PREFACE

This Overview is a supplement to CWI Annual Report 1997, which highlights CWI research in 1997. It reports extensively on the various activities in 1997 of CWI's four scientific clusters, viz.

- Probability, Networks and Algorithms;
- Software Engineering;
- Modelling, Analysis and Simulation;
- Information Systems.

Per cluster 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.

PROBABILITY, NETWORKS AND ALGORITHMS

General

The research of PNA covers a broad spectrum of topics, often on the borderline between mathematics and computer science. Among the topics that presently receive special emphasis are: combinatorial optimization, constraint programming, control theory of hybrid systems and of discrete event systems, performance of communication networks, multiresolution imaging, stochastic processes, and ergodic theory.

Most of the research in PNA is methodologically oriented, but has natural applications in computer technology, communications, logistics, and transportation. In line with this, members of PNA maintain extensive contacts with both academia and industry. Knowledge transfer also receives much attention: In 1997, members of PNA have again organized five regular seminars and a few conferences, and have taught courses in several graduate networks; Apt, Boxma, Keane, and Schrijver hold part-time professorships, while Van Schuppen has received an appointment for a part-time full professorship at the TUE, starting January 1, 1998; and in 1997, part-time associations of Van den Berg with the UvA and of Heijmans with the TUD have been established.

Among a large number of publications, the research highlights include two Ph.D. dissertations and the books *Geometry of Cuts and Metrics* of M. Deza and M. Laurent and *Local Search in Combinatorial Optimization* of E.H.L. Aarts and J.K. Lenstra.

PNA has in 1997 been successful in acquiring external grants: Two TMR projects, three SWON projects, and one STW, NWO/OTKA, ERCIM and INTAS project. Unfortunately, it appears to be difficult to fill the resulting vacancies.

Finally it deserves to be mentioned that advisor Verduyn Lunel has been appointed full professor at the VU, that advisor Cohen has received a Lifetime Achievement Award from ITC, and that former Ph.D. student Borst has received the Gijs de Leve award, for the best Dutch Ph.D. thesis in Operations Research in The Netherlands in the period 1994–1996.

Staff 1997

- Networks and Logic – Optimization and Programming – PNA1
  - A.M.H. Gerards
  - K.R. Apt
  - T. Fleiner
  - N. Francez
  - M. Laurent
  - J.K. Lenstra
  - E. Marchiori
  - S. Marzola
  - E. Monfroy
  - F. van Raamsdonk
  - A. Schrijver
  - A.G. Steenbeek
  - A.S. Troelstra
- Traffic and Communication – Performance and Control – PNA2
  - J. van den Berg
  - R.J. Boucherie
  - O.J. Boxma
  - J.W. Cohen
  - V. Dumas
  - F.A. van der Duyn Schouten
  - R. Núñez Queija
  - J.H. van Schuppen
  - A.P. Zwart
- Stochastics – PNA3
  - J. van den Berg
  - O.J. Boxma
  - K. Dzhaparidze
  - A. Ermakov
  - R. Helmers
  - R. van der Horst
  - M.S. Keane
  - B. Lemmens
  - I.W. Mangku
  - D. Maslen
  - B.A.M. Schouten
  - S.M. Verduyn Lunel
  - D. White

- Signals and Images – PNA 4

  - F.M. Dekking
  - H.J.A.M. Heijmans
  - Z. Kato
  - M.S. Keane
  - A.A.M. Kuijk
  - M.-C. van Lieshout
  - P. Perez
  - P.J. Oonincx
  - B.A.M. Schouten
  - A.G. Steenbeek
  - N.M. Temme
  - P. de Zeeuw
  - R.A. Zuidwijk

- Secretary: L.M. Schultze

Networks and Logic – Optimization and Programming – PNA1

Staff

- Dr. ir. A.M.H. Gerards, theme leader
- Prof. dr. K.R. Apt, senior researcher
- T. Fleiner, M.Sc., Ph.D. student
- Prof. dr. N. Francez, visiting researcher (Technion, Haifa)
- Dr. M. Laurent, visiting researcher (ENS, Paris)
- Prof. dr. J.K. Lenstra, senior researcher
- Dr. E. Marchiori, post-doctoral researcher
- S. Marzola, trainee (University of Padova)
- Dr. E. Monfroy, post-doctoral researcher
- Dr. F. van Raamsdonk, post-doctoral researcher
- Prof. dr. A. Schrijver, senior researcher
- A.G. Steenbeek, programmer
- Prof. dr. A.S. Troelstra, visiting researcher (University of Amsterdam)

Scientific Report

Optimization in Networks
With J. Keijsper (University of Amsterdam), *A. Schrijver* considered $R - S$ connectors; that is, sets of edges each component of which intersect both classes of a given partition of the vertex set V into two classes R and S. In particular, a min-max relation is given for the maximum number of pairwise disjoint R–S connectors. It has as special cases Tutte and Nash-Williams' characterization of the maximum number of pairwise disjoint spanning trees in a graph, and König's edge-colouring theorem.

T. Fleiner derived a min-max result on special partially ordered sets conjectured by András Frank. It contains as special cases Dilworth's theorem and the well-known min-max formula for the minimum edge cover of a graph.

Together with M. Conforti (Italy), *A.M.H. Gerards* continued the investigation of the structure (in terms of decomposition and of forbidden subconfigurations) of graphs in which the maximum number of pairwise edge disjoint odd circuits is equal to the size of the complement of a MAX CUT. A report has been prepared. With M. Conforti (Italy) and M. Burlet (Grenoble) the investigation of the stable set polytope for 'cap free graphs' has been continued.

Graphs and semi-definite matrices
M. Laurent proved a conjecture posed by Agler, Helton, McCullough and Rodman in 1988 concerning the characterization of the graphs of order 2 (that is, the graphs G for which every positive semidefinite matrix with zero pattern outside of the edge set of G can be decomposed as a sum of rank ≤ 2 matrices). She showed that such graphs can be characterized by a list of certain forbidden induced subgraphs and that they can be decomposed into a number of basic classes; in particular, they can be recognized in polynomial time. This question comes up in connection with the completion problem for positive semidefinite matrices. She is also investigating the complexity of the completion problem within this class of order 2; this question is of particular interest in light of the fact that the problem is polynomial for graphs of order 1 (they are the chordal graphs) but that its complexity is not known in general.

M. Laurent also showed that the order of a graph is less than or equal to one plus its minimum fill-in (that is, the minimum number of edges to be added to G to make it chordal); this answers a question posed by Helton, Pierce and Rodman in 1989.

M. Laurent also investigated the link with other completion problems related to Euclidean distance matrices, embeddings of graphs in the Euclidean space and graph rigidity; this led to a survey article published in Mathematical Programming and presented at the *Lausanne Mathematical Programming Symposium.*

Factors in bipartite graphs
A. Schrijver answered a question of Erdős and Rényi on the number of 1-factors in k-regular bipartite graphs. It is shown that this number is at least $((k-1)^{k-1}/k^{k-2})^n$ (where n is half of the number of vertices of the graph), and that the ground number is best possible for any fixed k.

Polytopes
Together with V. Kaibel and G. Rote, T. Fleiner obtained a new upper bound on the number of facets of a 0/1 polytope.

GF(4)-representable matroids
At the end of 1995 J. Geelen (Australia), A.M.H. Gerards and A. Kapoor (India) characterized the GF(4)-representable matroids in terms of forbidden minors. In 1997, the final report has been completed and submitted for publication.

Constraint Programming
K.R. Apt worked on constraint propagation algorithms. In an invited lecture at the ICALP '97 conference he showed that these algorithms are instances of algorithms that deal with chaotic iteration.

A paper of J.N. Kok, *E. Marchiori* and M. Marchiori (appeared in the International Journal on Artificial Intelligence Tools) deals with the treatment of overconstrained problems. A novel semantic technique is introduced which allows one to extract 'optimal' partial solutions for overconstrained problems. This technique is applied to the specific paradigm of constraint logic programming. Finally, in a paper (appeared in the Proceedings of the 1997 International Conference on Genetic Algorithms) a novel technique is introduced for solving constraint satisfaction problems using genetic algorithms.

E. Monfroy studied an alternative way of designing cooperative constraint solver systems using a control-oriented coordination language. The idea is to take advantage of the coordination features of *Manifold* for improving the constraint solver collaboration language of BALI. The validity of the ideas is demonstrated by presenting the advantages of such a realization and its (practical as well as conceptual) improvements of constraint solving. Monfroy is convinced that cooperative constraint solving is intrinsically linked to coordination, and that coordination languages, and Manifold in particular, open new horizons for systems like BALI.

Constraint propagation consists in reducing a CSP into another one that is equivalent, but simpler. E. Monfroy studies alternative way of designing non-linear polynomial solvers based on interval arithmetic. Box-consistency is very expensive to enforce during the whole computation. Thus, another approach based on chaotic iteration is considered where various domain reduction functions are used, and possibly one that insures box-consistency at the end of the computation. This mechanism also allows the use of specialized functions for linear constraints, quadratic constraints, etc. A first prototype to validate the approach is realized. The results are promising: applying basic reduction functions before enforcing box-consistency significantly improves the efficiency of our constraint solver. A paper on this matter has been completed and submitted for publication.

ALMA-0
K.R. Apt worked with J. Brunekreef, A. Schaerf and V. Partington on a programming language, called ALMA-0 that combines the advantages of imperative and logic programming in order to deal in a natural way with algorithmic problems that involve search. The technical report describes the use of the language, its semantics and implementation. The original paper, by Apt and Schaerf appeared in the Proceedings of the POPL '97 conference.

Program transformation and verification
With F. de Boer, M. Gabbrielli, and C. Palamidessi, E. Marchiori studied the correctness of concurrent constraint programs (ccp's). In the resulting joint paper (appeared in the ACM TOPLAS), an elegant denotational semantics for ccp's has been introduced and used for developing a proof method for proving the partial correctness of ccp's. With S. Etalle and M. Gabbrielli, E. Marchiori studied transformations of logic programs with delay declarations; a joint paper appeared in the Proceedings of the 1997 ACM-SIGPLAN Symposium on Partial Evaluation and Semantic-Based Program Manipulation. In particular, the authors develop a transformation technique that allows one to prove deadlock freedom of queries.

Parallel Declarative Programming
F. van Raamsdonk worked on the transformation from logic to functional programming, partly in collaboration with S. Etalle (UvA). Jointly with S. Etalle, she worked on the description of a framework of logic programming that permits to express computations yielding partial results. F. van Raamsdonk wrote *Higher-order rewriting* which will appear as a chapter in volume 2 of *Term Rewriting Systems*, edited by M. Bezem, J.W. Klop and R. de Vrijer. F. van Raamsdonk continued the work on: rewriting and type theory; on termination, in collaboration with G. Barthe (formerly CWI, now Chalmers, Sweden): and on transformations from conditional rewriting systems to unconditional rewriting systems

Books
K.R. Apt finished the revision of his book with E.-R. Olderog entitled *Verification of Sequential and Concurrent Programs* (Springer-Verlag). The book provides a structured introduction to program verification using one of the most common approaches, called the assertional method. It considers sequential programs and concurrent programs together with proof systems for the verification of their partial and total correctness.

M. Laurent completed the book *Geometry of Cuts and Metrics* (with M. Deza, No. 15 in the series *Algorithms and Combinatorics*. Springer-Verlag, 1997).

With W.J. Cook, W.H. Cunningham, and W.R. Pulleyblank, A. Schrijver finished the book *Combinatorial Optimization* (John Wiley & Sons, New York, 1998).

With E.H.L. Aarts, J.K. Lenstra edited *Local Search in Combinatorial Optimization* (Wiley, Chichester 1997, 512 pp.).

A.M.H. Gerards and M. Laurent continued working on a book on binary spaces and optimization.

A. Schrijver continued finishing his book *Polyhedral Combinatorics*.

Organization of Conferences, Workshops, Courses, etc.

- 'ESA '97, 5th Annual European Symposium on Algorithms': J.K. Lenstra, member Program Committee.
- 'ERCIM Working Group on Constraints Kick-off Meeting', Institut Henri Poincaré, Paris, France, January 14th: E. Monfroy, member Organizing Committee.
- 'Twenty-Second Conference on the Mathematics of Operations Research/Eight International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 14–16: A.M.H. Gerards, member Organizing Committee.
- 'International Conference on Logic Programming (ICLP '97)', Leuven, July: K.R. Apt, member Programming Committee.
- '16th International Symposium on Mathematical Programming', Lausanne, Switzerland, August 24–29: A. Schrijver, member Symposium Advisory Committee and member International Program Committee.
- 'International Conference on Declarative Programming Languages in Education (DPLE '97)', Southampton, Great Britain, September: K.R. Apt, member Programme Committee.
- 'International Workshop on Verification, Model Checking and Abstract Interpretation', Port Jefferson, NY, USA, October 16–17: E. Marchiori, member Organizing Committee.
- 'ERCIM/COMPULOG Workshop on Constraints', Schloß Hagenberg, Austria, 27–28 October: K.R. Apt, E. Monfroy, members Organizing Committee.
- 'Ninth Dutch/Belgian Artificial Intelligence Conference (NAIC-97)', Antwerp, Belgium, November: K. R. Apt, member Programming Committee.
- 'Twenty-Third Conference on the Mathematics of Operations Research/Ninth International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 13–15, 1998: A.M.H. Gerards, member Organizing Committee.
- 'LATIN'98 - Latin American Theoretical INformatics', Campinas, Brazil, 20–24 April 1998: A. Schrijver, member Program Committee.
- 'Sixth MPS Conference on Integer Programming and Combinatorial Optimization', Houston, US, June 22-24, 1998: A.M.H. Gerards, member Programming Committee.
- '17th International Symposium on Mathematical Programming', J.K. Lenstra, member International Advisory Committee: A. Schrijver, member International Advisory Committee.
- 'TRISTAN III, 3rd Triennial Symposium on Transportation Analysis': J.K. Lenstra, member Scientific Committee.

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

- University Cá Foscari, Venice, Italy, January 1 – June 30: E. Marchiori
- Tagung 'Mathematical Optimization', Oberwolfach, Germany, January 5–11: J.K. Lenstra
- 'ERCIM Working Group on Constraints Kick-off Meeting', Institut Henri Poincaré, Paris, France, January 14: E. Monfroy
- 'Twenty-Second Conference on the Mathematics of Operations Research/Eight International Workshop Landelijk Netwerk Mathematische Besliskunde', Lunteren, The Netherlands, January 14–16: T. Fleiner, A.M.H. Gerards, J.K. Lenstra
- 'The 24th Annual ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages (POPL '97)', Paris, France, January 15–17: K.R. Apt
- 'Conférence Belge de Recherche Opérationelle', Han-sur-Lesse, Belgium, February 7–8: A. Schrijver
- University of Padova, Italy, March 16–24: A.M.H. Gerards
- INRIA Sophia-Antipolis, April 1 – June 6: F. van Raamsdonk
- '3rd International Conference on Typed Lambda Calculi and Applications', Nancy, France, April 2–4: F. van Raamsdonk
- '32e Nederlands Mathematisch Congres', Landbouwuniversiteit Wageningen, April 3–4: A.M.H. Gerards
- 'Workshop on Models and Algorithms for Planning and Scheduling Problems', Cambridge, UK, April 7–11: J.K. Lenstra

- 'Meeting of TMR Networks Panel on Mathematics & Information Sciences', Brussels, Belgium, April 21–22: J.K. Lenstra
- Université Pierre et Marie Curie, Paris, France, April 23–24: A.M.H. Gerards
- Denish University of Technology, Lyngby, Danmark, April 29–30: J.K. Lenstra
- 'Program Committee Meeting of ESA '97, 5th Annual European Symposium on Algorithms', Graz, Austria, May 9–10: J.K. Lenstra
- 'Tutte Symposium', University of Waterloo, Waterloo, Ontario, Canada, May 16–17: A.M.H. Gerards
- Università di Bologna, Bologna, Italy, May 17–22: J.K. Lenstra
- 'Matroid Representativity Day', University of Waterloo, Waterloo, Ontario, Canada, May 19: A.M.H. Gerards
- University of Waterloo, Waterloo, Ontario, Canada, May 20–24: A.M.H. Gerards
- '11th International Workshop on Unification', Orléans, France, May 28–30: F. van Raamsdonk
- 'Seminar on Scheduling in Computer and Manufacturing Systems', Dagstuhl, Germany, June 2–6: J.K. Lenstra
- '14th International Conference on Logic Programming', Leuven, Belgium, June 8–10: F. van Raamsdonk
- 'Eidma Minicourse Computational Combinatorial Optimization', Eindhoven, The Netherlands, June 9–13: T. Fleiner
- 'Max-Clique '97, a Workshop on the Maximum Clique Problem and its Applications', Trieste, Italy, June 17–18: E. Marchiori
- 'Strategic Planning Workshop of Compulog Net', Rome, June 20–21: K.R. Apt
- 'Symposium Gravity, Black Holes & Strings', Amsterdam, The Netherlands, June 21: A. Schrijver
- '16th British Combinatorial Conference', London, UK, July 7–11: A. Schrijver
- '24th International Colloquium on Automata, Languages, and Programming (ICALP '97)', Bologna, Italy, July 7–11: K.R. Apt
- 'EURO XV/INFORMS XXXIV Joint International Meeting', Barcelona, Spain, July 14–17: J.K. Lenstra
- '7th International Conference on Genetic Algorithms', East Lansing, Michigan, USA, July 19–23: E. Marchiori
- '16th International Symposium on Mathematical Programming', Lausanne, Switzerland, August 24–29: T. Fleiner, A.M.H. Gerards, M. Laurent, J.K. Lenstra, A. Schrijver
- 'DGOR-GMÖOR Symposium on Operations Research 1997', Jena, Germany, September 3–5: J.K. Lenstra
- Eindhoven University of Technology, September 19: E. Monfroy, Working Visit
- European Research Conference 'Algebra and Discrete Mathematics', San Feliu de Guixols, Spain, September 27 – October 2: T. Fleiner, M. Laurent, A. Schrijver
- 'INFORMS National Meeting', Dallas, USA, October 26–29: J.K. Lenstra item 'International Conference on Constraint Programming (CP97)', Schloß Hagenberg, Austria, October 29 – November 1: K.R. Apt, E. Monfroy
- 'Second ERCIM Working Group on Constraints Workshop', Schloß Hagenberg, Austria, October 29–30: K.R. Apt, E. Monfroy
- 'First COTIC workshop', Schloß Hagenberg, Austria, October 30: K.R. Apt, E. Monfroy
- Workshop 'Computational Integer Programming', Berlin, Germany, November 16–18: A. Schrijver
- Tagung 'Polytopes and Optimization', Oberwolfach, Germany, November 16–22: T. Fleiner
- Institut für Operations Research, ETH Zürich, Switzerland, December 15–16: A. Schrijver

Memberships of Committees and Other Professional Activities

Ph.D. Committees

- D.J.B. Bosscher (University of Amsterdam): K.R. Apt
- E.B. Diks (Eindhoven University of Technology): J.K. Lenstra
- H. van Hintum (Eindhoven University of Technology): K.R. Apt
- E. de Klerk (Delft University of Technology): A. Schrijver
- E.S. van der Poort (University of Groningen): J.K. Lenstra
- S. Uskudarli (University of Amsterdam): K.R. Apt
- A.P.A. Vestjens (Eindhoven University of Technology): J.K. Lenstra
- E. Visser (University of Amsterdam): K.R. Apt
- V.C.S. Wiers (Eindhoven University of Technology): J.K. Lenstra
- P. Zwaneveld (Erasmus University Rotterdam): A. Schrijver

Organizational Activities

- Association for Logic Programming: K.R. Apt, President
- EIDMA – Euler Institute for Discrete Mathematics and Its Applications: A. Schrijver, member Board
- ERCIM Working Group on Constraints: K.R. Apt, chairman; E. Monfroy, secretary

- KNAW Akademie Raad voor de Wiskunde: J.K. Lenstra, member Board, A. Schrijver, member
- Koninklijke Nederlandse Akademie van Wetenschappen: A. Schrijver
- Landelijk Netwerk Mathematische Besliskunde: A.M.H. Gerards, J.K. Lenstra, A. Schrijver, member Governing Board Mathematical Programming Society: J.K. Lenstra, vice-chairman (until August 1997), member Publications Committee; A. Schrijver, member Symposium Advisory Committee
- Scientific Commission for Computer Science of the Belgian National Fund for Scientific Research: K.R. Apt
- Stichting Wiskunde Onderzoek Nederland: A. Schrijver, member Board (treasury)
- Stieltjes Instituut voor Wiskunde: A. Schrijver, member Science Council
- TMR Networks Panel on Mathematics & Information Sciences: J.K. Lenstra
- Werkgemeenschap Mathematische Besliskunde en Systeemtheorie: A.M.H. Gerards, vice-chair, A. Schrijver, member Science Council
- Werkgemeenschap Discrete Wiskunde: A. Schrijver, member Science Council

Editorial Activities

- *ACM Journal of Experimental Algorithmics*, J.K. Lenstra, member Advisory Board
- *Combinatorica*, A. Schrijver, editor-in-chief
- *CWI Tracts & Syllabi*, J.K. Lenstra, editor
- *CWI Tracts & Syllabi*, K.R. Apt, managing editor
- *CWI Quarterly*, A.M.H. Gerards, editor, F. van Raamsdonk, editor.
- *Discrete Applied Mathematics*, A. Schrijver, editor
- *Discrete Mathematics and Theoretical Computer Science*, A.M.H. Gerards, editor
- *Excerpta Informatica*, J.K. Lenstra, member Advisory Board
- *Fundamenta Informaticae*, K.R. Apt
- *Information and Computation*, K.R. Apt
- *INFORMS Journal on Computing*, J.K. Lenstra, Area Editor for Design & Analysis of Algorithms
- *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
- *Journal of Logic and Computation*, K.R. Apt
- *Journal of Logic Programming*, K.R. Apt
- *Kluwer Series in Operations Research/Computer Science Interface*, J.K. Lenstra, member editorial Advisory Board
- *Mathematical Programming*, Series B, J.K. Lenstra, Guest Editor of issues in memory of E.L. Lawler
- *Mathematics of Operations Research*, A. Schrijver, associate editor
- *North-Holland Mathematical Library*, A. Schrijver, advisory editor
- *SCIMA Special Series*, J.K. Lenstra, member Advisory Board
- *SIAM Journal on Discrete Mathematics*, A. Schrijver, editor
- *SIAM Journal on Optimization*, A. Schrijver, editor
- *SIAM Monographs on Discrete Mathematics and Applications*, A. Schrijver, member editorial board
- *Wiley/Interscience Series in Discrete Mathematics and Optimization*, J.K. Lenstra, advisory editor
- Wiley/Teubner Series in *Computer Science*, K.R. Apt

Visitors

- Maarten van Emden, University of Victoria, Canada, June 4–6 (*A common operational fixpoint semantics for constraint processing and logic programming*)
- François Laburthe, ENS, Paris, France, June 18–20 (*Constraint Programming and Hybrid Algorithms for Combinatorial Optimization*)
- Ernst-Rüdiger Olderog, University of Oldenburg, Germany, October 1–3 (*Development of Correct Real-Time Systems*)
- A.V. Karzanov, Institute of Systems Studies, Moscow, November 12–14

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

External orders:

- Timetable development Railned
- Stageplanning medical students Rijksuniversiteit Limburg

Graduate courses:

- Advanced Graph Theory, EIDMA and Stieltjes Research Schools, February–May: A. Schrijver
- Combinatorial Optimization 1, Landelijk Netwerk Mathematische Besliskunde, November–December: A.M.H. Gerards

Books

E.H.L. AARTS, J.K. LENSTRA (editors), *Local Search in Combinatorial Optimization*. Wiley, Chichester, 1997, 512 pp.

K.R. APT, E.-R. OLDEROG, *Verification of Sequential and Concurrent Programs*. Springer-Verlag. Second edition: Graduate Texts in Computer Science, 1997, 364 + xviii pages).

M. DEZA, M. LAURENT. *Geometry of Cuts and Metrics*. No. 15 in the series *Algorithms and Combinatorics*. Springer-Verlag, 1997.

Papers in Journals and Proceedings

K. AARDAL, C.P.M. VAN HOESEL, J.K. LENSTRA, L. STOUGIE (1997). A decade of combinatorial optimization. W.K. KLEIN HANEVELD, O.J. VRIEZE, L.C.M. KALLENBERG (eds.). *Ten Years LNMB; Ph.D. Research and Graduate Courses of the Dutch Network of Operations Research*, CWI Tract **122**, CWI, Amsterdam, 5–14.

E.H.L. AARTS, J.K. LENSTRA (1997). Introduction. E.H.L. AARTS, J.K. LENSTRA (red.). *Local Search in Combinatorial Optimization* Wiley, Chichester, 1–18.

K.R. APT (1997). From chaotic iteration to constraint propagation. *Proc. 24th International Colloquium on Automata, Languages, and Programming (ICALP '97)*, (invited lecture), Springer-Verlag Lecture Notes in Computer Science **1256**, 36–55.

K.R. APT, A. SCHAERF (1997). Search and imperative programming. *Proc. 24th Annual SIGPLAN-SIGACT Symposium on Principles of Programming Languages (POPL '97)*, 67–79.

G. BARTHE, F. VAN RAAMSDONK (1997). Termination of algebraic type systems: the syntactic approach. M. HANUS, J. HEERING (eds.). *Proceedings of the Sixth International Joint Conference ALP '97 - HOA '97*, Volume 1298 of *Lecture Notes in Computer Science*, Southampton, UK, Springer-Verlag, 174–193.

F.S. DE BOER, M. GABBRIELLI, E. MARCHIORI, C. PALAMIDESSI (1997). Proving concurrent constraint programs correct. *International ACM Journal on Transactions On Programming Languages and Systems*.

J. EDMONDS, M. LAURENT, A. SCHRIJVER (1997). A minor-monotone graph parameter based on oriented matroids. *Discrete Mathematics* **165/166**, 219–226.

S. ETALLE, M. GABBRIELLI, E. MARCHIORI (1997). A transformation system for CLP with dynamic scheduling and CCP. *ACM–SIGPLAN Symposium on Partial Evaluation and Semantics-Based Program Manipulation.*

T. FLEINER (1997). Covering a symmetric poset by symmetric chains. *Combinatorica* **13**, 339–344.

J.A. HOOGEVEEN, J.K. LENSTRA, S.L. VAN DE VELDE (1997). Sequencing and scheduling. M. DELL'AMICO, F. MAFFIOLI, S. MARTELLO (eds.). *Annotated Bibliographies in Combinatorial Optimization*, John Wiley, Chichester, 180–197.

M. DE GRAAF, A. SCHRIJVER (1997). Making curves minimally crossing by Reidemeister moves. *Journal of Combinatorial Theory, Series B* **70**, 134–156.

M. DE GRAAF, A. SCHRIJVER (1997). Decomposition of graphs on surfaces. *Journal of Combinatorial Theory, Series B* **70**, 157–165.

J.H.M. KORST, E.H.L. AARTS, J.K. LENSTRA (1997). Scheduling periodic tasks with slack. *INFORMS Journal on Computing* **9**, 351–362.

M. LAURENT (1997). Max-cut problem. M. DELL'AMICO, F. MAFFIOLI, S. MARTELLO (eds.). *Annotated Bibliographies in Combinatorial Optimization*, John Wiley, Chichester, 241–259.

M. LAURENT (1997). The real positive semidefinite completion problem for series-parallel graphs. *Linear Algebra and its Applications* **252**, 347–366.

M. LAURENT (1997). Cuts, matrix completions and graph rigidity. *Mathematical Programming* **79**, 255–283.

M. LAURENT, S. POLJAK, F. RENDL (1997). Connections between semidefinite relaxations of the max-cut and stable set problems. *Mathematical Programming* **77**, 225–246.

E. MARCHIORI (1997). Combining constraint processing and genetic algorithms for constraint satisfaction problems. *7th International Conference on Genetic Algorithms*, 330–337.

E. MARCHIORI, M. MARCHIORI, J.N. KOK (1997). A novel search technique for solving over-constrained problems. *International Journal on Artificial Intelligence Tools (IJAIT)*, World Scientific.

F. VAN RAAMSDONK (1997). Translating logic programs into conditional rewriting systems. L. NAISH (ed.). *Proceedings of the Fourteenth International Conference on Logic Programming (ICLP '97)*, MIT Press, Leuven, Belgium, 168–182.

F. VAN RAAMSDONK (1997). Outermost-fair rewriting. J.R. HINDLEY, PH. DE GROOTE (eds.). *Proceedings of the Third International Conference on Typed Lambda Calculi and Applications (TLCA '97)*, Volume 1210 of *Lecture Notes in Computer Science*, Springer-Verlag, Nancy, France, 284–299.

A. SCHRIJVER (1997). Minor-monotone graph invariants. R.A. BAILEY (ed.). *Surveys in Combinatorics* Cambridge University Press, Cambridge, 163–196.

D.P. WILLIAMSON, L.A. HALL, J.A. HOOGEVEEN, C.A.J. HURKENS, J.K. LENSTRA, S.V.

SEVAST'JANOV, D.B. SHMOYS (1997). Short shop schedules. *Operations Research* **45**, 288–294

CWI Reports

PNA-R9711. J.F. GEELEN, A.M.H. GERARDS, A. KAPOOR. *The excluded minors for $GF(4)$-representable matroids*.

PNA-R9713. K.R. APT, J. BRUNEKREEF, A. SCHAERF, V. PARTINGTON. ALMA-0: *An imperative language that supports declarative programming*.

Other Publications

J.K. LENSTRA (1997). Een rustige zomer. *Matrix* **4**, (winter 1997), 18–19.

M. DESROCHERS, C.V. JONES, J.K. LENSTRA, M.W.P. SAVELSBERGH, L. STOUGIE (1997). *Towards a Model and Algorithm Management System for Vehicle Routing and Scheduling Problems*. Memorandum COSOR 97-10, Facultyof Mathematics and Computer Science, University of Technology Eindhoven.

Traffic and Communication – Performance and Control – PNA2

Staff

- Dr. ir. J.H. van Schuppen (Program leader and senior researcher)
- Dr. J. van den Berg
- Dr. R.J. Boucherie (till October 31, 1997 part time for 0.2, funded by KNAW; from November 1, part time 0.4, funded by STW and affiliated with UvA)
- Prof. dr. ir. O.J. Boxma
- Prof. dr.ir. J.W. Cohen
- Dr. V. Dumas (till September 30, funded by the French government)
- Prof. dr. F.A. van der Duyn Schouten
- R. Núñez Queija
- A.P. Zwart (from September 1, funded by SWON)

Note Only those activities, publications etc. of part-time members of the staff R.J. Boucherie and F.A. van der Duyn Schouten have been mentioned, that have a direct relation with PNA2.

External Funding and International Cooperation

National projects:

- SWON project *Regular variation in broadband ISDN*.
- SWON Groot Project *Stochastic networks*.
- STW project *Stochastic network analysis for the design of self-optimising cellular mobile communications systems*.

Projects funded by the European Commission:

- DACCORD (TR 1017) financially supported by the Telematics Applications Programme – Sector Transport, 1996–1998.

Scientific Report

Communication and Computer Networks – PNA2.1

Project LRD

A.P. Zwart. Modern teletraffic applications have spurred the interest in queueing models with heavy-tailed service time distributions. On September 1, A.P. Zwart started his Ph.D. research on this topic. A.P. Zwart is currently studying the sojourn time asymptotics in the M/G/1 processor sharing queue in which the service time distribution has a regularly varying tail.

O.J. Boxma & V. Dumas. Boxma and Dumas have completed an invited survey paper on fluid queues fed by non-exponential on/off sources. The central model is a fluid queueing system fed by N sources that alternate between silence and activity periods. The distribution of the activity periods of at least one source is assumed to be long-tailed. Main object of study is the effect of this tail behaviour on the steady-state distributions of the buffer content (which is related to the dimensioning of buffers) and the busy periods (which can propagate long tails in networks of fluid queues). Both exact results and bounds are discussed.
Subsequently Boxma and Dumas have focused on the busy periods of this model, assuming that the sources have exponential silence periods and general activity periods, and inflow rates (during activity) are at least as large as the outflow rate of the buffer. A paper has been written on the subject and submitted to a conference. Firstly, they characterize the Laplace-Stieltjes transforms of the busy periods via the unique solution in $[0,1]^N$ of a set of N equations. Secondly, they show that all the busy period distributions have regularly varying tails of index $-\nu$ iff the heaviest of the tails of the activity period distributions are regularly varying of index $-\nu$; moreover, the contribution of the sources with lighter associated tails is equivalent to a simple reduction of the outflow rate.
A paper of Dumas on FIFO fluid networks has been revised and accepted for publication in *IEEE Trans. Aut. Contr.* (August 1998).

O.J. Boxma & J.W. Cohen. Cohen has studied an ordinary M/G/1 queue with heavy-tailed service time distribution. He has proposed a particular class of regularly varying service time distributions with the attractive feature that the Laplace-Stieltjes transform can be determined explicitly. This LST is used to derive a series development of the waiting time distribution and to give a detailed heavy-traffic analysis. In a series of studies, some of them jointly with Boxma, he has subsequently investigated the heavy-traffic behaviour of the waiting time distribution in the GI/G/1 queue with general, heavy-tailed, interarrival and/or service time distribution. The results supplement the classical heavy-traffic theory (that applies when both the interarrival and service time distribution have a finite variance). The main results are: if the tail of the service time distribution is heavier than that of the interarrival time distribution, and the traffic load $a \to 1$, then the waiting time W, multiplied by an appropriate 'coefficient of contraction' that is a function of a, converges in distribution to the Kovalenko distribution. If the tail of the interarrival time distribution is heavier than that of the service time distribution, and the traffic load $a \to 1$, then W, multiplied by another appropriate 'coefficient of contraction' that is a function of a, converges in distribution to the negative exponential distribution. The case in which both tails are similar is also studied.
For the M/G/1 queue, the heavy-traffic limit theorem has been shown numerically to yield a quite accurate approximation for the tail of the waiting time distribution. Presently, the heavy-traffic behaviour is studied of the (residual) busy period of the GI/G/1 queue with heavy-tailed interarrival and/or service time distribution.

Project ATM

R. Núñez Queija. The study of performance issues of ABR (Available Bit Rate) traffic in ATM (Asynchronous Transfer Mode) networks has been continued. The paper *Analysis of a multi-server queueing model of ABR*, which is joint work with O.J. Boxma, has been submitted for publication in the *Journal of Applied Mathematics and Stochastic Analysis*. In this paper the influence of higher priority traffic in ATM networks (e.g. Constant Bit Rate and Variable Bit Rate traffic) on the ABR buffer content process is studied by means of a two-dimensional Markov Chain. This work is an extension of the earlier CWI Report BS-R9613. Further generalizations and new results are reported in CWI Report PNA-R9712 by R. Núñez Queija.
In continuation, R. Núñez Queija has started a study on delay times of ABR-traffic (an important issue in the performance of ABR) by analyzing the sojourn times of customers in an $M/G/1$ processor sharing queue with server breakdowns. He is currently writing a paper on the results of this study. In the near future attention will focus on the possibility of extending these results for processor sharing queues in which the server alternates between several *positive* service rates.

Project MOBILECOM

R.J. Boucherie & O.J. Boxma. The STW project: *Stochastic network analysis for the design of self optimising cellular mobile communications systems* has started on October 1st. Within this project work on a survey on computational methods for layered cellular mobile communications networks has begun. In addition, the Equivalent Random Method for obtaining blocking probabilities in overflow systems is being extended towards layered cellular networks.

Project CONTROL

J.H. van Schuppen. Control of hybrid systems and of discrete event systems. An approach was developed for control synthesis of hybrid systems. A sufficient condition for the existence of a hybrid controller of a hybrid control system was established. A lecture on the topic was presented at the NATO Advanced Study Institute on Verification of Digital and Hybrid Systems. This summer school was held near Antalya in Turkey in May-June. Lectures on the same topic were presented at several other universities. A sufficient condition for the controllability of hybrid systems was proven. A paper on a game theory approach to decentralized supervisory control was completed and submitted for publication. Research was carried out on communication of information and control in decentralized control of discrete event systems.
A paper will appear in the Proceedings of the NATO Advanced Study Institute on Verification of Digital and Hybrid Systems. Another paper will appear in the Proceedings of the Workshop on Hybrid Systems 1998. Two other papers are currently under review.

Project DACCORD

J.H. van Schuppen. As part of the EU Project DACCORD (TR 1017) research was carried out on routing control of motorway networks and on integrated control of such networks. For the routing control problem a dynamic game approach was pursued and a control algorithm detailed and analyzed. Two reports were included in a deliverable of the project. A paper will appear in a conference proceedings in 1998.

Project RAILCON

J.H. van Schuppen. As part of a project financed by Railned, papers on control of railway traffic were studied. A lecture was presented at the 1997 European Control Conference on control of railway traffic.

Project RESI

J.H. van Schuppen. System theory and system identification. Together with Dr. A.A. Stoorvogel research was carried out on the approximation of a stationary Gaussian process by the output of a time-invariant finite-dimensional Gaussian system according to the divergence rate criterion. Expressions for the criterion, first-order conditions, analytic properties of the approximation problem, and numerical algorithms were formulated. A paper is in preparation. A paper on primes in the positive matrices was accepted for publication in *Linear Algebra and its Applications* and will appear in 1998. Two other papers are currently under review.

Organization of Conferences, Workshops, Courses, etc.

- Workshop on Hybrid Systems 1999. Workshop Chairmen are Prof. dr. F.W. Vaandrager (KUN) and J.H. van Schuppen.

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

- Participation Conference on the Mathematics of Operations Research, Lunteren, January 14–16: Boucherie, Boxma, Cohen, Dumas, Núñez Queija (lecture).
- Participation in DACCORD Meeting, Haarlem, January 20–21: J.H. van Schuppen.
- Participation in COST 257 meeting, Leidschendam, January 22–23: Boxma, Núñez Queija.
- Participation in the 16th Benelux Meeting on Systems and Control, March 5–7, Houffalize, Belgium: J.H. van Schuppen. Lecture *Control of hybrid systems*.
- Participation in the exam committee of Ir. J.J.H. Fey at the Mechanical Engineering Department of the Eindhoven University of Technology, March 10, Eindhoven: J.H. van Schuppen.
- Participation in International Workshop on Hybrid and Real-Time Systems (HART'97), at Grenoble, France, March 26–28: J.H. van Schuppen. He was chairman of a plenary morning session. He became member of the Steering Committee for the Workshops on Hybrid Systems: Computation and Control.
- Working visit to Department of Electrical Engineering and Computer Science of the University of Padova, Italy, April 14–16: J.H. van Schuppen. Lecture *Control of hybrid systems*.
- Participation in 6th DACCORD meeting, Verona and Mestre, Italy, April 17–18: J.H. van Schuppen.
- Visit to the MAB, Université de Bordeaux (France), April 24: Dumas. Lecture *Étude de stabilité de réseaux de files d'attente: approche par les limites fluides associées (Stability analysis of queueing networks: approach via the associated fluid limits)*.
- Working visit to Department of Electrical Engineering, University of Gent in Gent, Belgium, May 7–9: J.H. van Schuppen. Lecture *Control of hybrid systems – Examples and control synthesis*.
- Participation in workshop Telecommunications: Statistical Analysis and Performance Evaluation, Höllviken, Sweden, May 29–30: Boxma. Invited lecture *Fluid queues and regular variation*.
- Participation in NATO Advanced Study Institute on Verification of Digital and Hybrid Systems, Belek, Antalya, Turkey, May 26–June 6: J.H. van Schuppen. Invited lecture *Control and system theory of hybrid systems*.
- Participation in CWI National Queueing Seminar, Amsterdam, June 2: Boucherie (lecture), Boxma, Cohen (lecture), Dumas, Núñez Queija.
- Participation in the IFAC Symposium Transportation Systems 1997, Chania, Crete, Greece, June 16–18: J.H. van Schuppen. Lecture *Integrated traffic control of motorway networks*.
- Participation in a DACCORD Project Meeting, Chania, Crete, Greece, June 19 and 20: J.H. van Schuppen.
- Participation in LNMB workshop, Leiden, June 17–19: Núñez Queija.
- Participation in LNMB 10th anniversary, Leiden, June 20: Boxma, Núñez Queija.
- Participation in the Summer School on Neural Networks in Systems and Control (Organized by DISC), June 24, 25, and 27, at Zeist: J.H. van Schuppen.
- Participation in the 15th ITC Conference, Washington (USA), June 23–27: Boucherie, Boxma (lecture and member of the closing panel), Cohen (lecture), Núñez Queija.
- Participation in the 9th INFORMS Conference on Applied Probability, Boston (USA), June 30–July 2: Boucherie, Boxma (lecture and organization of a session), Cohen (lecture, session chairman), Dumas, Núñez Queija (lecture).

- 4th European Control Conference (ECC97), Brussels, Belgium, July 1–4: J.H. van Schuppen. Lecture *Control of railway traffic*. J.H. van Schuppen was chairman of a session.
- Working visit to the Mathematics Department of the University of Wisconsin (as M. Bramson's guest), Madison (USA), July 3–18: Dumas.
- Participation in the EURO-INFORMS Joint International Conference, Barcelona (Spain), July 14–17: Núñez Queija (lecture).
- ERNSI Workshop System Identification 1997, Stockholm, Sweden, September 8–10: J.H. van Schuppen. Van Schuppen chaired several sessions and chaired a meeting of the team leaders of ERNSI.
- Working visit to University of Linköping, Linköping, Sweden, September 11 and 12: J.H. van Schuppen. Lecture *Control and system theory of hybrid systems*.
- Lecture at CWI, October 17: J.H. van Schuppen. Lecture *Decentralized supervisory control*.
- Working visit to the Department of Electrical Engineering and Computer Science, University of Michigan, Ann Arbor, MI, USA., October 20–24: J.H. van Schuppen. Lecture one on October 20 *Routing control of motorway networks*. Lecture two on October 23 *Control and system theory of hybrid systems*.
- Stochastic models for cellular mobile communications networks, Colloquium LNMB, Utrecht, October 27: Boucherie.
- Participation in DACCORD Project Meeting, The Hague, November 3: J.H. van Schuppen.
- Participation in the Workshop Operator Theory and Analysis, November 12–14, Vrije Universiteit, Amsterdam: J.H. van Schuppen.
- Visit to the Department of Industrial Engineering, Technion, Haifa, Israel, November 17–21: Cohen. Lecture *The GI/G/1-queueing model with heavy-tailed distributions*.
- Visit to the Department of Operations Research and Statistics, Tel Aviv University, November 24–27: Cohen. Lecture *The GI/G/1-queueing model with heavy-tailed distributions*.
- Participation in internal PNA-2 seminar: all staff members. Lectures by Borst (formerly PNA2), Núñez Queija and Zwart.
- Participation in CWI National Queueing Seminar, Amsterdam, December 15: Van den Berg, Boucherie, Boxma, Cohen, Núñez Queija (lecture), Zwart.
- Participation in the Mini Conference on Heavy Tailed Distributions and Extreme Values, Rotterdam, December 19: Zwart.

Memberships of Committees and Other Professional Activities

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.*
- Member of IFIP Working Group 7.3 (also of its membership election committee).
- Member of the Committee for Conferences on Stochastic Processes of the Bernoulli Society for Mathematical Statistics and Probability.
- Project leader SWON project *Regular variation in broadband ISDN*.
- Member of the CWI committees MT and IR.
- Member of the Ph.D. committee of B.J. van Rijnsoever (TUE) and F.J.M. Panken (KUN).
- Member of the program committee of the 9th Conference on Modelling Techniques and Tools for Computer Performance Evaluation (St Malo, June 1997) and ACM Sigmetrics/Performance '98 (Madison, June 1998).

J.W. Cohen:
- Member of the advisory board of Telecommunication Systems.
- Honorary member of the IAC of ITC.

F.A. van der Duyn Schouten:
- Associate editor of *Management Science*.

R. Núñez Queija:
- Member of the Master Thesis Committee of D. van Vuuren, Department of Econometrics, Free University of Amsterdam.

J.H. van Schuppen:
- Co-Editor of the journal *Mathematics of Control, Signals, and Systems* since 1994.
- Department Editor of the journal *Discrete Event Dynamic Systems* since 1990.
- Chairman of the Steering Committee of the ERCIM Working Group Control and System Theory, since November 1995.
- Member of the Steering Committee, of the International Symposia on the Mathematical Theory of Networks and Systems since 1989.
- Member of the Steering Committee, of the Workshop Series Hybrid Systems, since March 1997. Also handled in 1997 papers for a workshop.
- Member of IFAC Technical Committee on Modeling, Identification, and Signal Processing since 1994. (IFAC – International Federation of Automatic Control). Since 1994.
- Member of IFAC Technical Committee on Stochastic Systems since 1994.

