R9327.

J. DAVY, I. HERMAN, G.J. REYNOLDS (1994). MADE: an Environment for Object-oriented Multimedia Support. *Proc. of Multimedia et Normalisation de la Telematique a la Television Numerique*, Colloque International, 22/23 Mars, Paris.

I. HERMAN, G.J. REYNOLDS, J. DAVY (1993). MADE: A Multimedia Application development environment. L.A. BELADY, S.M. STEVENS, R. STEINMETZ (eds.). *Proc. of the IEEE International Conference on Multimedia Computing and Systems*, IEEE CS Press, Los Alamitos, Boston, California. Also CS-R9360.

I. HERMAN, G.J. REYNOLDS, J. DAVY (1994). MADE: A Multimedia application development environment. *CWI Quarterly* 7(1).

F.C. HEEMAN, I. HERMAN, G.J. REYNOLDS (1994). Interaction Objects in the MADE Multimedia Environment. W. HERZNER, F. KAPPE (eds.). *Proc.*

of the 1st Eurographics Symposium on Multimedia, Graz, Springer Verlag. Also in: CWI Reports, CS-R9516.

J.E.A. VAN HINTUM, G.J. REYNOLDS (1995). Multimedia Constraint System (or do we have it MADE?). *Computer Graphics Forum (Eurographics'95 Conference Issue)* **14**.

M. HAINDL, M.M. DE RUITER (1993). The MADE Help System. *Computer Graphics Forum (Eurographics'95 Conference Issue)* **14**. Also in: CWI Reports, CS-R9528.

G.J. REYNOLDS, F.C. HEEMAN, I. HERMAN (1996). Towards a Metaphor-Neutral Service Kernel for Multimedia Composition, submitted for publication.

PREMO Related Publications (Journals, Conferences, etc.)

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.). *Proc. of the 1st Eurographics Symposium on Multimedia,* Graz, Springer Verlag.

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.). *Proc. of the Second ACM International Conference on Multimedia (MM'94),* San Francisco, ACM Press.

D.A. DUCE, D.J. DUKE, P.J.W. TEN HAGEN, I. HERMAN, G.J. REYNOLDS (1995). Formal Methods in the Development of PREMO. *Computer Standards & Interfaces* **17**,491–509. Also in: CWI reports, CS-R9465.

I. HERMAN, G.J. REYNOLDS, J. VAN LOO (1996). PREMO: An emerging standard for multimedia. Part I: Overview and Framework. *IEEE Multimedia.*

I. HERMAN, G.J. REYNOLDS, J. VAN LOO (1996). PREMO: An emerging standard for multimedia. Part II: Specification and Applications. *IEEE Multimedia.*

I. HERMAN, G.J. REYNOLDS, N. CORREIA, D.J. DUKE, D.A. DUCE (1996). A Model for Multimedia Synchronization: the PREMO Synchronization Objects.

Additional MADE Documents

I. HERMAN (1995). *MCThreads: A Low-level Threads Interface,* Version 2.

F. ARBAB, J. DAVY, F.C. HEEMAN, I. HERMAN, O. JOJIC, G.J. REYNOLDS, M.M. DE RUITER (1995). *Specification of the MADE Object Model and the mC++ Language,* Version 3.

J. DAVY, F.C. HEEMAN, I. HERMAN, O. JOJIC, G.J. REYNOLDS, P. SMADJA, M.M. DE RUITER (1995). *The mC++ Runtime Environment in MADE,* Version 3.

J.E.A. VAN HINTUM (1995). *Implementation of the Constraint Objects,* Version 1.

F.C. HEEMAN AND I. HERMAN (1994). *Finite State Machines in mC++ for Interaction Objects,* Version 2.

G.J. REYNOLDS AND F.C. HEEMAN (1995). *MADE Input Model Specification,* Version 2.2, 1995

I. HERMAN, F.C. HEEMAN, F. LEYGUES (1995). *Interfacing Script Languages,* Version 3.2.

G.J. REYNOLCS, F.C. HEEMAN (1995). *Presentation Scheme, Services Specification,* Version 2.

G.J. REYNOLDS, F.C. HEEMAN, H. NOOT (1995). *Initial Specification of the Prototype Authoring Tool,* Version 1.

Delivered Software and Documentation

M. HAINDL, M.M. DE RUITER. ESPRIT Project 6307 (MADE), *Help Browser,* U/GHE/P.1, Final Release.

M. HAINDL, M.M. DE RUITER. ESPRIT Project 6307 (MADE), *Object Monitoring,* T/OBM/P.1, Final Release.

F. HEEMAN, G. REYNOLDS. ESPRIT Project 6307 (MADE), *Composition Utility,* U/CU/P.2. Final Release.

F. HEEMAN, H. NOOT, G. REYNOLDS. ESPRIT Project 6307 (MADE), *Input Model and Sensor Specification.*

F. VAN DIJK. ESPRIT Project 6307 (MADE), *Database Object,* T/DBO/P.2, Final Release.

H. NOOT, G. REYNOLDS. ESPRIT Project 6307 (MADE), *Prototype Authoring,* U/PAT/P.2 Final Release.

CWI Reports

CS-R9516. F.C. HEEMAN, I. HERMAN, G.J. REYNOLDS. *Interaction Objects in the MADE Multimedia Environment.*

CS-R9528. M. HAINDL, M.M. DE RUITER. *The MADE Help System.*