- Member of the Program Committee of the Workshop on Real-Time and Hybrid Systems held in March 1997 at Grenoble, France.
- Member of Program Committee of Workshop on Discrete Event Systems 1998, scheduled for August 1998 (WODES98).
- Member of the International Program Committee of the 1999 European Control Conference.
- Member of the Dutch Institute of Systems and Control (DISC), since September 1995.

Visitors

- Prof. V. Schmidt (Univ. Ulm, Germany), January 13 and 17.
- Prof. G. Weiss (Haifa Univ., Israel), January 17.
- Ms. Ir. H.B. Sipma, (Dept. of Computer Science, Stanford University, Stanford, CA, USA), April 10. Lecture *Reactive, real-time, and hybrid systems*.
- Prof. K. Sigman (Columbia University, New York, USA), June 2–11. Lecture *On the M/G/1 queue with subexponential service time distribution*.
- Dr. D. Nesic (University of Melbourne, Melbourne, Australia/Université Catholique de Louvain, Louvain-la-Neuve, Belgium), September 30. Lecture *An algebraic-geometric approach to deadbeat controllability for a class of polynomial systems*.
- Prof. J. Maciejowski (University of Cambridge, Cambridge, United Kingdom/temporarily at the Delft University of Technology, Delft), November 18. Lecture *The implicit daisy-chaining property of constrained predictive control*.
- Dr. S.C. Borst (Lucent), October 13–December 5. Lecture *Performanc analysis of call centers*.
- Dr. Ph. Nain (INRIA Sophia-Antipolis), December 15. Lecture *Further asymptotic results for fluid queues fed by on/off sources*.
- Prof. D. Perry (Univ. Haifa; temporarily EUR), December 15. Lecture *Five clearing policies for a production/inventory jump diffusion model*.

Miscellaneous

Participation in CWI-in-Bedrijfdag, October 3. O.J. Boxma (lecture), R. Núñez Queija, J.H. van Schuppen.

Relations with industry and public relations
- Railned. Contacts were maintained with Railned. A small project was started in 1997.

Doctoral students taking courses
- LNMB course on Game Theory, February–April: R. Núñez Queija.
- LNMB course on Combinatorial Optimization, September–December: A.P. Zwart.
- AIO course in Stochastics on Large Deviations Theory, September–December: A.P. Zwart.

Teaching
- R. Núñez Queija replaced O.J. Boxma in his Queueing Theory course at the Katholieke Universiteit Brabant on October 2 and December 4.

Special awards
- Lifetime Achievement Award, from International Council for Teletraffic Congresses: J.W. Cohen.
- Gijs de Leve prize for the best Dutch Ph.D. thesis in Operations Research in the period 1994–1996: S.C. Borst (Ph.D. student in the group during 1990–1994).

Papers in Journals and Proceedings

S.C. BORST, O.J. BOXMA (1997). Polling models with and without switchover times. *Operations Research* **45**, 536–543.

R.J. BOUCHERIE, O.J. BOXMA, K. SIGMAN (1997). A note on negative customers, GI/G/1 workload, and risk processes. *Probability in the Engineering and Informational Sciences* **11**, 305–311.

O.J. BOXMA, D.G. DOWN (1997). Dynamic server assignment in a two-queue model. *EJOR* **103**, 101–115.

O.J. BOXMA (1997). Regular variation in a multisource fluid queue. V. RAMASWAMI, P.E. WIRTH (eds.). *Teletraffic Contributions for the Information Age*, (Proc. ITC-15), North-Holland, Amsterdam, 391–402.

O.J. BOXMA, U. YECHIALI (1997). An M/G/1 queue with multiple types of feedback and gated vacations. *J. Appl. Probability* **34**, 773–784.

J.W. COHEN (1997). On the determination of the stationary distribution of a symmetric clocked buffered switch. V. RAMASWAMI, P.E. WIRTH (eds.). *Teletraffic Contributions for the Information Age*, (Proc. ITC-15), North-Holland, Amsterdam, 297–308.

J.W. COHEN, D.G. DOWN (1996). On the role of Rouché's theorem in queueing analysis. *Queueing Systems* **23**, 281–291.

R. DEKKER, F.A. VAN DER DUYN SCHOUTEN, R.E. WILDEMAN (1997). A review of multi component models with economic dependence. *Mathematical Models of Operations Research* **45**, 411–435.

V. DUMAS (1996). A multiclass network with non-linear, non-convex, non-monotonic stability conditions. *Queueing Systems* **25**, 1–43.

F.A. VAN DER DUYN SCHOUTEN, P.A. SCARF (1997). Editorial Eleventh EURO Summer Institute:

Operations Research Models in Maintenance. *European Journal of Operational Research* **99**, 491–492.

J.M. VAN DEN HOF (1997). Realization of positive linear systems. *Linear Algebra and its Applications* **256**, 287–308.

J.M. VAN DEN HOF (1997). Realization of continuous-time positive linear systems. *Systems and Control Letters* **31**, 243–253.

A. OVERKAMP (1997). Supervisory control using failure semantics and partial specifications. *IEEE Trans. Automatic Control* **42**, 498–510.

J.H. VAN SCHUPPEN (1997). Integrated traffic control of motorway networks. M. PAPAGEORGIOU, A. POULIEZOS (eds.). *Preprints 8th IFAC/IFIP/IFORS Symposium Transportation Systems*, Chania, Crete, Greece, 1156–1161.

W. SLOB, P.H.M. JANSSEN, J.M. VAN DEN HOF (1997). Structural identifiability of PBPK models: Practical consequences for modeling strategies and study designs. *Critical Reviews in Toxicology* **27**, 261–272.

M. SMITH, T. AVEN, R. DEKKER, F.A. VAN DER DUYN SCHOUTEN (1997). A survey on the interval distribution of failure prone systems. *Advances in Reliability* **3**, 1727–1740.

P.R. DE WAAL, A. OVERKAMP, J.H. VAN SCHUPPEN (1997). Control of railway traffic on a single line. *Proc. 4th European Control Conference (ECC97)*, Brussels, Belgium, (Published on CD-Rom only).

CWI Reports

PNA-R9702. J.W. COHEN. *On the M/G/1 queue with heavy-tailed service time distributions*.

PNA-R9705. O.J. BOXMA, V. DUMAS. *Fluid queues with long-tailed activity period distributions*.

PNA-R9709. J.W. COHEN. *A heavy-traffic theorem for the GI/G/1 queue with a Pareto-type service time distribution*.

PNA-R9710. O.J. BOXMA, J.W. COHEN. *Heavy-traffic analysis for the GI/G/1 queue with heavy-tailed distributions*.

PNA-R9712. R. NÚÑEZ QUEIJA. *Steady-state analysis of a queue with varying service rate*.

PNA-R9714. J.W. COHEN. *The M/G/1 fluid model with heavy-tailed message length distributions*.

PNA-R9716. J.H. VAN SCHUPPEN. *Control for a class of hybrid systems*.

PNA-R9718. O.J. BOXMA, V. DUMAS. *The busy period in the fluid queue*.

PNA-R9719. J.W. COHEN. *Heavy-traffic limit theorems for the heavy-tailed GI/G/1 queue*.

Other Publications

J.H. VAN SCHUPPEN (1997). Routing control of motorway networks. Appendix D in *Coordinated Control Strategies*, Deliverable D06.1 of Project DACCORD, Hague Consulting Group, The Hague.

J.H. VAN SCHUPPEN (1997). Integrated control of motorway networks, Appendix E in *Coordinated Control Strategies*, Deliverable D06.1 of Project DACCORD, Hague Consulting Group, The Hague.

Stochastics – PNA3

Staff

- Dr. J. van den Berg, senior researcher
- Prof. dr. ir. O.J. Boxma, senior researcher (0.1 fte)
- Dr. K. Dzhaparidze, senior researcher
- Dr. A. Ermakov, Ph.D. student (NWO, until November)
- Dr. R. Helmers, senior researcher
- R. van der Horst, programmer (0.5 fte)
- Prof. dr. M.S. Keane, theme leader (0.4 fte)
- Drs. B. Lemmens, Ph.D. student (NWO, from March, 0.2 fte)
- I.W. Mangku, Ph.D. student (Indonesian cooperation)
- Drs. D. Maslen, postdoctoral fellow (CIMS – NWO, from August)
- B.A.M. Schouten, Ph.D. student (NWO, from December)
- Prof. dr. S.M. Verduyn Lunel, advisor (from February, 0.2 fte)
- D. White, Ph.D. student (NWO, 0.2 fte)

Scientific Report

In 1997, research highlights in PNA3 included the following items:

- Acquisition of a SWON proposal by Van den Berg and Keane for a two-year postdoctoral fellow, who has been selected and will begin his work in 1998.
- Acquisition of a SWON proposal by Dzhaparidze and Keane for a four-year Ph.D. student, who has been selected and will begin his work in 1998.
- Successful defences of two dissertations.
- Acquisition of a new advisor, Verduyn Lunel, in February. In September, Verduyn Lunel was appointed full professor at the Free University of Amsterdam, as successor of Kaashoek.
- Extension of a cooperation grant by NWO and OTKA for exchange and a postdoctoral fellow, managed by Van den Berg and Keane at CWI, and by Fritz, Szasz, and Tóth in Budapest.

- Participation in a research program at DIMACS, February–July, by van den Berg.
- Our two active seminars, Spatial Stochastics Seminar (Tuesdays) and Dynamics in Amsterdam (Thursdays) continue to provide a forum and a binding factor for our research.

The following details form a summary of the individual activities and collaborations in 1997.

Research of J. van den Berg

Epidemics: In the first months of 1997 a preliminary paper (written in 1996) on spatial epidemics (joint work with G. Grimmett and R. Schinazi) has been thoroughly revised. The new version has been submitted to the Annals of Applied Probability.

Coalescing random walks (cooperation with H. Kesten): in 1996 some refined asymptotics for standard coalescing random walks on the d-dimensional grid had been obtained. Quite annoying, even for small modifications of the standard model the method failed. However, a breakthrough by Kesten has led to a much more robust method. A still open problem is to make it work for any dimension larger than two.

A symmetry problem in percolation: This is a continuation of attempts, made in earlier years by Van den Berg and Ermakov, to prove a tantalizing conjecture of Kasteleyn. Van den Berg realized that one of the simplest cases of the conjecture gives rise to another conjecture (a kind of conditioned FKG inequality) which looks interesting in itself. He has discussed the latter with J. Kahn (Rutgers University) who obtained an elegant proof. However, the original problem is still open.

Exact simulation and finitary codings for random fields: Van den Berg and Steif (Gothenburg) have shown that certain stationary random fields are (and certain others are not) a finitary factor of a finite-valued i.i.d. process. In particular, they show that the plus state for the ferromagnetic Ising model is (not) such a finitary factor when the interaction parameter is below (above) its critical value. Part of the results were inspired by the Propp-Wilson algorithm for exact simulation of finite Markov chains. A paper has been completed.

Disjoint occurrences of events: Motivated by discussions with D. Reimer (who spent the spring at the Institute for Advanced Study in Princeton), Van den Berg has continued attempts to extend Reimer's famous result to 'sampling without replacement'. The hope was to find, for a relatively simple case, a computer-assisted proof. However, in spite of extensive computer search by A. Steenbeek, no suitable combinatorial structure has been found, so that new ideas are needed.

Further, during his stay at DIMACS, Van den Berg has had many discussions (in particular with P. Tetali, J. Kahn, P. Winkler, E. Vigoda and M. Jerrum) on the critical value of the hard-core model in high dimensions (does it tend to zero or not?), spatial mixing of random fields, and rapid convergence of markov chains (it appears that both mathematical physicists and theoretical computer scientists are very interested in these things, but they often speak different languages which makes comparison of results difficult). Van den Berg still has regular e-mail contact with some of the above mentioned people, with the aim to shed more light on these matters.

Research of K. Dzhaparidze

Most of the time was spent on the research in the area of Mathematical Finance, namely the theory of options valuation in securities markets. Three papers were written for the *CWI Quarterly* with the common title *Introduction to Option Pricing in a Securities Market*. In the beginning of this year the first of these papers received the final touch to be published in the first of the special issues of the *Quarterly* on *Mathematical Finance*. Soon afterwards, the paper for the second issue was completed. Finally, at the end of this year the third paper was submitted to the Quarterly, which deals with the Black-Scholes model for a securities market. Activities in this direction got a new impulse with the appointment of a Ph.D. student starting in the course of the next year.

The results obtained in this year in the area of the statistical inference on stochastic processes will be reported under the title *On a posterior information process for parametric families of experiments*. A research memorandum by K. Dzhaparidze, P. Spreij (VU, Amsterdam) and E. Valkeila (Helsinki) is in a final stage.

Research of A. Ermakov

Ermakov has continued his research on the one-dimensional coalescing ideal gas, partly in cooparation with B. Toth (Budapest) and W. Werner (Paris). This has led to two papers which, together with his earlier papers on percolation forms the main part of his Ph.D. thesis which he defended successfully on December 1.

Research of R. Helmers and I.W. Mangku

The research of R. Helmers was continued in various directions. Joint work with B.Y. Jing and G. Qin (Hong Kong) resulted in an article on saddle-

point approximations for trimmed means, with application to the bootstrap. The paper was submitted for publication to a journal. Earlier work with M.H. Wegkamp (Yale) on wild bootstrapping in finite populations was accepted for publication by the Scandinavian Journal of Statistics. The collaboration with M. Hušková (Prague) on change point estimation and H. Putter (Cambridge) on a quantile problem in nonparametric regression was continued. Report PNA-R9704 (joint work with A.J. van Es and M. Hušková), was tentatively accepted by Statistica Neerlandica. Further, Helmers's article with Gilat (Tel Aviv) on strong laws and earlier work on the local time of the empirical process were published.

I.W. Mangku – in cooperation with Helmers – studied the problem of estimating the period of a cyclic Poisson process from a single realization of it. A 'nonparametric' estimator for the period was proposed and shown to be consistent when the 'observation region' expands to the whole real line. Also the rate of consistency was investigated. A first report on these matters will appear early in 1998. In addition, joint work with R. Zitikis (Ottawa), who visited CWI in December, resulted in a consistent estimator of the intensity function of a cyclic Poisson process.

Research of M.S. Keane, B. Lemmens, and S.M. Verduyn Lunel

Keane has published an article in cooperation with Hooghiemstra of Delft University of Technology on a problem due to Wellner concerning a central limit theorem for sums of correlated products. The main problem here is, however, yet unresolved. In collaboration with his Ph.D. student Harris, an article has appeared on random coin tossing. In addition, three further articles with Keane as co-author have been accepted for publication. Cooperation with T. Hamachi of Kyushu University was continued in the area of noncommutative ergodic theory, and a long article is to be submitted for publication soon.

Lemmens began his doctoral studies in March, 1997, under the supervision of Verduyn Lunel and Keane. A number of initial results in the area of determination of possible sizes for rigid sets under various norms in finite-dimensional spaces have been obtained.

Verduyn Lunel and Keane have produced preliminary results on superexponential convergence of iterates of operators connected with delay equations. Work is still in progress.

Verduyn Lunel, Lemmens, and Keane co-organize the weekly Dynamics in Amsterdam seminar. This seminar did not take place in the fall of 1997 because of the special programme at the Lorentz Center in Leiden.

Research of D. Maslen

Since Maslen joined CWI in August, he has written two articles 'Double coset decompositions and compuational harmonic analysis on groups' (joint with D. Rockmore, Dartmouth College), and 'The eigenvalues of Kac's master equation'. Apart from this Maslen has worked on limit theorems on motion groups (with M. Keane), the convergence of random walks, and quantum algorithms for subgroup detection.

Maslen and Keane are preparing an article on metastable limit theorems for rand om walks on the group of motions of Euclidean space, with applications to steering of robot arms.

Research of D. White

White works in the area of spatial stochastics, in particular percolation, supervised by M. Keane and R. Meester.

In collaboration with J. van den Berg and one of his supervisors, R. Meester, White published the article 'Dynamic Boolean models' in Stochastic Processes and their Applications. In this paper we consider a random collection of balls in Euclidean space, and we say that the balls 'percolate' if the region occupied by them has an infinite connected component. Now we let the balls move at random, independently of each other. We show that under certain conditions, if originally the balls percolate with probability one, then they percolate at all times with probability one. An analogous statement is valid in the case that the balls do not percolate.

White completed a preprint *Backbends in Directed Percolation* (submitted for publication) jointly with the Indian probabilists Rahul Roy and Anish Sarkar. The topic of this paper was motivated by the physical problem of particle transport in random media in the presence of a field. Work by Ramaswamy and Barma shows us that particles prefer to flow through the network along the least tortuous path, as it is difficult for particles to follow paths that have long 'backbends' against the direction of the field. In this paper the concept of 'backbend' is formalized and studied.

White is currently working on the topic of Fractal Percolation or Random Cantor Sets, which was introduced by Benoit Mandelbrot in 1974. In 1988 J.T. Chayes, L. Chayes and R. Durrett proved that the model in two dimensions exhibits a first order phase transition. White is working to simplify their proof

and to extend it to general dimension.

Organization of Conferences, Workshops, Courses, etc.

- Seminar *Spatial Stochastic*: 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.
- Lunteren Conference on Stochastics, November 11–13. Organized by M. Keane (joint with W.R. van Zwet (Leiden)).
- International Conference *Fractals*, April 7–12, Denver, Colorado, USA. Keane was member of the paper selection committee.
- International Symposium on Mathematical Physics, Delft University of Technology, April 25, organized by Keane.
- Diderot Mathematical Forum, December 19–20, Amsterdam, Venice, Madrid (teleconference) on the mathematics of water and environment, coorganized by Keane and Schouten (PNA4).
- J. van den Berg, M. Keane and B. Tóth have taken the first steps to organize a workshop on mathematical physics which will be held in Budapest in 1999.

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

- Participation in the DIMACS/IAS program on Discrete Probability, February–July. Van den Berg.
- Distinguished Lecturer Series, DIMACS (lecture by Van den Berg on February 28).
- Workshop on Statistical Physics methods in Discrete Probability, Combinatorics and Theoretical Computer Science, DIMACS (Rutgers) and the IAS (Princeton), March 23–27 (two lectures by Van den Berg).
- Workshop on Probabilistic Analysis of Algorithms, May 11–14, Princeton University. Van den Berg.
- Microsurveys in Discrete Probability, IAS (Princeton), June 2–6. Van den Berg.
- Lunch seminar Courant Institute, New York University, May 29 (lecture by Van den Berg).
- Discrete Mathematics seminar, Princeton University, regularly in the spring of 1999. Van den Berg.
- Workshop on Percolation, Particle Systems and Ergodic Theory, Gothenburg, October 26–31 (lecture by Van den Berg).
- Lunteren Stochastics meeting, November 17–19. All theme members.
- Workshop on *Statistical Inference for Stochastic Processes*, Rennes, April 24–26, K. Dzhaparidze.
- III Italian Conference on *Mathematical Finance*, Trento, May 26–30, K. Dzhaparidze.
- Working visit to *Helsinki University*, November 22–29, K. Dzhaparidze.
- Working visit (and invited lecture) by Ermakov to the Math. Institute of the Hungarian Academy of Sciences, Budapest, one week in January.
- Working visit by Ermakov to DIMACS, Rutgers University, March 11 April7.
- One-week working visit (with invited lecture) by Ermakov to E.N.S. , Paris.
- Working visit (+invited lecture) to Queens College, City University of New York, USA, May 1–10, R. Helmers.
- 51st Session of ISI, Istanbul, August 18–26, invited lecture in meeting on *Statistical methods in Auditing*, R. Helmers.
- CIMPA Summer School, January 11–24, Temuco, Chile. M. Keane delivered course of 8 lectures on *Ergodic Theory of Continued Fractions*.
- Lecture in the seminar *Analysis on Symmetric Cones*, University of Amsterdam, March 7, by M. Keane.
- International Conference on Ergodic Theory, March 16–21, Haifa, Israel, invited lecture on *Simple proofs of ergodic theorems* by M. Keane.
- Working visit by M. Keane, March 21–28, The Hebrew University of Jerusalem, and colloquium lecture.
- Working visit by M. Keane, April 7–16, University of North Texas, Denton, Texas, and invited lecture in Southwest Dynamical Systems Conference, April 12–14.
- Invited lecture, University of Texas at Dallas, April 15, by M. Keane.
- Colloquium lecture, Delft University of Technology, April 23, by M. Keane.
- Working visit by M. Keane to Erwin Schrödinger Institute, Vienna, Austria, May 5–31. Two invited lectures.
- Invited lecture, Mark Kac Seminar for Stochastics and Physics, Utrecht, June 6, by M. Keane.
- Invited colloquium lecture, University of Bielefeld, Bielefeld, Germany, June 13, by M. Keane.
- Festkolloquium U. Krengel, University of Göttingen, Göttingen, Germany, June 20–21, attended by M. Keane.
- Colloque International Y. Guivarc'h, Dinard, France, June 29–July 2, attended by M. Keane.
- Invited lecture, Mathematics Colloquium of the University of Erlangen, Erlangen, Germany, July 11, by M. Keane.

- Ergodic Theory Conference, Szklarska Poręba, Poland, September 7–13, attended by M. Keane.
- Working visit by M. Keane to Politechnika Wroclaw, Poland, August 31–September 6.
- Working visit by M. Keane to Hewlett Packard Laboratories, Bristol, UK, October 9–21.
- Festkolloquium W. Kaup, Tübingen, Germany, October 31–November 2, attended by M. Keane.
- Working visit, Université de Paris VI, November 23–30, and invited lecture on November 25 by M. Keane.
- Courses Aio Network Stochastics (biweekly), attended by I.W. Mangku.
- March 1997, talk on Dynamic Boolean Models at the Probability Seminar in Groningen. D. White.
- Workshop on Statistical Physics Methods in Discrete Probability, Combinatorics and Theoretical Computer Science at Princeton University and DIMACS in New Jersey. Lecture by D. White.
- University of Utrecht Stochastics Colloquium, September. Lecture by D. White.
- Workshop on Percolation, Particle Systems and Ergodic Theory in Gothenburg, Sweden. Lecture by D. White.
- Working visits to England in April and October; attendance at probability seminars at the Statistical Laboratory in Cambridge, Queen Mary and Westfield College in London, and Hewlett-Packard Laboratories in Bristol. D. White.

Memberships of Committees and Other Professional Activities

J. van den Berg:
- Member of the Ph.D. committe of D. Reimer (Rutgers University, April 22).
- Member of the Ph.D. committee of A. Ermakov (TUD, December 1).
- Participant in the national research project CIMS.
- Co-organiser of a Dutch-Hungarian program supported by NWO.
- Supervisor of Ph.D. student A. Ermakov.

K. Dzhaparidze:
- Member of the research network in pursuance of the Human Capital Programme, EC project 'Statistical inference for stochastic processes'.

R. Helmers:
- Advisor Coopers & Lybrand, Amsterdam.
- Participation in cooperation project *Applied Mathematics and Computational Methods* (1995–1999) between The Netherlands and Indonesia.
- Member steering committee Statistical Auditing of the Limperg Institute. June 26.

M.S. Keane:
- 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.*
- Member Akademieraad voor de Wiskunde.
- Thesis advisor, Matthew Harris, 28 April (TU Delft).
- Master's thesis committee, R. van Egmond, 4 June (TU Delft).
- Thesis committee, R. van der Hofstad, 16 June, University of Utrecht.
- Thesis advisor, Alexei Ermakov, 1 December (TU Delft).
- Member NRCM panel, selected as *key researcher* for stochastics.

Visitors

- M. Aizenman (Princeton), T. Bountis (Patras), A. Bovier (Berlin), R. Burton (Corvallis), H. Farkas (Budapest), D. Gilat (Tel Aviv), A. Greven (Erlangen), G. Grimmett (Cambridge), R. Haveneers (Utrecht). T. Hill (Atlanta), F. den Hollander (Nijmegen), A.-J. Homburg (Berlin), M. Huśková (Prague), A. Iwanik (Wroclaw), C. Kraaikamp (Delft), B. Krauskopf (Amsterdam), H. Kuiper (Tuscon), Y. Lacroix (Brest), J.-F. Le Gall (Paris), V. Lotov (Novosibirsk), J. Mémin (Rennes), M. Maes (Eindhoven), K. Marton (Budapest), R. Meester (Utrecht), M. Menshikov (Moscow), A. Nobel (Chapel Hill), H. Osinga (Minneapolis), R. Roy (New Delhi), J. Serafin (Wroclaw), M. Smorodinsky (Tel Aviv), B. Tóth (Budapest), M. Vervoort (Amsterdam), R. de Vilder (Amsterdam), R. Zitikis (Ottawa).

Miscellaneous (Consultancy, knowledge transfer, etc.)

- A SWON proposal by J. van den Berg and M. Keane (involving a postdoc position) has been accepted.
- Course on measure/integration theory for 2nd year statistics students (UvA) given by J. van den Berg.
- Course on Markov Fields and Phase Transition for 4th year students (UvA) given by J. van den Berg.
- Coopers & Lybrand: Research by R. Helmers concerning inference on rare errors resulted in a manuscript, which was submitted for publication. The

Monte Carlo simulations which were needed to assess the performance of a new upper confidence limit for the total error amount in various audit populations of practical interest were carried out by R.van der Horst.
- M. Keane was consultant for selection of national mathematics subsidies for 1997–2000, for the Chilean Research Council, January 12–14, Santiago, Chile.
- M. Keane did preliminary consulting work for the NAM in Assen.
- M. Keane is Senior Consulting Fellow, Hewlett Packard Laboratories, Bristol, UK.
- M. Keane delivered a lecture to high school students in the national programme *Wiskunde in Actie*, Delft, November 4.
- In November, M. Keane began his work as an advisor for Philips Research Laboratories for one day a week, in Eindhoven.
- J. van den Berg and M. Keane are the Dutch coordinators for the joint NWO-OTKA grant for cooperation between Hungary and The Netherlands.

Papers in Journals and Proceedings

T. BEDFORD, J. VAN DEN BERG (1997). A remark on the Van Lieshout and Baddeley J-function for point processes. *Adv. Appl. Prob.* **29**, 19–25.

J. VAN DEN BERG, R. MEESTER, D. WHITE (1997). Dynamic Boolean models. *Stochastic Processes and their Applications* **69**, 247–257.

J. VAN DEN BERG (1997). A constructive mixing condition for 2-d Gibbs measures with random interactions. *The Annals of Probability* **25**, 1316–1333.

K. DZHAPARIDZE, P. SPREIJ, E. VALKEILA (1997). On Hellinger processes for parametric families of experiments. *Statistics and Control of Stochastic Processes; The Liptser Festschrift.* World Scientific, Singapore, 41–61.

K. DZHAPARIDZE (1997). Introduction to option pricing in a securities market-II: Poisson approximation. *CWI Quarterly* **10**, 65–100.

D. GILAT, R. HELMERS (1997). On strong laws for generalized L-statistics with dependent data. *Comment. Math.Univ.Carolinae* **38**, 187–192.

R. HELMERS (1997). A note on bootstrapping the local time of the empirical process. *Statistics and Decisions* **15**, 295–300.

G. HOOGHIEMSTRA, M. KEANE (1997). A central limit theorem for sums of correlated products. *Statistica Neerlandica* **51**, 23–34.

M. HARRIS, M. KEANE (1997). Random coin tossing. *Probability Theory and Related Fields* **109**, 27–37.

D. MASLEN, D. ROCKMORE (1997). Separation of variables and the computation of Fourier transforms on finite groups. *J. Amer Math. Soc.* **10**, 169–214.

D. MASLEN (1997). The efficient computation of Fourier transforms on the symmetric group. *Proceedings FPSAC '97.*

CWI Reports

PNA-R9704. A.J. VAN ES, R. HELMERS, M. HUŠKOVÁ (1997). *On a crossroad of resampling plans: Bootstrapping elementary symmetric polynomials.*

Other Publications

A. ERMAKOV (1997). *Percolation and Coalescing Particle Systems*, Dissertation, Delft University of Technology. Supervised by J. van den Berg, thesis advisor M. Keane.

Signals and Images – PNA4

Staff

- Prof. dr. F.M. Dekking
- Dr. ir. H.J.A.M. Heijmans
- Dr. Z. Kato
- Prof. dr. M.S. Keane
- Dr. A.A.M. Kuijk
- Dr. M.N.M. van Lieshout
- Dr. P. Perez (INRIA): May–September
- Drs. P.J. Oonincx
- Drs. B.A.M. Schouten
- A.G. Steenbeek
- Dr. N.M. Temme
- Dr. P.M. de Zeeuw
- Dr. R.A. Zuidwijk

Scientific Report

Image Modelling and Coding – PNA4.1

F.M. Dekking researched stochastic tree models in relation to quadtree representations of images, in particular branching cellular automata.

M.S. Keane. The research by Keane has been described under PNA3.

B.A.M. Schouten has been on leave from the institute.

Wavelets – PNA4.2

P.J. Oonincx continued his research on the analysis of seismic signals. To analyze short segments in a

seismogram with a Fourier or wavelet transform, one has to deal with uncertainty. Generally the (wavelet) spectrum cannot be computed exactly. We introduced a preprocessing algorithm, which was already standard practice in Fourier signal analysis, in combination with the wavelet transform. Mathematical properties of this new approach, called tapered wavelet analysis, have been deduced and experiments with synthetic and seismic data have taken place and will still take place in close collaboration with the seismology department of the KNMI.

N.M. Temme published a paper on the distribution of zeros of certain polynomials related with Daubechies wavelets and delivered several introductory lectures on wavelets.

The main object of research of R.A. Zuidwijk was the wavelet X-ray transform. This transform combines useful properties of two well-known integral transformations, the wavelet transform and the X-ray (or Radon) transform. The transform performs an analysis of multi-dimensional data sets in terms of direction and time-scale. Besides a thorough analysis of the integral transformation, a discretization and numerical implementation of the transform has been established. A code has been incorporated in Matlab which is currently being applied to seismic data sets. First results in this direction are promising.

In January, De Zeeuw defended his thesis on multilevel methods. Subsequently he became a member of the PNA cluster and was deployed to the STW-project of PNA4. In cooperation with R.A. Zuidwijk he developed a prototype version of the fast wavelet X-ray transform for the purification of datasets of seismic signals.

Morphological Image Processing – PNA4.3

There exists increasing interest in the development of tools that consider images at different scales of resolution. In this respect pyramidal image structures are of particular interest. A well-known instance of such a structure is the wavelet transform, but there exist others, such as the Gaussian pyramid. In collaboration with Prof. J. Goutsias (Johns Hopkins University, Baltimore), H.J.A.M. Heijmans is investigating pyramid structures based on morphological operators. One of the ambitious goals of this project is to make a systematic study of nonlinear (morphological) pyramids and wavelets. The first results will be published in 1998 in two technical reports.

Heijmans continued his work on connected morphological operators. Connected operators are operators that can delete edges, but that cannot change them, neither their shape nor their location. As a result, connected operators are well-suited for many imaging tasks, such as segmentation, filtering, and coding. The aim of this project is to develop a consistent mathematical theory for connected operators, and to investigate their implementation using a tailor-made graph structure. A first report, dealing exclusively with the binary case, has been completed. The next step will be to extend the results for grey-scale images.

In the literature, one finds two concepts for expressing the similarity of shapes: distance functions measuring assimilarity, and similarity measures expressing how similar two shapes are. Similarity measures can be used to compute 'how symmetric a given shape is', e.g. with respect to reflection in a given line. For many objects, presence or absence of symmetry is a major feature, and therefore the problem of object symmetry identification is of great interest in image analysis and recognition, computer vision and computational geometry. H.J.A.M. Heijmans, in collaboration with J.B.T.M. Roerdink (RU Groningen) and A. Tuzikov (Minsk) continued his work on the construction of similarity and symmetry measures for convex shapes which are invariant under various transformation groups such as rotations, affine transformations, etc. A technical report dealing with the 3-dimensional case has been finished recently.

Stochastic Geometry – PNA4.4

Spatial statistics

Van Lieshout and Baddeley (University of Western Australia) developed new summary statistics for quantifying several forms of dependence between types in a spatial pattern of points classified into distinct types. They are based on comparing distances from a type i point to either the nearest type j point or to the nearest point in the pattern regardless of type to these distances seen from an arbitrary point in space. Information about the effective range of interaction (defined in terms of Papangelou conditional intensities) can also be inferred.

Size-weighted Boolean models

Granulometries have proved a useful tool in mathematical morphology for measuring the size of particles and pores in images. In this research, granulometries are compared to the contact distribution function used in stochastic geometry. A suitable size distribution function for random sets is defined and employed as a tool in exploratory data analysis. A new Hanisch-style estimator is proposed and Markov random sets are constructed which use the size distribution function to favour certain sizes of the random set above others.

Markov point processes

Work on a monograph on Markov point processes (Imperial College Press) has started and will be continued in 1998.

Image Generation for Virtual Environments – PNA4.5

Design and simulation of a new display technology in the form of a high speed high quality rasterization engine. The rasterization engine (the so-called Multi Sample Engine) is based on a linear array of Multi Sample Processors to compute pixel values in real-time. It is a fast rasterizer designed to facilitate traditional realistic rendering techniques, image based rendering and image reconstruction techniques. Pixel values are computed by evaluating polynomials of arbitrary degree or by taking samples of pixel spans stored in memory. Data stored in the sample memory are texture data, wavelet functions and/or fractal samples. A.A.M. Kuijk investigated functional-level simulation of the system. This will be the basis to further investigate the capability of the system to reconstruct images by means of direct basis accumulation for the wavelet transform or accumulation of samples of fractal coded images.

A.A.M. Kuijk assisted *T. van Rij* (formerly IS1) with her research on adaptive rendering. This work involved design, implementation, analysis and testing of 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. By means of an experimental setup, the consistency with human perceptual characteristics was verified. Publications on this topic are expected in 1998.
A.A.M. Kuijk was involved in the design and development of a software environment for incremental visibility calculation and view volume culling. In this project, novel multiresolution techniques are being investigated as a means to improve the efficiency of the visibility calculation algorithm. Results of this research will form the basis for implementation of a software environment that aims at sufficient and efficient support for animation and direct manipulation.

Organization of Conferences, Workshops, Courses, etc.

- *Branching Processes*, Graduate Course, January-May: F.M. Dekking
- Minisymposium Numerieke Wiskunde van het Nederlands Mathematisch Congres, Wageningen, April 3–4: P.M. de Zeeuw
- On November 6, Oonincx, Temme, De Zeeuw and Zuidwijk organized a one-day course at CWI on wavelets for students of the MRI Master-class (University of Utrecht) and for interested CWI colleagues
- ASCI course *Mathematical Morphology: Principles, Algorithms and Applications*, June 23–27 (3 lectures by H.J.A.M. Heijmans)
- Session on *Spatial interaction in stochastic systems* at the 22nd European Meeting of Statisticians to be held in Vilnius, August 1998: M.N.M. van Lieshout
- Videoconference: Diderot Mathematical Forum on the mathematics of water and environment, December 18–19, Venice, Madrid, Amsterdam

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

- *Fractals in Engineering* Conference, Arcachon, France, June 25–27: F.M. Dekking (Invited lecture)
- EIDMA Seminar, TU Eindhoven: F.M. Dekking (Invited lecture)
- Mark Kac Seminar, Utrecht, November 7: F.M. Dekking (Invited lecture)
- Workshop *Interactions in space: improving the mean field approximation*, Lorentz Center, Leiden, October 29–November 1: F.M. Dekking (+ lecture on October 30)
- Algemeen Wiskunde Colloquium, Amsterdam, January 8: De Zeeuw (Acceleration of iterative techniques by coarse grid corrections)
- Working visit to MARIN, Wageningen, March 24: P.J. Oonincx, N.M. Temme, P.M. de Zeeuw and R.A. Zuidwijk
- Nederlands Mathematisch Congres, Wageningen, April 3–4: P.J. Oonincx, N.M. Temme, P.M. de Zeeuw and R.A. Zuidwijk
- Workshop on *Asymptotics* (Hong Kong), May 22–28: N.M. Temme (Asymptotics and zero distribution of zeros of polynomials that are related to Daubechies wavelets)
- Summer school *École d'Été d'Analyse Numérique*, Ablis, France, June 30–July 11: P.J. Oonincx and R.A. Zuidwijk
- SPIE Annual meeting: *Wavelet Applications in Signal and Image Processing*, San Diego, US, July 27–August 3: R.A. Zuidwijk (*The discrete and continuous wavelet X-ray transform*)
- IEEE Symposium on *Applications of Time-Frequency and Time-Scale Methods*, Coventry, UK, August 27–29: P.J. Oonincx (*Analysing earthquake data: Tapered wavelet analysis*), R.A.

Zuidwijk (*Directional time-scale analysis with wavelet X-ray transform*)
- Conferentie Numerieke Wiskunde, Woudschoten, September 24–26: P.M. de Zeeuw
- Seminar *Signals and Images* (CWI), October 21: P.J. Oonincx (Tapered Wavelet Analysis)
- De Leidsche Flesch Symposium *De Toekomst*, Leiden, November 19: N.M. Temme (*Wavelets: Een nieuwe golf in de wiskunde*)
- Seminar on *Analysis and Operator Theory*, VUA, November 20: R.A. Zuidwijk (*Wavelet X-ray analysis of seismic data: A topic in operator theory?*)
- Working visit to KNMI (Dr. H. Haak and dr. B. Dost), November 25: P.J. Oonincx and R.A. Zuidwijk
- Stieltjes Course *Modern Computational Fluid Dynamics*, Leiden, November 27: P.M. de Zeeuw (*Robust coarse-grid corrections*)
- Working group on splines, UvA, December 19: R.A. Zuidwijk (*The fast wavelet X-ray transform*)
- Working visits at Shell International Exploration and Production B.V., Research and Technical services, Rijswijk, October 17, November 17, December 1 and 8: P.M. de Zeeuw and R.A. Zuidwijk
- 7th International Conference *Computer Analysis of Images and Patterns, CAIP'97*, Kiel, Germany, September 10–12: H.J.A.M. Heijmans (lecture)
- STW Gebruikerscommissie, October 16: H.J.A.M. Heijmans (lecture)
- 1997 IEEE International Conference on Image Processing (ICIP 97), Santa Barbara, California, October 27–29: H.J.A.M. Heijmans (lecture)
- Working visit to Johns Hopkins University, Baltimore, USA, October 30–November 2: H.J.A.M. Heijmans (+ lecture)
- Invited lecture at Universiteit Gent, faculty Applied Mathematics and Computer Science, November 18: H.J.A.M. Heijmans

M.N.M. van Lieshout:
- Working visit to University of Warwick, Coventry, UK, June 10–29
- Workshop on the art and science of Bayesian image analysis, Leeds, UK, June 30–July 2
- Working visit to Prof. A.J. Baddeley, University of Western Australia, Perth, Australia, August 3–23
- Bernoulli society meeting on mathematical statistics and its applications in biosciences, Rostock, Germany, August 31–September 4
- European Science Foundation workshop on reversible jump MCMC and model choice applications, Brockenhurst, UK, September 21–24
- Workshop on percolation, particle systems and ergodic theory, Gothenburg, Sweden, October 26–31
- Bijeenkomst Stochastici, Lunteren, November 17–19
- European Science Foundation workshop on exact simulation, Rold, Denmark, November 29–December 2
- Conference on spatial statistics, Milton Keynes, UK, December 17

A.A.M. Kuijk:
- International Siggraph/Eurographics Workshop on Graphics Hardware, Los Angeles, USA, August 3–4
- Siggraph'97, Los Angeles, USA, August 4–8
- Software Technology Workshop, Senter, Maastricht, Oktober 30
- Virtual Reality in Industry and Research, Euro-VR Mini-Conference '97, Amsterdam, November 10–11

Memberships of Committees and Other Professional Activities

F.M. Dekking:
- Chairman of MSc. Graduation Committees:
  R.J. van Egmond, *Recognition of bit error patterns on digital transmission channels*, June 4
  M. Bogers, *A simulation study of the Eurotransplant liver allocation procedure*, October 3
- Member of Ph.D. Graduation Committees:
  M. Harris, *Coin tossing, random mirrors and dependent percolation: three paradigms of phase transition*, April 28
  R.R.G.G. Godderij, *A 3-dimensional interface model for steam drive in heterogeneous reservoirs*, October 27
  A. Ermakov, *Percolation and coalescing particle systems*, December 1

N.M. Temme:
- STW Users Committee, Project Wavelets: Analysis of Seismic Signals (chair)

P.M. de Zeeuw:
- Secretary Werkgemeenschap Numerieke Wiskunde
- Editor *Het Nummer* (newsletter Werkgemeenschap Numerieke Wiskunde)

H.J.A.M. Heijmans:
- Member of editorial board *Journal of Mathematical Imaging and Vision*
- Editor of electronic newsletter *Morphology Digest*
- Coordinator of INTAS project 96-785 *Multi-scale Image Analysis and Applications*
- Participant of the COPERNICUS (1994) project *BENEFIT Concerted Action for Stimulation of East-West Collaborations in the Areas of Microelectronics and Signal Processing*

H.J.A.M. Heijmans and M.N.M. van Lieshout:

- Editor of a special issue of *CWI Quarterly* devoted to image analysis (to appear 1998)

M.N.M. van Lieshout:
- Member of Ph.D. committee Karin Nelander, Chalmers University of Technology, Gothenburg, Sweden
- Co-editor (with O. Barndorff-Nielsen and W.S. Kendall) of the proceedings of the Seminaire Européen de Statistique *Stochastic geometry, likelihood and computation*, Chapman and Hall
- Together with H.J.A.M. Heijmans, editor of a special issue of *CWI Quarterly* devoted to image analysis (to appear 1998)

A.A.M. Kuijk
- Member program committee 1997 Siggraph/Eurographics Workshop on Graphics Hardware

Visitors

- V. Vatutin, Stechlov Institute, Moscow, January 11–16.
- J. Weickert, U Utrecht, February 25
- F. Meyer, Centre de Morphologie Mathématique, Fontainebleau, France
- E. Pauwels, Katholieke Universiteit Leuven
- J. Goutsias, The Johns Hopkins University, June 15–22
- V. Ramesh (Siemens Corporate Research, NJ) August 29
- M. Aizenman (Princeton), September 23
- J. Memin (Rennes), September 30
- A. Salden, INRIA, October 7
- M. Hušková (Prague), October 14
- M. Fiocco (Leiden), November 4
- E.W. van Zwet (Utrecht), November 25
- R. Zitikis (Ottawa), December 2
- R. Meester (Utrecht), December 16
- A.J. Baddeley (Australia), October 11–16, working visit

Miscellaneous (Concultancy, Knowledge Transfer, etc.

- Lecture series *Mathematical Methods in Image Analysis*, Technical University of Delft, (14 lectures): H.J.A.M. Heijmans
- H.J.A.M. Heijmans, P.J. Oonincx, P.M. de Zeeuw and R.A. Zuidwijk contributed a poster site and demonstrations on wavelets during the annual manifestation *CWI in the Market Place*, October 3
- R.A. Zuidwijk exchanged ideas with Ir. K. Kannegieter (Elin Holec High Voltage B.V., Amersfoort) on an integral equation that arises in the analysis of current distribution in conductors
- Review and referee work N.M. Temme: see MAS 2.8
- Dutch patent 1003363 on a Multi Sample Engine, Assignee: Stichting Mathematisch Centrum, Inventor: A.A.M. Kuijk

Papers in Journals and Proceedings

F.M. DEKKING, E.R. SPEER (1997). On the shape of the wavefront of branching random walk. K.B. ATHREYA, P. JAGERS (eds.). *Classical and Modern Branching Processes*, IMA Volumes in Mathematics and its Applications Vol. **84**, Springer, New York, 73–88.

F.M. DEKKING, J.J. KALKER, E.A.H. VOLLEBREGT (1997). Simulation of rough elastic contacts. *J. Appl. Mechanics* **64**, 361–368.

F.M. DEKKING (1997). What is the long range order in the Kolakoski sequence? R.V. MOODY (ed.). *The Mathematics of Long-Range Aperiodic Order*, (Waterloo, Can., 1995). *NATO Adv. Sci. Inst.*, Kluwer Acad. Publ., Dordrecht, 115–125.

F.M. DEKKING (1996). The fractal geometry of random Cantor sets. I.B. JUNG, S. LEE (eds.). *Proc. of the Topology and Geometry Research Center* **7**, Kyungpook National Univ., Taegu, Korea, 39–61.

R.M. BURTON, T. COFFEY, K. HYMAN (1997). Fractal percolation with neighbour interaction. J. LEVY-VEHEL, E. LUTTON, C. TRICOT (eds.). *Fractals in Engineering*, Springer, Berlin, 106–114.

P.J. OONINCX (1997). Analysing earthquake data: Tapered wavelet analysis. *Proc. 2nd IEEE Symposium on Applications of Time-Frequency and Time-Scale Methods*, 13–16.

N.M. TEMME (1997). Asymptotics and zero distribution of zeros of polynomials that are related to Daubechies wavelets. *Appl. Comput. Harmon. Anal.* **4**, 414–428.

R.A. ZUIDWIJK (1997). Quasicomplete factorizations of rational matrix functions. *Integral Equations and Operator Theory* **27**, 111–124.

R.A. ZUIDWIJK (1997). Complementary triangular forms, Linear Operators. *Banach Center Publications* **38**, 443–452.

R.A. ZUIDWIJK (1997). Directional time-scale analysis with wavelet X-ray transform. *Proceedings UK Symposium on Applications of Time-Frequency and Time-Scale Methods*, University of Warwick, Coventry, 169–171.

R.A. ZUIDWIJK (1997). The discrete and continuous wavelet X-ray transform. *SPIE proceedings* **3169**, Wavelet Applications in Signal and Image Processing V, 357–366.

H.J.A.M. HEIJMANS (1997). Composing morphological filters. *IEEE Transactions on Image Processing* **6**(5), 713–723.

H.J.A.M. HEIJMANS, P. MARAGOS (1997). Lattice calculus of the morphological slope transform. *Signal Processing* **59**(1), 17–42.

H.J.A.M. HEIJMANS (1997). Connected morphological operators and filters for binary images. *Volume 2 of Proceedings of IEEE International Conference on Image Processing*, Santa Barbara (CA), 211–215.

H.J.A.M. Heijmans (1997). Morphological grain operators for binary images. G. SOMMER, K. DANIILIDIS, J. PAULI (eds). *Computer Analysis of Images and Patterns, CAIP'97*, Lecture Notes in Computer Science **1296**, Springer, Berlin, 392–399.

A. TUZIKOV, H.J.A.M. HEIJMANS (1997). Comparing convex shapes using Minkowski addition. G. SOMMER, K. DANIILIDIS, J. PAULI (eds). *Computer Analysis of Images and Patterns, CAIP'97*, Lecture Notes in Computer Science **1296**, Springer, Berlin, 138–145.

M.N.M VAN LIESHOUT (1997). On likelihoods for Markov random sets and Boolean models. D. JEULIN (ed.). *Proceedings of the International Symposium on Advances in Theory and Applications of Random Sets*, World Scientific Publishing, Singapore, 121–135.

M.N.M VAN LIESHOUT. I.S. MOLCHANOV (1997). Shot-noise-weighted processes: a new family of spatial point processes. *Stochastic Models* **14.**

M.N.M VAN LIESHOUT (1997). Prior distributions for Bayesian image analysis. C.A. GILL, R.G. AYKROYD (eds.). *K.V. Mardia*, Proceedings in the art and science of Bayesian image analysis, Leeds University Press, 30–35.

A. TUZIKOV, H.J.A.M. HEIJMANS (1997). On one problem of convex polygon decomposition (in Russian). *PRIP'97 International Conference*, Minsk, Belarus, 20–22.

CWI Reports

PNA-R9701. S.J.L. VAN EIJNDHOVEN, P.J. OONINCX. *Frames, Riesz systems and MRA in Hilbert spaces.*

PNA-R9703. R.A. ZUIDWIJK. *The wavelet X-ray transform.*

PNA-R9708. H.J.A.M. HEIJMANS. *Connected morphological operators for binary images.*

PNA-R9715. M.N.M VAN LIESHOUT. *Size distributions in stochastic geometry.*

PNA-R9717. P.C. MARAIS, E.H. BLAKE, A.A.M. KUIJK. *Quadratic vs cubic spline-wavelets for image representation and compression.*

PNA-R9720. P.J. OONINCX. *On time-frequency analysis and time-limitedness.*

Other Publications

A. TUZIKOV, J.B.T.M. ROERDINK, H.J.A.M. HEIJMANS (1997). *Similarity Measures for Convex Polyhedra Based on Minkowski Addition*, Research Report RU Groningen, CS-R9708.

M.N.M. VAN LIESHOUT (1997). *Prior Distributions for Bayesian Image Analysis*, Research report 305, University of Warwick, February 1997.

M.N.M. VAN LIESHOUT, A.J. BADDELEY (1997). *Indices of Dependence Between Types in Multivariate Point Patterns*, Research report 1997/17, University of Western Australia.

A. TUZIKOV, H.J.A.M. HEIJMANS, G.L. MARGOLIN, S. SHEYNIN (1997). *Convex Polygon Similarity Measures*, (in Russian). Doklady Academii Nauk Belarusi.

M.N.M. VAN LIESHOUT (1997). Review of *The Statistical Theory of Shape*, by C.G. SMALL. Short book reviews.

SOFTWARE ENGINEERING

General

On January 1, 1997, CWI's cluster SEN (for Software Engineering) started its activities. Its four constituent themes were formed from research groups of the former CWI departments Software Technology and Interactive Systems. The overview in the following pages provides a variety of data on the research performed by the themes. Some selected facts are presented here:

- the SEN staff produced more than one hundred publications in the categories Papers in Journals and Proceedings and in Other Publications. Among the research highlights we mention the work of Jan Heering et al. on the PIM logic; of Robert van Liere on scientific visualization through virtual reality; of Jan Friso Groote on the definition of timed μCRL; of Joost Warners on OR methods applied to propositional logic; of Farhad Arbab on formal models and applications for the coordination language MANIFOLD; of Jan Rutten on the use of coalgebras in the theory of systems, and of Cees van Kemenade on theory and applications of evolutionary algorithms
- SEN was involved in a large number of externally funded projects, such as

  - projects directly funded by industry (Philips, Railconsult, ...)
  - projects funded by NWO Foundations (SION, SWON, ...)
  - projects funded by other Dutch government agencies (SENTER, HPCN, ...)
  - projects funded by EU programmes (ESPRIT LTR, TMR, ...)

  All together, SEN participated – mostly in consortia with academic or industrial partners – in more than 20 such projects;
- the staff of the pilot theme SEN4 was reinforced by the appointment of dr. J.A. La Poutré as theme leader, and of several junior staff members;
- from the new initiatives in which SEN is involved we mention: our participation in a number of projects – in varying stages of preparation – (to be) included in the research program of the Telematics Institute; our taking part in the collaboration between the CWI and our ERCIM partner GMD, and new sizable contracts with the Dutch Ministry of Public Works and Water Management, and with Delft Hydraulics;
- as a personal highlight we recall that on September 1, 1997, prof. Paul Klint, theme leader of SEN1, celebrated the 25th anniversary of his appointment at the CWI.

Staff 1997

- Interactive Software Development and Renovation – SEN1

  - P. Klint
  - J.A. Bergstra
  - M.G.J. van den Brand
  - T.B. Dinesh
  - A. van Deursen
  - J.A. Harkes
  - J. Heering
  - M. Hoogenboom
  - J.H. Kniesmeijer
  - J.J. Krieger
  - T. Kuipers
  - W.C. de Leeuw
  - R. van Liere
  - J.D. Mulder
  - K.E. Shahroudi
  - H.R. Walters
  - J.J. van Wijk

- Specification and Analysis of Embedded Systems – SEN2

  - J.F. Groote
  - G. Barthe
  - J.A. Bergstra
  - I. Bethke
  - D.J.B. Bosscher
  - H. Elbers
  - W.O.D. Griffioen
  - M.J. Hollenberg
  - J.W. Klop
  - B. Lisser
  - S.P. Luttik
  - S. Mauw
  - J.M.T. Romijn
  - J.G. Springintveld
  - J. van Wamel
  - J.P. Warners

- Coordination Languages – SEN3

  - J.J.M.M. Rutten
  - F. Arbab
  - J.W. de Bakker

  - C.L. Blom
  - P. Bouvry
  - F.J. Burger
  - A. Corradini
  - C.T.H. Everaars
  - A. Fagot
  - E.B.G. Monfroy
  - A. Scutellá

- Evolutionary Computation and Applied Algorithmics – SEN4

  - J.A. La Poutré
  - C.H.M. van Kemenade
  - J.N. Kok
  - R. van Stee
  - P. Svestka
  - M.C. van Wezel

- Secretary: J.J. Bruné-Streefkerk

Interactive Software Development and Renovation – SEN1

Staff

- Prof. dr. P. Klint, theme leader
- Prof. dr. J.A. Bergstra, advisor
- Dr. M.G.J. van den Brand, project member (seconded since October 1)
- Dr. T.B. Dinesh, postdoc (SION)
- Dr. A. van Deursen, project leader
- Drs. J.A. Harkes, Ph.D. student
- Drs. M. Hoogenboom (CAP-Volmac, until June 1)
- J. Heering, project leader
- Drs. J.H. Kniesmeijer (CAP-Volmac)
- Drs. J.J. Krieger (CAP-Volmac, since November 1)
- Drs. T. Kuipers, Ph.D. student
- Dr. W.C. de Leeuw, postdoc
- Ir. R. van Liere, project leader
- Drs. J.D. Mulder, Ph.D. student
- Dr. K.E. Sharoudi, postdoc (SION, until April 1)
- Dr. H.R. Walters, project member (until November 1)
- Dr. J.J. van Wijk, advisor (until April 1)

Scientific Report

The group has continued and extended its efforts to develop advanced tools that address software engineering problems such as prototyping, program understanding, program optimization, and visualization of large software systems.

The research was concentrated in four areas: interactive language prototyping, software renovation, optimization of scientific software, and interactive visualization environments.

Language prototyping is based on the ASF+SDF Meta-Environment, a system for interactive language development and incremental programming environment generation. It serves as an environment for developing application languages (domain specific languages) (SEN1.1), tools for software renovation (SEN 1.1), and tools for program analysis and optimization (SEN 1.2). The Meta-Environment itself is also the subject of a major renovation (SEN 1.2). Work on interactive visualization environments is shifting to the management of scientific data and Virtual Reality (SEN 1.3).

Development of new technology for the renovation and maintenance of legacy systems – SEN 1.1

For the Resolver project, 1997 started with the completion of its first Release. In January, a full day session was organized attended by over 50 people from all participating organizations. An important ingredient of Release I consisted of technology for solving the year 2000 problem, which has resulted in several CWI publications.

Most of 1997 was invested in the second release of Resolver, which was completed in October. CWI's involvement consisted of research in the area of extracting object-oriented components from legacy software. Moreover, CWI actively participated in the Resolver project management, coordinating the activities of a team of seven researchers from CWI and the University of Amsterdam.

Looking for techniques supporting the development of systems with improved maintainability, further SEN 1.1 research was carried out in the area of *domain specific languages*. The maintenance implications of such languages and the relationship with object-oriented frameworks has been studied, resulting in two further publications.

Last but not least, SEN 1.1 assisted in the organization of a major conference on reverse engineering, the *IEEE Working Conference on Reverse Engineering* held at CWI from September 6–8.

Generic Tools for Program Analysis and Optimization – SEN 1.2

Dinesh/Haveraaen (UiB)/Heering—supported in part by ESPRIT project *Scientific Computing and Algebraic Abstractions (SAGA)*: SAGA investigates an approach to writing PDE solvers in C++ which should close the gap between the underlying coordinate-free mathematical theory and the way

actual solvers are written. A C++ source-to-source optimizer was written in ASF+SDF to reduce the run-time penalty associated with the SAGA style. Positive preliminary results were obtained for a seismic simulation code in C++ on the Silicon Graphics/Cray Research Origin 2000 supercomputer at Parallab High Performance Computing Center in Bergen (Norway). A deliverable describing the optimizer was contributed to SAGA's First Phase Final Report.

Bergstra/Dinesh/Field (IBM)/Heering/Tip (IBM)—supported in part by SION project *Generic Tools for Program Analysis and Optimization*: PIM is an equational logic for symbolic execution and optimization of programs in imperative languages such as C. An extensive article appeared in *ACM Trans. Progr. Languages and Systems*. An introductory article explaining the principles underlying PIM was accepted for publication in *ACM Computing Surveys* (SEN-R9722). Work on enrichment of PIM with loop transformations, emphasizing the restrictions to be imposed to obtain completeness results, was continued. Cooperating with Tip, Dinesh investigated the feasibility of using slicing techniques for automating the process of locating type errors in a program. This work was presented at two conferences.

Walters—supported in part by SION project *Generic Tools for Program Analysis and Optimization*: The earlier work done in collaboration with Kamperman on a Term Rewriting System to ARM code compiler was consolidated and documented in two reports (SEN-R9721, SEN-R9724). Walters' involvement in the project ended on November 1.

Dinesh/Üsküdarli (University of Amsterdam/Philips Research Palo Alto): The work done in 1996 on tools for a meta-environment for visual languages based on the ASF+SDF Meta-Environment was described in two conference publications.

Interactive Visualization Environments – SEN 1.3

The objectives of the visualization group are to study, develop, and put into practice methods for interactive scientific visualization. Primary areas of interest are management of scientific data, virtual reality, and techniques for higher level input.

J. Harkes, M. Hoogenboom, J. Kniesmeijer, S. Krieger and R. van Liere continued work on the HPV project. Harkes and Van Liere worked on the distributed data management of large data sets, resulting in a various extensions for the efficient transport of data sets in a heterogeneous environment. Hoogenboom developed a set of user interface tools and integrated these in the current environment. Kniesmeijer worked on portability issues, particulary those issues concerning Windows NT and laptop display devices. Krieger started work on applying the developed techniques in a immersive environment.

W. de Leeuw finished his Ph.D. thesis *Presentation and Exploration of Flow Data* and defended it successfully on January 27, 1997. He continued working on the HPV project. Together with Van Liere, he worked on high performance techniques for flow visualization. This resulted in a collaboration with Prof. Veldman at the University of Groningen, in which a number of very large data sets were explored. In addition, together with Van Liere, De Leeuw worked with MAS1 in applying these techniques to global smog models.

J. Mulder continued work on 3D presentation, interaction and viewing. The work involves research and development of novel interaction techniques which allow users to specify visualization in intuitive ways. In addition, Mulder studied a number of novel techniques to render a large number of transparent objects. Mulder is expected to finish his Ph.D. early 1998.

J. Mulder, W. de Leeuw and R. van Liere initiated a number of studies of applications of virtual reality techniques to interactive scientific visualization. These studies are intended to get acquainted with the field of virtual reality and has resulted in various case studies in the CAVE at SARA.

K.E. Shahroudi and J.J. van Wijk successfully finished work on the SION funded project. The goal of this work was to research high level input techniques for interactive scientific visualization.

Organization of Conferences, Workshops, Courses, etc.

- A. van Deursen, ASF+SDF '97, September 25–26.
- R. van Liere, VR '97 symposium, Amsterdam, November 10–11.

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

- *DSL '97/POPL '97/CW '97/FOOL4 workshops*, Paris, France, January 14–18: T.B. Dinesh, A. van Deursen (*Little Languages—Little Maintenance?*), P. Klint.
- *SAGA Project Working Visit University of Bergen* (M. Haveraaen), Norway, February 26–28: T.B. Dinesh (*Source to Source Transformation of C++ Code Using the ASF+SDF Environment*), J. Heering (*The SAGA CodeBoost Tool*).
- *Working Visit IBM T.J. Watson Research Center* (F.

Tip), Yorktown Heights, USA, March 3–12: T.B. Dinesh (*Share-Where Maintenance*).
- *Logic for Systems Engineering*, Dagstuhl, Germany, March 3–7: A. van Deursen (*Formalizing Mass Migrations*).
- *ASF+SDF/ELAN Meeting*, Nancy, France, March 20–21: A. van Deursen (*An Implementation of Origin Tracking*), P. Klint (*The ToolBus Coordination Architecture*), T. Kuipers, H.R. Walters.
- *IPA Course*, Utrecht, April 16: A. van Deursen (*Language Prototyping Using ASF+SDF*).
- *HPCN '97*, Vienna, Austria, April 28–30: R. van Liere (*Steering Smog Simulation*).
- *8th Eurographics Workshop on Visualization*, Boulogne sur Mer, France, April 29–May 1: J.D. Mulder (*Parametrizable Cameras for 3D Computational Steering*), J.J. van Wijk.
- *SGI HPC Seminar*, Amsterdam, May 6: R. van Liere (*High Performance Smog Forecasting*).
- *Symposium on High Performance Computing/SAGA Project Working Visit University of Bergen* (M. Haveraaen), Bergen, Norway, May 14–16: T.B. Dinesh, J. Heering.
- *Systeemrenovatie, HISCOM*, Leiden, May 26: P. Klint.
- *Het Jaar 2000: Overgang of Ondergang? Focus Conferentie over het Jaar 2000 Probleem*, May 28: P. Klint.
- *WADT '97*, Rome, Italy, May 29-June 7: A. van Deursen (*A Transformational Approach to Origin Tracking*).
- *Dagstuhl Seminar on Scientific Visualization*, Dagstuhl, Germany, June 8–13: W.C. de Leeuw (*Spot Noise for Large DNS Simulation*), J.J. van Wijk.
- *STJA '97*, Erfurt, Germany, September 9–11: A. van Deursen (*Domain-Specific Languages versus Object-Oriented Frameworks: A Financial Engineering Case Study*).
- *ASF+SDF '97*, Amsterdam, September 24–26: A. van Deursen, T.B. Dinesh, J. Heering, P. Klint (*Renovation of the ASF+SDF Meta-Environment—Current State of Affairs*).
- *FSE/OOR*, Zürich, Switzerland, September 25–28: A. van Deursen and T. Kuipers (*Finding Classes Using Cluster Analysis*).
- *Vereniging voor Informaticarecht Advocaten (VIRA)*, Amsterdam, October 2: P. Klint (*Het Jaar 2000 Probleem*).
- *WCRE '97*, Amsterdam, October 6–10: M.G.J. van den Brand, A. van Deursen (*Program Plan Recognition for Year 2000 Tools*), T.B. Dinesh, P. Klint.
- *Workshop on Codebase Management Systems*, Amsterdam, October 9: P. Klint (*Essential Ingredients of a CBMS*).
- *USENIX Conference on Domain Specific Languages*, Santa Barbara, USA, October 14–19: T.B. Dinesh (*A Slicing-Based Approach for Locating Type Errors*).
- *IEEE Visualization '97*, Phoenix, USA, October 16–25: R. van Liere (*Ubiquitous Computational Steering*).
- *Super Computing '97*, San Jose, USA, November 17–21: W.C. de Leeuw, R. van Liere (*Divide and Conquer Spot Noise*).
- *Euro-VR Mini-Conference '97*, Amsterdam, November 10–11: W.C. de Leeuw, R. van Liere, J. Mulder, S. Krieger.
- *CSN '97*, Utrecht, November 25: R. van Liere (*Analysis of Biological Structures by Virtual Reality Techniques*).
- *ASIAN '97*, Kathmandu, Nepal, December 8–12: T.B. Dinesh (*Share-Where Maintenance in Visual Algebraic Specifications*).

Memberships of Committees and Other Professional Activities

M.G.J. van den Brand:
- PC member *WCRE '97*

J. Heering:
- PC member *Joint ALP '97—HOA '97, ASF+SDF '97*

P. Klint:
- President *European Association for Programming Languages and Systems* (EAPLS)
- Member steering committee ETAPS (*European Joint Conferences on Theory and Practice of Software*)
- Member advisory board *ID Research*
- External advisor PNO, Fenit
- Ph.D. thesis advisor Susan Uskudarli, *Algebraic Specification of Visual Languages*, University of Amsterdam, March 24
- Ph.D. thesis advisor Eelco Visser, *Syntax Definition and Language Prototyping*, University of Amsterdam, September 22
- Member Ph.D. committee Phillippe Canalda, University of Orleans, USA, July 4; Van Diessen, Universiteit van Amsterdam, September 15; Erik Kwast, Universiteit van Utrecht, October 31; Annius Groenink, Universiteit van Utrecht, November 7; Jan Pellenkoft, Universiteit van Amsterdam, November 25
- PC member TAPSOFT '97, DPLE '97

W.C. de Leeuw:
- VISTAN member
- Referee: *IEEE CG and A*

R. van Liere:

- VISTAN member
- Referee: *IEEE CG and A, FGCS*
- Review of several research proposals (STW, SION)

Visitors

- M. Haveraaen (University of Bergen) August 8 (SAGA project working visit).
- K. Meinke (KTH Stockholm) September 24–26.
- S. Oberoi (Unisys, Bombay) May 26–28 (Aspects of the Year 2000 problem).

Papers in Journals and Proceedings

J.A. BERGSTRA, T.B. DINESH, J. FIELD, J. HEERING (1997). Toward a complete transformational toolkit for compilers. *ACM Transactions on Programming Languages and Systems* **19**, 639–684.

M.G.J. VAN DEN BRAND, J. HEERING, P. KLINT (1997). Renovation of the ASF+SDF Meta-Environment—Current state of affairs. M.P.A. SELLINK (ed.). *2nd International Workshop on the Theory and Practice of Algebraic Specifications (ASF+SDF '97)*, Electronic Workshops in Computing, Springer, 1–13.

M.G.J. VAN DEN BRAND, P. KLINT, C. VERHOEF (1997). Reverse engineering and system renovation: an annotated bibliography. *ACM Software Engineering Notes* **22**(1), 42–57.

M.G.J. VAN DEN BRAND, P. KLINT, C. VERHOEF (1997). Re-engineering needs generic programming language technology. *ACM SIGPLAN Notices* **32**(2), 54–61.

M.G.J. VAN DEN BRAND, T. KUIPERS, L. MOONEN, P.A. OLIVIER (1997). Implementation of a prototype for the new ASF+SDF Meta-Environment. M.P.A. SELLINK (ed.). *2nd International Workshop on the Theory and Practice of Algebraic Specifications (ASF+SDF '97)*, Electronic Workshops in Computing, Springer.

M.G.J. VAN DEN BRAND, A. SELLINK, C. VERHOEF (1997). Generation of components for software renovation factories from context-free grammars. I. BAXTER, A. QUILICI, C. VERHOEF (eds.). *Proceedings of the Fourth Working Conference on Reverse Engineering*, IEEE Computer Society, 144–153.

A. VAN DEURSEN (1997). Domain-specific languages versus object-oriented frameworks: a financial engineering case study. *Proceedings Smalltalk and Java in Industry and Academia (STJA '97)*, Report, University of Ilmenau, 35–39. (Invited talk)

A. VAN DEURSEN, P. KLINT (1997). Little languages: little maintenance? *Proceedings of the First ACM-SIGPLAN Workshop on Domain-Specific Languages (DSL '97)*, Report, University of Illinois at Urbana-Champaign, 109–127.

A. VAN DEURSEN, P. KLINT (1997). Het jaar-2000-probleem. *Computerrecht* **6**, 266–271.

A. VAN DEURSEN, T. KUIPERS (1997). Finding classes in legacy code using cluster analysis (position paper). S. DEMEYER, H. GALL (eds.). *Proceedings of the ESEC/FSE'97 Workshop on Object-Oriented Reengineering*, Report TUV-1841-97-10, Technical University of Vienna.

A. VAN DEURSEN, S. WOODS, A. QUILICI (1997). Program plan recognition for year 2000 tools. I. BAXTER, A. QUILICI, C. VERHOEF (eds.). *Proceedings of the Fourth Working Conference on Reverse Engineering*, IEEE Computer Society, 124–133.

T.B. DINESH, F. TIP (1997). A slicing-based approach for locating type errors. *Proceedings of the Conference on Domain-Specific Languages*, USENIX Association, 77–88.

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T.B. DINESH, S. ÜSKÜDARLI (1997). Share-Where maintenance in visual algebraic specifications. *Advances in Computing Science (ASIAN '97)*, Lecture Notes in Computer Science, **1345**, Springer-Verlag, 297–311.

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J.D. MULDER, J.J. VAN WIJK (1997). Parametrizable cameras for 3D computational steering. W. LEFER, M. GRAVE (eds.). *Proceedings of the 8th EG Workshop Visualization in Scientific Computing '97*, Springer-Verlag, 165–175.

R. VAN LIERE, J.D. MULDER, J.J. VAN WIJK (1997). Computational steering. *Future Generation Computer Systems* **12**, 441–450.

W. DE LEEUW, R. VAN LIERE (1997). Divide and conquer spotnoise. *Proceedings of Super Computing '97*, IEEE Society.

J.J. VAN WIJK, R. VAN LIERE (1997). An environment for computational steering. G.M. NIELSON, H. MULLER, H. HAGEN (eds.). *Scientific Visualization: Overview, Methodologies and*

Techniques, IEEE Computer Society, 89–110.

R. VAN LIERE, J.J. VAN WIJK (1997). Steering smog prediction. B. HERTZBERGER, P. SLOOT (eds.). *Proceedings of the 1997 Conference on HPCN-Europe*, Lectures Notes in Computer Science, **1225**, Springer-Verlag, 241–252.

CWI Reports

SEN-R9701. K.E. SHAHROUDI. *Design by continuous collaboration between manual and automatic optimization.*

SEN-R9702. K.E. SHAHROUDI. *Aircraft conceptual design by collaborative manual and automatic agents.*

SEN-R9703. K.E. SHAHROUDI. *Flipping the analytical coin: closing the information flow loop in high speed (real-time) analysis.*

SEN-R9704. A. VAN DEURSEN, P. KLINT. *Little languages: little maintenance?*

SEN-R9712. A. VAN DEURSEN, S. WOODS, A. QUILICI. *Program plan recognition for year 2000 tools.*

SEN-R9713. A. VAN DEURSEN, P. KLINT, A. SELLINK. *Validating year 2000 compliance.*

SEN-R9714. J.J. VAN WIJK. *A model for strategy in constraint solving.*

SEN-R9715. W.C. DE LEEUW, R. VAN LIERE. *Divide and conquer spot noise.*

SEN-R9716. R. VAN LIERE, J.J. VAN WIJK. *Steering smog prediction.*

SEN-R9717. J.D. MULDER, J.J. VAN WIJK. *Parametrizable cameras for 3D computational steering.*

SEN-R9718. J.J. VAN WIJK, R. VAN LIERE, J.D. MULDER. *Bringing computational steering to the user.*

SEN-R9719. J.J. VAN WIJK, H.J.W. SPOELDER, W.J.J. KNIBBE, K.E. SHAHROUDI. *Interactive exploration and modeling of large data sets: a case study with Venus light scattering data.*

SEN-R9721. W.J. FOKKINK, J.F.TH. KAMPERMAN, H.R. WALTERS. *Within ARM's reach: compilation of left-linear rewrite systems via minimal rewrite systems.*

SEN-R9722. J. FIELD, J. HEERING, T.B. DINESH. *Equations as a uniform framework for partial evaluation and abstract interpretation.*

SEN-R9724. H.R. WALTERS. *Epic and ARM – user's guide.*

Other Publications

H. BOSMA, A. VAN DEURSEN, E. FIELT, J.-W. HUBBERS, T. KUIPERS, T. WIGGERTS. (1997). Migrating COBOL to Object Oriented COBOL. Introduction. Chapter 6 of *Program Transformations for System Renovation*; Resolver Release II.

H. BOSMA, A. VAN DEURSEN, E. FIELT, J.-W. HUBBERS, T. KUIPERS, T. WIGGERTS. (1997). Migrating COBOL to Object Oriented COBOL. Conclusions. Chapter 12 of *Program Transformations for System Renovation*; Resolver Release II.

M. VAN DEN BRAND, A. SELLINK, C. VERHOEF (1997). Generation of Components for Software Renovation Factories from Context-free Grammars. Chapter 4 of *Program Transformations for System Renovation*; Resolver Release II.

M. VAN DEN BRAND, A. SELLINK, C. VERHOEF (1997). Control Flow Normalization for COBOL/CICS Legacy Systems. Chapter 5 of *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN, P. KLINT, G.M. WIJERS (eds.) (1997). *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN, P. KLINT, G.M. WIJERS (1997). An Overview of Resolver Release II. Chapter 1 of *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN, T. KUIPERS (1997). Structural Information from Legacy Systems. Chapter 7 of *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN, T. KUIPERS (1997). Clustering Techniques. Chapter 8 of *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN, T. KUIPERS (1997). Experiments Supporting OO Design Extraction. Chapter 9 of *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN, P. KLINT (1997). The Resolver Glossary. Chapter 16 of *Program Transformations for System Renovation*; Resolver Release II.

A. VAN DEURSEN (1997). The date crisis: windowing is not bad advice (Letter to the editor), *Communications of the ACM* **40**(5), p. 26.

T.B. DINESH, P. GRANT, M. HAVERAAEN, J. HEERING, G. MANOGG, J. SIMMONS, S. SØREIDE, M. WEBSTER (1997). *Final Report First Phase ESPRIT Project 21871—Scientific Computing and Algebraic Abstractions (SAGA).*

M. HANUS, J. HEERING, K. MEINKE (eds.) (1997). *Algebraic and Logic Programming: 6th International Joint Conference, ALP '97—HOA '97*, Lecture Notes in Computer Science **1298**, Springer-Verlag.

Specification and Analysis of Embedded Systems – SEN2

Staff

- Dr. ir. J.F. Groote, theme leader
- Dr. G. Barthe, postdoc SWON (till October 1)
- Prof. dr. J.A. Bergstra, advisor
- Dr. I. Bethke, project member (SION)
- Drs. D.J.B. Bosscher, junior researcher (Ph.D. student, till March 31)
- Drs. H. Elbers, junior researcher SION (Ph.D. student)
- Drs. W.O.D. Griffioen, junior researcher SION (Ph.D. student)
- Drs. M.J. Hollenberg, project member (from October 1)
- Prof. dr. J.W. Klop, project leader
- Drs. B. Lisser, programmer
- Drs. S.P. Luttik, junior researcher SION (Ph.D. student)
- Dr. S. Mauw, project member (seconded)
- Drs. J.M.T. Romijn, junior researcher (Ph.D. student)
- Dr. J.G. Springintveld, project member
- Dr. J. van Wamel, project member
- Ir. J.P. Warners, junior researcher SION (Ph.D. student)

Scientific Report

Jan Friso Groote continued his work on μCRL, process algebra, propositional logic, and practical applications. After three years of study, a simple, conservative timed extension to μCRL was completed. A syntax and semantical checker for it was developed (documented release is expected in 1998). Furthermore, work was done on constructing a linearizer for μCRL, which compiles a certain class of μCRL processes into a restricted, linear form, which is expected to be a suitable platform for the next generation validation techniques. The μCRL simulator was adapted to operate properly with the new linearizer, and starts having an acceptable performance. Together with J. Springintveld and F. Monin (TUE Eindhoven), the mechanical proof checking of a correctness proof of a distributed summing protocol was completed, providing one of the most complex computer checked protocols that exist today.
Regarding practical work, together with M. Hollenberg and B. van Vlijmen (Utrecht University), the language *LARIS* was developed as a specification language for next generation railway control systems. Regarding propositional logic, work was done to substantially clarify the relation between binary decision diagrams and resolution, showing in effect that they are not polynomially comparable.

Gilles Barthe continued his work until October 1 in the WINST project, concerned with combining type theory, term rewriting and computer algebra.

Inge Bethke worked in cooperation with Jan Willem Klop on an origin tracking proof of Berry's Sequentiality Theorem in lambda calculus, in the course of which a strengthened version was found that yields more undefinability results.

Doeko Bosscher finished his Ph.D. thesis, *Grammars Modulo Bisimulation*, and defended it on October 23. He left CWI March 31 and is now employed at ID Research.

Hugo Elbers continued his Ph.D. work in the WINST project. His Ph.D. thesis, *Connecting Formal and Informal Mathematics*, is scheduled for completion in the middle of 1998. A major part of the thesis is concerned with the extension of type theories with constructor systems with priorities.

David Griffioen worked on formalization of IO-Automata theory. For the formalization of executions and traces, possibly infinite sequences are needed, this turned out to be a subject on its own. Furthermore, the Tree Identify Phase of the IEEE 1394 protocol is specified at several levels of abstraction which are related via simulations. From this 'practical' work a new notion of simulations emerged, so-called normed simulations. Normed simulations allow one to reason over transitions (and norms) only, instead of reasoning over executions. This is especially useful in mechanical reasoning. A constant in this work is that it is all done using PVS.

Marco Hollenberg started working for CWI on October 1. Together with Jan Friso Groote and Bas van Vlijmen (Utrecht University) he worked (full-time) till December 1 in a project for Holland Railconsult. In this project, the syntax and semantics have been developed of a symbolic variant *LARIS* of the graphical specification language *Euris*, used by Dutch Railways to specify railway systems.

Jan Willem Klop continued the participation in writing a book on term rewriting together with co-editors R.C. de Vrijer (VUA) and M. Bezem (UU) and various chapter contributors. Volume I is scheduled to appear in 1998. A new line of investigation together with Inge Bethke was the study of origin tracking in a theoretical context; for first-order rewriting, lambda calculus, and infinitary rewriting.

Bas Luttik finished, in the first part of the year, a specification of part of the IEEE-1394 protocol in μCRL and presented it at the COST 247 work-

shop on Applied Formal Methods in System Design, held in Zagreb. Together with Piet Rodenburg and Rakesh Verma, a paper was completed on the transformation of rewriting systems. In ASF+SDF a tool is specified to normalize μCRL process terms to basic term format. This led to a joint paper with Eelco Visser in which a language to specify rewriting strategies is described. An interpreter for such a strategy language in ASF+SDF was built. Currently, the denotational/operational and algebraic semantics for this strategy language are being defined. The second part of the year was mainly devoted to joint work with Jan Friso Groote on completeness results for μCRL.

Judi Romijn worked mainly on research concerning reduction in the size of test suites based on symmetry properties, and on a case study in formal specification and verification of a part of the IEEE 1394 protocol. The research on the IEEE 1394 protocol has led to the appearance of a technical report in Nijmegen. The cooperation with Philips Multimedia Center in Palo Alto and the Philips Research Laboratories in Eindhoven that was planned in 1997, did not succeed due to logistic difficulties and divergence of approaches.
Beside this research, a small survey was written of the panel discussion of the IPA Workshop on Embedded Systems (November 1996), which appeared in *IEEE Concurrency* in January. In May, a paper on conformance testing was accepted at the workshop IWTCS '97 in South Korea.

Jan Springintveld started working for CWI on June 1, 1997. From August 1, he works, with Sjouke Mauw, two days a week in a project for the Telematica Research Centre, now Telematics Institute (Enschede). This project, subcontracted to CWI by TUE, aims to investigate whether model checkers, such as Spin, can be fruitfully employed to analyze business processes as modelled in the graphical language Amber.
Beside this practical work, work was done on testing theory. With Judi Romijn a paper is being written on a technique for exploiting symmetry in the structure of computer systems to reduce the size of sound and complete test suites. With prof. dr. F.W. Vaandrager (University of Nijmegen), papers are written extending traditional, untimed, testing theory to timed systems, i.e., systems whose correct behaviour crucially depends on timing requirements. Results of this work will be completed and submitted early in 1998.

Jos van Wamel spent most of his time in the Philips project *System compliance for the SAA7203 IC*, where the compliance of a source decoder for MPEG2 and DVB (Digital Video Broadcast) was tested. The project was joint work with people from Philips Research Labs Eindhoven; the IC under test is being developed by Philips Semiconductors. The work consisted of: derivation of a set of conformance requirements from the relevant international standards for MPEG2 and DVB; formulation of an adequate set of 'test purposes'; development of test tools; definition and implementation of tests; execution of tests; evaluation of test results; and evaluation of the total project. This project was finished successfully in December 1997. A similar project, *Compliance of the Audio/Video/Graphics core of the IC*, has started in January 1998. CWI is again involved.
Beside this practical work, work has been done om the specification, in μCRL, of components and data types that can be used for the specification of proposition solvers. The components are specified in such a way that they may serve as building blocks in various applications. At the moment, experiments with such applications are being carried out.

Joost Warners focused on algorithms for the satisfiability problem of propositional logic in general. Last year the main focus was on applying techniques from nonlinear optimization to help solving satisfiability problems. Nonlinear structures were used to approximate and solve MAX2SAT, and to obtain efficient branching and probing heuristics for general SAT. Furthermore, polynomially solvable instances of SAT were investigated that can be recognized by nonlinear representations. Also local search techniques were considered.

Organization of Conferences, Workshops, Courses, etc.

- J.W. Klop organized a symposium day of the NVTI (Nederlandse Vereniging voor Theoretische Informatica), on February 28, Utrecht
- J.W. Klop and I. Bethke organized the second workshop of ESPRIT WG Confer 2, October 20–22, Amsterdam

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

- *International Workshop on the Mathematics of Operations Research*, Lunteren, January 14–16: J. Warners (*A nonlinear approach to combinatorial optimization*)
- *Working visit University of Munich*, Munich, Germany, January 26–February 2: W.O.D. Griffioen (*Finite and Infinite sequences*)

- *IPA Lentedagen*, Mierlo, March 10–11: W.O.D. Griffioen, S. Mauw (*Message Sequence Charts*), J. Romijn (*From abstract tests to test execution*), J. Springintveld (*Automatic Test Derivation using Finite State Machines*)
- *PC meeting ICALP '97*, Bologna, Italy, March 14–16: J.W. Klop
- *Spring School OZSL*, Course on term rewriting, Mierlo, March 17–20: J.W. Klop
- *Spring School Methods and Tools for Verification of Infinite State Systems*, Grenoble, France, March 23–25: J. Romijn
- *ESPRIT WG Confer meeting*, Bologna, Italy, March 24–26: I. Bethke, J.W. Klop (*Sequentiality via Origin Tracking*)
- *MFPS '97*, Pittsburgh, USA, March 23–26: G. Barthe (*A notion of Classical Pure Type System*)
- *Dutch Proof Tools Day*, Nijmegen, April 25: W.O.D. Griffioen, J. Romijn
- *Working visit Chalmers University*, Chalmers, Sweden, May 5–10: G. Barthe (*Algebraic type systems*)
- *Working visit Copenhagen University*, Copenhagen, Denmark, May 9–12: G. Barthe (*Algebraic type systems*)
- *Termination Workshop*, Ede, May 20–23: J.W. Klop
- *5th Twente workshop on graphs and combinatorial optimization*, Enschede, May 21–23, J. Warners (*Bounds and fast approximation algorithms for binary quadratic optimization problems with application to MAX 2SAT and MAX CUT*)
- *PC meeting CSL '97*, Aarhus, Denmark, June 13–15: J.W. Klop
- *COST 247 meeting*, Zagreb, Croatia, June 17–20: J.F. Groote, S.P. Luttik (*Description and Formal Specification of the Link Layer of P1394*)
- *ERCIM Workshop*, Cesena, Italy, July 3–5: J.F. Groote (*A note on n parallel processes*)
- *LFCS '97*, Slaroslavl, Russia, July 5–13: G. Barthe (*Domain-Free Pure Type Systems*)
- *Summer School IPA*, Course on term rewriting, Mierlo, August 11–22: J.W. Klop
- *Summer School IPA*, Lectures 4 and 5 on process algebra, August 21–22: J.F. Groote
- *International symposium on Mathematical Programming*, Lausanne, Switzerland, August 24–29: J. Warners (*A nonlinear approach to a class of combinatorial optimization problems and Elliptic approximations of satisfiability problems*)
- *IWTCS '97*, Cheju, Korea, September 8–10: J. Romijn (*A Two-level Approach to Automated Conformance Testing of VHDL Designs*)
- *EXPRESS Final Meeting*, S. Margherita Ligure, Italy, September 8–12: I. Bethke, J.W. Klop and D. Plump (*Confluent Rewriting of Bisimular Term Graphs*)
- *Eighth SDL Forum*, Evry, France, September 21–26: S. Mauw (*Operational semantics for MSC96 and High-level Message Sequence Charts*)
- *Calculemus Workshop*, Edinburgh, UK, September 24–28: H. Elbers (*Extending Pure Type Systems with Pattern Matching*)
- *ITT-Colloquium*, Nijmegen, September 26: W.O.D. Griffioen (*Het 1394 protocol in al z'n facetten*)
- *Derde Nederlandse Testdag*, Eindhoven, TUE, October 1: J.F. Groote, J. Romijn, J. Springintveld (*Testing Timed Automata*), J. van Wamel (*System compliance for the SAA7203 IC and Testing a source decoder for MPEG2 and DVB*)
- *Working visit University of Stirling*, Stirling, UK, October 10: J.F. Groote (*Two examples of verifications: a remote control protocol and safety of railway yards*)
- *COST 247 meeting*, Stirling, UK, October 10–14: J.F. Groote (*Timed μCRL*)
- *Experts Meeting ITU SG10*, Lutterworth, UK, October 13–16: S. Mauw (*Semantics of disrupts and interrupts, A hierarchy of communication models for Message Sequence Charts and A note on MSC and data*)
- *Computer Science Colloquium*, University of Wales, Swansea, UK, October 14: J. Romijn (*Analysing a fragment of the IEEE 1394 Serial Bus*)
- *Informs Fall meeting*, Dallas, USA, October 25–31: J. Warners (*Potential reduction algorithms for combinatorial optimization problems and Satisfiability problems with balanced polynomial representation*)
- *Working visit University of Erlangen*, Erlangen, Germany, October 23–26: S. Mauw (*MSC trends at TUE and ITU, An operational semantics of MSC96 and A hierarchy of communication models for message sequence charts*)
- *Mini-course at BRICS*, Aarhus, Denmark , November 8–9: G. Barthe (*Pure Type Systems and Applications*)

Memberships of Committees and Other Professional Activities

J.F. Groote:

- Chair of Program Committee *ERCIM workshop on formal methods 1997*
- Chair of Program Committee *ERCIM workshop on formal methods 1998*

- Member Program Committee *COST 247 second International Workshop on Applied Formal Methods in System Design*, Zagreb (1997)
- Member Program Committee *Asian Computing Science Conference*, Khatmandu, Nepal, December 9–11, 1997
- Moderator of the concurrency mailing list
- Member National Management Committee COST 247 project *Formal specification and verification/validation and testing of software using formal specification techniques*. Chair of workpackage 2 *Analysis and validation techniques for distributed systems* (1994–)
- Member IEEE, EATCS, IPA, and NVTI
- Editor special issue *Science of Computer Programming* on applications of formal methods
- Reviewer *Zentralblatt für Mathematik*

D.J.B. Bosscher:

- Member of EATCS.

J.W. Klop:

- Professor of Computer Science at the Vrije Universiteit, Amsterdam
- Coordinator HCM Network *EXPRESS* (jointly with J.F. Groote).
- Scientific Secretary of NVTI (*Nederlandse Vereniging voor Theoretische Informatica*)
- Editor of *NVTI Nieuwsbrief* (jointly with J. Rutten, J.J. Bruné)
- Member Ph.D. Committee R. Bloo, TUE, October 2
- Member Ph.D. Committee M.H. Sorensen, DIKU, Copenhagen, Denmark, May 8–9.
- Member Ph.D. Committee T. Arts, May 16, Utrecht
- Member Science Committee IPA
- Member PC *ICALP 97*
- Member PC *CSL 97*
- Member PC *EXPRESS 97*
- Member PC *ALP/HOA97*

S. Mauw:

- Co-promotor J.J. Vereijken, December 8, Eindhoven
- Associate reporter of ITU-TS working group Q.9/10

Visitors

- Dr. M. Marchiori, University of Padova, Italy, February 15–August 15
- D. Plump, University of Bremen, Germany, April 1–December 1
- F. Kamareddine, University of Glasgow, UK, June 2–20
- Dr. O. Kullmann, University of Frankfurt, Germany, July 20–October 20
- S. Kleuker, University of Oldenburg, Oldenburg, Germany, November 11–12
- Dr. R. Mateescu, Institut National Polytechnique de Grenoble, from December 1

Papers in Journals and Proceedings

Z.M. ARIOLA, J.W. KLOP, D. PLUMP (1997). Confluent Rewriting of Bisimilar Term Graphs. *Proceedings Fourth Workshop on Expressiveness in Concurrency*, Electronic Notes in Theoretical Computer Science **7**, Elsevier.

G. BARTHE, F. VAN RAAMSDONK (1997). Termination of Algebraic Type Systems: the Syntactic Approach. M. HANUS, J. HEERING (eds.). *Proceedings of ALP '97 – HOA '97*, LNCS **1298**, Springer, 174–193.

G. BARTHE, F. KAMAREDDINE, A. RIOS (1997). Explicit substitutions for the $\lambda\Delta$-calculus. M. HANUS, J. HEERING (eds.). *Proceedings of ALP '97 – HOA '97*, LNCS **1298**, Springer, 209–223.

G. BARTHE, J. HATCLIFF, M.J. SÖRENSEN (1997). A notion of classical pure type system. S. BROOKES, M. MISLOVE (eds.). *Proceedings of MFPS '97*, ENTCS.

G. BARTHE, J. HATCLIFF, M.J. SÖRENSEN (1997). Reflections on reflections. H. GLASER, P. HARTEL, H. KUCHEN (eds.). *Proceedings of PLILP'97*, LNCS **1292**, Springer, 241–258.

G. BARTHE, M.J. SÖRENSEN (1997). Domain-free pure type systems. S. ADIAN, A. NERODE (eds.). LNCS **1234**, 9–20.

G. BARTHE, J. HATCLIFF, M.J. SÖRENSEN (1997). CPS-translation and applications: the cube and beyond. O. DANVY (ed.). *Proceedings of the Second ACM SIGPLAN Workshop on Continuations*, BRICS Notes, NS-96-13, 4/1-4/31.

G. BARTHE, P.-A. MELLIÈS (1997). On the subject reduction property for algebraic type systems. D. VAN DALEN, M. BEZEM (eds.). *Proceedings of CSL'96*, LNCS **1258**, 34–57.

M.A. BEZEM, R.N. BOL, J.F. GROOTE (1997). Formalizing Process Algebraic Verifications in the Calculus of Constructions. *Formal Aspects of Computing* **9**, 1–48.

L.-Å. FREDLUND, J.F. GROOTE, H. KORVER (1997). Formal Verification of a Leader Election Protocol in Process Algebra. *Theoretical Computer Science* **177**, 459–486.

M.C.A. DEVILLERS, W.O.D. GRIFFIOEN, O. MÜLLER (1997). Possibly infinite sequences in theorem provers: a comparative study. E.L. GUNTER, A. FELTY (eds.). *10th International Conference on*

Theorem Proving in Higher Order Logics, TPHOLs '97, LNCS **1275**, Murray Hill, NJ, USA, 89–105.

A. ENGELS, L.M.G. FEIJS, S. MAUW (1997). Test generation for intelligent networks using model checking. E. BRINKSMA (ed.). *Proceedings of TACAS'97*, LNCS **1217**, Springer, 384–398.

A. ENGELS, S. MAUW, M.A. RENIERS (1997). A hierarchy of communication models for Message Sequence Charts. T. MIZUNO, N. SHIRATORI, T. HIGASHINO, A. TOGASHI (eds.). *Proceedings of FORTE/PSTV'97*, Chapman and Hall, Osaka, Japan, 75–90.

J.F. GROOTE (1997). A Note on n Similar Parallel Processes. S. GNESI, D. LATELLA (eds.). *Second International ERCIM Workshop on Formal Methods for Industrial Critical Systems*, Cesena, Italy, 65–75.

J.R. KENNAWAY, J.W. KLOP, M.R. SLEEP, F.J. DE VRIES (1997). Infinitary lambda calculus. *Theoretical Computer Science* **175**(1) 93–125.

S.P. LUTTIK (1997). Description and formal specification of the Link Layer of P1394. I. LOVREK (ed.). *Proceedings of the 2nd International Workshop on Applied Formal Methods in System Design*, Zagreb, Croatia.

S.P. LUTTIK, E. VISSER (1997). Specification of Rewriting Strategies. A. SELLINK (ed.). *Proceedings of the 2nd International Conference on the Theory and Practice of Algebraic Specification (ASF+SDF97), Electronic Workshops in Computing*, Springer-Verlag.

H. VAN MAAREN, J.P. WARNERS (1997). Bounds and fast approximation algorithms for binary quadratic optimization problems with application to MAX 2SAT and MAX CUT. *Proc. 5th Twente Workshop on Graphs and Combinatorial Optimization*.

S. MAUW, M.A. RENIERS (1997). High-level Message Sequence Charts. A. CAVALLI, A. SARMA (eds.). *Proceedings of the Eighth SDL Forum*, SDL'97: Time for Testing – SDL, MSC and Trends, Evry, France, 291–306.

S. MAUW, M.A. RENIERS (1997). Operational semantics for MSC'96. A. CAVALLI, D. VINCENT (eds.). *Tutorials of the Eighth SDL Forum*, SDL'97: Time for Testing – SDL, MSC and Trends, Evry, France, 135–152.

J.R. MOONEN, J.M.T. ROMIJN, O. SIES, J.G. SPRINGINTVELD, L.M.G. FEIJS, R.L.C. KOYMANS (1997). A two-level approach to automated conformance testing of VHDL designs. *Testing of Communicating Systems* **10**, Chapman & Hall, 432–447.

J.P. WARNERS, T. TERLAY, C. ROOS, B. JANSEN (1997). Potential Reduction Algorithms for Structured Combinatorial Optimization Problems. *Operations Research Letters* **21**, 55–64.

J.P. WARNERS, T. TERLAY, C. ROOS, B. JANSEN (1997). A Potential Reduction Approach to the Frequency Assignment Problem. *Discrete Applied Mathematics* **78**(1–3), 215–282.

CWI Reports

SEN-R9706. S.P. LUTTIK. *Description and formal specification of the Link layer of P 1394.*

SEN-R9707. J.R. MOONEN, J.M.T. ROMIJN, O. SIES, J.G. SPRINGINTVELD, L.M.G. FEIJS, R.L.C. KOYMANS. *A two-level approach to automated conformance testing of VHDL designs.*

SEN-R9708. L. ACETO, J.F. GROOTE. *A complete equational axiomatization for MPA with string iteration.*

SEN-R9709. J.F. GROOTE. *The syntax, semantics of timed μCRL.*

SEN-R9710. J.P. WARNERS. *Nonconvex continuous models for combinatorial optimization problems with application to satisfiability and node packing problems.*

SEN-R9720. B. LISSER, J. VAN WAMEL. *Specification of components in a proposition solver.*

Other Publications

I. BETHKE, J.W. KLOP, R.C. DE VRIJER (1997). Looking back. *Dat is dus heel interessant. Liber Amicorum Paul Klint*, 42–53.

I. BETHKE, J.W. KLOP, R.C. DE VRIJER (1997). *Origin tracking in orthogonal rewriting*, Technical Report IR-441, Free University, Amsterdam.

D.J.B. BOSSCHER (1997). *Grammars Modulo Bisimulation*, Ph.D. thesis, University of Amsterdam.

J.M.H. COBBEN, A. ENGELS, S. MAUW, M.A. RENIERS (1997). *Formal Semantics of Message Sequence*, Report 97/19 Department of Computer Science, Eindhoven University of Technology.

M.C.A. DEVILLERS, W.O.D. GRIFFIOEN (1997). *A Formalization of Finite and Infinite Sequences in PVS*, Technical Report CSI-R9702, Computing Science Institute, University of Nijmegen.

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W. JANSSEN, S. MAUW, J.G. SPRINGINTVELD (1997). *Feasibility of Model Checking in the Context of Business Processes Using Amber and Spin*, Testbed/wp4/n011/v001, Telematica Research Centre.

M. HOLLENBERG, A. VISSER (1997). *Dynamic Negation: the One and Only*, Logic Group Preprint Series 179, Department of Philosophy, Utrecht University.

S.P. LUTTIK, E. VISSER (1997). *Specification of Rewriting Strategies*, Report P9710, Programming Research Group, University of Amsterdam.

H. VAN MAAREN, J.P. WARNERS (1997). *Bounds and Fast Approximation Algorithms for Binary Quadratic Optimization Problems with Application to MAX 2SAT and MAX CUT*, Technical Report 97–35, Faculty of Technical Mathematics and Informatics, Delft University of Technology.

J.G. SPRINGINTVELD, F.W. VAANDRAGER, P.R. D'ARGENIO (1997). *Testing Timed Automata*, Technical Report CSI-R9712, Computing Science Institute, University of Nijmegen.

J.P. WARNERS, H. VAN MAAREN (1997). *Satisfiability Problems with Balanced Polynomial Representation*, Technical Report 97–47, Faculty of Information Technology and Systems, Delft University of Technology.

Coordination Languages – SEN3

Staff

- Dr. J.J.M.M. Rutten, theme leader
- Dr. F. Arbab, researcher
- Prof. dr. J.W. de Bakker, cluster head and researcher
- Drs. C.L. Blom, programmer
- Dr. P. Bouvry, postdoc (till June 30)
- F.J. Burger, programmer
- Dr. A. Corradini, TMR fellow (till September 1)
- Drs. C.T.H. Everaars, programmer
- Dr. A. Fagot, postdoc (from November 1)
- Dr. E.B.G. Monfroy, postdoc (0.5 at PNA1)
- Drs. A. Scutellá, SION OIO

Scientific Report

Arbab and the Manifold group: Manifold was used in a number of applications in 1997. Notably, they include the single and multi-grid domain decomposition of the Euler solver algorithm developed in MAS2 (B. Koren and P. Hemker); the restructuring of the shallow water modelling and simulation application of the Delft Hydraulics Labs; and the distributed constraint management system project in PNA1 (E. Monfroy and Krzysztof Apt). A number

of language extensions were identified as necessary to enhance usability of Manifold. The implementation of these extensions was started in 1997.
The ESPRIT KIT proposal (INCO-DC EC program) to use the IWIM model and Manifold for modelling of Information Systems was granted and the work on this project is to start in 1998.
The work on the visual programming environment, *Visifold*, was disrupted by early departure of P. Bouvry in June 1997. Presently, Visifold is a good prototype for demonstrating the concepts of coordination programming in a visual environment. A new postdoc (A. Fagot) joined us in November to replace P. Bouvry and to work on the visual analysis and debugging of Manifold programs.
The work on the formal semantics of Manifold was started in 1997 and culminated in a number of scientifically interesting results, to be published in 1998.

Corradini continued the study of the theory of coalgebras and of coalgebraic specifications started during the first part of his one-year stay at CWI. He addressed the problem of formulating and proving a coalgebraic version of Birkhoff's completeness theorem of equational deduction. Restricting the focus to a subclass of polynomial functors (not allowing for coproducts), he has found a set of deduction rules that are proved to be sound and complete for equational deduction in coalgebraic specification. The result has been extended by allowing for the colouring of the elements of the carrier over a fixed set of colours, a generalization that corresponds (in the algebraic case) to passing from ground equations to equations with variables. The new set of rules is shown to be sound and complete also for equations on hidden sorts. These results have been discussed in depth with Jan Rutten, Bart Jacobs (Catholic University of Nijmegen) and Ulrich Hensel (University of Dresden).

Corradini continued some previous research with Fabio Gadducci (Technical University of Berlin) aimed at providing an abstract, categorical representation of rewriting formalisms based on terms or term graphs, using some kind of s-monoidal categories and the corresponding 2-categorical version. Such a framework has been applied to the presentation of Rational Term Rewriting and its correspondence with μ-Term Rewriting, and to the rewriting of possibly cyclic term graphs. Corradini also continued some work on the concurrent semantics of graph grammars in the double-pushout approach, and on the definition of a new kind of Event Structures (called 'Asymmetric') able to model P/T Petri Nets with contexts (in cooperation with Ugo Montanari (SRI, Stanford) and Paolo Baldan (Dipartimento di Informatica, Pisa)).

Rutten continued the work on coalgebras as a general framework for infinite data types, automata, transition systems, and dynamical systems. A theory of universal coalgebra, along the lines of universal algebra, has been described in a report that appeared early 1997. The theory has been extended to models for probabilistic transition systems and programming languages (in joint work with Erik de Vink, VUA). Together with Jaco de Bakker (CWI/VUA), Erik de Vink (VUA), and Jos Baeten (TUE), a SION-project (ProMACS) has been started on probabilistic methods for the analysis of continuous systems.
As an application of the theory of universal coalgebra, simple yet effective coinduction principles have been derived for various kinds of (classical) automata. A beginning has been made with a further extension of universal coalgebra, dealing with general ways of composing different systems, using natural transformations. A possible area of application will be a compositional semantics for coordination languages (such as MANIFOLD).
The work on generalized metric spaces has resulted in a report on an enriched-categorical account of the notion of limit, using weighted (co)limits. The theory has been used to relate closed balls and so-called formal balls, which play a role in computational models of metric spaces (as in the work of Lawson and Edalat).
Part of the research described above was carried out during a sabbatical stay at the University of Bologna, in the period 15 January–15 July. Together with various members of the group of Roberto Gorrieri, a variety of coordination languages and models has been studied, as well as the use of coalgebras as semantic models. A Ph.D. student from Bologna, G. Zavattaro, will come to CWI early 1998 as a follow-up of this work.

A. Scutellá started his activity at CWI on February 1997. The first six months have been devoted to acquire a basic background in the theory of transition systems. After that he has been involved in studying a formal semantics for the coordination language MANIFOLD (developed at CWI), as well as defining the lines for its future investigations which will focus on practical aspects of the Theory of Coordination. The main part of these activities has involved a group composed by Jaco de Bakker, Farhad Arbab, and Jan Rutten (from CWI), and Marcello Bonsangue from the Rijks Universiteit Leiden.

De Bakker also worked – in a collaboration with dr. E.P. de Vink and drs. J.J. den Hartog from the Vrije Universiteit Amsterdam – on the semantics of

action refinement. They succeeded in considerably simplifying earlier models for this construct; moreover, a full abstractness result exploiting the use of metric structures for these models was obtained.

Organization of Conferences, Workshops, Courses, etc.

- *ACG* – the *Amsterdam Coordination Group*. ACG is an – on average biweekly – seminar in which ongoing research on semantics, with special emphasis on coordination languages and models, is discussed by members and former members of SEN3, and invited visitors. External participants include dr. E. de Vink (VUA), prof. dr. J.N. Kok (RUL), dr. M. Bonsangue (RUL), dr. F.C. van Breugel (McGill, Montreal), dr. B. Jacobs (KUN), and drs. J.J. den Hartog (VUA)
- *Model Coupling Forum*, September 25. This forum is a platform held 3 or 4 times a year to discuss how numerical algorithms and software systems (models) for applications such as Computational Fluid Dynamics can be coupled together, to construct larger models and systems. The participants in this forum are from the industry, government, and research institutes (e.g., NLR, RIKZ, TNO, GMD, and CWI)

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

- *HICSS-30*, Maui, Hawaii, USA, January 7–10, F. Arbab (The Influence of Coordination on Program Structure)
- *Working visit University of Waterloo*, Waterloo, USA, (Prof. F. Mavaddat), January 16–17, F. Arbab (Lecture on Manifold)
- *University of Bologna* (Prof. dr. R. Gorrieri), Italy, Sabbatical stay, 15 January–15 July, J.J.M.M. Rutten. Various lectures on semantics and coalgebra, also at the universities of Milano (Nicoletta Sabadini, Felice Cardone, Bob Walters), Venezia (Annalisa Bossi), Udine (Furio Honsell and Marina Lenisa)
- *NVTI jaarvergadering*, Utrecht, February 28, J.W. de Bakker, J.J.M.M. Rutten
- *FEA '97*, North Carolina, USA, March 1–5, P. Bouvry (Distributed Evolutionary Optimization in Manifold)
- *Working visit TU Berlin*, Berlin, Germany (Prof. Ehrig), March 4–9, A. Corradini
- *Electors' Meeting Chair Computing Science*, Oxford University, Oxford, UK, March 13, J.W. de Bakker
- *MFPS '97*, Pittsburgh, USA, March 22–27, J.J.M.M. Rutten
- *Program Committee Meeting COORDINATION '97*, London, UK, April 4, J.W. de Bakker
- *Meeting EU European Science and Technology Assembly*, Brussels, Belgium, April 8–9, J.W. de Bakker
- *IPA course on Formal Methods*, Utrecht/Eindhoven, April 22–24, A. Scutellá
- *Proof Tool Day*, Nijmegen, April 25, A. Corradini
- *Model Coupling Forum*, May 3, F. Arbab (Manifold)
- *Working visits University of Pisa*, Pisa, Italy (Prof. Moggislo), May 26–30, June 9–11, July 4–14, A. Corradini
- *12th Workshop on Abstract Data Types*, Tarquinia Lido, Italy, June 3–7, A. Corradini
- *Meeting on 'Aspects of Modularity in Graph Transformations'*, Berlin, Germany, June 7–8, A. Corradini
- *Euro-POS '97*, Barcelona, Spain, June 9–11, P. Bouvry (Parallel Evolutionary Computation Mult. Agents GA).
- *Workshop of the ESPRIT Working Group APPLIGRAPH*, Bremen, Germany, June 26–27, A. Corradini
- *Working visits University of Sydney*, Sydney, Australia (Prof. B. Walters), July and November, A. Scutellá
- *Workshop on 'New trends in semantics'*, Bologna, July 4–5, J.J.M.M. Rutten (Transformations of coalgebras)
- *ICALP '97*, Bologna, Italy, July 4–11, J.J.M.M. Rutten.
- *IPA/BRICS/TUCS Summer School on Computational and Syntactic Methods*, Mierlo, August 11–22, A. Scutellá
- *COORDINATION '97*, Berlin, Germany, September 1–3, J.W. de Bakker, J.J.M.M. Rutten, A. Scutellá
- *ESPRIT Working Group COORDINA*, Berlin, Germany, September 4, J.W. de Bakker, J.J.M.M. Rutten
- *Eurographics Workshop on Programming Paradigms for Graphics*, Budapest, Hungary, September 8–9, F. Arbab
- *4th Int. Conference on Parallel Computer Technology (PaCT '97)*, Yaroslavl, Russia, September 8–12, F. Arbab (Parallel and Dist. Evolutionary Comp. with Manifold)
- *6th International Conference AMAST '97*, Sydney, Australia, December 13–17, A. Scutellá

Memberships of Committees and Other Professional Activities

F. Arbab:
- Editorial Board Member, *Computers & Graphics, An International Journal*
- Editorial Board Member, *Parallel Computing* journal
- Guest Co-editor, special issue of *Parallel Computing* on 'Coordination Languages and Systems,' to appear in Spring '98
- Program Committee, PARCO '97
- Co-chair, Eurographics Workshop on Programming Paradigms for Graphics '97
- Advisory Board Member, EuroPar '97
- Coordinator, ESPRIT INCO-DC EC project 962144

J.W. de Bakker:
- Professor of Computer Science, Vrije Universiteit Amsterdam
- Member Koninklijke Nederlandse Akademie van Wetenschappen
- Member Akademieraad voor de Wiskunde
- Member Academia Europaea
- Member AE committee on Mathematics and Informatics
- 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
- Board member IPA, Dutch Graduate School Institute for Programming and Algorithmics
- Site leader, EU Human Capital and Mobility Network/Fellowships to Institutes project EUROFOCS
- Member ESPRIT Working Group Coordina
- Project leader SION project COLA: Coordination Languages
- Program Committee member COORDINATION '97, Berlin, September 1997
- Program Committee member ESOP '98, Lisbon, April 1998
- Tutorial chair 18th International Conference on Distributed Computer Systems, Amsterdam, May 1998
- Elector Professorship of Computing Science, Oxford University
- Chairman SION Evaluation Committee
- Referee for LTR (EU), NSF (USA), EPSRC (UK)
- Member Steering Committee European Educational Forum (IPA, BRICS - Aarhus, TUCS - Turku)
- Member Selection Committee Blaise Pascal chair, RU Leiden.

A. Corradini:
- European Coordinator of the TMR Network GETGRATS, *General Theory of Graph Transformation Systems*
- Member of the Esprit Working Group *APPLIGRAPH*

J.J.M.M. Rutten:
- Member of the SION project COLA: Coordination Languages
- Member of the SION project *ProMACS: Probabilistic Methods for the Analysis of Continuous Systems*
- Site coordinator of ESPRIT Working Group Coordina
- Editor of Elseviers *Electronic Notes in Theoretical Computer Science*
- Board member of the *NVTI* (*Dutch Association of Theoretical Computer Science*)
- Editor of the *Nieuwsbrief van de NVTI*
- Member of the publicity board of *ICALP'97*
- Member of the programme committee of *MFPS'97* (*Mathematical Foundations of Programming Semantics*)
- Member of the programme committee of *Fossacs'98* (*Foundations of software science and computation structures*)
- Co-organizer of the first workshop on *Coalgebraic Methods in Computer Science* (CMCS'98)
- External referee Ph.D. thesis Marina Lenisa (Univ. of Udine)

Visitors

- A. Thijs, University Groningen, January 7
- F. Gadducci, Technical University Berlin, Berlin, Germany, January 28
- E. Todoran, Technical University of Cluj-Napoca, Romania, February 4
- S. Grenholm, Brooklyn, USA, February 16–28
- F. Seredynsky, Polish Academy of Sciences, Warsaw, Poland, April 9–12
- M. Tudruj, Polish Academy of Sciences, Warsaw, Poland, April 17
- R. Kelleners, Eindhoven University of Technology, April 29
- F. van Breugel, University of Pisa, Italy, May 13
- M. Menni, University of Buenos Aires, Argentina, May 14–20
- A. Fagot, LNC-IMAG, Grenoble, France, May 16

- G. Papadopoulos, University of Cyprus, Greece, November 10–14
- C. Cirstea, University of Oxford, UK, December 1–3
- C. Faggian, Imperial College, UK, December 9

Papers in Journals and Proceedings

F. ARBAB (1997). The Influence of Coordination on Program Structure. *Proceedings of the* 30^{th} *Hawaii International Conference on System Sciences*, Wailea, Maui, Hawaii, USA, IEEE.

A. CORRADINI, F. GADDUCCI (1997). A 2-Categorical Presentation of Term Graph Rewriting. *Proceedings CTCS'97*, LNCS **1290**, Springer Verlag.

A. CORRADINI, R. HECKEL, H. EHRIG, U. WOLTER (1997). Integrating the Specification Techniques of Graph Transformation and Temporal Logic. *Proceedings MFCS'97*, LNCS **1295**, Springer Verlag.

B. KOREN, P. W. HEMKER, C.T.H. EVERAARS (1997). Multiple semi-coarsened multigrid for 3D CFD. *Proceedings of the 13th AIAA Computational Fluid Dynamics Conference, Snowmass Village, CO, 1997*, Reston, USA, American Institute of Aeronautics and Astronautics, 892–902.

G.A. PAPADOPOULOS, F. ARBAB (1997). Control-Driven Coordination Programming in Shared Dataspace. V. MALYSHKIN (ed.). *Proceedings of PaCT-97*, LNCS **1277**, Yaroslavl, Russia, Springer-Verlag.

G.A. PAPADOPOULOS, F. ARBAB (1997). Coordination of Distributed and Parallel Activities in the IWIM model. *International Journal of High Speed Computing*, World Scientific.

G.A. PAPADOPOULOS, F. ARBAB (1997). Control-based Coordination of Human and Other Activities in Cooperative Information Systems. *Proceedings of the Second International Conference on Coordination Languages and Models*, LNCS **1282**, Berlin, Germany, Springer-Verlag, 422–425.

F. SEREDYNSKI, P. BOUVRY, F. ARBAB (1997). Distributed Evolutionary Optimization in MANIFOLD: the Rosenbrock's Function Case Study. *FEA'97 – First International Workshop on Frontiers in Evolutionary Algorithms (part of the third Joint Conference on Information Sciences)*, Duke University (USA).

F. SEREDYNSKI, P. BOUVRY, F. ARBAB (1997). Parallel Evolutionary Computation: Multi Agents Genetic Algorithms. E. LUQUE, A.R. HURSON, H. EL-REWINI (eds.). *International Conference on Parallel and Distributed Systems (Euro-PDS '97)*, Spain, Barcelona, 293–298.

F. SEREDYNSKI, P. BOUVRY, F. ARBAB (1997). Parallel and Distributed Evolutionary Computation with Manifold. V. MALYSHKIN (ed.). *Proceedings of PaCT-97*, LNCS **1277**, Yaroslavl, Russia, Springer-Verlag, 94–108.

E.P. DE VINK, J.J.M.M. RUTTEN (1997). Bisimulation for probabilistic transition systems: a coalgebraic approach (extended abstract). P. DEGANO ET AL (eds.). *Proceedings of ICALP'97*, LNCS **1256**, 460–470. This extended abstract also appeared as Technical Report IR-423, Vrije Universiteit, Amsterdam.

B.P.F. JACOBS, J.J.M.M. RUTTEN (1997). A Tutorial on (Co)Algebras and (Co)Induction. *Bulletin of EATCS* **62**, 222–259.

Books

Proceedings of the 6th Eurographics Workshop on Programming Paradigms in Graphics, F. ARBAB, P. SLUSALLEK (eds.). Eurographics, 1997.

CWI Reports

SEN-R9705. C.T.H. EVERAARS, B. KOREN. *Using coordination to parallelize sparse-grid methods for 3D CFD problems.*

SEN-R9723. A. CORRADINI. *A complete calculus of equational deduction in coalgebraic specification.*

Other Publications

J.W. DE BAKKER (1997). Paul and the Others : 1 + 155. *Dat is dus heel interessant– Liber Amicorum voor Paul Klint*, 25–32.

J.J.M.M. RUTTEN (1997). Regular expressions and coinduction. *Dat is dus heel interessant– Liber Amicorum voor Paul Klint*, 189–198.

Evolutionary Computation and Applied Algorithms – SEN4

Staff

- Dr. ir. J.A. La Poutré, theme leader (from September 1)
- Drs. C.H.M. van Kemenade, Ph.D. student
- Prof. dr. J.N. Kok, advisor
- Drs. R. van Stee, SION Ph.D. student (from September 1)
- Dr. P. Svestka, researcher (from October 1)
- Drs. M.C. van Wezel, Ph.D. student

Scientific Report

The pilot group was characterized by being in a building-up phase, where several new people joined the group during the course of the autumn, and where new research was developed or initiated.

J.A. La Poutré started at the theme group on September 1. He worked on genetic algorithms, on-line optimization and unsupervised image classification. Topics concern economic strategies and modelling, optimization problems in computer systems, and processing remote sensing data.

C.H.M. van Kemenade continued his research on Evolutionary Computation methods, Evolutionary Air Traffic Flow Management (ATFM), and unsupervised image classification. Work on ATFM was done in cooperation with J.N. Kok (Leiden University) and J.M. van den Akker (National Aerospace Laboratories NLR). The project on unsupervised image classification is a cooperation with R.J. Mokken (CCSOM, University of Amsterdam), P. LaPotin (CRREL, Hanover USA), and J.A. La Poutré (Leiden University/CWI). Transmission function models of evolutionary algorithm were developed and studied.

R. van Stee worked as OIO on the SION/NWO project *Dynamic Algorithms for On-line Optimization*. He has been working on an on-line scheduling problem, where a job has to be run on a network of workstations, whose availability is modeled with a Markov chain.

P. Svestka started on October 1. He did literature research on evolutionary algorithms, with respect to optimization and strategy development.

M.C. van Wezel worked on the project *Using Neural Networks for Building Learning Organisations*, in cooperation with Nijenrode University for the Directorate-General of Public Works and Water Management. A software package called 'neural vision' was developed, enabling multidimensional data to be projected and visualized by various neural networks, both linear and non-linear. He also devoted his time to the study of literature in order to establish a basis for his Ph.D. research (e.g. Bayesian Neural Networks).

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

- *Leiden Evolutionary Algorithm Day (LEAD2)*, Leiden, January 13, C.H.M. van Kemenade
- *Presentation WSO*, January 22, C.H.M. van Kemenade
- *International Conference on Genetic Algorithms*, Michigan, USA, July 19–23, C.H.M. van Kemenade (*Cross-competition between building blocks*)
- *Working visit CRREL*, Hanover, USA, July 28–29, C.H.M. van Kemenade (*Spatial Image Analysis and Bio Computing*)
- *Workshop on Genetic Algorithms*, Helsinki, Finland, August 18–22, C.H.M. van Kemenade (*Modelling Elitism*)
- *School on Natural Computation*, Turku, Finland, August 25–29, C.H.M. van Kemenade, J.A. La Poutré, M.C. van Wezel
- *IPA Herfstdagen*, Heijen, October 27–31, C.H.M. van Kemenade, J.A. La Poutré, P. Svestka
- *Sentient Machine Research research colloquium*, Amsterdam, October 30, M.C. van Wezel (*Various Topics in Neural Computing, Data Mining and Data Visualisation*)
- *CSN '97*, Utrecht, November 25, J.A. La Poutré

Papers in Journals and Proceedings

A.E. EIBEN, C.H.M. VAN KEMENADE (1997). Diagonal crossover in genetic algorithms for numerical optimization. *Journal on Control and Cybernetics*, vol. **26**(3), 447–466.

S. HARING, J.N. KOK, M.C. VAN WEZEL (1997). Finding Feature selection for Neural Networks through Functional Links found by Evolutionary Computation. X. LIU, P. COHEN, M. BERTHOLD (eds.). *Proceedings Advances in Intelligent Data Analysis*, LNCS **1280**, Springer-Verlag, London, UK, 199–210.

C.H.M. VAN KEMENADE (1997). The Mixing Evolutionary Algorithm - independent selection and allocation of trials. *Proceedings of the IEEE conference on Evolutionary Computation*, 13–18.

C.H.M. VAN KEMENADE (1997). Cross-competition between Building Blocks, propagating information to subsequent generations. *Proceedings of the Seventh International Conference on Genetic Algorithms*, 1–8.

C.H.M. VAN KEMENADE (1997). Modeling elitist genetic algorithms with a finite population. *Proceedings of the Third Nordic Workshop on Genetic Algorithms*, 1–10.

W.A. KOSTERS, J.A. LA POUTRÉ, M.C. VAN WEZEL (1997). Understanding Customer Choice Processes Using Neural Networks. *Proceedings of the First International Conference on the Practical Application of Knowledge Discovery and Data Mining (PADD '97)*, 167–178.

M.C. VAN WEZEL, J.N. KOK, W.A. KOSTERS (1997). Two Neural Network Methods for Multidimensional Scaling. *Proceedings of the European Symposium on Artificial Neural Networks (ESANN'97)*, 97–102.

CWI Reports

SEN-R9725. C.H.M. VAN KEMENADE. *Modeling of genetic algorithms with finite population.*

SEN-R9726. C.H.M. VAN KEMENADE. *The mixing evolutionary algorithm - independent selection and allocation of trials -.*

Other Publications

C.H.M. VAN KEMENADE, J. KOK, M. VAN DEN AKKER (1997). Evolutionary 3D-Air Traffic Flow Management. *Handbook on Evolutionary Computation part G3.9*, Oxford University Press Inc., New York.

MODELLING, ANALYSIS AND SIMULATION

General

The research in MAS concentrates on the qualitative, numerical and computational aspects of mathematical models arising in a wide range of applications within the Dutch society. Particular attention is given to models describing continuum processes. As examples we mention free fluid and porous media flow, chemical reactions in the atmosphere and circuit analysis. The applications are combined into two extensive programmes or themes, each containing a number of characteristic projects. They are accounted for in detail in the theme descriptions of MAS1 and MAS2. New developments include the projects MAS2.1 (Computational fluid dynamics, a collaboration with MARIN) and MAS2.7 (Mathematics of Finance). Preliminary contacts have been made with TNO-TPD and across the border with GMD in Germany. It is expected that new projects will emerge from these contacts.

In the midst of much applied work, MAS continues to contribute significantly to the scientific development in the areas of qualitative, numerical and computational methods for partial differential equations. The number of papers appeared in international journals is certainly satisfactory, and with five PhD theses MAS contributes substantially to the scientific output of the CWI.

Separately from the themes, the Dynamical Systems Laboratory (DSL) operated as an independent unit. During the past years DSL has played a leading role in the software development for bifurcation of equilibria of systems of ordinary differential equations. An extensive description of their activities is given in the DSL contribution. This year was the last year of DSL, which officially ended when Dr. Yu.A. Kuznetsov left the CWI (November 1st, 1997).

MAS is very pleased to have Professor Piet van der Houwen as a CWI Fellow in its ranks. His high level scientific input, interaction with young researchers and involvement with several project is very much appreciated.

Staff 1997

- Dynamical Systems Laboratory – DSL
  - Yu.A. Kuznetsov
  - V.V. Levitin
  - J.A. Sanders
- Environmental Modelling and Porous Media Research – MAS1
  - J.G. Verwer
  - C.J. van Duijn
  - J. Hulshof
  - P.J. van der Houwen
  - J.G. Blom
  - C. Cuesta
  - M.I.J. van Dijke
  - G. Galiano
  - W. Hundsdorfer
  - J. Kok
  - D. Lanser
  - B. Lastdrager
  - M.A.A. van Leeuwen
  - W.M. Lioen
  - M. van Loon
  - J. Molenaar
  - R.J. Schotting
  - B.P. Sommeijer
  - E.J. Spee
  - J. de Vries
  - P.M. de Zeeuw
- Industrial Processes – MAS2
  - E.H. van Brummelen
  - S. Cavallar
  - M.K. Çamlıbel
  - M. Genseberger
  - T. Hantke
  - P.W. Hemker
  - J. Hoogland
  - P.J. van der Houwen
  - K. Karamazen
  - M. Kirkilionis
  - A. de Koeijer
  - B. Koren
  - D. Lanser
  - B. Lastdrager
  - W.M. Lioen
  - P.L. Montgomery
  - M. Nool
  - J. Noordmans
  - O. Penninga
  - A. van der Ploeg
  - H.J.J. te Riele
  - A.J. van der Schaft
  - J.M. Schumacher
  - B.P. Sommeijer
  - W.J.H. Stortelder
  - J.B. de Swart
  - N.M. Temme
  - W.A. van der Veen
  - D.T. Winter
  - P. Wesseling
- Secretary: N. Mitrovic

Dynamical Systems Laboratory – DSL

Staff

- J.A. Sanders
- Yu.A. Kuznetsov
- V.V. Levitin

CONTENT Development

During 1997, two versions of CONTENT, 1.3 and 1.4, were released on ftp.cwi.nl in directory pub/CONTENT.

Release 1.4 – December, 1997
New features:
- new class of dynamical systems is supported: differential- algebraic equations (DAEs) Mx'=f(x,p) with possibly singular matrix M;
- numerical integration of stiff ODEs and DAEs using RADAU5 code;
- three-parameter continuation of all codim 2 bifurcations of ODEs (cusp, Bogdanov-Takens, generalized Hopf, zero-Hopf, and double Hopf);
- two-parameter continuation of Hopf bifurcation using the bordered squared Jacobian matrix;
- symbolical calculation of derivatives of the 4th order using the *Maple* system.

Release 1.3 – August, 1997
New features:
- one-parameter continuation of limit cycles in ODEs;
- detection and branch switching at codim 1 bifurcations of limit cycles;
- one-parameter continuation of fixed points of iterated maps;
- detection and normal form analysis of codim 1 bifurcations of iterated maps;
- 3D graphic windows;
- Staircase window for scalar iterated maps.

At the moment, CONTENT completely supports one-parameter analysis of equilibria and cycles in ODEs and iterated maps. To complete the support of two-parameter analysis of ODEs, one has to implement the continuation of codim 1 bifurcations of cycles (i.e., fold, period- doubling, and Neimark-Sacker bifurcations), as well as the homoclinic bifurcations of saddle and saddle-node equilibria, and branch switching between them. CONTENT provides the environment to implement all of these continuations. Also, the computation of the remaining normal form coefficients at codim 2 bifurcations of equilibria has to be implemented in CONTENT (see below).

Research and algorithm development

Yu.A. Kuznetsov derived explicit normal form coefficients for the reduced to the central manifold equations for all codim 2 equilibrium bifurcation of ODEs. A CWI Report is published.
Yu.A. Kuznetsov (together with W. Govaerts and B. Sijnave, Gent University) developed new algorithms to continue codim 1 and 2 bifurcations of equilibria in 2 and 3 parameters, respectively. The algorithms were implemented in CONTENT.
Yu.A. Kuznetsov (together with A. Champneys (Bristol) and B. Sandstede (Berlin)) implemented the homoclinic continuation into AUTO97, the latest version of the continuation/bifurcation software by E. Doedel (Concordia University, Montreal). Now it is the standard part of AUTO.
The text of the second edition of the book by Yu.A. Kuznetsov *Elements of Applied Bifurcation Theory* has been sent to the Production Department of Springer-Verlag in September 1997 and will be published in 1998.

Visitors

- E. Doedel (Concordia University, Montreal, Canada) June 15–28.
  The visit was devoted to discussions of new methods to continue codim 1 bifurcations of limit cycles. In particular, a new method to continue the period-doubling bifurcation was proposed that combines orthogonal collocation technique with matrix bordering.
- O. De Feo (Swiss Federal Institute of Technology, Lausanne, Switzerland) September 1–30.
  During the visit, RADAU5 method for the numerical integration of ODEs and DAEs was translated from FORTRAN to C and implemented into CONTENT. A paper on homoclinic bifurcations in a 3D food chain model was practically finished.
- W. Govaerts and B. Sijnave (University of Gent, Belgium) June 19–22.
  Bordering methods to continue codim 1 and 2 bifurcation of equilibria were discussed. A prototype method to continue the Bogdanov-Takens bifurcation was implemented during the visit. The continuation of all other codim 2 bifurcations of equilibria in three parameters was implemented later in 1997.
- A. Shilnikov (Institute of Applied Mathematics and Cybernetics, Nizhnii Novgorod, Russia) May 30.
  A lecture was given at CWI on 'A blue-sky catastrophe model', demonstrating a new way of a de-

struction of a limit cycle.
- Yu.A. Kuznetsov gave invited lectures on CONTENT at the International Workshop 'Numerical analysis of Dynamical Systems', IMA, Minneapolis, USA, September 15–19, and at the Workshop 'Hybrid-methods for Bifurcation and Dynamics of Partial Differential Equations', University of Marburg, June 8–11.

CWI Reports

MAS-R9730. YU.A. KUZNETSOV. *Explicit normal form coefficients for all codim 2 bifurcations of equilibria in ODEs.*

Other Publications

E.J. DOEDEL, A.R. CHAMPNEYS, T.F. FAIRGRIEVE, YU.A. KUZNETSOV, B. SANDSTEDE, X.-J. WANG (1997). *AUTO97: Continuation and Bifurcation Software for Ordinary Differential Equations (with HomCont).* User's Guide, Concordia University, Montreal, Canada.

W. GOVAERTS, YU.A. KUZNETSOV, B. SIJNAVE (1997). *Implementation of Hopf and double Hopf Continuation Using Bordering Methods*, Department of Applied Mathematics and Computer Science, University of Ghent, Belgium.

W. GOVAERTS, YU.A. KUZNETSOV, B. SIJNAVE (1997). *Computation and Continuation of Codimension 2 Bifurcations in CONTENT*, Department of Applied Mathematics and Computer Science, University of Ghent, Belgium.

YU.A. KUZNETSOV (1997). Centre manifold; Codimension-two bifurcations; Equivalence of dynamical systems; Homoclinic bifurcations; Hopf bifurcation; Saddle-node bifurcation. M. HAZEWINKEL (ed.). *Encyclopaedia of Mathematics. Supplement Volume I*, Kluwer Academic Publishers, The Netherlands, 179–181, 190–101, 240, 293–294, 296–297, 444–445.

Environmental Modelling and Porous Media Research – MAS1

Staff

- Dr. J.G. Verwer, researcher, theme leader
- Prof. dr. ir. C.J. van Duijn, researcher, cluster leader
- Dr. J. Hulshof, advisor
- Prof. dr. P.J. van der Houwen, researcher, CWI fellow
- Drs. J.G. Blom, researcher
- Mrs. C. Cuesta, Ph.D. student
- Drs. M.I.J. van Dijke, Ph.D. student
- Dr. G. Galiano, postdoc
- Dr. W. Hundsdorfer, researcher
- Drs. J. Kok, researcher
- Ir. D. Lanser, Ph.D. student
- Drs. B. Lastdrager, Ph.D. student
- Dr. M.A.A. van Leeuwen, postdoc
- Drs. W.M. Lioen, programmer
- Dr. M. van Loon, postdoc
- Dr. J. Molenaar, postdoc
- Ir. R.J. Schotting, researcher
- Dr. B.P. Sommeijer, researcher
- Drs. E.J. Spee, Ph.D. student
- Dr. J. de Vries, researcher
- Drs. P.M. de Zeeuw, programmer, till February 1

Scientific Report

The general purpose of this research theme is to develop, analyze and implement mathematical and numerical models for application to complex problems arising in environmental modelling and porous media research. MAS1 is particular concerned with ordinary and partial differential equations, describing fluid flow, transport of pollutants and chemical and bio-chemical processes. These differential equations lie at the heart of simulation models used in atmospheric air quality modelling, in surface water and groundwater water quality modelling, and in porous media research directed for example at enhanced oil recovery. The research subthemes cover a wide range of scientific activities, ranging from fundamental mathematical and numerical analysis of differential equations and development of new computational techniques for use on vector/parallel and massively parallel computers and heterogeneous networks (HPCN), to implementation of fully integrated models and application to real life problems. Extensive co-operations and contacts are maintained with researchers from the academic world and from the environmental and porous media application fields. External financing comes from a variety of sources, such as industry, special programs from the Netherlands Organization for Scientific Research, research programs from the European Union and the national HPCN program funded through the Ministry of Economic Affairs. In 1997 research was organized in four subthemes:

Numerical Algorithms for Air Quality Modelling – MAS1.1

The research concerns the numerical modelling of the long range transport and chemical exchange of atmospheric air pollutants. Within the Netherlands

co-operation has existed with KEMA, NLR, RIVM, TUD, TNO and UU/IMAU. At the international level, two joint papers with CGRER (Center for Global and Regional Environmental Research, University of Iowa), have been published in Atmospheric Environment (See Sandu et al.). The CWI group is also active within the European network GLOREAM and among others involved in the organization of an International Conference on Air Pollution in Paris in 1998. January 23, 1998, Edwin Spee will defend his Ph.D. Thesis Numerical Methods in Global Transport Models at the University of Amsterdam. Two new Ph.D. students have recently joined the group, viz. Debby Lanser and Boris Lastdrager. In 1997 MAS1 worked on the following projects:

RIFTOZ – The technique of data-assimilation has been examined for improving results of model simulations by usage of actual measurements. A special implementation of an extended Kalman filter has been shown promising, see Report MAS-R9702 for details. The project forms part of an EU project in which CWI has been active through a subcontract with TUD. At CWI the project has now been terminated with the departure of Dr. M. van Loon to TNO. The Kalman filter will be further tested by TNO for use in their dispersion model LOTOS.

LOTOS – Here the objective is to develop a regional, three-dimensional, long term ozone simulation model. This LOTOS model should replace at due time an existing regional forecasting model in use at TNO. The model is developed in co-operation with TNO researchers. At TNO the focus lies on physical, meteorological and chemical aspects. The CWI research focuses on the design of the mathematical model for a so-called hybrid (terrain following and pressure based) coordinate system and, in particular, of tailored numerical algorithms and implementations on super and parallel computers. The project is part of the TASC project 'HPCN for Environmental Applications' which is funded by the Dutch HPCN program. At the end of 1997 the project was halfway. A first running operational prototype implemented at CWI has recently been transferred to TNO. Research details are found in the reports MAS-N9701, R9717.

NCF – This one-year project is linked with the LOTOS project and concerns aspects of massive parallelism, in particular for T3E implementations. Special attention has been given to the question to which extent massive (meteo) I/O can degrade the parallel performance of models used in atmospheric simulations. Results will be reported early 1998. Support is provided by the NCF/Cray University Grant program. The project lasts until April next year. Early 1997 the Report MAS-R9702 was finished. This publication concerns research in a similar NCF project terminated in February, 1997.

CIRK – This Ph.D. project has been terminated at the end of 1997 with the departure of Drs. Edwin Spee. He will defend his Thesis at the University of Amsterdam on January 23, 1998. The project is similar to the LOTOS project, but here the particular objective was to develop numerical algorithms for use in 3D models for the whole of the global troposphere/stratosphere. In this last year we have worked on various aspects of a Rosenbrock method (see Report MAS-R9717), including stiff chemistry integration and a factorization approach within the Rosenbrock framework. The factorization idea was investigated to provide an alternative for time or operator splitting. A second main activity has been the validation of various advection schemes in a real life radon experiment, using analyzed wind fields from the ECMWF (see Report MAS-R9710). Support for this project was obtained from the RIVM and very fruitful scientific co-operation has existed with IMAU/UU. This co-operation will continue in a following project, planned for the next three years. The new project is centered around the existing model TM3. With support from SWON two postdocs will be hired for algorithmic and parallel software research.

GOA – This activity concerns a new Ph.D. project on the 'Analysis and Validation of Operator Splitting in Air Quality Modeling'. This project has been granted by GOA, the Netherlands Geosciences Foundation. It started September 1, 1997 with the employment of Ir. Debby Lanser. A first article on the analysis of Strang-splitting for PDEs of the advection-diffusion-reaction type is already in preparation.

SWON – A second new project Ph.D. project started December 1, 1997 with the employment of Drs. Boris Lastdrager. This project has been granted by SWON and concerns 'Sparse Grid Methods for Time-Dependent PDEs'. Atmospheric transport-chemistry problems provide a highly useful application for sparse-grid research. The project is a joint activity between MAS1 and MAS2 (Dr. ir. B. Koren).

Numerical Algorithms for Surface Water Quality Modelling – MAS1.2

The research concentrates on the design of parallel numerical methods for the simulation of water pollution (calamitous releases), the marine eco-system,

dispersion of river water, sediment transport, etc. Our activities in 1997 included:

HPCN – In 1996 we started the development of a special purpose 3D transport model based on finite difference space-discretization and unconditionally stable, implicit time-discretization. In 1997 we analyzed an iterative approach for solving the implicit relations. This iteration process is based on approximate factorization such that only one-dimensionally implicit, linear systems occur in the algorithm. In co-operation with C. Eichler-Liebenow from the University of Halle, the convergence region of the iteration method and its effect on the overall stability of the integration method has been analyzed, see Report MAS-R9718. Furthermore, we started the development of tools for domain decomposition with domains of varying grid resolutions. Part of the research was carried out within the research consortium TASC, with support from the Dutch HPCN programme.

SWEM –The velocity field needed by transport models either is read from input files or is computed simultaneously with the computation of the pollutant concentrations by means of a hydrodynamical model. In view of the complicated data structures involved, we decided to focus on the second approach, because the hydrodynamical model can be designed such that it uses the same data structures as the transport model. Such an approach is justified, because the underlying partial differential equations are to a large extent identical. By choosing the same type of spatial and temporal discretizations, the same decomposition in domains with the same resolutions, and the same stepsizes in both algorithms, we achieve that the data structures are exactly the same. Since the transport solver is designed and tuned with parallel computer systems in mind, the velocity field solver will also be tuned to parallel computer systems. Moreover, each velocity-field-solver step can be performed in parallel with the corresponding transport-solver step. In 1997 a first analysis of the underlying numerical model has been performed.

Partial Differential Equations in Porous Media Research – MAS1.3

This subtheme coordinates a number of research activities in analysis of nonlinear partial differential equations and in mathematical modelling of flow and transport through porous media. The character of the research ranges from very applied to theoretical. An example of an applied activity is the NAM-project, where software was developed to study the mixing of gases in underground reservoirs. An example of a theoretical activity is the collaboration with H.W. Alt (Universität Bonn), which involves a detailed study of a free boundary problem with a cusp. This project participates in the interaction platform 'Nonlinear Transport Phenomena in Porous Media', which brings together researchers from TUD, RUL, LUW, RIVM and CWI, and which is supported by the NWO Priority Programme 'Nonlinear Systems'. There are also numerous international contacts. The scientific output in 1997 includes two Ph.D. theses: *Problems in Degenerate Diffusion* by Mark Peletier and *Multi-Phase Flow Modeling of Soil Contamination and Soil Remediation* by Rink van Dijke.

PDE RESEARCH – Nonlinear PDEs arising in models for porous media flow form the backbone of this project. Particular attention was given to systems consisting of a convection-diffusion equation coupled with an ordinary differential equation. The general case, in which the ODE is in the time variable, is treated in the thesis of M.A. Peletier. A particular case, where the ODE is in a space coordinate, appears in a model for salt uptake by mangroves, see Report MAS-R9728. This leads to non-local convection, which is shown to imply non-uniqueness. A second activity involves the collaboration Alt - Van Duijn. In a series of papers they study the behaviour of the interface between fresh and salt groundwater in the presence of wells. The interface appears as a free boundary in an elliptic problem. Depending on the pumping rate of the wells, a singularity develops in the free boundary in the form of a cusp. A detailed local analysis of the free boundary near such a cusp is presented in Report MAS-R9703.

FTPM – This project deals with density driven flow in porous media. In 1997 research concentrated on brine transport problems that are related to high-level radioactive waste disposal in salt domes. High salt concentrations give rise to nonlinear transport phenomena such as enhanced flow due to volume (compressibility) effects and the reduction of hydrodynamical dispersion due to gravity forces. Mainly (semi) analytical techniques (similarity and Von Mises transformations) were used to study the volume effects, see Report MAS-R9724. Report AM-R9616 (Brine transport in porous media: Self-similar solutions) has been accepted for publication in Advances in Water Resources. Using experimental data of Dr. H. Moser (Technische Universität Berlin) we also verified a nonlinear dispersion theory proposed by Dr. S.M. Hassanizadeh (Delft University of Technology), which includes the effect of dispersion reduction due to local high salt concentrations. The nonlinear theory is in excellent agreement with the experimental

results, see Report MAS-R9734. We further considered the interface between fresh and salt groundwater in heterogeneous media. This subject is related to salt water intrusion problems in coastal aquifers. The interface approximation can be justified when the width of the mixing zone between the fluids is small compared to the vertical extension of the aquifer. We studied the resulting set of interface equations numerically, using a moving mesh Finite Element Method. Moreover, several simplified Dupuit problems were studied and the results were compared with FEM solutions, see Report MAS-R9735.

NAM – This project deals with the mathematical modelling of gas injection. The dispersion is studied for gas injection into a reservoir. The aim is to understand and quantify the relevant physical processes that lead to mixing of injected gas with residual gas in old reservoirs. The project is sponsored by the NAM (Nederlandse Aardolie Maatschappij). In cooperation with the Faculty of Mining and Petroleum Engineering of the Delft University of Technology a numerical model is being developed at CWI to study the mixing of the gases in detail.

NOBIS – Within this project we study soil remediation techniques. Organic contaminants may be removed from the soil either by pumping methods or by injecting air, which enhances biodegradation and volatilization. The corresponding flow of groundwater, organic contaminant and air is described using multi-phase flow models. Air injection into groundwater (air sparging) in a horizontally layered medium has been studied in Report MAS-R9729. Accurate numerical simulations of the full transient two-phase flow equations were carried out and an almost explicit solution for the steady state air flow just below a less permeable soil layer was derived. The latter solution showed almost perfect agreement with the numerical results when heterogeneity of the layers was increased. To model pumping of a lens of light organic liquid from an aquifer, multi-phase seepage face conditions were applied at the well boundary (Report MAS-R9725). For two different geometries of the lens similarity solutions provided good approximations of the removal rate and the location of the remaining contaminant as a function of time. The above results and other work on behaviour of a lens of organic contaminant and on air sparging have been gathered in Rink van Dijke's Ph.D. thesis: 'Multi-phase flow modeling of soil contamination and soil remediation', which was defended at Wageningen Agricultural University on December 5, 1997.
NWO-NLS – This is the Ph.D. project 'Mathematical Analysis of Dynamic Capillary Pressure Relations in Porous Media Flow'. It started in November 1997, with the employment of C.M. Cuesta. It is supported by the NWO Priority Programme 'Nonlinear Systems'. The aim is to study PDEs with higher order mixed derivatives. Such equations arise in models for unsaturated groundwater flow, taking into account dynamic capillary pressure.

Exploratory research: Analysis of PDEs and their Discretization – MAS1.4

In 1997 two different subjects have been studied. Report MAS-R9721 contains the results of an investigation to the stability of approximate factorization for θ-methods. Approximate factorization seems for certain multi-space dimensional PDEs a viable alternative to time-splitting as a splitting error is avoided. The investigation, however, has revealed limitations of the approximate factorization technique with regard to numerical stability. The second subject concerns RKC (Runge-Kutta-Chebyshev), an explicit time integrator specifically suitable for multi-space dimensional parabolic PDEs. In RKC the stability limitation inherent in explicit methods is greatly reduced by the use of a three-step Chebyshev recursion. The current study has specifically dealt with the development of a production-grade code for non-experencied users. The work has been carried out in co-operation with Prof. L. Shampine, University of Dallas. Details are given in Report MAS-R9715. This report has been accepted for publication in the Journal of Computational and Applied Mathematics.

Organization of Conferences, Workshops, Courses, etc.

- *Mini-symposium on Numerical Analysis*, Wageningen, April 3–4. Organizer: P.M. de Zeeuw. Speakers: W. Hundsdorfer (*Stability of the Douglas Splitting Method*), E.J. Spee (*Advectieschema's op een Bol voor Atmosferische Ttransport Modellen*).
- *Meeting of the Steering Committee of the ESF-Programme 'Free Boundary Problems*, Theory and Applications', CWI, April 26. Organizer: C.J. van Duijn.
- *TASC Symposium 7*, CWI, June 20. Organizers: J.G. Verwer and J. Kok. Speakers: P.J.H. Builtjes (MEP-TNO) (*Atmospheric Transport-chemistry Modelling and HPCN*), J.G. Blom (*LOTOS, a 3D Atmospheric Air Pollution Model*), J. Kok (*Porting Atmospheric Transport-Chemistry Software to the NEC SX–4*), K. Dekker (TUD) (*Modification of Flow Fields to Recover the Property of Divergence Freedom*), G.S. Stelling (WL) (*Nonhydrostatic*

Pressure in Free Surface Flows) and B.P. Sommeijer (*Recent Progress in an Implicit Shallow Water Transport Solver*).

- *Colloquium 'Flow and Transport in Porous Media'*, CWI, September 10. Speakers: G. Dagan (Tel-Aviv) and S.E.A.T.M. van der Zee (LUW). Organizers: R.J. Schotting and C.J. van Duijn.
- *TASC Symposium 8 ('HPCN-Platformdag')*, CWI, September 10. Organizers: J.G. Verwer and J. Kok. Speakers: J.G. Verwer (*Het TASC Project HPCN voor Milieutoepassingen*), M. van Loon (MEP-TNO) (*Langetermijnsimulatie van Ozon*), J.G. Blom (*Rekenen aan Ozon*), B.P. Sommeijer (*Simulatie van Transport in Ondiep Water*), E.A.H. Vollebregt (TUD) (*Parallelle Software voor Stromings- en Transportmodellen*) and G.S. Stelling (WL) (*Simulatie van Afvalwaterlozingen*).
- *Mini-symposium on Partial Differential Equations at SciCADE97 – International Conference on Scientific Computation and Differential Equations*, Grado, September 15–19. Organizer: J.G. Verwer. Speakers: K. Dekker (TUD) (*Parallel GMRES and Domain Decomposition*), W. Hundsdorfer (*Trapezoidal and Midpoint Splittings for Initial Boundary-value Problems*), B.P. Sommeijer (*RKC, an Explicit Solver for Parabolic PDEs*) and J.M. Hyman (Los Alamos) (*Minimizing Numerical Errors Introduced by Operator Splitting Methods*)
- *Colloquium 'Flow and Transport in Porous Media'*, CWI, September 24. Speakers: A. de Wit (Brussels) and R.J. Schotting (CWI). Organizers: R.J. Schotting and C.J. van Duijn.
- *Workshop 'Interfaces and Parabolic Regularisation'*, Lorentz Center (RUL), November 5–7. International workshop with 25 speakers and 40 participants. Organizers: J. Hulshof and C.J. van Duijn.
- *MAS Colloquium*, CWI, December 9. Organizer: C.J. van Duijn. Speakers: C.N. Dawson (UT at Austin) (*Dynamic Adaptive Methods for Chemically Reactive Transport in Porous Media*), P. Wesseling (TUD) (*Numerical Solution of Hyperbolic Systems with Nonconvex Equation of State*) and W.A. Mulder (Shell Rijswijk) (*Finite Differences and Finite Elements for Seismic Simulation*).
- TASC Symposium 9, CWI, December 11. Organizers: J.G. Verwer and J. Kok. Speakers: A. Petersen (IMAU) (*More Efficient Advection Schemes for the Global Atmospheric Tracer Model*), H. Elbern (EURAD) (*A Parallel Implementation of a 4D-variational Chemistry Data Similation Scheme*), E.J. Spee (*Rosenbrock Methods for Atmospheric Dispersion Problems*) and M. Krol (IMAU) (*The TM3 Model: Numerical Aspects of Atmospheric Chemistry Aplications*).

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

- 2nd Annual Meeting MMARIE Concerted Action, Barcelona, January 15–17: B.P. Sommeijer (*Domain Decomposition for an Implicit Shallow-water Transport Solver*).
- Meeting of the DFG Panel for the Sonderforsbereich 1578, München, January 16–17: Participation by C.J. van Duijn.
- Meeting of the Scientific Council of the Weierstrass Institut für Angewandte Analysis und Stochastik, Berlin, January 24: C.J. Van Duijn participates and is elected vice-chairman of this council.
- Guest Lectures at the University of Amsterdam, within the framework of the course '*Parallel Scientific Computing and Simulation*', February 21 and 26: B.P. Sommeijer (Parallel ODE solvers).
- Harburger Sommerschulen, TU Hamburg-Harburg, February 24–28: J.G. Verwer invited speaker (three lectures on the Method of Lines).
- Universidad Complutense de Madrid, Madrid, March 19–23: C.J. van Duijn visits J.I. Diaz.
- 32e Nederlands Mathematisch Congres, Wageningen, April 3–4: W. Hundsdorfer (*Stability of the Douglas Splitting Method*), E.J. Spee (*Advectieschema's op een Bol voor Atmosferische Transport-modellen*).
- Istituto per le Applicazioni del Calcolo 'Mauro Picone', Rome, April 7–11: C.J. van Duijn visits M. Bertsch.
- 1st ERCIM Environmental Modelling Group Workshop on Air Pollution Modelling, GMD FIRST, Berlin, April 7–8: J.G. Blom (*An Evaluation of the Cray T3D Programming Paradigms in Atmospheric Chemistry/transport Problems*), J.G. Verwer (*A Numerical Study for Atmospheric Chemistry/transport Problems*). Both invited.
- Measurements and Modelling in Environmental Pollution, Madrid, April 22–24: M. van Loon (*Data Assimilation for Atmospheric Chemistry Models*).
- 22nd General Assembly of the European Geophysical Society, Vienna, April 21–25: B.P. Sommeijer (*A Fully Implicit 3D Transport-chemistry Solver Combined with Domain Decomposition*).
- NWO Symposium Massaal Parallel Rekenen, Veldhoven, May 22: J.G. Verwer invited speaker (*High Performance Computing and Environmental Pollutions*).

- Workshop Transport de contaminants multiespèces en milieux poreux, Rocquencourt, June 2–5: W. Hundsdorfer, C.J. van Duijn invited speaker (*Three Lectures on Reactive Solute Transport in Porous Media*).
- ITW symposium 'Milieu en duurzame technologie', NITG-TNO Delft, June 12: B.P. Sommeijer invited speaker (*Numerieke Modellen voor Transportproblemen op Supercomputers*).
- SIAM Conference on Mathematical and Computational Issues in the Geosciences, Albuquerque, June 16–19: C.J. van Duijn invited speaker (*Uniqueness in a Hyperbolic Model for Oil Recovery by Steamdrive*).
- 17th Biennial Conference on Numerical Analysis, Dundee, June 24–27: W. Hundsdorfer (*Stability of the Douglas Splitting Method*).
- 15th IMACS World Congress, Berlin, August 24–29: J.G. Verwer inivited speaker (*Numerical Algorithms in Air Pollution Research*).
- 8th NUMDIFF Conference '*Numerical treatment of differential equations*', Alexisbad, September 1–5: B.P. Sommeijer invited speaker (*Domain Decomposition for an Implicit Transport Solver*).
- GLOREAM Workshop, Aachen, September 10–12: J.G. Blom, J.G. Verwer (*A Second Order Rosenbrock Method for Atmospheric Chemical Kinetics Problems*).
- SciCADE97 – International Conference on Scientific Computation and Differential Equations, Grado, September 15–19: J.G. Verwer (Organizer of mini-symposium on Partial Differential Equations), W. Hundsdorfer (*Trapezoidal and Midpoint Splittings for Initial Boundary-value Problems*), B.P. Sommeijer (*RKC, an Explicit Solver for Parabolic PDEs*).
- Air pollution 97, Bologna, September 16–18: E.J. Spee (*Development of Advection Schemes for Global 3D Chemistry-transport Models*).
- Institut für Angewandte Mathematik der Universität Bonn, March 5–8, May 21–24, August 21–23, October 15–18: C.J. van Duijn visits H.W. Alt.
- Cambridge University (Institute for Theoretical Physics and Applied Mathematics), Cambridge, October 4–7: C.J. van Duijn visits J. Lister.
- Universidad de Chile, Santiago de Chile, November 14–30: C.J. van Duijn visits R. Manasevich and gives four lectures on PDE subjects related to flow through porous media.
- ITW-Symposium Theorie en Praktijk van Parallel Rekenen, Utrecht, December 12: J.G. Blom invited speaker (*LOTOS-HPCN: Rekenen aan Ozon*).
- Diderot Mathematical Forum from the European Mathematical Society, Video Conference Amsterdam/Madrid/Venice, December 19–20: B.P. Sommeijer invited speaker (*Numerical Modelling of Three-dimensional Bio-chemical Transport in Shallow Seas*), C.J. van Duijn invited speaker (*Saltwater Intrusion in Coastal Regions*).

Memberships of Committees and Other Professional Activities

J.G. Verwer:

- Member Advisory Committee of CMUC (The Centre for Mathematics of the University of Coimbra, Portugal)
- Member Organizing Committee APMS'98, Conference on Air Pollution Modelling and Simulation.
- Member Technical Advisory Board of EnviroComp (Internet based International Institute of Environmental Sciences and Environmental Computing)
- Senior Editor *Applied Numerical Mathematics*
- Editor Special Issue on Time Integration for *Applied Numerical Mathematics*, Proceedings HCM Workshop, CWI, Oct. 30 - Nov. 1, 1996. Jointly with J.M. Sanz-Serna, Univ. Valladolid
- Coordinator Research Consortium TASC
- Coordinator of the TASC project *HPCN for Environmental Applications*
- Organizer invited mini-symposium on Partial Differential Equations at SciCADE97
- Organizer invited mini-symposium on Numerical Algorithms in Air Quality Modeling at the 1998 SIAM Annual Meeting

C.J. van Duijn:

- Professor of Applied Mathematics, Delft University of Technology
- Editor-in-Chief of *Computational Geosciences*
- Chairman of the Panel of the NWO Priority Programme *Nonlinear Systems*
- Coordinator of the Dutch Interaction Platform *Nonlinear Transport Phenomena in Porous Media*
- Member of the Steering Committee of the ESF Programme *Free Boundary Problems, Theory and Applications*
- Member Ph.D. Committee G. Galiano, *Energy Methods for the Localization of Interfaces*, Ph.D. thesis Universidad Complutense de Madrid, March 20
- Member Ph.D. Committee G. Prokert, *Parabolic Evolution Equations for Quasi-stationary Free Boundary Problems in Capillary Fluid Mechanics*, Ph.D. thesis Eindhoven University of Technology, June 25

- Member Ph.D. Committee R. Godderij, *A Three Dimensional Interface Model for Steam Drive in Heterogeneous Reservoirs*, Ph.D. thesis Delft University of Technology, October 27

P.J. van der Houwen:

- Ph.D. thesis advisor W.A. van der Veen, *Parallelism in the numerical solution of ordinary and implicit differential equations*, University of Amsterdam, May 21
- Referent Ph.D. thesis F.A.J. Straetemans, *Resolvent conditions and stability for discretizations of initial value problems*, University of Leiden, May 24
- Committee member Ph.D. thesis M.J.J.J-B. Maes, University of Amsterdam, October 6.
- Ph.D. thesis advisor J.J.B. de Swart, *PSIDE: Parallel Software for Implicit Differential Equations*, University of Amsterdam, November 28
- 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* (till April 15)
- Member Users Committee STW project *Parallel Codes for Circuit Analysis and Control Engineering*

J. Kok:

- Organizer of the annual Dutch Conference on Numerical Analysis.

B.P. Sommeijer:

- Member Ph.D. Committee J.J.B. de Swart, *Parallel Software for Implicit Differential Equations*, Ph.D. thesis University of Amsterdam, November 28
- Member Ph.D. Committee W.A. van der Veen, *Parallelism in the Numerical Solution of Ordinary and Implicit Differential Equations*, Ph.D. thesis University of Amsterdam, May 21

Visitors

- C.J. Budd, School of Mathematics, Univ. Bath, UK, January 7
- G. Carmichael, Univ. Iowa, USA, March 5–7
- C. Eichler-Liebenow, Univ. Halle, Germany, March 3–27
- F. Potra, Univ. Iowa, USA, March 12–16
- R. Kersner, Paris, France, March 16–April 18
- G.M. Homsy, Univ. Stanford, USA, March 17–20
- G. de Josselin de Jong, TU Delft, March 24–26
- H.W. Alt, Univ. Bonn, Germany, April 4–6
- M. Ughi, Univ. Trieste, Italy, April 13–19
- C. Werner (France), I. Athanasopoulos (Greece), J.I. Diaz (Spain), M. Niezgodka (Poland), A. Bossavit (France), H.W. Alt (Germany), J.F. Rodrigues (Portugal), April 26–27
- Zhang Hongfei, Indiana, USA, May 4–June 4
- J. Trangenstein, Duke University, USA, August 10–17
- B. Grundy, St. Andrews, Scotland, August 28–September 2
- G. Dagan, Tel Aviv University, Israel, September 7–13
- G. Heat, CSIRO, Canberra, Australia, 11.9–13.9.97.
- A. de Wit, Univ. Libre de Bruxelles, Belgium, September 24–26
- U. Becker-Lemgau, R. Hess, R. Lorentz, K. Oosterlee, U. Trottenberg, A. Schueller, all GMD-SCAI, Germany, October 27–28
- M. Bertsch, Rome, Italy, November 2–4
- R. dal Passo, Rome, Italy, November 2–4
- J. Philip, CSIRO, Canberra, Australia, October 27–November 17
- C.N. Dawson, Univ. of Texas at Austin, USA, December 7–13
- A. Petersen, M. Krol (Univ. Utrecht), H. Elbern (Univ. Keulen), December 11

Papers in Journals and Proceedings

M.I.J. VAN DIJKE, S.E.A.T.M. VAN DER ZEE (1997). A similarity solution for oil lens redistribution including capillary forces and oil entrapment. *Transport in Porous Media* **29**, 99–125.

C.J. VAN DUIJN, P. KNABNER (1997). Travelling wave behaviour of crystal dissolution in porous media flow. *Euro. Applied Mathematics* **8**, 49–72.

C.J. VAN DUIJN, R.E. GRUNDY, C.N. DAWSON (1997). Large time profiles in reactive solute transport. *Transport in Porous Media* **27**, 57–84.

P.J. VAN DER HOUWEN, B.P. SOMMEIJER (1997). Splitting methods for three-dimensional transport models with interaction terms. *J. Scientific Computing* **12**.

J. FRANK, W. HUNDSDORFER, J.G. VERWER (1997). On the stability of implicit-explicit linear multistep methods. *Applied Numerical Mathematics* **25**, 193–205.

P.J. VAN DER HOUWEN, B.P. SOMMEIJER, J. KOK (1997). The iterative solution of fully implicit discretizations of three-dimensional transport models. *Applied Numerical Mathematics* **25**, 243–256.

M. VAN LOON, A.W. HEEMINK, P.J.H. BUILTJES (1997). Data assimilation for atmospheric chemistry models. R. SAN JOSE, C.A. BREBBIA (eds.). *Measurements and Modelling in Environmental Pollution*, Computational Mechanics Publications, Southampton, UK, 293–300.

A. SANDU, J.G. VERWER, M. VAN LOON, G.R. CARMICHAEL, F.A. POTRA, D. DABDUB, J.H. SEINFELD (1997). Benchmarking stiff ODE solvers for atmospheric chemistry problems I: Implicit versus explicit. *Atmospheric Environment* **31**, 3151–3166.

A. SANDU, J.G. VERWER, J.G. BLOM, E.J. SPEE, G.R. CARMICHAEL (1997). Benchmarking stiff ODE solvers for atmospheric chemistry problems II: Rosenbrock solvers. *Atmospheric Environment* **31**, 3459–3472.

E.J. SPEE (1997). Development of advection schemes for global 3D chemistry-transport models. H. POWER, T. TIRABASSI, C.A. BREBBIA (eds.). *Proc. Air Pollution V: Modelling, Monitoring and Management*, Southampton, 177–186.

B.P. SOMMEIJER, J. KOK (1997). Domain decomposition for an implicit shallow-water transport solver. B. HERTZBERGER, P. SLOOT (eds.). *Proc. HPCN Europe 1997 Conference*, Lect. Notes in Comp. Sc. 1225, Springer, 379–388.

J.G. VERWER, B.P. SOMMEIJER (1997). Stability analysis of an odd-even hopscotch method for three-dimensional advection-diffusion problems. *SIAM J. Numer. Anal.* **34**, 376–388.

CWI Reports

MAS-R9702. E.J. SPEE, J.G. VERWER, P.M. DE ZEEUW, J.G. BLOM, W.H. HUNDSDORFER. *A numerical study for global atmospheric transport-chemistry problems*.

MAS-R9703. H.W. ALT, C.J. VAN DUIJN. *A free boundary value problem involving a cusp. Part II: local analysis*.

MAS-R9707. M.A.A. VAN LEEUWEN. *Edge sequences, ribbon tableaux, and an action of affine permutations*.

MAS-R9708. M.A.A. VAN LEEUWEN. *Some bijective correspondences involving domino tableaux*.

MAS-R9709. M.A.A. VAN LEEUWEN. *The Littlewood-Richardson rule, theory and implementation*.

MAS-R9710. E.J. SPEE, A.C. PETERSEN, H. VAN DOP, W.H. HUNDSDORFER. *Sensitivity of atmospheric transport model performance to mumerical advection schemes and resolution*.

MAS-R9711. M. VAN LOON, A.W. HEEMINK. *Kalman filtering for nonlinear atmospheric chemistry models: first experiences*.

MAS-R9712. J. MOLENAAR. *Nonlinear multigrid for fully-implicit and high-order accurate simulation of multiphase flow in porous media*.

MAS-R9714. M.A. KIRKILIONIS, O. DIEKMANN, B. LISSER, M. NOOL, A.M. DE ROOS, B.P. SOMMEIJER. *Numerical continuation of equilibria of physiologically structured population models. I. Theory*.

MAS-R9715. B.P. SOMMEIJER, L.F. SHAMPINE, J.G. VERWER. *RKC: an explicit solver for parabolic PDEs*.

MAS-R9717. J.G. VERWER, E.J. SPEE, J.G. BLOM, W.H. HUNDSDORFER. *A second order Rosenbrock method applied to photochemical dispersion problems.*

MAS-R9718. C. EICHLER-LIEBENOW, P.J. VAN DER HOUWEN, B.P. SOMMEIJER. *Analysis of approximate factorization in iteration methods*.

MAS-R9719. G. GALIANO. *Spatial and time localization of solutions of the Boussinesq system with nonlinear thermal diffusion*.

MAS-R9721. W.H. HUNDSDORFER. *Stability of approximate factorization with θ-methods*.

MAS-R9722. J.I. DIAZ, G. GALIANO. *Existence and uniqueness of solutions to the Boussinesq system with nonlinear thermal diffusion*.

MAS-R9723. J.I. DIAZ, G. GALIANO, A. JÜNGEL. *On a quasilinear degenerated system arising in semiconductors theory. Part I: existence and uniqueness of solutions*.

MAS-R9724. C.J. VAN DUIJN, R.J. SCHOTTING. *Brine transport in porous media: On the use of Von Mises and similarity transformations.*

MAS-R9725. M.I.J. VAN DIJKE, S.E.A.T.M. VAN DER ZEE. *Analysis of oil lens removal by extraction through a seepage face.*

MAS-R9728. C.J. VAN DUIJN, G. GALIANO, J.H. KNIGHT, M.A. PELETIER. *How mangroves*

salinize the soil.

MAS-R9729. M.I.J. VAN DIJKE, S.E.A.T.M. VAN DER ZEE. *Modelling of air sparging in a layered soil: numerical and analytical approximations*.

MAS-R9734. R.J. SCHOTTING, H. MOSER, S.M. HASSANIZADEH. *High-concentration gradient dispersion: Experiments, analysis and approximations*.

MAS-R9735. R.J. SCHOTTING, J.F. SCHEID. *The interface between fresh and salt groundwater in heterogeneous aquifers: a numerical approach*.

MAS-N9701. J.G. BLOM, M.G.M. ROEMER. *Description of the 3D LOTOS model. Part I: Dynamics*.

Other Publications

M.I.J. VAN DIJKE (1997). *Multi-phase Flow Modeling of Soil Contamination and Soil Remediation*, Ph.D. Thesis Wageningen Agricultural University.

W. LOEVE, J. VERWER, E. SNYDOODT, A. TEN DAM (1997). *Classifical HPCN Geared to Application in Industry*, Report NLR TP 97229 L, NLR, Netherlands.

M.A. PELETIER (1997). *Problems in Degenerate Diffusion*, Ph.D. Thesis Leiden University.

Industrial Processes – MAS2

General

The research activities in the MAS2 theme were spread over a number of sub-themes (projects), each with its own staff and responsible project leader. Below the reports are given for each sub-theme separately. In 1997 the sub-themes in MAS2 were:

1. Computational fluid dynamics (Koren)
2. Circuit simulation (van der Houwen)
3. Plasma physics simulation (te Riele)
4. Discontinuous dynamical systems (Schumacher)
5. Computational number theory and data security (te Riele)
6. Modeling of processes in biology and chemistry (Hemker)
7. Mathematics of finance (Schumacher)
8. Exploratory research (Hemker)

As a central activity a *Workshop Industrial Mathematics "de Wiskundige Werkvloer"* was zrganised at CWI, April 25. The workshop was held in cooperation with the University of Amsterdam and with ITW (Stichting Industriële en Toegepaste Wiskunde).

The organizing committee consisted of Prof. dr. ir. C.J. van Duijn, Prof. dr. P.W. Hemker, Prof. dr. P.J. van der Houwen, Dr. ir. B. Koren, Dr. ir. H.J.J. te Riele, Prof. dr. J.M. Schumacher and Dr. J.G. Verwer, all members of MAS.

During the workshop a small number of invited lectures have been given. The major part of the workshop was devoted to the presentation of posters and of a number of selected real-life industrial problems, and discussions on their solution. About 65 people, from different industries and research institutions, took part in the activities of the workshop.

Invited lectures were presented by: Dr. ir. B. Koren (CWI), *CFD voor KONI en Akzo-Nobel: oliestroming in schokdempers, luchtstroming in garenblazers*, Dr. M. Knaap (SRTCA, Amsterdam), *Wiskunde-problemen uit de Shell-praktijk*, Dr. D. Reefman (Philips Natlab, Eindhoven), *Perfecte roosters en Thiessen triangulatie*.

Real-life problems were introduced by: Dr. W. Schilders (Philips Natlab, Eindhoven) *Reductie van RC-circuits (het modelleren van complexe electrische circuits door eenvoudiger)*, Dr. S.P. Van Helden (Organon, Oss) *Structuur-activiteits-relaties in de geneesmiddelen ontwikkeling*, Dr. S. Rienstra (IWDE, Eindhoven) *Kruisende stroomlijnen in een dunne waterlaag-stroming*, Ir. K. Kannegieter (Elin Holec, Amersfoort) *Stroomverdeling in een geleider*, Dr. K. Hemmes (Materiaalkunde, TUD) *Wiskundige modellering van brandstofcellen*.

Posters were presented by: T. van Noorden (UvA), M. Nikolova (KUN) *Adaptive refinement for convection-diffusion problems based on a defect-correction technique and finite difference method*, A. Padiy (KUN) *Scalable and robust iterative solvers for second-order elliptic problems*, L.W. Vijfvinkel (KUN) *Bubble-functies als foutschatter voor het Stokes-probleem*, M. Genseberger (UU/CWI).

A computer demonstration was given by Drs. J. Kok: *"SPIDS, een programma voor identificatie van parameters in niet-lineaire dynamische systemen: toepassingen in de (bio)-chemie"*.

Computational Fluid Dynamics – MAS2.1

Staff

- Ir. E.H. van Brummelen, Ph.D. student (since September 1)
- Prof. dr. P.W. Hemker, researcher
- Dr. ir. B. Koren, researcher, project leader
- D. Lanser, trainee (until July 1)
- Drs. B. Lastdrager, Ph.D. student (since December 1, shared with MAS1.1)
- Ir. J. Noordmans, Ph.D. student

- Prof. dr. ir. P. Wesseling, advisor

Scientific Report

Hemker and *Noordmans* continued research on sparse-grid algorithms for three-dimensional problems. The work is directed towards the efficient solution of large, elliptic boundary-value problems originating from tribology and ship hydrodynamics (the anisotropic Stokes equations and the Poisson equation for pressure on high mesh-ratio grids, respectively). The convergence behaviour has been investigated of solution algorithms for the anisotropic Poisson problem on partially ordered, sparse families of regular, 3D grids. In order to study multilevel techniques on sparse families of grids, first the convergence of a two-level algorithm has been studied. The algorithm applies semi-coarsening in each of the coordinate directions. The algorithm shows good convergence, but recursive application of the successive semi-coarsening is not sufficiently efficient. Therefore another algorithm has been introduced, which uses collective, 3D semi-coarse-grid corrections. The convergence behaviour of this collective version is worse, due to the lack of correspondence between the solutions on the different grids. Good convergence behaviour of the collective version of the algorithm can be retained, in case the different solutions are sufficiently coherent. In order to solve non-trivial problems, a defect-correction process has been proposed. This process makes use of hierarchical smoothing in order to deal with the problems related to the lack of coherence between the solutions on the different grids. Now good convergence rates are obtained also for non-trivial solutions. The results show convergence rates bounded, independent of the discretization level and of the anisotropy in the problem. Details can be found in CWI-Report MAS-R9713.

C.T.H. Everaars (SEN3) and *Koren* finished their investigation on the distributed computing aspects of the sparse-grid approach, with the Manifold language compiler. The expected good parallel computing properties of sparse-grid solution techniques were confirmed. To this end, an existing, sequential CFD code, for a standard 3D problem from computational aerodynamics, has been restructured into a parallel application. The restructuring has been organized according to a master/worker protocol. The coordinator modules have been implemented in the coordination language Manifold and have been coded such that they are applicable to other problems as well. Performances have been measured of both sequential and parallel versions of the code. The results were as good as expected. In addition, a theoretical analysis has been made of speed-up through parallelization, in a multi-user single-machine environment. Details can be found in CWI-Report SEN-R9705. The paper will appear in a coordination-languages issue of Parallel Computing.

Koren and *Lanser* finished their contract work for Akzo/Nobel Central Research in Arnhem: the development of a numerical method for computing the compressible air flow in a nozzle, which is used for drawing fibers in melt-spinning processes. (Melt spinning is a process to make non-woven cloth, a basic product in the production of many other products, ranging from carpets and roofings to wound-dressings. At the start of the process, a polymer is melted and extruded into a large set of very thin fibers, which are drawn by a high-subsonic air flow, through a nozzle. The air flow in the nozzle is fed from two tanks of pressurized air.) The industrial goal of this research was to have an aerodynamic design tool for the nozzle, in order to reduce its relatively large running costs. For this purpose, the availability of a reliable computational method for internal aerodynamics with mixed inlet-outlet ports is a prerequisite. A start was made in developing and applying such a method. The flow model considered consists of the 2D, steady, compressible Navier-Stokes equations in Cartesian coordinates. For the major part, the discretization and solution method that have been applied, are standard. The new numerical ingredients were: a boundary-condition treatment for mixed inlet-outlet ports (a treatment which admits the unconstrained occurrence of a vortex at a boundary) and a condition improvement of the discrete Navier-Stokes equations in low-Mach number regions. The numerical method has been applied to a simplified part of the nozzle. It appeared to be promising for more realistic computations. Details can be found in CWI-Report MAS-N9202.

In the period February–April, *Koren* has made a feasibility study of the level-set method, a promising method for the computation of moving material interfaces (free boundaries) in various application areas such as forging, sloshing and explosions in water. Particularly in the first application area the accuracy requirements imposed on the resolution of the material interface are very high. The study was contract work for MacNeal-Schwendler European Development Center B.V. (Gouda), and was financially supported by the Netherlands Ministry of Economic Affairs, through Senter. In some applications, practical use can be made of the property that at one side of the interface, the material can be modelled as

void. For example, with steel and air at either side of the interface, the modeling of air as void is quite realistic. In the study, the level-set method has not been applied to real material-interface problems, but to clarifying model problems with known exact solutions. Here, the level-set method shows its ability to improve the geometrical resolution of free boundaries. Concerning the improvement of other than merely geometrical free-boundary properties, the level-set method performs very well for downstream-facing fronts and is promising for upstream-facing ones. Details of the work can be found in CWI-Report MAS-R9731.

On the basis of a one-year consultancy contract with the Maritime Research Institute Netherlands (MARIN, Wageningen), *Hemker* and *Koren* started a study on robustness improvement of MARIN's viscous CFD code PARNASSOS, which is based on the steady, incompressible, 3D Navier-Stokes equations, in which the diffusion terms in main flow direction have been neglected. So far, a study has been made on the well-posedness of the problem considered by MARIN. Fourier analysis has been applied to the full, linearized system of continuous equations, in order to study the qualitative solution behaviour,

On the basis of a four-year research contract with MARIN, *Van Brummelen, Hemker* and *Koren* started research which is directed towards the extension of PARNASSOS with a free surface. This extension will allow for a ship's wave making, and therefore – in principle – for the simultaneous computation of both viscous and wave drag. The main use of PARNASSOS at MARIN lies in flow-topology studies (flow separation, re-attachment, vortex formation, etc.) around ship sterns. At CWI, so far, a study has been made of various methods for computing the free-surface flow. The methods studied range from the simple water-height method to general methods such as the volume-of-fluid, marker-and-cell and level-set methods. Since modification of MARIN's PARNASSOS method for the bulk flow is not excluded, and since a small and flexible research code will be written for testing some different free-surface-flow methods, a study has also been made of various aspects of computing the bulk flow. The aspects concerned both the continuous and the discrete equations and the solver.

Koren, Lastdrager (MAS1.1 / MAS2.1) and *Verwer (MAS1.1)* just started a four-year, SWON-supported research project on sparse-grid methods for transport problems. Goal of the research is to develop a computationally efficient method for unsteady, 3D fluid-flow problems. The advantage of sparse-grid methods will be investigated through error analyses and numerical experiments. The possibilities of distributed computing will also be investigated.

Organization of Conferences, Workshops, Courses, etc.

B. Koren:

- Scientific Meeting MAS-SCAI, CWI, October 27–28.

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

- Working visit University of Twente, Faculty of Mechanical Engineering, Fluid Mechanics Group, January 16: Koren (*Een Numerieke Methode voor de Berekening van Instationaire Oliestromingen, Toepassing op Hydraulische Schokdempers*).
- Working visit Holec Machines en Apparaten B.V., Ridderkerk, January 24: Koren.
- Working visits for Akzo/Nobel-project on nozzle flow: Akzo/Nobel Central Research, Arnhem, February 4, April 17; CWI, February 27, May 14; Delft University of Technology, March 20, June 12: Koren, Lanser.
- Working visit MARIN, Wageningen, February 12: Hemker, Koren.
- HPCN Symposium, CWI, February 13: Koren, Hemker.
- Consultancy visits MacNeal-Schwendler E.D.C. B.V., Gouda: February 20, March 11, April 18: Koren.
- CWI Scientific Meeting, February 28: Hemker (*Three-Dimensional Multigrid*), Koren, Noordmans.
- 28th Lecture Series Computational Fluid Dynamics, Von Karman Institute for Fluid Dynamics, Rhode-Saint-Genèse, March 3–7: Hemker (*Multilevel Acceleration of Finite Volume Methods for Compressible Flow; 3D Multigrid on Partially Ordered Sets of Grids*), Koren (*Standard Multigrid Techniques for CFD; Solution-Adaptive Multigrid for Steady Gas Dynamics Problems*).
- Mini-Symposium Wiskunde Toegepast, Agricultural University of Wageningen, April 3: Hemker, Koren.
- MAS Werkbespreking, April 21, Hemker (*Progress in Sparse Grids*).
- Workshop Industriële Wiskunde, De Wiskundige Werkvloer, CWI, April 25: Hemker, Koren (*CFD voor KONI en Akzo/Nobel: Oliestroming in Treindempers, Luchtstroming in Garenblazers*), Lanser, Noordmans.

- Godunov Symposium, University of Michigan, Department of Aerospace Engineering, Ann Arbor, Michigan, May 1–2: Koren (invited member discussion panel).
- Summerschool on multilevel preconditioning methods with parallel implementation aspects and applications in scientific computing (KUN, May 19–26) Hemker (*Lecture on 'Sparse Grids'*), Noordmans.
- Algemeen Wiskunde Colloquium, Universiteit van Amsterdam, May 24: Hemker (*3D Multigrid on Partially Ordered Sets of Grids*).
- MAS-Werkbespreking, May 26: Koren (*Computational Fluid Dynamics*).
- Conference on Preconditioned Iterative Solution Methods for Large Scale Problems in Scientific Computing, PRISM'97, May 27–29, Nijmegen: Hemker (*Convergence Results for 3D Sparse Grid Approaches*).
- Working visit Delft University of Technology, Faculty of Mechanical Engineering, Laboratory of Aero- and Hydrodynamics, June 12: Koren (*CFD for KONI and Akzo/Nobel: Oil Flow in Shock Absorbers for Trains, Air Flow in Nozzles for Fiber Transport*).
- Working visit Institute for Algorithms and Scientific Computing (SCAI), GMD, Schloss Birlinghoven, June 25: Koren.
- 13th AIAA Computational Fluid Dynamics Conference, Snowmass Village, Colorado, June 29–July 2: Koren (*Multiple Semi-Coarsened Multigrid for 3D CFD*).
- Working visit MARIN, Wageningen, September 8: Van Brummelen, Hemker, Koren.
- Inaugural speech Prof. dr. ir. C.B. Vreugdenhil, University of Twente, September 11: Koren.
- Meeting STW-project C.H. Venner and D. van Odijck, University of Twente, Faculty of Mechanical Engineering, Tribology Group, September 24: Koren.
- Woudschoten Conferentie, September 24–26: Van Brummelen, Hemker, Koren.
- CWI in Bedrijf, October 3: Van Brummelen, Hemker, Koren (poster and demonstration, together with Ir. D. Lanser and Ir. H. Persoon, Akzo/Nobel).
- Scientific Meeting MAS-SCAI, CWI, October 27–28: Van Brummelen, Hemker (*Sparse Grids Iterative Methods*), Koren (*A Level-Set Method for Moving Material Interfaces*).
- Stieltjes Analysis Colloquium, Leiden University, November 10, P.W. Hemker (*Sparse Grid Approximation and Subspace Correction Techniques*).

Memberships of Committees and Other Professional Activities

P.W. Hemker:
- See section MAS2.8.

B. Koren:
- Consultant MacNeal-Schwendler European Development Center B.V., Gouda (until April 30).
- Lecturer Thomas Stieltjes Institute (Ph.D.-course Modern Computational Fluid Dynamics, guest lecturers: P.M. de Zeeuw (PNA4) and C.T.H. Everaars (SEN3)).
- Editor *CWI-Quarterly*, since April 14.
- Member STW-committee C.H. Venner and D. van Odijck (University of Twente, Faculty of Mechanical Engineering, Tribology Group).
- Member Ph.D. committee P.M. de Zeeuw (University of Amsterdam, January 22).
- Member M.Sc. committee D. Lanser (Delft University of Technology, June 26).
- Member Ph.D. committee P. Van Ransbeeck (Free University of Brussels, December 19, private defence).

Visitors

- Ir. K. Kannegieter (Elin Holec High Voltage B.V., Amersfoort), February 3.
- Ir. A.C.J. Venis (MacNeal-Schwendler E.D.C. B.V., Gouda), April 4.
- Drs. W.A. de Zeeuw (Holec Machines en Apparaten B.V., Ridderkerk), April 10.
- Drs. W.A. de Zeeuw and Dr. ir. R. de Weerdt (Holec Machines en Apparaten B.V., Ridderkerk), April 21.
- Together with MAS1.1: Dr. U. Becker-Lemgau (*GRISSLi: Multiphysics Problems*), Dr. R. Hess (*Contributions to the Design of a New Grid Point Oriented Weather Forecast Model*), Dr. R. Lorentz (*Constructing Hierarchical Riesz Bases in Sobolev Spaces: Theory and Practice*), Dr.ir. C. Oosterlee, Prof. dr. U. Trottenberg and Dr. A. Schüller (SCAI, GMD), October 27–28.

Miscellaneous

B. Koren:
- Review of journal papers and research proposals.

Papers in Journals and Proceedings

E.F.F. BOTTA, K. DEKKER, Y. NOTAY, A. VAN DER PLOEG, C. VUIK, F.W. WUBS, P.M. DE ZEEUW (1997). How fast the Laplace equation was solved in 1995. *J. Applied Numerical Mathematics* **24**, 439–455.

P.W. HEMKER (1997). Finite volume multigrid for 3D-problems. *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig, 485–509.

P.W. HEMKER, C. PFLAUM (1997). Approximation on partially ordered sets of regular grids. *Applied Numerical Mathematics* **25**, 55–87.

P.W. HEMKER, B. KOREN, W.M. LIOEN, M. NOOL, H.T.M. VAN DER MAAREL (1997). Multigrid for steady gas dynamics problems. *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig, 393–417.

P.W. HEMKER, P.M. DE ZEEUW (1997). A data structure for 3-dimensional sparse grids. *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig, 443–484.

B. KOREN, P.W. HEMKER, C.T.H. EVERAARS (1997). Multiple semi-coarsened multigrid for 3D CFD. Proceedings *13th AIAA Computational Fluid Dynamics Conference*, Snowmass Village, CO, (AIAA-paper 97-2029), American Institute of Aeronautics and Astronautics, Reston, VA, 892–902.

B. KOREN, P.W. HEMKER, P.M. DE ZEEUW (1997). Semi-coarsening in three directions for Euler-flow computations in three dimensions. *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig, 547–567.

B. KOREN, B. VAN LEER (1997). Improving Euler computations at low Mach numbers. *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig, 419–441.

P.M. DE ZEEUW (1997). Multiple semi-coarsening techniques. *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig, 511–545.

CWI Reports

MAS-R9713. J. NOORDMANS, P.W. HEMKER. *Convergence results for 3D sparse grid approaches.*

MAS-R9731. B. KOREN, A.C.J. VENIS. *A level-set method for moving material-void interfaces.*

MAS-N9702. D. LANSER. *Numerieke berekeningen aan een luchtstroming in een spleetblazer, uit het oogpunt van trekkrachtgeneratie in een nonwoven-produktieproces.*

Other Publications

H. DECONINCK, B. KOREN (EDS.) (1997). *Euler and Navier-Stokes Solvers Using Multi-Dimensional Upwind Schemes and Multigrid Acceleration*. European Community Research in Aeronautics, *Notes on Numerical Fluid Mechanics* **57**, Vieweg, Braunschweig.

P.W. HEMKER, B. KOREN (1997). Standard multigrid techniques for CFD. *28th Computational Fluid Dynamics, VKI LS 1997–02*, Von Karman Institute for Fluid Dynamics, Rhode-Saint-Genèse.

P.W. HEMKER, B. KOREN, W.M. LIOEN, M. NOOL, H.T.M. VAN DER MAAREL (1997). Solution-adaptive multigrid for steady gas dynamics problems. *28th Computational Fluid Dynamics, VKI LS 1997–02*, Von Karman Institute for Fluid Dynamics, Rhode-Saint-Genèse.

P.W. HEMKER, B. KOREN, J. NOORDMANS (1997). 3D multigrid on partially ordered sets of grids. *28th Computational Fluid Dynamics, VKI LS 1997–02*, Von Karman Institute for Fluid Dynamics, Rhode-Saint-Genèse.

B. KOREN, P.W. HEMKER (1997). Godunov-type schemes, sparse grids and 3D CFD. *Godunov's Method for Gas Dynamics: Current Applications and Future Developments*, Department of Aerospace Engineering, The University of Michigan, Ann Arbor, MI.

B. KOREN, P. WESSELING, P.M. DE ZEEUW (eds.) (1997). *Het Nummer* **36**, Stichting Mathematisch Centrum, Amsterdam.

P.M. DE ZEEUW (1997). *Acceleration of Iterative Methods by Coarse Grid Corrections*, Ph.D. thesis, University of Amsterdam.

Numerical Algorithms for Initial-Value Problems – MAS2.2

Staff

- Prof. dr. P.J. van der Houwen, project leader
- Dr. B.P. Sommeijer, researcher
- Drs. J.J.B. de Swart, Ph.D. student
- Drs. W.A. van der Veen, Ph.D. student
- Drs. W.M. Lioen, scientific programmer

Scientific Report

PSIDE – In the last year of the STW project 'Parallel Codes for Circuit Analysis and Control Engineering', which was terminated on 30 November 1997, the main focus was on the further development of the code PSIDE (Parallel Software for Implicit Differential Equations) and the CWI test set for IVPs. Firstly, as a result of a working visit of J.J.B de Swart to Prof. G. Söderlind of the university of Lund, PSIDE was equipped with several strategies for error and stepsize control. Secondly, we started the design of a facility enabling PSIDE to switch automatically from stiff to non-stiff mode and vice versa. This technique is based on the approximate factorization of the Newton matrix used in the stiff

mode. First experiments show that the efficiency improves considerably. Thirdly, the documentation of PSIDE and the CWI test set has been completed and published in the Ph.D. theses of W.A. van der Veen and J.J.B de Swart, together with the analysis of the underlying algorithms for PSIDE. Finally, in the period May '97–November '97 J.J.B de Swart spent two days per week at PRLE in order to investigate the applicability of the current version of PSIDE in PSTAR, the circuit simulator of Philips.

WAVE EQUATION – This activity concerns the stiff, second-order initial-value problems which arise in the spatial discretization of initial-boundary value problems for the wave equation. We focus on the construction and analysis of iterative solution methods which are effective in cases where the Jacobian of the right-hand side of the differential equation can be split into a sum of matrices with a simple structure. These iterative methods consist of the modified Newton method and an iterative linear solver to deal with the linear Newton systems. The linear solver is based on the approximate factorization of the system matrix associated with the linear Newton systems. The project was a joint activity with E. Messina from the University of Naples.

Organization of Conferences, Workshops, Courses, etc.

- NUMDIFF-8 – Eighth International Seminar Numerical Treatment of Differential Equations, Alexisbad, September 1–5. Co-chairman: P.J. van der Houwen.
- Minisymposium on Parallel ODE methods at SciCADE97 – International Conference on Scientific Computation and Differential Equations, Grado, September 15–19. Organizer: P.J. van der Houwen. Speakers: L. Brugnano (Parallelism across the steps by using boundary value methods), J.J.B. de Swart (A parallel linear system solver for Runge-Kutta methods), H. Suhartanto (On the integration of non-stiff and stiff IVPs for ODEs with parallel iterated multistep Runge-Kutta methods.

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

- Workshop on Special Functions & Differential Equations, Institute of Mathematical Sciences Madras, January 13–24: P.J. van der Houwen (Four lectures on Parallel methods for initial-value problems).
- Stieltjes Analysis Colloquium, Mathematical Institute Leiden University, February 27: P.J. van der Houwen (*Analysis of Iterative Linear Solvers in the Integration of Initial-value Problems*).
- Visit of J.J.B. de Swart to Prof. L.F. Shampine at Southern Methodist University, Dallas, Texas, USA, April 28–30. Lecture '*Solving Implicit Differential Equations on Parallel Computers*' on April 30.
- Project meeting on Mathematical Modeling of Open Dynamical Systems, CWI, May 26: P.J. van der Houwen (*Numerical Integration of DAEs*).
- Summer Course on Advanced Topics in Numerical Mathematics, Scuola Matematica Interuniversitaria, Cortona, July 19 – August 11: P.J. van der Houwen (17 lectures and 15 working seminars on *Parallel Aspects of Integration Methods for Initial-value Problems*).
- 15th IMACS World Congress, Berlin, August 24–29: P.J. van der Houwen (Two lectures on *Parallel Methods for ODEs and VIDEs*), J.J.B. de Swart (*Parallel Linear System Solvers for Runge-Kutta Methods*).
- SciCADE97, Grado, September 15–19: J.J.B. de Swart (*Parallel Iterative Linear System Solvers for Runge-Kutta Methods*).
- HPCN Platform, Eindhoven, November 26: J.J.B. de Swart (*Optimization with Differential-algebraic Equations*)
- Universiteit van Amsterdam, Algemeen Wiskunde Colloquium, December 17: J.J.B. de Swart (*Parallel Software for Implicit Differential Equations*).

Memberships of Committees and Other Professional Activities

P.J. van der Houwen:
- See report of MAS1.

Visitors

- Prof. dr. G. Söderlind (Univ. of Lund, Sweden) February 4–8.
- C. Eichler-Liebenow (Univ. Halle, Germany) March 3–27.
- Prof. M.M. Chawla (Univ. Koeweit) April 15–16.
- Prof. K.S. Rao (Univ. Madras, India) May 5, November 3–5.

Papers in Journals and Proceedings

W. HOFFMANN, J.J.B. DE SWART (1997). Approximating Runge-Kutta matrices by triangular matrices. *BIT* **37**, 346–354.

P.J. VAN DER HOUWEN (1997). Parallel iterative linear solvers for Runge-Kutta discretizations of VIDEs. ACHIM SYDOW (ed.). *Proceedings of the*

15th IMACS World Congress, Volume **2**, Wissenschaft und Technik Verlag, Berlin.

P.J. VAN DER HOUWEN, E. MESSINA (1997). Parallel linear system solvers for Runge-Kutta-Nyström methods. *J. Comput. Appl. Math.* **82**, 407–422.

P.J. VAN DER HOUWEN, B.P. SOMMEIJER (1997). Euler-Chebyshev methods for integro-differential equations. *Appl. Numer. Math.* **24**, 203–218.

P.J. VAN DER HOUWEN, J.J.B. DE SWART (1997). Parallel Linear System Solvers for Runge-Kutta Methods. *Adv. Comp. Math.* **7**, 157–181.

P.J. VAN DER HOUWEN, J.J.B. DE SWART (1997). Parallel linear system solvers for Runge-Kutta methods. ACHIM SYDOW (ed.). *Proceedings of the 15th IMACS World Congress* **2**, Wissenschaft und Technik Verlag, Berlin, 63–68.

P.J. VAN DER HOUWEN, W.A. VAN DER VEEN (1997). Waveform relaxation methods for implicit differential equations. *Adv. Comp. Math.* **7**, 183–197.

E. MESSINA, J.J.B. DE SWART, W.A. VAN DER VEEN (1997). Parallel iterative linear solvers for Multistep Runge-Kutta methods. *J. Comput. Appl. Math.* **85**, 145–167.

J.J.B. DE SWART (1997). A simple ODE solver based on 2-stage Radau IIA. *J. Comput. Appl. Math.* **84**, 277–280.

J.J.B. DE SWART, G. SÖDERLIND (1997). On the construction of error estimates for implicit Runge-Kutta methods. *J. Comput. Appl. Math.* **86**, 347–358.

CWI Reports

MAS-R9705. J.D. PINTER, W.J.H. STORTELDER, J.J.B. DE SWART. *Computation of elliptic Fekete point sets.*

MAS-R9704. J.J.B. DE SWART, G. SÖDERLIND. *On the construction of error estimates for implicit Runge-Kutta methods.*

MAS-R9732. P.J. VAN DER HOUWEN, B.P. SOMMEIJER. *The use of approximate factorization in stiff ODE solvers.*

Other Publications

W.M. LIOEN, J.J.B. DE SWART, W.A. VAN DER VEEN (1997). *Test set for IVP solvers*, available via WWW at URL: http://www.cwi.nl/cwi/projects/IVPtestset/

W.M. LIOEN, J.J.B. DE, SWART, W.A. VAN DER VEEN (1997). *PSIDE users' guide*, available via WWW at URL: http://www.cwi.nl/cwi/projects/PSIDE/

J.J.B. DE SWART, W.M. LIOEN, W.A. VAN DER VEEN (1997). *Specification of PSIDE*, available via WWW at URL: http://www.cwi.nl/cwi/projects/PSIDE/.

J.J.B. DE SWART (1997). *PSIDE: Parallel Software for Implicit Differential Equations*, PhD thesis, University of Amsterdam.

W.A. VAN DER VEEN (1997). *Parallelism in the numerical solution of ordinary and implicit differential equations*, PhD thesis, University of Amsterdam.

Plasma Physics Simulation – MAS2.3

Staff

- Dr. ir. H.J.J. te Riele, project leader
- Drs. M. Nool, scientific programmer
- Dr. ir. A. van der Ploeg, researcher
- Drs. M. Genseberger, Ph.D. student

Scientific Report

Introduction.

In this project parallel iterative methods are developed, implemented and analyzed for the computation of eigenvalues and eigenvectors of generalized eigenvalue problems, where the matrices are very large, sparse and (complex) non-Hermitian. The algorithms are tested on problems coming from plasmaphysics. The main motivation for this interdisciplinary project is the question from physicists whether parallel computers are suitable tools to handle problems which are larger than those which can still be tackled with the help of super (vector-) computers. In addition, other parallel numerical algorithms are studied and implemented as background research for this project.

Scientific collaboration exists with the groups of Prof. H.A. van der Vorst (Utrecht University), and Prof. J.P. Goedbloed (FOM Institute for Plasmaphysics Rijnhuizen). Access is available to the Cray C90 supercomputer at SARA (with 12 CPUs), a Cray T3E parallel computer in Delft (with 80 processing elements), a Cray T3E in Eagan (MN, USA) with 512 processing elements, and to an IBM SP-2 parallel computer at SARA (with 76 nodes).

This project was started in September 1993. 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 (project 95MPR04). This is a joint project of the FOM Institute for Plasmaphysics Rijnhuizen,

Utrecht University (the Mathematical, Astronomical, Computational Physics, and Geodynamics Research Institutes), CWI, the Institute for Marine and Atmospheric Research Utrecht, and the Computational Physics Institute of Delft University of Technology. Additional funding was obtained from a one-year Cray Research Grant of the Dutch National Computing Facilities Foundation NCF (project CRG 96.14: *Parallel Numerical Algorithms for Large Generalized Non-Hermitian Eigenvalue Problems in Linear Magneto-hydrodynamics*), which started in March 1996 and was completed in June 1997 (delayed by three months because of difficulties with the access to a T3D computer at Eagan).

Report

Attention has been focused on the eigenvalue problems arising in the CASTOR finite-element spectral code which has been developed at FOM Rijnhuizen for the stability investigation of tokamak plasmas. The Jacobi-Davidson method of Sleijpen and Van der Vorst appears to be an excellent method for parallel computation of a few selected eigenvalues, because the basic ingredients are matrix-vector products, vector updates and inner products. An existing sequential code for the Jacobi-Davidson method has been taken as a basis for the development of a parallel code for finding several eigenvalues. The first parallel results have been presented at the HPCN Europe '97 conference.
The computation of an approximate solution of a large system of linear equations is usually the most expensive step in the Jacobi-Davidson algorithm. By using a suitable preconditioner, only a moderate number of steps of an inner iteration is required in order to retain fast convergence for the JD process. In Report MAS-R9733 several preconditioning techniques are discussed. It is shown that, for our application, a proper preconditioner is a complete block LU decomposition, which can be used for the computation of several eigenpairs. Reordering strategies based on a combination of block cyclic reduction and domain decomposition result in a well-parallelizable preconditioning technique. The resulting code has been tested on a Cray T3D in Eagan (USA) and on the Cray T3E in Delft using up to 64 processing elements. Comparisons have been made with well-vectorized code implemented on one (fast) processor of a Cray C90. The main reason to study implementations on distributed memory machines like the T3E is the memory bound of shared memory machines. With the current Delft's T3E configuration, we cannot solve larger problems than on the C90. Therefore, we have started to test our algorithms on a large Cray T3E in Eagan (USA) with up to 512 processing elements. Results will be presented at VECPAR '98 in Porto.
The DDCR method has also been implemented in High Performance Fortran (HPF) on the IBM SP2 at SARA. The numerical experiments show that for the DDCR method it is indeed possible to obtain high performance in HPF. Results will be presented at the HPCN '98 conference in Amsterdam.
An essential step in the Jacobi-Davidson algorithm is the projection of the space in which a solution is sought to a much smaller space. Some variations of the original projection operator are being studied. A report is in preparation.
Solvers for block penta- and block heptadiagonal systems of linear equations have been combined with the VAC-code. The preconditioning techniques described in a contribution to HPCN '97 strongly improve the convergence behaviour of iterative methods in the VAC-code. A block-form of the well-known Eisenstat trick guarantees that the memory requirements for the preconditioner are very low, and the matrix-vector multiplication with the preconditioned matrix costs about the same number of floating point operations as the matrix-vector multiplication with the unpreconditioned matrix.

Organization of Conferences, Workshops, Courses, etc.

- *Working Group Parallel Computation in Magneto-hydrodynamics and Astrophysics*
  This group started in October 1993 to discuss the progress in the NWO pilot MPR (Massaal Parallel Rekenen) project *Parallel Computation in Magneto-hydrodynamics and Astrophysics*, and, as of September 1995, in the four-year MPR project 95MPR04 of NWO: *Parallel Computational Magneto-Fluid Dynamics: Nonlinear dynamics of thermonuclear, astrophysical, and geophysical plasmas and fluids*.
  The group met seven times, namely on
  January 15 (at FOM Rijnhuizen, with a contribution by Auke van der Ploeg entitled: Efficient solution of block tridiagonal and block pentadiagonal systems of linear equations),
  February 26 (at the Mathematical Institute, Utrecht University, with a contribution by Margreet Nool entitled: Working with Jacobi-Davidson on the Cray T3D),
  April 21 (at CWI, with a contribution by Auke van der Ploeg entitled: Preconditioners for large sparse linear systems and eigenvalue problems),

June 4 (at FOM Rijnhuizen),
August 27 (at FOM Rijnhuizen with a contribution by Auke van der Ploeg and Margreet Nool entitled: Solution of large eigenvalue problems: can the Cray T3E beat the C90?),
October 15 (at CWI, with a demonstration by Auke van der Ploeg and Margreet Nool of an interactive program for computing eigenvalues),
December 4 (at FOM Rijnhuizen).

- *Working Group Large-Scale Computing*
  This group meets at irregular times, and discusses new developments in high performance scientific computing. Participants come from the University of Amsterdam, the University of Utrecht, Delft University of Technology, the FOM Institute for Plasmaphysics Rijnhuizen, and CWI. In 1997, four meetings took place. The dates, speakers and their subjects were:
  February 14:
  Penny Wijnandts (Faculty WINS, Univ. of Amsterdam), Parallel implementation of Gauss-Huard's method using PVM.
  Kees Dekker (Dept. of Mathematics, Delft University of Technology), Parallel GMRES and Domain Decomposition: Back to Basics
  March 7:
  Menno Genseberger (Utrecht University & CWI), Parallel numerical algorithms based on subspace expansions.
  Mikhail Botchev (Utrecht University), Enhancing stability of time-step integration by low-dimensional residually optimally iterations.
  May 16:
  Freddy Wubs (Groningen University), MRILU, it's the preconditioning that counts.
  Kees Dekker (Dept. of Mathematics, Delft University of Technology), Efficient implementation of a parallel GMRES-type method.
  October 8:
  Gerard Sleijpen (Utrecht University), The main effects of rounding errors in Krylov solvers for symmetric linear systems.
  Auke van der Ploeg, A Parallel Jacobi-Davidson Method for solving Generalized Eigenvalue Problems in linear Magneto-hydrodynamics.
- *APPEL project*
  On February 3, a TMR Research Network Proposal named *APPEL* (Advancing Parallel Processing ExpLoitation) has been submitted to the European Commission by an ERCIM consortium consisting of CCL (UK), CNR/CNUCE (Italy), CWI, FORTH (Greece), GMD (Germany), INRIA (France) and IWR (Switzerland) together with the two companies Dolphin (Norway), which is specialized in hardware and software for Networks of Workstations, and Quadrics Supercomputers World Ltd. (Italy) which is building a new MPP computing system called PQE 2000. CWI Amsterdam (Te Riele) was the coordinator of this proposal.
  APPEL is a Training and Research Network which aims to advance the exploitation of parallel processing in a synergetic fashion across Architecture, Programming Models, and Applications. The focus is on three carefully selected application areas, namely, Financial Systems, Atmospheric Air Quality Control, and Computational Chemistry. Each of them has its own parallel characteristics. Both modern networks of workstations (NOWs) and MPP Systems are considered as potential HPC platforms on which these applications can be run.
  The proposal was rejected on July 25 with assessment: 'generally good proposal, which however contains elements that need improving', and a total score of 78 (out of 100) where the average score of selected proposals was 85.

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

- *Distributed Computing '97*, Amsterdam, January 17, H.J.J. te Riele
- *NICE Symposium HPCN-CFD*, Delft, January 28, A. van der Ploeg
- *HPCN '97*, Vienna, April 28–30, M. Nool (poster presentation with A. van der Ploeg: *Parallel Solution of Generalized Eigenvalue Problems*)
- Summerschool *Multilevel Preconditioning Methods with Parallel Implementation Aspects and Applications in Scientific Computing*, Faculteit Wiskunde & Informatica, Katholieke Universiteit Nijmegen, Nijmegen, May 19–26, M. Genseberger
- *Evaluation Meeting of MPR-clusters*, Veldhoven, May 21, M. Nool (poster presentation), A. van der Ploeg, H.J.J. te Riele
- *Conference on Preconditioned Iterative Solution Methods for Large Scale Problems in Scientific Computing*, PRISM'97, May 27–29, Nijmegen: Hemker (*Convergence Results for 3D Sparse Grid Approaches*), A. van der Ploeg.
- *NWO Symposium Massaal Parallel Rekenen*, Veldhoven, May 22, M. Genseberger, M. Nool, A. van der Ploeg, H.J.J. te Riele
- *Cursus T3E*, Delft, July 1, M. Nool
- *Conferentie voor Numeriek Wiskundigen*, Woudschoten, September 24–26, M. Genseberger, M. Nool, A. van der Ploeg, H.J.J. te Riele

Memberships of Committees and Other Professional Activities

M. Nool:
- Member of the CWI Works Council

A. van der Ploeg:
- Referee of papers for various scientific journals

H.J.J. te Riele:
- Chairman of the ERCIM Parallel Processing Working Group
- Coordinator of ERCIM project proposal *APPEL* (*Advancing Parallel Processing ExpLoitation*) 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*
- Chairman CWI – Bibliotheekcommissie

Visitors

- APPEL TMR Proposal Meeting, January 15: Peter Arbenz (Institute of Scientific Computing, ETH Zürich, Switzerland); Ranieri Baraglia (CNUCE Institute, Pisa, Italy); Hans-Georg Galbas (Institut für Algorithmen und Wissenschaftliches Rechnen, GMD, Sankt Augustin, Germany); Chris Greenough (Dept. for Computation & Information, Rutherford Appleton Laboratory, Chilton, Didcot, UK); Domenico Laforenza (CNUCE Institute, Pisa, Italy); Bernard Philippe (IRISA/INRIA, Rennes, France).
- Carlo Alberto Marchi (Quadrics Supercomputers World Ltd., Rome, Italy), February 10.

Papers in Journals and Proceedings

M. NOOL, A. VAN DER PLOEG (1997). A parallel solution for generalized eigenvalue problems. B. HERTZBERGER, P. SLOOT (eds.). *High-Performance Computing and Networking*, Lecture Notes in Computer Science, Springer-Verlag, 1047–1049.

A. VAN DER PLOEG, R. KEPPENS, G. TÓTH (1997). Block incomplete LU-preconditioners for implicit solution of advection dominated problems. B. HERTZBERGER, P. SLOOT (eds.). *High-Performance Computing and Networking*, Lecture Notes in Computer Science, Springer-Verlag, 412–430.

CWI Reports

MAS-R9733. M. NOOL, A. VAN DER PLOEG. *A Parallel Jacobi-Davidson Method for Solving Generalized Eigenvalue Problems in Linear Magnetohydrodynamics.*

Discontinuous Dynamical Systems – MAS2.4

Staff

- Prof. dr. J.M. Schumacher, project leader
- Dr. A.J. van der Schaft, researcher
- K. Karamazen, Ph.D. student
- M.K. Çamlıbel, Ph.D. student

Scientific Report

The group continued its activities in the modelling of dynamical systems with discontinuities, with particular attention to specification and well-posedness. An important part of the work concentrated on the analysis of piecewise linear systems. Jointly with W.P.M.H. Heemels (Eindhoven/Tilburg) and S. Weiland (Eindhoven), Schumacher defined a new class of dynamical systems called 'Linear complementarity systems', which combine linear dynamics with a complementarity structure such as also occurs in the Linear Complementarity Problem (LCP) of mathematical programming. The mathematical framework of linear complementarity systems applies for instance to linear mechanical systems with unilateral constraints, electrical networks with ideal diodes, and linear-quadratic optimization problems with state constraints. A paper was written which specifies the complete dynamics of linear complementarity systems and gives sufficient conditions for existence and uniqueness of solutions; the paper has been submitted for publication. A follow-up paper is in preparation which gives alternative conditions for well-posedness.

Van der Schaft and *Schumacher* revised their paper on *Complementarity modeling of hybrid systems*, which is now scheduled to appear in *IEEE Transactions on Automatic Control*. They formulated a proposal for a course on Hybrid Systems in the graduate program of the research school Dutch Institute of Systems and Control (DISC). The proposal was accepted, and the course will be taught in March of 1998. Schumacher also undertook editorial activities in the area of discontinuous dynamical systems as a Guest Editor of a special issue on Hybrid Systems of *Automatica*, the journal of the International Federation of Automatic Control (IFAC).

Karamazen took part in the following courses of the DISC graduate program: Design methods for control systems, System and control theory of nonlinear systems, Linear matrix inequalities in control, System identification, and Stochastic signal proces sing in systems and control. In this way he com-

pleted the course requirements of DISC, and he received the corresponding certificate in November. In his research he has studied the possible use of algebraic specification methods for the specification of the dynamics of physical systems that can be described in the bond graph language.

Çamlıbel arrived in the Netherlands in January of 1997 with a fellowship from the Turkish national science organisation TÜBITAK, to do PhD research under Schumacher's supervision. He followed several DISC graduate courses: Linear matrix inequalities in control, System identification, and Mathematical models of systems. Also he co-authored a paper with Lootsma (Twente) and Van der Schaft on the uniqueness of solutions of relay systems. The paper has been submitted for publication.

Organization of Conferences, Workshops, Courses, etc.

J.M. Schumacher:

- 17th Benelux Meeting on Systems and Control Mierlo, the Netherlands, March 4–6, 1998
- Hybrid Systems '97 University of Notre Dame, September 11–13, 1997 (member Program Committee)
- IFAC Conference System Structure and Control, Nantes, July 8–10, 1998 (member Program Committee)

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

- UNIT DISC Day, University of Twente, February 6: A.J. van der Schaft (*Dissipative Systems Theory: Origins and New Developments*), K. Karamazen.
- 16–th Benelux Meeting on Systems and Control, Houffalize, Belgium, March 5–7: M.K. Çamlıbel, A.J. van der Schaft, J.M. Schumacher (*Specification of Hybrid Dynamics*).
- System Theory Day, University of Twente, March 21: M.K. Çamlıbel, K. Karamazen, A.J. van der Schaft, J.M. Schumacher.
- Hybrid and Real-Time Systems 1997, Grenoble, France, March 26–28: A.J. van der Schaft, J.M. Schumacher (*Hybrid Systems Described by the Complementarity Formalism*).
- 32nd Dutch Mathematical Congress, Wageningen, April 3–4: J.M. Schumacher.
- Meeting SWON Large Project *Mathematical Modelling of Open Dynamical Systems*, CWI, May 26: M.K. Çamlıbel (*Complementarity Modeling of Piecewise Linear Systems*), K. Karamazen, A.J. van der Schaft, J.M. Schumacher.
- DISC Summer School on *Neural Networks in Systems and Control*, Zeist, June 24–27: M.K. Çamlıbel, K. Karamazen.
- European Control Conference 1997, Brussels, July 1–4: A.J. van der Schaft (*Hybrid Systems Modeling and Complementarity Problems*), J.M. Schumacher.
- COSY European Science Foundation workshop *Mathematical Modelling of Complex Systems*, Groningen, August 29–30: K. Karamazen, A.J. van der Schaft (*Mechanical Systems Modeling*), J.M. Schumacher (*Hybrid Systems Modeling*).
- Workshop on *Robustness and Stabilization of Nonlinear Systems: Methods and Applications*, Bremen, Germany, September 15–17: A.J. van der Schaft (*Implicit Hamiltonian Systems and Dirac Structures*), J.M. Schumacher (*Hybrid Systems: Mixing the Continuous and the Discrete*).
- Workshop *Operators, Systems and Linear Algebra: Three Decades of Algebraic Systems Theory* in honor of Professor Paul Fuhrmann, Kaiserslautern, Germany, September 23–26: M.K. Çamlıbel, J.M. Schumacher (*Linear Systems and Discontinuous Dynamics*).
- Meeting ASF+SDF'97, CWI, September 25–26: K. Karamazen.
- Meeting SWON Large Project *Mathematical Modeling of Open Dynamical Systems*, Groningen, November 28: M.K. Çamlıbel, K. Karamazen, A.J. van der Schaft (*Stability of Interconnected Mechanical Systems*), J.M. Schumacher.

Memberships of Committees and Other Professional Activities

J.M. Schumacher:

- Professor of Mathematics (0.2), Tilburg University.
- Corresponding Editor *SIAM Journal on Control and Optimization*.
- Associate Editor *Systems and Control Letters*.
- Guest Editor *Automatica* (Special Issue on Hybrid Systems).
- Member editorial board, *CWI Tracts & Syllabi* Series.
- Ph.D. committee A.A. ten Dam, Groningen, June 23.
- Ph.D. committee P. Smit, Tilburg, October 17.
- Ph.D. committee R.A.B. van der Geest, Twente, October 31.
- Ph.D. committee J.C. de Vos, Tilburg, December 3.
- M.Sc. committee J.W. Bohlander (Eindhoven University of Technology, Department of Electrical Engineering), February 10.
- Ph.D. advisory committee F. Kraffer (University of Twente, Department of Applied Mathematics)

- Ph.D. advisory committee E.J. Quirijns (Wageningen Agricultural University, Department of Agricultural Technology and Physics)
- Member research school Dutch Institute of Systems and Control (DISC); member DISC Management Team and head of DISC department at CWI
- Fellow, Center for Economic Research (CentER), Tilburg University

Visitors

- Prof. B. Brogliato (Laboratoire d'Automatique de Grenoble), December 18–19.

Papers in Journals and Proceedings

M.K.K. CEVIK, J.M. SCHUMACHER (1997). Regulation as an interpolation problem. *Linear Algebra and Its Applications* **253**, 311–340.

W.P.M.H. HEEMELS, J.M. SCHUMACHER, S. WEILAND (1997). Complementarity models of physical systems. *Proc. IEEE Conf. Dec. Contr.*, San Diego, 1243–1248.

U. HELMKE, J. ROSENTHAL, J.M. SCHUMACHER (1997). A controllability test for general first-order representations. *Automatica* **33**, 193–201.

M.S. RAVI, J. ROSENTHAL, J.M. SCHUMACHER (1997). Homogeneous behaviours. *Math. Control Signals Systems* **10**, 61–75.

J. ROSENTHAL, J.M. SCHUMACHER (1997). Realization by inspection. *IEEE Trans. Automat. Contr.* **AC–42**, 1257–1263.

A.J. VAN DER SCHAFT, J.M. SCHUMACHER (1997). Hybrid systems described by the complementarity formalism. O. MALER (ed.). *Hybrid and Real-Time Systems, Proc. Intl. Workshop HART'97*, Grenoble, France, March 1997. Lect. Notes Comp. Sci. **1201**, Springer, Berlin, 403–408.

A.J. VAN DER SCHAFT, J.M. SCHUMACHER (1997). Hybrid systems modeling and complementarity problems. *Proc. European Control Conference*, Brussels, nr. 868 (CD-ROM).

J.M. SCHUMACHER (1997). Linear systems and discontinuous dynamics. U. HELMKE, D. PRAETZEL-WOLTERS, E. ZERZ (eds.). *Operators, Systems, and Linear Algebra*, B.G. Teubner, Stuttgart, 182–195

CWI Reports

MAS-R9736. U. BAŞER, J.M. SCHUMACHER. *Descriptor representations of jump behaviours*.

Other Publications

W.P.M.H. HEEMELS, J.M. SCHUMACHER, S. WEILAND (1997). *Linear Complementarity Systems*, Report 97 I/01, Measurement and Control Systems, Dept. of Electrical Engineering, Eindhoven University of Technology.

Y. LOOTSMA, A.J. VAN DER SCHAFT, M.K. ÇAMLIBEL (1997). *Uniqueness of Solutions of Relay Systems*, Memorandum 1406, Dept. of Appl. Math., University of Twente.

Computational Number Theory and Data Security – MAS2.5

Staff

- Dr.ir. H.J.J. te Riele, project leader
- Drs. W.M. Lioen, scientific programmer
- D.T. Winter, scientific programmer
- Dr. P.L. Montgomery (San Rafael, Ca., USA), researcher
- Drs. S. Cavallar, Ph.D. student
- O. Penninga (Leiden University), trainee

Scientific Report

Introduction

Computational number theory studies problems from elementary, algebraic and analytic number theory which require the help of fast computers, particularly vector and parallel systems. This enlarges knowledge, insight and understanding in this field and leads to mathematical and numerical solution techniques for the problems studied. Many problems in this field are extremely suitable for parallelization, and can be used as test-cases for HPCN techniques. The emergence of public-key cryptography has particularly triggered the study of algorithms for factorization and primality testing, for computing discrete logarithms, and for the solution of large sparse systems of linear equations over finite fields. These algorithms are the main study objects in this project. If time and man power permits, additional research will be carried out on problems which have traditionally been studied at CWI in the past, like the Riemann hypothesis, the Goldbach conjecture, special number-theoretic (aliquot) sequences and cycles (like amicable numbers), continued fractions of algebraic numbers, and the systematic computation of multiplicative number-theoretic functions with help of a generalization of the sieve of Eratosthenes.
For these tasks the group has access to the idle cycles of about 80 SGI workstations at CWI, the Cray C90 supercomputer (with 12 CPUs) and an IBM SP-2 parallel computer (with 76 nodes) at SARA.
Scientific collaboration exists with (the groups of)

Prof. R.P. Brent (The Australian National University, Canberra, Australia), Prof. G.L. Cohen (University of Technology, Sydney, Australia), Prof. J.-M. Deshouillers (Univ. Bordeaux 2, France), Prof. M. García (New York, USA), Dr. A.K. Lenstra (Citibank, New York, USA), Dr. P.L. Montgomery (San Rafael, California, USA), J.M. Pedersen (Vejle Business College, Vejle, Denmark), Prof. M. van der Put (Groningen University), Dr. Y. Saouter (Institut de Recherche en Informatique Toulouse, France), and Prof. R. Tijdeman (Leiden University).

Report

Factorization with the Number Field Sieve (NFS) (S. Cavallar, 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 her doctor's thesis. The CWI NFS program was used to factor several Most and More Wanted numbers in the Cunningham and the Extended Cunningham Tables.
On September 3, a new factoring world record was established at CWI by the computation of the factors of the 180-digit number $N = (12^{167} + 1)/13$ with the Special Number Field Sieve algorithm. The previous record for SNFS was the 167-digit number $(3^{349} - 1)/2$, completed by NFSNET (Number Field Sieve NETwork) on February 4. The sieving part of the NFS program used was at least 30 % faster than the version used for the 167-digit record, primarily due to better cache utilization and fewer mispredicted branches. The sieving lasted 10.3 calendar days spanning two weekends, from August 22 to September 2, 1997. During this period, 85 SGI machines (a mixture of O2's, Indy's, R4600's, and one PowerChallenge) contributed a combined 13027719 relations in 560 machine-days. It took 1.6 more calendar days to process the data. This processing included 16 CPU-hours on the Cray C90 at SARA to carry out the Block Lanczos iterative algorithm for finding dependencies in a 1969262×1986500 matrix with 57942503 nonzero entries.
A new subproject was started to implement the Wiedemann method for solving large sparse linear equation over finite fields, and to investigate the suitability for parallel execution of this method. A comparison will be made with an implementation by Montgomery of the block Lanczos method. Solving large sparse linear systems over GF(2) is an important step in sieve-based factoring methods (like NFS), and a reduction of the memory requirements in this step is crucial for further improvement of these algorithms.

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 his doctor's thesis.

Extending the Cunningham table (P.L. Montgomery, H. Boender, S. Cavallar, R.-M. Elkenbracht-Huizing, W.M. Lioen, H.J.J. te Riele, D.T. Winter).
Montgomery and Boender 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 and MPQS factoring methods. Most of the work was carried out on 70 SGI workstations at CWI and 30 workstations at Leiden University. A third update to this table (originally published as Report NM-R9419 in September 1994) will be published in 1998: all composites smaller than 10^{100} are scheduled to be factored in this update.
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.

The Goldbach conjecture (W.M. Lioen, H.J.J. te Riele)
The Goldbach conjecture has been checked completely up till the bound 10^{14} and partially near various powers of ten up till 10^{300}. This result has been applied to reduce the lower bound in the three-primes version of the Goldbach conjecture as studied by Hardy & Littlewood and by Vinogradov.

Amicable and related numbers (H.J.J. te Riele)
In 1995, Jan Munch Pedersen of Vejle Business College in Vejle, Denmark, started to create a list of all the known amicable pairs. This list can be accessed through the World Wide Web via URL
http://www.vejlehs.dk/staff/jmp/aliquot/knwnap.htm
The number of pairs in this list now exceeds $300,000$. A survey paper which documents the main developments leading to this explosion of known amicable pairs is in preparation.
The joint paper with Graeme Cohen on ϕ-amicable pairs (analogues of Carmichael's multiply amicable pairs), has been accepted for publication in *Mathematics of Computation* (NM-R9524).

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

- *Algemeen CWI Colloquium*, January 14: R.-M. Elkenbracht-Huizing (Factoring by the Number Field Sieve)
- *Wiskunde Colloquium*, Groningen, January 21: H.J.J. te Riele (Ontbinden van grote getallen in priemfactoren: de stand van zaken)

- *Intercity Colloquium Getaltheorie*, Universiteit van Amsterdam, January 31: R.-M. Elkenbracht-Huizing (Factoring by the Number Field Sieve), H.J.J. te Riele (Computations related to Goldbach's conjecture)
- *Universities of Bordeaux 1 and 2*, February 26–28: H.J.J. te Riele (New computations concerning the Goldbach conjecture)
- *Intercity Colloquium Getaltheorie*, Mathematisch Instituut RU Leiden, June 6: S. Cavallar, H.J.J. te Riele (Monte Carlo methods and low-discrepancy sequences applied to problems in mathematical finance)
- *Vorking visit Math. Instituut RU Groningen*, June 24: S. Cavallar, H.J.J. te Riele
- *Lecture Day on Computational Finance*, Delft, June 25: H.J.J. te Riele
- *SARA HPCN Gebruikersdag*, Vrije Universiteit Amsterdam, November 12: W.M. Lioen, H.J.J. te Riele (Het Goldbach vermoeden: op superhoogte met supercomputers?)

Memberships of Committees and Other Professional Activities

H.J.J. te Riele:
- See section MAS 2.3.

Visitors

- Tim Langtry (University of Technology, Sydney), December 10–12.
- Spassimir Paskov (Barclays Bank, New York), December 12.

Papers in Journals and Proceedings

J.-M. DESHOUILLERS, G. EFFINGER, H. TE RIELE, D. ZINOVIEV (1997). A complete Vinogradov 3-primes theorem under the Riemann hypothesis. *Electronic Research Announcements of the AMS* **3**, 99–104. URL: http://www.ams.org/journals/era/home-1997.html .

R.-M. ELKENBRACHT, P.L. MONTGOMERY, R.D. SILVERMAN, R. WACKERBARTH, S.S. WAGSTAFF, JR. (1997). The number field sieve on many computers. RAJIV GUPTA, KENNETH S. WILLIAMS (eds.). *Proceedings of the Fifth Conference of the Canadian Number Theory Conference*, Amer. Math. Soc., to appear.

PETER L. MONTGOMERY, STEFANIA CAVALLAR, HERMAN TE RIELE (1997). A new world record for the special number field sieve factoring method. *CWI Quarterly* **10**(2).

Other Publications

H. BOENDER (1997). *Factoring Large Integers with the Quadratic Sieve*, Ph.D. thesis, Leiden University.

R.M. ELKENBRACHT-HUIZING (1997). *Factoring Integers with the Number Field Sieve*, Ph.D. thesis, Leiden University.

Modelling of Processes in Biology and Chemistry – MAS2.6

Staff

- Prof. dr. P.W. Hemker, project leader
- Ir. W.J.H. Stortelder, Ph.D. student (until May 1)
- Dr. M. Kirkilionis, researcher (until October 1)
- Drs. A. de Koeijer, Ph.D. student (until March 1)
- T. Hantke, Ph.D. student (until March 1)

Scientific Report

During 1997 the work in this sub-theme was finished.

Stortelder completed the draft of his thesis on *Parameter Estimation in Nonlinear Dynamical Systems*. It is expected that, based on this work, he will receive the doctor's degree from the University of Amsterdam in March 1998. It concludes the STW-project CWI22.2695: *Parameter-identificatie en model-analyse voor niet-lineaire dynamische systemen*. The work described in the thesis also resulted in a piece of software, called *SPIDS*, that serves as a tool for parameter estimation in modeling of dynamical systems that are described by systems of differential-algebraic equations.

In the framework of the STW-project it is was possible to construct a system that serves as a tool for the analysis of dynamical systems as they arise in modeling of real-life problems e.g. in (bio)chemistry and biology. Many applictions of the system are described in the thesis. Two copies of the system (including hardware and sofware) were realized and were used in practice, a.o. at SRTCA (Amsterdam) and at Akzo-Nobel (Arnhem). Soon the system will also be used at the Biomedical Centre of the University of Maastricht. In the past years many demonstrations were given with the system e.g. by J. Kok at the *Wiskundige Werkvloer* (see above).

The work of *Kirkilionis* was financed by the NWO via the MPR (Massaal Parallel Rekenen) project. This project focuses on individual-based modeling of biological systems, an approach where parallel algorithms have to be used because of the complexity

of the computations. The MPR subcluster *Numerical continuation methods for physiologically structured population models* is developing new numerical techniques for this kind of individual-based modeling. Continuation and also bifurcation analysis are very useful for the investigation of the asymptotic behaviour of such models when certain model parameters are varied.
The above described research is part of the activities of the MPR cluster 'Biologisch-dynamische systemen'. Several meetings took place during 1997 which were meant to coordinate the different activities of the subclusters. Members of the cluster include Prof. Kooijman (VU Amsterdam), Dr. Kooi (VU Amsterdam), Dr. Kaandorp (UvA), Dr. Sommeijer (CWI) and Prof. Diekmann (U Utrecht).
The algorithms developed were all implemented in the software package BASE. It can carry out continuation and bifurcation computations for a variety of problems. The software can be downloaded from the CWI ftp server.

Aline de Koeijer continued working on animal epidemiology. Extending the basic mathematical epidemiological work of Kermack and McKendrick from around 1920, the spread of infectious diseases in herds is studied. This is currently a main research topic.
Aline de Koeijer, now working for the Institute of Animal Science and Health, studied the influences of separate risk factors of the BSE infection in cattle (mad cow disease). Also a case study is continued on estimating the extinction time of a herpes virus infection (BHV) in cattle herds. The results of this research may support present attempts to eradicate BHV in the Netherlands. Part of this research has been carried out at the CWI.

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

- Werkbezoek SRTCA, Amsterdam, January 10, Hemker, Kok.
- MPR meeting, Congress centre 'Koningshof' in Veldhoven. General assembly of all MPR clusters. May 22, 1997 (Kirkilionis).
- TechKnowledge Fair, May 28–30, Jaarbeurs Utrecht: A demonstration of SPIDS was given by J. Kok.
- CIME '97, Martina Franca, Italy: A workshop on mathematical modeling. June 12–21 (Kirkilionis).
- International Conference on Deterministic and Stochastic Modeling of Biointeraction, Sofia, Bulgaria. August 28–31 (Kirkilionis).
- September 12–13 (Kirkilionis) workshop on *Structured Populations*, Leeds, UK.
- Meeting *Interactions in space: Improving the mean field approximation*, University of Leiden, Lorentz centre, The Netherlands. October 29–November 1 (Kirkilionis)

CWI Reports

MAS-R9705. J.D. PINTER, W.J.H. STORTELDER, J.J.B. DE SWART. *Computation of elliptic Fekete point sets.*

MAS-R9714. M.A. KIRKILIONIS, O. DIEKMANN, B. LISSER, M. NOOL, A.M. DE ROOS, B.P. SOMMEIJER. *Numerical continuation of equilibria of physiologically structured population models. I. Theory*.

Mathematics of Finance – MAS2.7

Staff

- Prof. dr. J.M. Schumacher, project leader
- Dr. J. Hoogland, researcher

Scientific Report

The project is new and in 1997 it has been in a start-up phase, in which much effort has been spent on building expertise, establishing contacts, and extending the group. In January the group was started with Schumacher as its only formal member. The project was extended in May by the appointment of Hoogland. Throughout the year also Te Riele (MAS2.3, MAS2.5) took considerable part in the activities.
During 1997, *Schumacher* acted as coordinator for the Special Year on the Mathematics of Finance that was funded by the mathematics branch SWON of the national science organisation NWO. This took much time, but the events that were organized (several lecture days, an introductory course, and an advanced workshop) were highly informative and, in addition to that, gave much opportunity to build up contacts in the area of mathematical finance both with the academic world and with the financial industry. In the spring semester, Schumacher organized a biweekly seminar on mathematical finance at CWI; during the fall semester, these activities were continued in a smaller reading group.

Hoogland started work as a CWI employee in May, although already before he had taken part extensively in seminar activities on mathematical finance at CWI. He has developed research activities both in computational finance and in the construction of financial models. In particular he has cooperated

with R.H.P. Kleiss (Nijmegen) on error estimates for Quasi-Monte Carlo (QMC) computations. The QMC method is a promising computational technique available for the valuation and hedging of financial derivatives depending on a large number of independent variables. A manuscript on the asymptotic distribution of discrepancies of point-sets, important for the proper use of QMC methods, has been submitted for publication. Further activities have included the modeling of event risk, the construction of low-discrepancy sequences (which form the basis of the Quasi-Monte Carlo method), and the valuation of derivatives with early-exercise opportunities. Together with colleagues at the universities of Delft, Groningen, and Twente, Schumacher prepared a proposal for a SWON project on Financial Derivatives. The project has received funding and will start in 1998.

Organization of Conferences, Workshops, Courses, etc.

J.M. Schumacher:

- Coordinator, Special Year on Mathematical Finance. Funded by SWON.
- Lecture Day *Finance and Optimization*, CWI, April 18.
- Workshop *Mathematics of Finance*, Amersfoort, December 15–17.
- CWI Study Group on Mathematical Finance. Subject spring semester 1997: Monte Carlo and Quasi-Monte Carlo methods.

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

- Conference *IMACS Seminar on Monte Carlo Methods*, Bruxelles, Belgium, April 1–3: J.K. Hoogland (*Quasi-Monte Carlo: Discrepancy Limits and Error-estimates*).
- Lecture Day *Finance and Optimization*, CWI, Apri: 18. J.K. Hoogland, J.M. Schumacher.
- Lecture Day *Interest Rate Models and Interest Rate Derivatives*, University of Twente, June 13: J.K. Hoogland, J.M. Schumacher.
- Lecture Day *Computational Finance*, Delft University of Technology, June 25: J.K. Hoogland, J.M. Schumacher.
- Lecture Day *Finance and Stochastics*, Utrecht University, October 3: J.K. Hoogland, J.M. Schumacher.
- Short Course on Mathematical Finance, University of Groningen, November 3–7: J.K. Hoogland, J.M. Schumacher.
- MAS-colloquium *Low-discrepancy Sequences with Applications in Mathematical Finance*, CWI, December 12: J.K. Hoogland (*Central Limits and Error Estimates for Quasi-Monte Carlo*), J.M.Schumacher.
- Workshop *Mathematics of Finance*, Amersfoort, December 15–17: J.K. Hoogland, J.M. Schumacher.

Visitors

- Dr. S.H. Paskov (Barclays Capital Group, New York), December 12.
- Prof. dr. T. Langtry (University of Technology, Sidney, Australia), December 11–12.

Other Publications

C. HEIJ, J.M. SCHUMACHER, B. HANZON, C. PRAAGMAN (1997). Introduction. C. HEIJ, J.M. SCHUMACHER, B. HANZON, C. PRAAGMAN (eds.). *System Dynamics in Economic and Financial Models*, Series in Financial Economics and Quantitative Analysis, Wiley, Chichester, xvii–xxvi.

C. HEIJ, J.M. SCHUMACHER, B. HANZON, C. PRAAGMAN (eds.) (1997). *System Dynamics in Economic and Financial Models*, Series in Financial Economics and Quantitative Analysis, Wiley, Chichester

Exploratory Research – MAS2.8

Staff

- Prof. dr. P.W. Hemker, project leader
- Dr. N.M. Temme, researcher

Scientific Report

In the framework of the NWO-project *Reliability and parallel computational efficiency in scientific computing* (NWO EB 047.003.017), a close cooperation existed between Hemker and Prof. dr. G.I. Shishkin and his group (Institute of Mathematics and Mechanics, Ural Branch of the Russian Academy of Science (UBRAS). In cooperation with Prof. Axelsson (KUN) regular workshops were organized with Russian numerical analysts to discuss the cooperation. Intensive interaction was possible also by e-mail contacts and longer visits.

In 1997 *Hemker* and *Shishkin* developed efficient numerical methods for singularly perturbed boundary value problems. To improve the order of ϵ-uniform convergence with respect to the time variable, they constructed a new method based on defect correction. The method has second-order accuracy in

space (up to a logarithmic factor) and higher-order accuracy in time. This new method uses the same grid for solving the different auxiliary problems; due to this fact the method becomes more convenient for application in practice. Particular attention was paid to the case of Neumann's problem.

To solve the discrete equations based on the defect correction principle, they developed effective parallel algorithms that can be easily implemented. This method allows us to improve the time-accuracy, maintaining ϵ-uniform second-order accuracy in space, and to parallelize computations for a parabolic PDE.

For singularly perturbed parabolic equations with a concentrated disturbance of the initial data (with a support of diameter 2δ) they constructed a novel difference scheme, based on floating condensed meshes, that converges (ϵ, δ)-uniformly.

Temme concluded a series of three papers with Prof. K.A. Driver (South Africa) on Hermite-Padé approximations to the exponential function. Uniform asymptotic methods for integrals have been used to obtain a precise description of the distribution of the zeros of polynomials and remainders that arise in the approximations. A description of the zeros has been given in terms of the zeros of Airy functions, in particular for the classical Padé approximations to the exponential function. Temme continued research on numerical Airy-type approximations for a class of special functions, and on model problems in singular perturbation theory.

Organization of Conferences, Workshops, Courses, etc.

P.W. Hemker:

- Second Workshop Cooperative Project *Reliability and Parallel Computational Efficiency in Scientific Computing* (NWO 047.003.017), University St.Petersburg, Russia, June 27.
- Third Workshop Cooperative Project *Reliability and Parallel Computational Efficiency in Scientific Computing* (NWO 047.003.017), CWI, Amsterdam, November 19.
- International workshop on the *Numerical Solution of Thin Layer Phenomena*, CWI, Amsterdam, November 20–21.
  In this workshop, that was also organized in the framework of the project NWO 047.003.017, more than 30 participants from 8 different counties discussed problems related with the numerical solution of singular perturbation problems. Lectures were held by the following people: M. Stynes (UC Cork, Ireland) & R.B. Kellogg *Optimal approximability of thin-layer solutions of differential equations*; A.E.P.Veldman (Univ. Groningen) *Strong Viscous-Inviscid Interaction and the Effects of Streamline Curvature*; J.J.H. Miller, (Univ. Dublin) E. O'Riordan, G.I. Shishkin *A Review of some Results on Parameter-robust Numerical Methods for Singular Perturbation Problems*; H. MacMullen, J.J.H. Miller, E. O'Riordan (Dublin City Univ.) and G.I. Shishkin *Overlapping Schwartz method for singularly perturbed reaction-diffusion problems*; W.H.A. Schilders (Philips Research Laboratories) *Singularly perturbed problems in the electronics industry*; Alan Hegarty (Univ. Limerick) *Numerical solution of convection-diffusion problems on fitted meshes*; Rein van der Hout (Akzo Nobel Central Research) *Flow alignment of nematic liquid crystals in plane or cylindrical Poiseuille-type flow*; H.-G. Roos (TU Dresden) *Finite Elements on Layer Adapted Grids for Singularly Perturbed Problems*; J.A. Mackenzie (Univ. Strathclyde) and G. Beckett *Uniform convergent difference schemes for singularly perturbed boundary value problems using mesh equidistribution*; G. Beckett (Univ. Strathclyde) and J.A. Mackenzie *The adaptive solution of self-adjoint boundary value problems using a posteriori error estimates and grid equidistribution*; M. Stynes & L. Tobiska (Univ. Magdeburg) *Analysis of Streamline-Diffusion-Type Methods on Arbitrary and Shishkin Meshes*; G. Lube (Univ. Göttingen), R. Hangleiter & F.-C. Otto *Stabilized Galerkin methods and layer-adapted grids for elliptic problems*; Pieter de Groen (Vrije Univ. Brussel) *Exponentially slow waves in a Burgers' type equation*; Owe Axelsson (KU Nijmegen) and Mariana Nikolova *Uniform in epsilon convergence of finite element methods for convection diffusion equations using a priori chosen meshes*; Owe Axelsson and Mariana Nikolova (KU Nijmegen) *Avoiding Slave Points in Adaptive Refinement Procedure for Convection-Diffusion Problems in 2D*; Riccardo Sacco (Politecnico di Milano) and Fausto Saleri *Stabilized Mixed Finite Volume Methods for Convection-Diffusion Problems*; P.W.Hemker, G.I.Shishkin and L.P.Shishkina (IMM, Ekaterinburg) *A Numerical Method on Floating Meshes for Singularly Perturbed Problems with a Concentrated Disturbance of the Initial Data*.

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

- Oberwolfach Meeting on *Adaptive Methods for Partial Differential Equations*, February 16–22,

P.W. Hemker.
- Workshop on *Asymptotics* (Hong Kong), May 22–28: N.M. Temme (*Analytical Methods for an Elliptic Singular Perturbation Problem in a Circle*).
- The *First Pan-China Conference on Differential Equations* (Kunming, China) May 31 – June 3: Temme (*Analytical Methods for a Selection of Elliptic Singular Perturbation Problems*).
- *International Algebraic Conference Dedicated to the Memory of D.K. Faddeev*, St. Petersburg, June 24–30: P.W. Hemker (*Convergence results for 3D sparse grid methods*), G.I. Shishkin (*On Discrete Methods Arising in the Numerical Solution of Singularly Perturbed Convection-diffusion Problems*).
- Meeting *Reliability and Parallel Computational Efficiency in Scientific Computing*, St. Petersburg, June 26: P.W. Hemker, G.I. Shishkin (*A Method of Floating Meshes for Singularly Perturbed Boundary Value Problems with a Local Disturbance of the Initial Data. Equations with Convective Terms*).
- Workshop on the *NIST Digital Library of Mathematical Functions* (NIST, USA) July 28–31: N.M. Temme (*Numerical Evaluation of Special Functions: Airy-type Expansions*).
- Workshop IFIP Working Group 2.5 on *Numerical Software*, Albuquerque, NM, USA, October 15–21, Hemker.
- NWO-project workshop, Amsterdam, November 19, P.W. Hemker, G.I. Shishkin, (*Parallel Methods Based on a Defect-correction Technique for Parabolic Singularly Perturbed Problems*).
- The International Workshop *The Numerical Solution of Thin Layer Phenomena*, Amsterdam, November 20–21, P.W. Hemker, G.I. Shishkin, (*A Numerical Method on Floating Meshes for Singularly Perturbed Problems with a Concentrated Disturbance of the Initial Data*).
- Conference *Tricomi's Ideas and Contemporary Applied Mathematics* to celebrate the 100th anniversary of the birth of Francesco G. Tricomi (Rome and Turin, Italy) November 28–December 2: N.M. Temme (*Recent Problems from Uniform Asymptotic Analysis of Integrals in Particular in Connection with Tricomi's $\Psi-$Function*).

Memberships of Committees and Other Professional Activities

P.W. Hemker:
- Professor of Industrial Mathematics, University of Amsterdam.
- Member Working Group 2.5 on Numerical Software, IFIP.
- Member Numerical Algorithms Group, NAG Inc.
- Beoordelingscommissie SWON (since May 1), member.
- Werkgemeenschapscommissie Werkgemeenschap Numerieke Wiskunde, member.
- Thesis Advisor P.M. de Zeeuw, *Acceleration of Iterative Methods by Coarse grid Corrections*, University of Amsterdam, 22 January.
- M.Sc. Committee M. Genseberger, University of Amsterdam, January 29 (member).
- Ph.D. Committee W.A. van der Veen, University of Amsterdam, May 21 (member).
- M.Sc. Committee J.A. Baker, University of Amsterdam, May 26 (member).
- M.Sc. Committee T. van Noorden, University of Amsterdam, October 2 (member).
- Thesis Advisor M. Maes, *Mathematical Methods for Reflector Design*, University of Amsterdam, October 6.
- M.Sc. Committee M. Nie, University of Amsterdam, November 5 (member).
- Ph.D. Committee J. de Swart, University of Amsterdam, November 28 (member).
- Ph.D. Committee N. Hakimi, Vrije Universiteit Brussel, November 28 (member).

N.M. Temme:
- Board of the *Thomas Stieltjes Institute for Mathematics* (advisory member).
- CWI Scientific Meetings (chair).
- Member of the board of editors of *Mathematics of Computation, SIAM Journal on Mathematical Analysis, ZAMP, Methods and Applications of Analysis, CWI Quarterly, Nieuws Analyse*.
- Associate editor of *The Digital Library of Mathematical Functions: A Web-Based Descendant of AMS 55 (Handbook of Mathematical Functions)*.

Miscellaneous

P.W. Hemker:
- Guest editor for a Special Issue on Multilevel Methods of *Applied Numerical Mathematics*, Volume 23, Number 1, February 1997. (ISSN 0168-9274)
- Review and referee work for *ANM, Computing, IMA, ITW, JCAM, JCP, NATO, NSF, Math Reviews, SIAM, ZAMM.*

N.M. Temme:
- Review and referee work for *Journal of Approximation Theory, Constructive Approximations, Mathematics of Computation, SIAM Journal on Mathematical Analysis, ZAMP, Methods and Applications of Analysis, Journal of Computational and Applied Mathematics, Zentralblatt für Mathematik.*

Visitors

- Prof. dr. G.I. Shishkin (Institute of Mathematics and Mechanics, Ural Branch of the Russian Academy of Science (UBRAS), Ekaterinburg, Russia), November 12 – December 3.
- Dr. L.P. Shishkina (Scientific Research Institute of Heavy Machine Building, Ekaterinburg, Russia), November 12 – December 3.
- Prof. C. Grossmann, (Mathematics and Computer Science, Kuwait University, Kuwait) November 17–22.

Papers in Journals and Proceedings

N.M. TEMME (1997). Numerical algorithms for uniform Airy-type asymptotic expansions. *Numerical Algorithms* **15**, 207–225.

P.W. HEMKER, G.I. SHISHKIN, L.P. SHISHKINA (1997). The use of defect correction for the solution of parabolic singular perturbation problems. *ZAMM*, **77**(1), 59–74.

CWI Reports

MAS-R9701. K.A. DRIVER, N.M. TEMME. *Zero and pole distribution of diagonal Padé approximants to the exponential function*.

MAS-R9706. N.M. TEMME. *Numerical algorithms for uniform Airy-type asymptotic expansions*.

MAS-R9716. K.A. DRIVER, N.M. TEMME. *On polynomials related with Hermite–Padé approximations to the exponential function.*

MAS-R9726. K.A. DRIVER, N.M. TEMME. *Asymptotics and zero distribution of Padé polynomials associated with the exponential function*.

MAS-R9727. N.M. TEMME. *Analytical methods for a selection of elliptic singular perturbation problems.*

Other Publications

P.W. HEMKER, G.I. SHISHKIN, L.P. SHISHKINA (1997). On discrete methods arising in the numerical solution of singularly perturbed convection-diffusion problems. *Abstracts of the International Algebraic Conference dedicated to the memory of D.K.Faddeev*, St. Petersburg, 56.

P.W. HEMKER, G.I. SHISHKIN, L.P. SHISHKINA (1997). The use of defect correction on unified time grids for the solution of parabolic singular perturbation problems. *Abstracts of the Sixth International Colloquium on Numerical Analysis and Computer Science with Applications*, Plovdiv, p. 54.

P.W. HEMKER, G.I. SHISHKIN, L.P. SHISHKINA (1997). A numerical method on floating meshes for singularly perturbed problems with a concentrated disturbance of the initial data. *Abstracts of the International Workshop on the Numerical Solution of Thin Layer Phenomena*, Amsterdam, p. 20.

INFORMATION SYSTEMS

General

The cluster Information Systems (INS) was established in January 1997 as a merger of the former Department of Algorithms and Architecture, and a major portion of Interactive Systems. The research themes assembled deal with most aspects of digital information systems, such as database technology, multimedia authoring, and digital libraries. A fundamental and theoretical angle is taken in the area of quantum computing, which promises major breakthroughs when it comes to processing large quantities of unstructured information and to factorize large numbers.

Most of the work in INS is driven by maintaining a balanced position between experimental, theoretical, and methodological work. In line with this, the theme members maintain close contacts with industry and many are involved in cooperative R&D activities. Moreover, were appropriate we take a proactive role to stimulate technology driven spinoff companies by former members. In recent years, Data Distilleries, General Design, and Digicash have effectively transfered research results into commercial products.

A strong portfolio of strategic research collaborations is maintained through many contracts from SION, STW, HPCN, and NWO with our peers at all Dutch universities. Knowledge transfer is further facilitated with part-time positions held by the senior researchers. In particular, De Bra, Van Eijk, Hazewinkel, Kersten, and Meertens hold a professorship position at a university.

A few activities in 1997 deserve special attention. INS3 has taken up the challenge created by the reorganization in bridging the gap between Computer Science and information management in pure Mathematics. Novel results in the area of digital libraries are likely to emerge in the coming period.

INS1 has initiated a large National project in the area of content-based retrieval of multimedia databases. This project is expected to be amongst the first to be started in the Telematics Institute. It aligns with special program initiated by NWO to foster this area of research through their subsidiary SION in the coming years.

In addition to the research products mentioned in the remaining section, we have observed a steady increase in access to the digital library of CWI electronic reports. In 1997 ca. 28000 (1996:14760, 1995:11037, 1994:5319) copies of internal CWI reports where downloaded. Interest in results produced by INS remains high with ca. 12000 downloads in 1997. The top reports accessed remain AA/CS-R9406 (2773), AA/CS-R9531 (1192), and AA/CS-R9429 (1182) all dealing with data mining.

Hiring qualified people has been a major concern. Many vacancies have been fulfilled using temporary contracts with visitors from abroad. Especially, INS1 and INS3 have seen a major change in their population.

Staff 1997

- Data Mining and Knowledge Discovery – INS1
  - A.P.J.M. Siebes
  - J.F.P. van den Akker
  - M. Bakker
  - I. Bartolini
  - P.M.E. De Bra
  - M.A. van den Brink
  - J.R. Castelo
  - F. van Dijk
  - W.H.A. Fieten
  - K. van 't Hoff
  - S. Karlsson
  - M.L. Kersten
  - W.D. Kwakkel
  - R. Leguijt
  - S. Manegold
  - T. Müller
  - J. Pellenkoft
  - H. Sprangers
  - Z.R. Struzik
  - F.J. Tuinstra
  - F. Waas
  - M.A. Windhouwer
- Multimedia and Human – Computer Interaction – INS2
  - D.C.A. Bulterman
  - A.M. Bleeker
  - J.A.F.C. van Disseldorp
  - H.L. Hardman
  - A.J. Jansen
  - L.G.L.T. Meertens
  - K.S. Mullender
  - S. Pemberton
  - L.W. Rutledge
  - L. Salvail
  - M. Theodoridou
  - O.J.M. Weber

- Interactive Information Engineering – INS3

  - P.J.W. ten Hagen
  - F. Denz
  - S. van Dongen
  - D.J.N. van Eijck
  - N. Francez
  - A.V. Groenink
  - M. Hazewinkel
  - I. Herman
  - J.E.A. van Hintum
  - M.S. Marshall
  - J.M.G.G. de Nivelle
  - H. Noot
  - M. Pauly
  - M.M. de Ruiter
  - Zs.M. Ruttkay
  - M.H.F. Savenije

- Quantum Computing and Advanced Systems – INS4

  - P.M.B. Vitányi
  - A.E. Brouwer
  - H.M. Buhrman
  - R. Cramer
  - W. van Dam
  - H.H. Ehrenburg
  - L. Fortnow
  - F. Gruau
  - P.D. Grünwald
  - D. van Melkebeek
  - B. Terhal
  - L. Torenvliet
  - J.T. Tromp
  - R.M. de Wolf

Data Mining and Knowledge Discovery – INS1

Staff

- Dr. A.P.J.M. Siebes, theme leader
- Drs. J.F.P. van den Akker, Ph.D. student (SION), till November 1
- Prof. dr. P.M.E. De Bra, senior researcher, part time (TUE)
- Ing. M.A. van den Brink, programmer, March 1 till August 16
- J.R. Castelo, Comp.Eng., researcher, till July 1 and from October 1
- Drs. F. van Dijk, programmer
- K. van 't Hoff, programmer
- S. Karlsson, M.Sc., researcher, from February 11
- Prof. dr. M.L. Kersten, cluster leader, senior researcher
- Ing. W.D. Kwakkel, programmer, March 1 till August 16
- Dipl.-Inform. S. Manegold, researcher, from October 1
- Ir. J. Pellenkoft, Ph.D. student, till September 1
- Drs. H. Sprangers, WWW-designer, till April 1
- Dr. ir. Z.R. Struzik, post doc, from February 1
- Dipl.-inform. F. Waas, researcher, from April 1
- Drs. M.A. Windhouwer, researcher (UvA), from November 16
- Ms. I. Bartolini, guest, from November 16
- Ms. ing. M. Bakker, trainee, till September 1
- W.H.A. Fieten, trainee, till April 1
- R. Leguijt, trainee, April 16 till October 16
- T. Müller, trainee, April 1 till August 1
- F.J. Tuinstra, trainee, April 1 till August 1

Scientific Report

Data Mining – INS1.1

This sub-theme concerns itself with research in data mining algorithms. All research is performed within the context of the KESO architecture, which provides a uniform framework for these algorithms.

KESO. Within the KESO project there have been two lines of work. Firstly, project obligations have been met by casting standard classification tree algorithms within the framework by Kwakkel and Siebes. The prototype implementations made by Kwakkel are currently under evaluation by the users in the project.
Secondly, research has been done in bayesian network inference algorithms suitable for data mining. These first steps by Castelo and Siebes have resulted in a first prototype implementation and experiments, with accompanying paper. These results proved to be so promising that Castelo has been hired to further investigate these matters.

IMPACT. Within the context of IMPACT, data mining is targeted at mining databases of financial time series. If standard data mining technology is to be used on such databases, these time series should be characterized by a fixed number of features. In the course of the year, two approaches to such transformations have been studied.
First, traditional statistical models, such as ARMA, have been used by Bakker and Siebes to extract characteristics from the series. The disadvantage of this approach appears to be that too much information is left out by adjusting for trends, seasonality etc. The second approach, pursued by Struzik and Siebes, is to find these characteristics via wavelet analysis. The first, promising, results along these lines will be presented in 1998. In order to make this approach viable, Struzik has performed fundamental research

in wavelet analysis, such as the extraction of negative moments.

Database Architecture – INS1.2

This sub-theme is devoted to the fundamental questions of database architecture in the context of the prototype DBMS MONET. This year we have seen the crowing of several years of research with granting the Ph.D. degree to J. Pellenkoft, who has gained international recognition with a series of papers on query optimization in top-level conferences. A first direct industry project was undertaken with Tandem computers to develop new database technology for data mining. This led to a Tandem product, DMS positioned as a specialized database server for data mining on NT-multiprocessors.

KESO. Query optimization is of prime importance for performant data mining. One of the challenges that data mining puts to query optimization is that of *query batch* optimization. Within the context of the KESO project this problem has been studied over the last few years. Results by Choeni, Kersten and Siebes in this area have been published this year.
Siebes and Kersten have initiated a different attack on this problem via data cubes. A first paper on this approach has been published this year and, together with Data Distilleries, a prototype implementation is on its way. This line of research will be continued, guided by the experimental results achieved with this implementation, provided the programming effort required can be hired.

IMPACT. Several young researchers were hired with a few years of postgraduation experience. S. Karlsson brought into the group strong experience in database kernel development and he is an expert of scalable data structures. From the Technical University of Berlin, we hired F. Waas and S. Manegold, both experienced junior researchers in the area of parallel database processing.
With this group installed, we are able to implement the National HPC project IMPACT. The results obtained in 1997 constitute several papers on parallel execution strategies and their analytical underpinning. Furthermore, the manpower was used to realign the development and maintenance duties for the database system, which has resulted in substancial improved software maintenance scheme. In particular, the Monet system was ported to SP/2 and Parsytec to lay the foundation for experiments in MPP-based query optimization.
This investment will pay itself back in the forthcoming experimentations, validations of cost-models and query optimization techniques. In close liaison with Data Distilleries, we have demonstrated viability of the technology against state-of-the-art DBMS products. Performance reports on other public benchmarks (TPC-D) have been prepared for publication.

Mercury. The Mercury project is a multi-year Esprit project together with ICL, Herriot-Watt University, and Ifatec. The project is run by K van't Hoff as subcontractor of the ING-bank and develop a business benchmark for performance assessment of large database systems. The results have been cast into project deliverables, including a web-based interface to experimental results.
To facilitate a career move and educational phase, F. van Dijk spent most of 1997 as a Database Administrator at the Postbank. Since this liaison turned out to be profitable for both parties involved, he decided to leave CWI after 25 years of front-line programming support.

AMIS. The ongoing activities in the area of Multimedia database is a cooperation with the ISIS group at the University of Amsterdam. With N. Nes we developed techniques to support region-based indexing in image databases and explored ways to scale-up algorithms for line cluster detection. Further progress can be reported on developing the necessary Monet extensions modules to support multimedia databases. Given the status of the database platform, we embarked upon the AMIS project, a national research initiative to broaden and deepen the understanding of methods for indexing and searching in multimedia databases. The methods should be both effective and efficient. In this project, several disciplines of computer science collaborate to achieve this one research goal of advancing insight into critical bottlenecks of multimedia system technology. This project is a cooperation between UvA, UU, UT, and CWI.
By the end of 1997, we formulated a companion project, called Digital Media Warehouses, which will start early 1998 as a national project aimed at indexing video and audio sources using database technology. This project is a co-production with UT, KPN and Syllogic.

Active Databases – INS1.3

The research in this sub-theme, by Van den Akker and Siebes is aimed at the development of the autonomous data model DEGAS. In this year, the development has mainly been aimed at the query model for DEGAS. Moreover, the question of Agents in an active database has been discussed in the context of DEGAS.

Van den Akker has spent the larger part of this year

writing his Ph.D. thesis, the defense of which will be in March 1998. Parts of the aspects of querying in autonomous databases, generalized to the relational model, will be published next year.

Organization of Conferences, Workshops, Courses, etc.

J. van den Akker:
- Database Research Group meetings. Attendees from the University of Amsterdam and Technical University of Eindhoven.

A. Siebes:
- KESO General meeting, February 17–18, Amsterdam
- KESO Developers meeting, May 5–6, Helsinki
- KESO General meeting, September 29–30, Amsterdam

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

J.F.P. van den Akker:
- CIA-97, Kiel, Germany, February 26–28 (*Enriching Active Databases with Agent Technology*)

J.R. Castelo:
- Jornados d'Intelligencia Artificial, Lleida, Spain, October 23–25 (*Bayesian Networks in a Data Mining tool*)

K. van 't Hoff (Mercury Meetings):
- ING techn. meeting, January 10
- Paris techn. meeting, April 21 (all partners)
- ING techn. meeting, June 2
- ING techn. meeting, June 10
- CWI techn. meeting, July 11 (all partners)
- ING techn. meeting, September 9
- Manchester review, October 6–7 (all partners)
- ING techn. meeting, December 15

M.L. Kersten:
- IMPACT Meeting at Cap Volmac, Utrecht, January 21
- Working meeting Tandem Computers, Frankfurt, Germany, February 12–13
- KESO General Meeting, February 17–18, CWI.
- Keynote speaker *Datamining* BIWIT-GFI'97, Ulm, Germany, March 5–7
- Keynote speaker *Database Systems for the 21th Century*, RIDE '97, Birmingham, April 7–8
- Toobis review meeting, Pliriforiki, Athens, Greece, May 2
- Tandem Working Meeting, Amsterdam, May 15–16
- Ercim XCOM meeting, INRIA, Rocquentcourt, May 21
- Magnum working meeting, University of Twente, May 23
- Working meeting IFIP WG 2.6 *A cellular database system*, Konstantz, Germany, June 1–4
- Working meeting Telematica Top Instituut, TNO/TPD, June 23
- Review HPretail project, Brussel, June 26
- Int. Conference on Very Large Database, Athens, Greece, August 27–29
- ERCIM XCOM-meeting, CNRI, Pisa, Italy, September 9
- Keynote speaker *Cellular Database Systems*, ARTDB '97, Como, September 9
- Toobis Review meeting, Athens, Greece, September 12
- Tandem Working Meeting, Edingburgh, Scotland, September 18–19
- Ph.D. committee H. Veenhof, Univ. Twente, September 10
- ERCIM XCOM meeting, Kopenhagen, November 4
- Ph.D. thesis advisor J. Pellenkoft, Univ. Amsterdam, November 25
- Program committee EDBT'98, ETH Zürich, December 4–5

J. Pellenkoft:
- DASFAA, Melbourne, Australia, April 1–4 (*Duplicate-free generation of alternatives in transformation-based optimizers*)
- VLDB, Athens, Greece, August 26–29 (*The complexity of transformation-based join enumeration*)

A.J.M. Siebes:
- KESO General Meeting, CWI, February 17–18
- KESDA98, Organisation Committee meeting, Luxemburg, March 13–14
- KESO developers meeting, Helsinki, May 3–7
- Ph.D. defense Sangüesa, UPC, Barcelona, May 20–22
- KESO review, München, May 31–June 2
- Working visit, UPC, Barcelona, July 1–4 (*An introduction to Data Mining*)
- KDD'98, Los Angelos, August 12–19 (*Keso: Minimizing Database Interaction*)
- Unilever Research Laboratory, Vlaardingen, August 27 (*Data Mining*)
- Dosis Meeting, Luxemburg, September 2–5 (KESO *progress report*)
- KESO general meeting and review, Helsinki, September 26–October 1
- Workshop WG 5.5.2 (GI) on Data Mining, Duisburg, October 8–9 (*A Framework for Data Mining*)
- Symposium Statistische Software, Utrecht, November 12 (*Data Mining: een introductie*)
- CRISP workshop, Amsterdam, November 20 (*Towards a Methodology of Data Mining*)

Z.R. Struzik:
- FRACTAL'97, Denver, USA, April 8–11 (*Fitting*

the Generic Multi-Parameter Cross-over Model: Towards Realistic Scaling Estimates)
- Working visit, faculty of Physics, Boston University, April 21–May 3 (*Fractals under the Microscope, or, Reaching Beyond the Dimensional Formalism of Fractals with the Wavelet Transform*)
- Centre de Formation de Marseille-Luminy, summer school 'New Interactions: Wavelets, Signal Analysis, Simulation and Probabilistic Models', July 21–26 (*Stability Considerations for Invariant Features in the Solution to the Inverse Fractal Problem with the Wavelet Transform*)
- AMC Physiology Seminar, December 9 (*Wavelet Transform in Biomedical Time-Series Analysis*)

F. Waas:
- Euro-Par'97, Passau, Germany, August 26–29
- Euro PVM-MPI'97, Krakow, Poland, November 3–5 (*In Quest of the Bottleneck–Monitoring Parallel Database Systems*)

Visitors

- M. Spiliopoulou and G. Faulstich, Humbold Universität, Berlin, Germany, August 7
- Tang, INRIA, Paris, France, October 2
- C.A. Galindo-Legaria, Microsoft, Redmond, USA, November 18–24
- Y. Ioannides, University of Athens, Athens, Greece, November 24
- P. Valduriez, INRIA, Paris, France, November 24

Memberships of Committees and Other Professional Activities

M.L. Kersten:
- Professor of Computer Science, University of Amsterdam
- Non-executive board member of ConsultData B.V., Amsterdam
- Co-founder of Data Distilleries B.V., Amsterdam
- Member editorial board *The VLDB Journal*, Springer-Verlag
- Member editorial board *Distributed and Parallel Databases*, Kluwer
- Member IFIP working group 2.6 Databases
- Member CEC evaluation committee ESPRIT-IV, Database Systems
- Member executive committee ERCIM.
- Keynote speaker *Database Systems for the 21th Century*, RIDE '97, Birmingham
- Keynote speaker *Datamining BIWIT-GFI'97*, Stuttgart, March 7, Germany.
- Keynote speaker *Cellular Database Systems, ARTDB '97*, Como, Italy.
- Member program committee *SOFSEM '97*, Milovy, Czech Republic
- Member program committee *Digital Libraries '97*, Italy
- Member program committee *EURO-PAR '97*, Germany
- Member program committee *RIDS '97*, Zürich
- Member program committee *ICDE '97*, Birmingham
- Member program committee *ACM SIGMOD '97*
- Member program committee *ADL'98*, USA
- Member program committee *Digital Libraries'98*, Greece
- Member program committee *EDBT'98*
- Member program committee *VLDB '98*
- Member VRI commissie Kwaliteitsprijs 1997
- CEC reviewer of ESPRIT IV projects *TOOBIS*, Hyperbank, Jedi, HPretail, Entice
- Rijksgecommitteerde HIO Oost-Nederland

A. Siebes:
- Editor *CWI Quarterly*
- Editor *Journal of Knowledge Discovery and Data Mining*
- Program Committees: *KDD'97, PKDD, IFIP 2.6 DS-7*
- Member Ph.D. committee Ramon Sangüesa, UPC, Barcelona

Papers in Journals and Proceedings

J. VAN DEN AKKER, A. SIEBES (1997). Enriching Active Databases with Agent Technology. *Proceedings of the First International workshop on Cooperative Information Agents (CIA-97)*, LNAI **1202**, Springer, Kiel, Germany, 116–125.

J. VAN DEN AKKER, A. SIEBES (1997). DEGAS: A Database of Autonomous Objects. *Information Systems* **22**(2/3), 121–138.

P.M.E. DE BRA (1997). Teaching Through Adaptive Hypertext on the WWW. *Int. Journal of Educational Telecommunications*, **3**(2/3), 163–180.

P.M.E. DE BRA, L. CALVI (1997). Creating Adaptive Hyperdocuments for and on the Web. *Proc. of the AACE WebNet'97 Conference*.

P.M.E. DE BRA, W. LEMMENS (1997). FishNet: Finding and Maintaining Information on the Net. *Proc. of the AACE WebNet'97 Conference*.

L. CALVI, P. DE BRA (1997). Using Dynamic Hypertext to Create Multi-Purpose Textbooks. *Proc. of the AACE ED-MEDIA'97 Conference*, 130–135.

L. CALVI, P.M.E. DE BRA (1997). Improving the Usability of Hypertext Courseware through Adaptive Linking. *Proc. of the Eighth ACM Conference on Hypertext*, 224–225.

R. CASTELO, A. SIEBES (1997). Bayesian Networks in a Data Mining tool. *Proceedings of the Jornades d'Inteligència Artificial: Noves Tendències* **12**, University of Lleida, Spain, Bulletin of the ACIA, 70–78.

S. CHOENNI, A.P.J.M. SIEBES (1997). Query Optimization to Support Data Mining. *Proceedings 8th International DEXA workshop (DEXA97)*, Toulouse.

S. CHOENNI, M.L. KERSTEN, J. VAN DEN AKKER (1997). A framework for multi query optimization. *Proceedings COMAD'97*, Madras, India.

G.J. HOUBEN, P.M.E. DE BRA (1997). World Wide Web Presentations for Volatile Hypermedia Database Output. *Proceedings AACE WebNet'97 Conference*.

M.L. KERSTEN (1997). A Cellular Database System for the 21th Century. *Proceedings ARTDB'97*, Springer-Verlag.

M.L. KERSTEN, A.P.J.M. SIEBES, M. HOLSHEIMER, F. KWAKKEL (1997). Research and Business challenges in Data Mining Technology. *Proceedings of Datenbanken in Büro, Technik und Wissenschaft (BTW '97)*.

S. MANEGOLD, J.K. OBERMAIER, F. WAAS (1997). Load Balanced Query Evaluation in Shared-Everything Environments. *Proc. European Conf. in Parallel Processing*, Passau, Germany.

S. MANEGOLD, F. WAAS, D. GUDLAT (1997). In Quest of the Bottleneck - Monitoring Parallel Database Systems. *Proc. European PVM-MPI Users' Group Meeting*, Krakow, Poland.

N.J. NES, M.L. KERSTEN (1997). Region-based indexing in an image database. *The International Conference on Imaging Science, Systems, and Technology*, Las Vegas, 207–215.

A. PELLENKOFT, C.A. GALINDO-LEGARIA, M.L. KERSTEN (1997). The Complexity of Transformation-Based Join Enumeration. *VLDB 1997*, 306–315.

A. PELLENKOFT, C.A. GALINDO-LEGARIA, M.L. KERSTEN (1997). Duplicate-Free Generation of Alternatives. *Transformation-Based Optimizers, DASFAA*, 117–124

A. SIEBES, M.L. KERSTEN (1997). Keso: Minimizing Database Interaction. *Proceedings of the third International Conference on Knowledge Discovery and Data Mining (KDD97)*, Newport Beach, August.

A. SIEBES (1997). Data Mining Algorithmen. *Informatie*.

A. SIEBES (1997). Data Mining, een Introductie. *Proceedings van het Symposium Statistische Software van de VVS (SSS97)*.

Z.R. STRUZIK, E.H. DOOIJES, F.C.A. GROEN (1997). Fitting the Generic Multi-Parameter Crossover Model: Towards Realistic Scaling Estimates. M.M. NOVAK, T.G. DEWEY (eds.). *Fractal Frontiers*, World Scientific.

Z.R. STRUZIK (1997). Stability Considerations for Invariant Features in the Solution to the Inverse Fractal Problem with the Wavelet. Transform, presented at *Proc. New Interactions: Wavelets, Signal Analysis, Simulation and Probabilistic Models*, Marseilles, France.

Z.R. STRUZIK (1997). Fractals under the Microscope, or, Reaching Beyond the Dimensional Formalism of Fractals with the Wavelet Transform. *CWI-Quarterly* **10.2**.

CWI Reports

INS-R9702. J.F.P. VAN DEN AKKER, A.P.J.M. SIEBES. *Designing active objects in DEGAS*.

INS-R9710. J.S. KARLSSON, M.L. KERSTEN. *Scalable storage for a DBMS using transparent distribution*.

Other Publications

J. PELLENKOFT (1997). *Probabilistic and Transformation based Query Optimization*, Ph.D. thesis University of Amsterdam.

K. VAN 'T HOFF (M. KERSTEN ed.) (1997). *Design of Experimentation platform interfaces*, Mercury WP2C/T1/d1.

K. VAN 'T HOFF, M. KERSTEN (1997). *Specifications for the SMART - STP interface*, Mercury WP2C/T3/d1.

A. BROEKEN, K. VAN 'T HOFF (1997). *Tool Evaluation: experimentation modules*, Mercury WP1/T3.

Multimedia and Human – Computer Interaction – INS2

Staff

- Dr. D.C.A. Bulterman, theme leader
- Drs. A.M. Bleeker, Ph.D. student, SION
- J.A.F.C. van Disseldorp (trainee, until April)
- H.L. Hardman, M.Sc., Researcher
- Drs. A.J. Jansen, Programmer
- Prof. L.G.L.T. Meertens, Researcher
- Drs. K.S. Mullender, Programmer
- S. Pemberton, Researcher
- L.W. Rutledge, Sc.D., Post-Doc
- L. Salvail, Ph.D., Post-Doc, (until June 1)

- M. Theodoridou, M.Sc., Visiting Researcher (until June 1)
- Ir. O.J.M. Weber, Ph.D. student, STW (until September 1)

Scientific Report

The Multimedia and Human-Computer Interaction theme studies the use of information presentation technology at the upper levels of systems architecture and the interface with the user. This work focuses on managing the definition and flow of information across networks, and covers issues ranging from hypermedia modelling, through the development of electronic books, to the development of secure protocols to protect information access.

The theme is divided into four sub-groups. It strikes a balance between abstract theory and practical implementation and demonstrates it relevance to the Institute and the scientific community by participating in a wide range of external research projects. Within the group, three researchers neared completion of their Ph.D. requirements this year (Hardman, Weber and Bleeker). The ACELA project concluded at the end of the summer, providing a period of reflection and evaluation for researchers in the Electronic Books group; this should bear fruit in new research directions during 1998. Work on secure protocols continued throughout the year, both in the SEMPER project and in the work of Meertens and Bleeker.

The core of the theme's activity focused on the definition and implementation of multimedia information presentation and management systems.

During 1997, the group participated in the following national and international research projects:

CHAMELEON (EU/Esprit-IV 20597) on the development of multimedia authoring systems for adaptive documents, conducted within INS2.1 – Multimedia Authoring Environments (Bulterman, Hardman, Jansen, Mullender, Rutledge, Theodoridou);

SEMPER (EU/ACTS-0032), on multimedia support within secure electronic marketplaces, conducted within INS2.2 – Distributed Multimedia Applications (Bulterman, Mullender, Salvail).

ACELA (NL/STW) on the construction of interactive books, conducted within the project INS2.3 – Interactive Books (Meertens, Pemberton, Weber);

Members of the group were also involved in the development of the W^{3}C SMIL language for integrating multimedia presentations over the WWW; this work is a direct outgrowth of our earlier CMIF and Amsterdam Hypermedia Model research.

The theme ended with a large number of openings for junior researchers, positions that are increasingly difficult to fill. While we expect the shortage of qualified Ph.D. candidates to continue, we expect to compensate for this short-fall by attracting top Post-Doc candidates to our group in the coming year. The shortage of junior staff members and the non-research pressures of managing a large number of external projects has caused the group to become more selective in its (external) research partnerships in an attempt to maintain quality research results and a positive group financial balance.

Dick Bulterman. As theme leader, Bulterman was responsible for the academic and economic well-being of the Multimedia and HCI group. He was also responsible for the multimedia activities of the theme. A major portion of this year was spent working with the W^{3}C on the development of the proposed SMIL language, together with other industrial and academic participants. During this year, he also published several papers on various aspects of multimedia systems design and authoring. 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 STEM projects during the year.

Annette Bleeker. The work, performed within the SION-sponsored project *Specification of Secure Protocols*, focussed on soundness and correctness criteria of cryptography-based protocols whose specification can be expressed in an extension of BAN logic. To formulate and prove correctness criteria, she developed and formalised an operational semantics for such protocols, as well as statically checkable acceptability constraints for secure protocols that must be imposed before the protocol can be formally verified.

Jeroen van Disseldorp. As a visitor from Utrecht University, van Disseldorp worked together with Pemberton on constraint-driven code generation.

H. Lynda Hardman. The major portion of the year was spent on the completion of Hardman's dissertation on Hypermedia Modelling, which was formally submitted in December. She published several papers on various aspects of hypermedia authoring and on hyper-structured document design. In addition, Hardman participated on a number of scientific committees and contributed to the hypermedia architecture of the W^{3}C SMIL language. Her perseverance on the research front was also matched by her feats (and feet!) on the ice, which landed her a skating medal in February.

Jack Jansen. Jansen contributed to the CMIFed/CHAMELEON runtime environments. He also worked on multi-platform support for CMIFed, specifically on the Macintosh port of this environment.

His CMIFed work focused on issues of scheduling the runtime execution of multimedia data fragments. He was also involved in OR activities at CWI. He was also a member of the board of the NLUUG.

Lambert Meertens. Together with Steven Pemberton and Olaf Weber he worked mainly within the Acela project, focussing 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. Together with Steven Pemberton he participated in the COCA project (*Cooperative Open Component Architecture*), a joint initiative of Utrecht University, Technological University Eindhoven and CWI. Together with Annette Bleeker he conducted research within the project INS2.4 *Specification of Secure Protocols* described below.

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, providing expertise on systems architecture and applications design and to the CHAMELEON project.

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. He was chair of ACM CHI 97, the international conference on Computer-Human Interaction, in Atlanta Georgia, as well as editor-in-chief of the SIGCHI Bulletin. At the end of the year he was appointed as editor-in-chief of ACM interactions. Pemberton worked on the HTML and CSS committees of the World Wide Web Consortium W^{3}C.

Lloyd Rutledge. Dr. Rutledge continued his work as a post-doc with the CHAMELEON project. His particular area of interest is the use of standard document description languages and formats (such as HyTime and MHEG) to describe complex multimedia applications. He published broadly on these topics during the year and he organized a HyTime workshop at CWI. He also contributed to SMIL.

Louis Salvail. Dr. Salvail completed his very successful post-doc stay as part of the SEMPER project in May. After a short stay in his native Montreal, he accepted a research position at the University at Arhus. With his departure, CWI's active participation in SEMPER came to an end.

Maria Theodoridou. Ms. Theodoridou worked on various aspects of the CMIFed authoring environment upto her return to Greece at the beginning of the summer. She also contributed heavily to the STEM project's architecture and interface for use by land managers through-out Europe.

Organization of Conferences, Workshops, Courses, etc.

- CHAMELEON Project Meeting, January 16–17: D.C.A. Bulterman
- SGML and HyTime Workshop, April: L. Rutledge
- CHAMELEON Project Meeting, September 16–17: D.C.A. Bulterman
- W^{3}C SYMM Standardization Meeting, September 8–10: D.C.A. Bulterman

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

- ACM CHI '97 Planning Meeting, Atlanta, January 22–26: S. Pemberton
- Chameleon Meetings, Brussels, February 11–12: Bulterman and Rutledge
- Semper Meeting, Zürich, February 17: Bulterman
- Chameleon Meeting, London, March 4: Bulterman
- INRIA Research Evaluation Committee, Sophia-Antipolis, March 5: S. Pemberton
- Semper Meeting, Munich, March 11–12: Bulterman and Salvail
- W^{3}C SYMM Meeting, San Jose, CA, March 17–20: Bulterman
- New Media Marketplace Lecture, Rotterdam, March 20: Hardman and Bulterman (*Authoring Tools for Networked Multimedia*)
- ACM CHI '97, Atlanta, March 22–27: S. Pemberton
- Chameleon Review, Brussels, April 1: Bulterman
- Hypertext 97, Southampton, UK, April 9–11: Hardman and Rutledge (*Style Sheet Support for Hypermedia Documents*)
- ACM SIGCHI Executive Committee, Monterey, April 11–13: S. Pemberton
- Schloß Dagstuhl, Saarbrücken, April 14–18: L. Hardman *(Evaluation of Multimedia Information Retrieval*)
- ICCC/IFIP Conference on Electronic Publishing '97, Kent UK, April 6: Rutledge *(Use of Standards for Hypermedia Generic Structure and Presentation Specifications*)
- Chameleon Meeting, London, April 8: Bulterman

- HyTime Workshop, Amsterdam, April 28: L. Rutledge and S. Pemberton
- Doors Internet Conference, Amsterdam, May 2: S. Pemberton
- ACM 97 Program Committee Meeting, Paris, May 5: Bulterman
- Matilda Symposium (*Mathematical Tools in Interactive Learning*) Amsterdam, May 12–13: S. Pemberton (*Interactive Books*)
- W^{3}C Technical Meeting, Nice, May 20–21: S. Pemberton
- Semper Meeting, Arhus, May 20–21: Salvail
- OpenMath Symposium, Nice, May 23–24: S. Pemberton (*Interactive Books*)
- Schloß Dagstuhl, Saarbrücken, Lecture, May 29–June 4: Bulterman (*Authoring Support for Synchronized Multimedia*)
- Chameleon Meeting, Metzova, Greece, June 2–4: Rutledge
- Haskell Workshop, Amsterdam, June 7: L. Meertens
- UvA/WINS, Invited Lecture, June 9: Hardman (*Hypermedia Design*)
- International Conference on Functional Programming '97, Amsterdam, June 9–11: L. Meertens
- Chameleon Meeting, 26 June: Bulterman and Rutledge
- W^{3}C SYMM Meeting, New York, June 29–30: Bulterman and Hardman
- Invited talks, Russian Scientific Methodics Council, St. Petersburg, June 30–July 3: S. Pemberton (*Approaches to HCI; Problems of HCI in Education*)
- ACM SIGCHI Executive Committee, Portland, Oregon, July 31–August 3: S. Pemberton
- ACM SIGCHI Conference Management Committee, Apeldoorn, August 13–14: S. Pemberton
- Design of Interactive Systems, Amsterdam, August 18–20: S. Pemberton
- Kestrel Institute, Palo Alto, California, August 24: L. Meertens (*Mechanical Support for Calculation*)
- HyTime '97 Paper, August 24–27: Rutledge (*Putting the Media back in Hypermedia: HyTime for Portable Multimedia Documents*)
- Chameleon Meeting, Edinburgh, August 25: Bulterman
- Chameleon Meeting, Edinburgh, September 1: Bulterman
- DIMACS Workshop on Design and Formal Verification of Security Protocols, New Brunswick, NJ, September 3–5: Bleeker
- Chameleon Review, Athens, September 15–18: Bulterman
- W^{3}C SYMM, Amsterdam, September 22–23: Bulterman, Hardman, Rutledge
- Hypertexts and Hypermedia, Paris, September 24: L. Rutledge (*Cooperative Use of MHEG-5 and HyTime*)
- Chameleon Meeting, London, October 20: Bulterman
- SIMOS Workshop, Lecce, Italy, October 30–31: Bulterman and Hardman (*The W^{3}C SMIL Language for Networked Multimedia*)
- European New Media Policy Conference, Amsterdam, October 31: S. Pemberton
- ACM Multimedia 97 Paper, Seattle, November 11–13: Rutledge, Bulterman, Hardman (*A Framework for Generating Hypermedia Documents*)
- ACM Multimedia 97 Session Chair, Seattle, November 11–13: Bulterman
- W^{3}C Technical Meeting, Austin, Texas, November 11–14: S. Pemberton
- W^{3}C SYMM Meeting, Seattle, November 14: Bulterman, Hardman, Rutledge
- Boeing Research, 2 Lectures, Seattle, November 13: Bulterman, Hardman, Rutledge (*The W^{3}C SMIL Standard; and Automatic Authoring of Hypermedia*)
- ACM Editors Workshop, New York, November 17–18: S. Pemberton
- Multimedia Modelling '97, Invited Talk, Singapore, November 18: Bulterman (*Models, Media and Motion – Using the Web to Support Multimedia Documents*)
- Multimedia Modelling '97, Tutorial, Singapore, November 17–20: Bulterman and Rutledge (*Modelling Support for Network-Based Multimedia Presentations*)
- IETC, Brussels, November 21–25: Rutledge, Mullender, Hardman, Bulterman
- Werkgemeenschap Informatiewetenschap, November 27: Bulterman, Hardman, Rutledge (*Models, Media and Motion – Multimedia and the WWW*)
- Chameleon Meeting, Paris, December 11–12: Bulterman and Hardman
- ACM SIGCHI Executive Committee, New York, December 12–14: S. Pemberton

Memberships of Committees and Other Professional Activities

D.C.A. Bulterman

- Technical director, ESPRIT-IV CHAMELEON project
- CWI project leader, ACTS SEMPER project
- Editorial board, *Multimedia Systems Journal* (ACM/Springer)
- Editorial board, *Multimedia Tools and Applications Journal* (Kluwer)

- Program committee, *ACM Multimedia '97* (Seattle; associate chair)
- Program committee, *Multimedia Modelling '97* (Singapore)
- Member, SION Stuurgroep Multimedia
- Member, W^{3}C Synchronized Multimedia working group

A. Bleeker:
- Organizing committee, EIDMA/CWI Cryptography Working Group Research Meetings

L. Hardman:
- Editorial board of *New Review of Hypermedia and Multimedia*
- Board Member, *Werkgemeenschap Informatiewetenschap*
- Program Committee, *ACM Hypertext '97*
- Reviewer, *ACM Multimedia '97*
- Reviewer, *Multimedia Modelling '97*
- Reviewer, *Computing Reviews*
- Reviewer, *Werkgemeenschap Informatiewetenschap '97*
- Member, *W^{3}C Working Group on Synchronized Multimedia (SYMM)*

J. Jansen:
- NLUUG Board
- Works Council
- Member, *W^{3}C SYMM group*

L. Meertens:
- Member IFIP Working Group 2.1 on *Algorithmic Languages and Calculi*
- Pproject leader in the STW project Acela
- Member Program Committee and co-editor Proceedings IFIP TC2 WG2.1 International Workshop on Algorithmic Languages and Calculi, Bisschofsheim (France) (1997)
- Member Program Committee *Mathematics of Program Construction* (1998)
- Member Ph.D. committee J.M. Vleugels, *On Fatness and Fitness – Realistic Input Models for Geometric Algorithms*, March 5 (UU)
- Member Ph.D. committee T.H.J.J. Arts, *Automatically Proving Termination and Innermost Normalisation of Term Rewriting Systems*, May 16 (UU)
- Member Ph.D. committee S. Haring, *Adaptive Image Analysis*, May 23 (UU)
- Member Ph.D. committee W.T.M. Kars, *Process-algebraic Transformations in Context*, June 6 (UT)
- Member Ph.D. committee W.A. de Graaf, *Algorithms for Finite-Dimensional Lie Algebras*, June 10 (TUE)
- Member Ph.D. committee P. Svestka, *Robot Motion Planning using Probabilistic Road Maps*, June 16 (UU)
- Member Ph.D. committee P.F. Hoogendijk, *A Generic Theory of Data Types*, June 24 (TUE)
- Member Ph.D. committee A.V. Groenink, *Surface without Structure*, November 7 (UU)

K.S. Mullender:
- Works Council
- Member, *W^{3}C SYMM group*
- Reviewer, *ACM MM'97*

S. Pemberton:
- Editor-in-chief *ACM SIGCHI Bulletin*
- Conference chair, *ACM CHI 97*
- Member ACM SIGCHI Executive Committee
- Member NNI (Dutch Standards Authority) Software Ergonomy Committee
- Chair, W^{4}G (European *World Wide Web Working Group*)
- Acela project manager
- Member W^{3}C HTML and CSS committees
- Member SIGCHI International Issues Task Force
- Member of research advisory board for HCI, INRIA
- Editor-in-Chief *ACM interactions*
- Papers chair, *Interaction and the Web* conference, Ede (NL) Jan. 1998.
- Founding member SIGCHI NL

L. Rutledge:
- Member, *W^{3}C SYMM group*
- Reviewer, *ACM MM'97*
- Reviewer, *MMM'97-Singapore*
- Reviewer, ACM/Springer *Multimedia Systems*
- Reviewer, Kluwer's *Multimedia Tools and Applications*

Visitors

- S. Newcomb, TechnoTeacher, Inc. (Rutledge)
- T. Kamps, GMD-IPSI (Hardman)

Awards

- ACM Recognition of Service Award (Pemberton)

Papers in Journals and Proceedings

R. BIRD, L. MEERTENS (eds.) (1997). *Algorithmic Languages and Calculi*, Chapman & Hall

A. BLEEKER, L. MEERTENS (1997). A Semantics for BAN Logic. *Proceedings of DIMACS Workshop on Design and Formal Verification of Security Protocols*, New Brunswick, NJ, USA.

D.C.A. BULTERMAN (1997). Authoring Multimedia: Experiences with CMIF. *Proc. of Dagstuhl Seminar 457*, Schloß Dagsthul.

D.C.A. BULTERMAN, L. HARDMAN (1997). Authoring Tools for Networked Multimedia. *Informatie en Informatiebeleid*.

L. HARDMAN, D.C.A. BULTERMAN (1997). Document Model Issues for Hypermedia. W.I.GROSKY, R. JAIN, R. MEHROTRA (eds.). *Handbook of Multimedia Information Management*, Prentice Hall.

L. HARDMAN, M. WORRING, D.C.A. BULTERMAN (1997). Integrating the Amsterdam Hypermedia Model with the Standard Reference Model for Intelligent Multimedia Presentation Systems. *Computer Standards & Interfaces.*

J. VAN OSSENBRUGGEN, L. HARDMAN, L. RUTLEDGE, A. ELIËNS (1997). Style Sheet Support for Hypermedia Documents. *ACM Hypertext '97 Short Paper*, Southampton, 216–217.

J. VAN OSSENBRUGGEN, L. HARDMAN, L. RUTLEDGE, A. ELIËNS (1997). Style Sheet Support for Hypermedia Documents. *Hypertext 97*, Southampton, UK.

S. PEMBERTON (ed.) (1997). *Proceedings of ACM Conference on Human Factors in Computing Systems*, CHI 97, Atlanta.

S. PEMBERTON (ed.) (1997). *Electronic Publications of the ACM Conference on Human Factors in Computing Systems*, CHI 97, Atlanta.

L. RUTLEDGE (1997). Putting the Media back in Hypermedia: HyTime for Portable Multimedia Documents. *Hy-Time 97*, Montreal, Canada.

L. RUTLEDGE, J. VAN OSSENBRUGGEN, L. HARDMAN, D.C.A. BULTERMAN (1997). Cooperative Use of MHEG-5 and HyTime. *Hypertexts and Hypermedia: Products, Tools, Methods (HHPTM'97)*, Paris, France.

L. RUTLEDGE, J. VAN OSSENBRUGGEN, L. HARDMAN, D.C.A. BULTERMAN (1997). Use of Standards for Hypermedia Generic Structure and Presentation Specifications. *ICCC/IFIP Conference on Electronic Publishing '97*, Kent, UK.

L. RUTLEDGE, J. VAN OSSENBRUGGEN, L. HARDMAN, D.C.A. BULTERMAN (1997). A Framework for Generating Hypermedia Documents. *ACM Multimedia 97*, Seattle WA, USA.

M. WORRING, C. VAN DEN BERG, L. HARDMAN, A. TAM (1997). System Design for Structured Hypermedia Generation. C. LEUNG (ed.). *Visual Information Systems, LNCS* **1306**.

Other Publications

S. PEMBERTON (1997). One Day at a Time. *ACM/interactions* 4.2.

S. PEMBERTON (1997). *Quick Reference to CSS1*, W^{3}C.

S. PEMBERTON (ed.) (1997). *SIGCHI Bulletin*, January.

S. PEMBERTON (ed.) (1997). *SIGCHI Bulletin*, April.

S. PEMBERTON (ed.) (1997). *SIGCHI Bulletin*, July.

S. PEMBERTON (ed.) (1997). *SIGCHI Bulletin*, October .

S. PEMBERTON (1997). Quick! The Future is Coming! *SIGCHI Bulletin*, January.

S. PEMBERTON (1997). If Six Were Nine. *SIGCHI Bulletin*, April.

S. PEMBERTON (1997). Programmers are Humans Too 2. *SIGCHI Bulletin*, July.

S. PEMBERTON (1997). Hell and Documentation. *SIGCHI Bulletin*, August.

Interactive Information Engineering – INS3

Staff

- Drs. P.J.W. ten Hagen, theme leader
- F. Denz, trainee (till July 1)
- Ir. S. van Dongen, Ph.D. student
- Prof. dr. D.J.N. van Eijck, researcher
- Dr. N. Francez, visitor (from February 27)
- Drs. A.V. Groenink, Ph.D. student
- Prof. dr. M. Hazewinkel, researcher
- Dr. I. Herman, researcher
- Drs. J.E.A. van Hintum, Ph.D. student (till March 1)
- M.S. Marshall, B.Sc., projectmember (from November 1)
- Dr. ir. J.M.G.G. de Nivelle, post doc, SION
- Drs. H. Noot, programmer
- M. Pauly M.Sc., Ph.D. student (from October 1)
- Drs. M.M. de Ruiter, programmer
- Ms. Dr. Zs.M. Ruttkay, researcher STW (from March 16)
- Drs. M.H.F. Savenije, researcher (from December 1)

Scientific Report

Information Engineering Framework – INS3.1

PREMO project
The proof-of-concept implementation of the PREMO standard has started. An implementation of Part 1 and Part 2 of PREMO in Java is now complete, and planning for the Part 3 and Part 4 implementations are in a good shape.

Independently of the implementation, a number of technical details on the PREMO specification proper has to be clarified, which was done in cooperation with the members of the ERCIM Computer Graphics Network and the SC24 PREMO rapporteur group. As a result, the specification is now complete, and the document will reach the International Standard stage in 1998. Finally, a more tutorial-oriented book is in preparation (co-authored by I. Herman (CWI) and D. Duke (Univ. of York)); about 30% of the book has been prepared in 1997

Information Visualization
The project started with an extensive paper and algorithm survey, and the best algorithm found for the visualization of trees has been adapted to our local need and implemented. A 3D version, using Python and VRML, was first implemented, but the results were inconclusive. Then a purely 2D version was implemented in Java, with very appropriate results. This basic implementation was then enriched with various tools and interactive facilities, to test the underlying principles. The tool reached a high level maturity by the end of the year, so that a specific application development can now be started.

Applied Logic and Interactive Books – INS3.3

Van Eijck worked on foundations of dynamic semantics for natural language, resulting in a journal publication and a report. Van Eijck also continued his work with Jaspars on reasoning and ambiguity. In October, Van Eijck and Pauly started work on Logic Dissemination for the Spinoza Logic in Action programme. Their first aim is to develop a core logic course using hyperlink technology. Groenink completed and defended his thesis on the complexity of mildly context-sensitive grammar formalisms. De Nivelle produced a prototype implementation of a fast resolution based theorem prover 'Bliksem', while Van Dongen worked on an implementation of a new graph clustering algorithm that has promising applications for information structuring.

Facial Animation – INS3.4

The FASE project started in March with an extensive literature survey and an evaluation of tools and techniques that make up the esperimental environment. A first workshop was organized together with the industrial committee to discuss the results and conclusions of the survey and the design of the environment. With the partners from TUD an interface for coupling the environments and exchanging data was decided. Many contacts were established with colleagues in The Netherlands and abroad. A first implementation of the initial animation system is underway.

Organization of Conferences, Workshops, Courses, etc.

Van Eijck:

- Logic, Structure and Proof, first year course, University of Amsterdam, together with Dr. C. Doets.
- Formal Forays into Language, graduate course on Logic and Language, University of Utrecht.
- Dutch Graduate School in Logic School Week, March 14–20, at CWI
- Dutch Graduate School in Logic School Week, October 6–10, at Uil-OTS, Utrecht.
- Mini Extravaganza on Language and Computation, November 7, Uil-OTS, Utrecht.

Hazewinkel:

- Algebra D, second year course Univ. of Utrecht, two hours weekly, second semester 1996/1997.
- Metadata Seminar, CWI, 2-nd semester 1996/1997, monthly (with Joost Kircz).
- Arrangements of hyperplanes, Masterclass course and seminar, two hours weekly, 2-nd semester 1996/1997, Utrecht (with Dirk Siersma).

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

Ten Hagen, Herman, De Ruiter, Ruttkay:

- Participated in the PREMO technical meeting, Nice, January 20–24: P.J.W. ten Hagen and I. Herman
- Went to the ESPRIT day in Rotterdam, March 25: P.J.W. ten Hagen and I. Herman
- Participated in the IPC meeting of EG97 and the EG Executive committee meeting in Budapest, March 12–15: P.J.W. ten Hagen and I. Herman
- Participated in the ISO meetings of SC24 and the PREMO Rapporteur group in Stockholm, May 20–30: P.J.W. ten Hagen and I. Herman
- Participated in the European IT prize committee meeting in Paris, May 28–30: P.J.W. ten Hagen
- Participated in the workshop at GMD on mutual research collaboration in Bonn, June 24–25: P.J.W. ten Hagen and I. Herman
- Participated in Eurographics 1997 in Budapest, September 3–7: P.J.W. ten Hagen, H. Noot, I. Herman, M.M. de Ruiter and Zs.M. Ruttkay
- Participated in the ESPRIT conference in Brussel, November 24–28: P.J.W. ten Hagen

- Participated in an ESPRIT call review meeting as a member of the review committee in Brussels from, October 26–31: P.J.W. ten Hagen
- Evaluation of the ESPRIT project MSC in Paris, November 5–6: P.J.W. ten Hagen
- Participated in the HPCN-conference in Amsterdam, November 10: P.J.W. ten Hagen and Zs.M. Ruttkay
- Made a working visit to the research labs of XEROX in Grenoble, December 8–9: P.J.W. ten Hagen and A.V. Groenink
- Participated in the Computer Animation workshop in Geneva, June 4–6: Zs.M. Ruttkay, where she also payed a working visit to the MIRA lab
- HCM Graphics network workshop, Abingdon, January 29: I. Herman
- ESPRIT MONI Project proposal meeting, Bordeaux, February 2: I. Herman
- DELOS Workshop Zürich, March 5: I. Herman
- ESPRIT MONI Project proposal meeting, Paris, March 26: I. Herman
- HCM Graphics network workshop, York, June 17: I. Herman
- ISO SC22 Java Study group meeting, London, June 31–July 1, I. Herman
- HCM Graphics network workshop, Grenoble, July 23: I. Herman
- ITEA International Jury meeting, Milaan, September 10: I. Herman
- York, PREMO Book working visit, Leeds, October 13: I. Herman
- Web2000 conference organizational meeting, Londen, October 20: I. Herman
- Visit to GMD GIPSI, Darmstadt, November 8: I. Herman, De Ruiter.
- Invited lecturer, Bordeaux, November 17–28: I. Herman

Van Eijck, Groenink, De Nivelle, Van Dongen, Pauly:

- 'Logic and Linguistics in the Netherlands', LOT Advisory Board Meeting, Utrecht, January 15: D.J.N. van Eijck
- 'Foundations of Dynamic Typed Logic', Groningen/Amsterdam Exchange, Groningen, January 24: D.J.N. van Eijck
- 'De Digitale Snelweg: Doorgaande Route naar Kennis en Inzicht?', Public Lecture, Hotel De Filosoof, Amsterdam, April 3: D.J.N. van Eijck
- 'Filosofie in het Digitale Tijdperk', Talk for KNAW Meeting on Computing and the Humanities, May 2: D.J.N. van Eijck
- 'Registers and States in Typed Dynamic Logic', Dynamics Workshop, Free University, Amsterdam, July 10: D.J.N. van Eijck
- 'Reject Grammars' Mini Extravaganza on Language and Computation, Uil-OTS, Utrecht, November 7: D.J.N. van Eijck
- 'Natural Deduction', Mastercourse Logic for Mathematics Teachers, University of Amsterdam, November 14: D.J.N. van Eijck
- 'Dynamic Reasoning Without Variables', Sinn und Bedeuting Conference, Berlin, December 5–7: D.J.N. van Eijck
- 'Graph Clustering and Information Structure', Accolade Conference, Dutch Research School in Logic, October 10: S. van Dongen
- 'Divergence and Dynamic Logic: A Predicate Transformer Approach', Accolade Conference, Dutch Research School in Logic, October 10: M. Pauly
- 'Mild context-sensitivity and Tuple-based extensions of context-free grammars', Xerox Grenoble, December 9: A.V. Groenink
- 'A Classification of Non-Liftable Orders for Resolution', CADE-14 conference, Townsville, Australia, July 17: J.M.G.G. de Nivelle
- 'A Resolution Based Decision Procedure for the Guarded Fragment', during: November 8–15: Working visit to Max Planck Institute, Saarbrücken: J.M.G.G. de Nivelle
- 'A Resolution Based Decision Procedure for the Guarded Fragment', RWTH Aachen, November 27: J.M.G.G. de Nivelle

Hazewinkel:

- January 31–February 1, Nationale lerarendagen, Noordwijkerhout.
- February 6–9, Working visit, University of München, CIS (Franz Guenthner, Commediant consortium).
- March 3–5, Canberra, Australia, National Library, 4-th Dublin Core metadata workshop.
- March 6–7, Working visit, Australian National University, Canberra.
- April 3–4, Nederlands Mathematisch Congres, Wageningen.
- May 15–17, Dept. Computer Science, University of Saarbruecken, working visit.
- April 19–24, TTI, Baltimore, working visit.
- July 14–17, Vilnius (University and Math. Inst. of the Academy), series of lectures and colloquium.

- July 18, Kaunas Technical University. Colloquium.
- September 23–26, Operators, systems, and linear algebra. Three decades of algebraic system theory, Kaiserslautern, Germany.
- October 12–15, Metadata: Qualifying web objects. Osnabrueck, Germany.
- November 1–7: Generalized function algebras workshop, Erwin Schroedinger Institute, Vienna.
- November 10–11: University of Karlsruhe, working visit to D Pallaschke and R Gamkrelidze.
- February 1, Topologie en de robot arm, Nationale leraren dagen, Noordwijkerhout. Lecture.
- March 4, Mathematical aspects of metadata, 4-th Metadata workshop, Australian National Library, Canberra. Lecture.
- May 14, Eindhoven, GEWIS Symposium, Mathematical problems arising from large databases. Lecture.
- 18 March, Metadata seminar, The Dublin Core initiative.
- July 14–16, MII Lithuanian Academy of Sciences. Six lectures on the mathematics of taxonomy.
- 17 July, Math Inst. Vilnius University. Colloquium: Lyndon words and the Ditters-Scholtens theorem. Lecture.
- July 18, Math. Inst., Kaunas Technical University. Colloquium: Combinatorical problems from classification theory. Lecture.
- September 24, Believing in polynomials. Remarks on the work and person of Paul Fuhrmann. Laudatio at the meeting 'Operators, systems, and linear algebra', Kaiserslautern, September 24–26.
- October 13, Topologies and metrics on information spaces. Invited lecture at the 'Metadata: qualifying web objects' meeting, Osnabrück, October 12–15.
- October 20, Mannheim, Germany. Colloquium: Mathematics of taxonomy and taxonomy of mathematics. Lecture.
- November 6, Vienna, Erwin Schroedinger Institute. Multiparameter quantum groups and applications. Lecture.

Visitors

Guests of Herman, Ten Hagen, Ruttkay:

- Gabor Renner, SZTAKI, Budapest, October 15
- Dr Chr. Thorisson from MIT, now at LEGO, Denmark, August 18
- Prof. dr. T. Vamos from SZTAKI, Budapest, June 6
- Dr. T. Gaal from XEROX research, Grenoble, October 30
- Dr. D. Duke from York University, December 15
- Maylis Delest, University of Bordeaux, France, January 14–17 and May 15–16
- Jean-Marc Dufour, University of Nice, France, January 14–17
- Jean-Marc Dufour, University of Nice, France, May 15–16
- Thomas Rist, DFKI, Saarbrücken, Germany, February 19
- Michael Wilson, RAL, Didcot, UK, February 19
- David Duke, University of York, April 22
- David Duke, University of York, August 13–14
- David Duke, University of York, December 15–17
- Gabor Renner, SZTAKI, Budapest, November 16

Guests of Van Eijck:

- N. Francez, Haifa, March–September (NWO Travel Grant)
- F. Denz, Stuttgart, January–June (Supported by University of Stuttgart)

Guests of Hazewinkel:

- Maylis Delest, Bordeaux, January 13–18 (Ding consortium)
- Jean-Marc Fedou, Nice, January 13–18 (Ding consortium)
- Olaf Ninnemann, FIZ/STN, Berlin, January 18–25 (Commediant consortium). Lecture in the Metadata seminar: January 21 Metadata aspects of the FIZ MATH database.
- Wolfgang Lenski, Heidelberger Akademie and Kaiserslautern, 18–22 Jan (Commediant consortium)
- Franz Guenthner, CIS, Muenchen, January 19–20 (Commediant consortium)
- R.V. Gamkrelidze, March 25–29
- Franz Guenthner, April 1, Commediant meeting
- Martin Fuchs, April 1, Commediant meeting
- P. Malyshev, April 14–20, working visit
- Rimas Maliukevicius, April 13–19, working visit
- Peter malyshev, Kiev, July 6–11, working visit
- R.V. Gamkrelidze, May 13–15, Comacs consortium.
- Peter Loeb, University of Illinois, June 7–8, working visit
- Enrique Planchard, Caracas, Venezuela, working visit, June 20
- Peter Malyshev, Kiev, Ukraine, working visit, September 29–October 7
- Rimas Maliukevicius, Dr Z Krizius (Vilnius), working visit, October 29–31

- Peter Malyshev, Kiev, Ukraine, working visit, December 14–21
- Vladimir Gorunovicz, Kiev, Ukraine, working visit, December 14–21
- R.V. Gamkrelidze, Moscow, Russia, working visit, November 18–19
- G Anastassiou, Memphis, Tennessee, December 12

Memberships of Committees and Other Professional Activities

Hazewinkel:
- Member Steering Committee MTNS 1985–...
- Liason member ECMI with the Euromath project.
- Member board CMF (Caribbean Mathematical Foundation)
- Member 'Benutzerbeirat STN', Karlsruhe
- Member ERCIM taskforce: support of the former Soviet Union
- Member board WG (= Dutch mathematical society), 1994–...
- President WG, 1996–1998
- Inspector of the library WG, 1994–...
- Archivaris WG, 1996–...
- Representative of WG to European Mathematical Society, 1994–... .
- Member Taskforce ERCIM-INTAS (now called Network Coordinating Committee), 1993–...
- Chairman Scientific Steering Group ERCIM-INTAS FSU, 1995–...
- Thesis committee O. de Mirleau, University of Amsterdam
- Reviewer of proposals:
  - NSA proposal (Flicker)
  - NWO, van Gogh grant
  - Austrian Science Foundation (Oberst) Kaiserslautern University (full professorship)
  - Mannheim University (applied mathematics programme)
  - NSF proposal (Hermann)
- (Co)-managing Editor journal: Nieuw Archief voor Wiskunde, Wiskundig Genootschap (=Dutch Math. Society), 1977–1997
- Ass. Editor journal: Systems and Control Letters, North Holland Publ. Co., 1981 ...
- Managing Editor book series: Mathematics and Its Applications, KAP
- Managing Editor journal: Acta Applicandae Mathematicae, KAP
- Managing Editor translation and revision of and supplements to the Russian Encyclopedia of Mathematics, KAP, 1977–1984 (volumes 1–10), 1997 (supplement I), ...
- Managing Editor Handbook of Algebra (to be published in 9 volumes), Elsevier Science Publishers; 1996 (Volume 1), ...
- Associate Editor journal Multi-dimensional system theory, Kluwer Boston, 1994 –...

Van Eijck:
- Professor of Logical Aspects of Computational Linguistics, University of Utrecht (since December 1990)
- member of the board of the Dutch Graduate School in Logic (from July, 1993, until Autumn 1997).
- program committee member of IWCS II (Second International Workshop on Computational Semantics), January 8-10, Tilburg
- Member of the European Network in Computational Logic (initiated by the ESPRIT Basic Research Action 'Compulog'), since March 1997
- Scientific Director of the Dutch Graduate School in Logic, ad interim: January 1997 – October 1997; full director: From November 1997
- Secretary of the Board of the Dutch Society for Logic (Vereniging voor Logica), since 1996
- Thesis advisor of Annius Groenink, Surface Without Structure, Utrecht, Nov 7 (second advisor: W.C. Rounds)
- Member of the thesis committee of Eelco Visser, September

Papers in Journals and Proceedings

J. VAN EIJCK (1997). Typed logics with states. *Logic Journal of the IGPL* **5**(5), 623–645.

J. VAN EIJCK AND J. JASPARS (1997) The logic of ambiguity. P. DEKKER, M. STOKHOF, Y. VENEMA (eds.). *Proceedings of the 11th Amsterdam Colloquium*, ILLC/Department of Philosophy, Amsterdam, 115–120.

M. HAZEWINKEL (1997). Enriched thesauri and their uses in information retrieval and storage. C THANOS (ed.). *Proceedings first DELOS workshop*, March 1996, ERCIM, 27–32.

H. DE NIVELLE (1997). A Classification of Non-Liftable Orders for Resolution. W. MCCUNE, G. SUTCLIFFE (eds.). *Proceedings of the 14th International Conference on Automated Deduction*, Springer Verlag.

D.J. DUKE, I. HERMAN, T. RIST, M. WILSON (1997). Relating the primitive hierarchy of the PREMO standard to the Standard Reference Model for Intelligent Multimedia Presentation Systems. *Computer Standards & Interfaces* **18**, 6–7.

D. WANG, I. HERMAN, G.J. REYNOLDS (1997). The Open Inventor Toolkit and the PREMO Standard. *Computer Graphics Forum* **16**(3), 159–176.

CWI Reports

INS-R9703. D.J.N. VAN EIJCK. *Typed logics with states.*

INS-R9704. D.J. DUKE, I. HERMAN, T. RIST, M. WILSON. *Relating the primitive hierarchy of the PREMO standard to the standard reference model for intelligent multimedia presentation systems.*

INS-R9705. D.J. DUKE, I. HERMAN. *Programming paradigms in a object-oriented multimedia standard.*

INS-R9706. N. FRANCEZ. *On the direction of fibring feature logics with concatenation logics.*

INS-R9707. N. FRANCEZ. *Hypothetical-reasoning and radical non-constituent coordination in categorial logic.*

INS-R9708. D.A. DUCE, D.J. DUKE, G. FACONTI, I. HERMAN, M. MASSINK. *PREMO: A case study in formal methods and multimedia system specification.*

Other Publications

D.J. DUKE, D.A. DUCE, I. HERMAN, G. FACONTI (1997). *Specifying the PREMO Synchronization Objects*, ERCIM Technical Report, ERCIM-02/97-R048.

D.A. DUCE, D.J. DUKE, G. FACONTI, I. HERMAN(1997). *The Changing Face of Standardization: a Place for Formal Methods?* ERCIM Technical Report, ERCIM-08/97-R050.

A. GROENINK (1997). *Surface without Structure – Word order and Tractability Issues in Natural Language Analysis*, Ph.D. thesis, University of Utrecht.

J.E.A. VAN HINTUM (1997). *Quality Contraints & Constrained Quality*, Ph.D. thesis Eindhoven University of Technology.

M. HAZEWINKEL (ed.) (1997). *Encyclopaedia of Mathematics*, Supplement I (Volume 11), KAP.

M. HAZEWINKEL (1997). Index Artificial Intelligence Volumes 1–89. *Artificial intelligence* **96**, 1–227.

J. VAN EIJCK (1997). Is the Generic Book a Good Buy? *JOLLI* **6**, 339–341.

J. VAN EIJCK (1997). Let's accept rejects, but only after repairs. A. VAN DEURSEN, J. HEERING (eds.). *Liber Amicorum for Paul Klint*, CWI.

J. VAN EIJCK (1997). *Proposal for a Centre of Excellence in Logic* (NWO Grant Proposal, September)

J. VAN EIJCK (1997). *Electronic Logic Modules* (SURF Grant Proposal, December)

M. HAZEWINKEL (1997). INTAS proposals, 2 April 1997:

– Regenerative analysis of reliability problems and statistics of weak regenerative queueing processes (96–794)

– Algorithmic methods in variational problems and topology (96-800)

– Symmetry and cohomology approach to equations of mechanics and mathematical physics (96–793)

– English-Russian enriched thesaurus in mathematics (96–741).

M. HAZEWINKEL (1997). EU proposals (DG XIII), May 1997:

– Comprehensive multilingual dictionary and thesaurus in mathematics and theoretical computer science (COMMEDIANT).

– Proposal to BMBF (Bonn), 16 May 1997: *COMACS, Comprehensive Mathematics and Computer Science on the Web* (Entwicklung des elektronisches Informationsnetzes).

Quantum Computing and Advanced Systems Research – INS4

Staff

- Prof. dr. ir. P.M.B. Vitányi, group leader
- Prof. dr. A.E. Brouwer
- Prof. dr. L. Fortnow (sabbatical University of Chicago)
- Dr. H.M. Buhrman, postdoc, NFI
- Dr. J.T. Tromp, postdoc (from April), CWI/NFI
- Dr. F. Gruau, postdoc
- Dr. R. Cramer, Ph.D. student
- Dr. L. Torenvliet (visiting University of Amsterdam from september)
- Drs. H.H. Ehrenburg, Ph.D. student, CWI
- Drs. P.D. Grünwald, Ph.D. student, SION
- Drs. B. Terhal, Ph.D. student, UvA
- Drs. W. van Dam, Ph.D. student, UvA
- Drs. R.M. de Wolf, UvA
- Drs. D. van Melkebeek, TMR (EU)

Scientific Report

The project works at algorithmic methods and complexity analysis. Specific subjects are quantum computing, quantum communication, and quantum information theory, 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.

Quantum Computing – INS4.1

The research of the group at CWI has a major commitment 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 ten 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 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 quantum mechanics, thus increasing our understanding of quantum phenomena. The project has no counterpart in the Netherlands. The INS4 group at CWI (Algorithms and Complexity) cooperates with the Theoretical Physics Department and the Computer Science and Logic Department of the University of Amsterdam and various major centres abroad: among others the Quantum Information Group at IBM T.J. Watson Research (C. Bennett), the Quantum Computation Group at the Clarendon Laboratory at Oxford University (A. Ekert), Computer Science Department of the University of Alberta at Calgary, Canada, (R. Cleve).

Buhrman and *Cleve* (University of Calgary, Canada) investigated the benefits of quantum mechanical effects in the setting of communication complexity. To this end they extended the usual model – where two (or more) players each have a part of the input to a function that has to be computed – with each player having a supply of *entangled qbits*. One can show that these entangled qbits can not be used to reduce communication. However they showed that in the scenario of communication complexity these entangled bits can be used to reduce the communication complexity of a function. The paper *Substituting Quantum Entanglement for Communication* containing these first results was published in Physical Review A (Volume **56**, Number 2).

Buhrman, *Cleve* , and *Van Dam* extended these results and their paper *Quantum Entanglement and Communication Complexity* was accepted for SIAM journal on Computing. *Buhrman*, *Van Dam*, *Høyer* (Odense Universty), and *Tapp* (Université de Montréal) generalized this idea further to a multiparty scenario and showed a reduction of the communication complexity with an unbounded factor. The referees of the journal *Physical Review A* described this work as 'extremely interesting' and 'breaking new ground in a rapidly moving field'.

Buhrman, *Cleve*, and *Wigderson* (Hebrew University) finally obtained the first asymptotical examples of functions where the gap between classsical communication complexity and quantum communication complexity is as big as exponential. The main tool in this paper is a reduction from quantum communication complexity to quantum black-box computation. As a consequence of this reduction they also obtain the first lower bounds for exact database search and computing the parity in the quantum black-box model. Their paper *Quantum vs. Classical Communication and Computation* is to appear at STOC'98 in Dallas.
Other papers on this subject are to be published in 1998 (communication complexity of the inner product function) or are in preparation (alternative multiparty communication schemes).

Van Dam. Led by the possible applications of entangled quantum bits, a closer look was taken to the so-called 'non-locality proofs' in quantum physics. In collaboration with Lucien Hardy and Jason Semitecolos at the Clarendon Laboratory in Oxford, Wim van Dam is currently analyzing the statistical differences between the various known proofs of non-locality for entangled systems. This may lead to a deeper understanding of this phenomenon which has no counterpart in classical information theory.

Van Dam, together with researchers from the Quantum Computation Group in Oxford, continued his research in optimal measurement procedures and accessible information in identical copies of unknown quantum states. A conjectured bound on the optimal quality of quantum mechanical measurements was proven correct by other researchers. Current investigations concentrate on the possible connections between quantum algorithms and state estimation procedures.

Beals (University of Arizona), *Buhrman*, *Cleve*, *Mosca* (University of Oxford), and De Wolf, proved that any quantum black-box algorithm that makes T calls to an oracle can be transformed in a $2T$ degree multivariate linear polynomial that represents the function computed by the quantum algorithm. This reduction enables them to show for a big class of functions tight upper and lower bounds. Another result is that any quantum algorithm computing a total function can be simulated by a *deterministic* al-

gorithm with at most a polynomial overhead in the number of oracle queries. These results are written in the manuscript *Tight Quantum Bounds by Polynomials*.

Terhal has been collaborating with the Quantum Information Theory Group at the IBM T.J.Watson Research Center on quantum information theory and quantum computation. During the first period of her visit at IBM a class of problems was found for which there exists quantum algorithms that have a quantum decision tree complexity equal to 1. A research was set up to determine the classical capacity of quantum channels that will find its continuation in 1998. During the second visit, work was done solving several problems related to the definition of quantum channel capacity which have led to a simplification of this quantity. Currently, research is pursued on the efficient simulation of quantum operations with mixed environments. In 1998 the collaboration will be continued and Barbara Terhal will address the question of the efficient simulation of quantum systems on a quantum computer.

Vitányi started an initial investigation into the proper approach to the quantitative definition of quantum information (quantum Kolmogorov complexity) and its properties.

Physics of Computation

Vitányi, Tromp and *M. Li* continued work on reversible computing and reversible simulation of irreversible computations. The final version of the paper is to appear in *Physica D*. This work has already led to several follow-up papers and interest in groups (like at MIT) implementing reversible electronic logic chips.

Machine Learning – INS4.2

Learning and data compression

Grünwald, P. Kontkanen, P. Myllymäki, T. Silander, and *H. Tirri* (Univ. of Helsinki), worked on Bayesian and MDL methods for machine learning problems. On the theoretical side, it was proven that Bayesian networks are a 'regular' model class in the sense that Rissanen's asymptotic expansion of the stochastic complexity applies to them. This implies that for Bayesian networks, the marginal distribution based on 'Jeffrey's Prior' can be used as an asymptotically perfect approximation of stochastic complexity, and as such, should yield very good results when actually used in prediction and classification tasks. In addition, another efficiently computable approximation to the stochastic complexity was developed and derived. These two approximations were then used for classification and prediction tasks for several real-world data sets. Their performance was compared to the performance of some standard Bayesian methods involving 'ESS' (Equivalent Sample Size) priors. Both Bayesian MAP (based on a single model) and Bayesian evidence (based on an average over all models) approaches were used. The results showed that the Bayesian evidence and Stochastic Complexity approaches both performed about equally well, clearly outdoing the Bayesian MAP approach.

Grünwald has written *Model Selection Based on the MDL Principle*, a general introduction to the MDL Principle and its use for Model Selection as an invited contribution to a special issue on model selection of the *Journal of Mathematical Psychology*. The intention of this issue is to familiarize mathematical psychologists with the latest developments in model selection.

Grünwald showed how the MDL Principle can be applied to Reasoning under Uncertainty in general. The paper *Non-deductive Inference and the MDL Principle* describes how the MDL Principle generalizes the popular Maximum Entropy (ME) Principle for Reasoning under Uncertainty. Using MDL instead of ME avoids certain anomalies of the latter approach, specifically its treatment of *disjunctive* knowledge.

Grünwald has continued his work on reasoning under uncertainty involving the *frame problem*. The results on the relation between causal and non-causal approaches to this problem that were obtained in 1996 were refined and put in a much simpler form. This led to the publication *Causation and Nonmonotonic Temporal Reasoning* that was presented at *KI '97* (the annual German AI conference). Furthermore, the connection between Pearl's theory of causation and Grünwald's work was formalized; a theorem showing essential equivalence between both approaches was proved.

Vitányi extended his work with M. Li treating the mathematical relation between data compression and learning, showing that compression is almost always the best strategy, both in hypotheses identification by using the minimum description length (MDL) principle and in prediction methods. This work was reported in the invited Paper in ECML'97, and the final version submitted to *IEEE Trans. Inform. Th.* was revised. This material is also (partially) covered in the Second Edition of the textbook *An Introduction to Kolmogorov Complexity and Its Applications* that appeared in 1997 and the Chinese translation of an abbri eviated version, to be published by the Chinese Science Press.

Tromp showed together with John Kececioglu and

Ming Li partial results on the genetic sequencing problem of how to infer a DNA sequence from erroneous copies. This work was published in *Theoret. Comput. Sci.*, 1997.

Evolutionary Computing
Gruau continued to work on his method to encode neural networks, called 'cellular encoding'. This includes developments in machine learning and parallelism.
In machine learning, he used cellular encoding to evolve a neural network to control the locomotion of an 8-legged robot, and presented the result at the European Conference on Artificial Life. During this conference, he also organized the 'First Autonomous Robotic Football Tournament'. This turned out to be the most exciting event of the conference. The final game was broadcast during the international news, in England, Spain, and Italy. He is now co-organizing the next tournament to take place in the National Science Museum, in London, July 1998.
In parallelism, Cellular Encoding leads to a new, memoryless model of massive fine grain parallelism. Gruau developed this model together with a language for it, and worked out examples. One of the basic operations of this model is expressed as the piling up of particles by a bounded 2D cellular automaton. He proposed a simple Cellular Automaton rule to do this task and proved that the task is completed in 3*h steps, where h is the height of the grid. These results where presented at the 'Institut National d'Informatique et Automatique' of Nancy, and at CWI. A research report is being submitted.

Vitányi revised his work on highly probable fitness optimization through evolutionary computing runs on small size populations in a very general setting. This has applications to evolutionary learning. Based on rapidly mixing Markov chains, the approach pertains to most types of evolutionary genetic algorithms, genetic programming and the like. He was program committee member for many conferences in the computational learning area including ALT97, ISAIM97, SNAC97, ECML97.

Algorithms and Complexity, Advanced Systems Research – INS4.3

Distributed and Network Computing

Buhrman, F. Franklin (AT&T, USA), *J. Garay, Hoepman, Tromp,* and *Vitányi* formulated a new type of search problem called 'mutual search', where players located in the nodes of a network are required to locate each other by posing 'anybody at node i?' queries (for example processes in a computer network). They designed algorithms showing that the minimal number of queries required by two players in a network of n nodes is considerably less than the $n-1$ queries one naively expects to be optimal. We also give upper and lower bounds for the deterministic worst case. These bounds are almost sharp (within 5 percent). They also exhibit a simple randomized algorithm whose cost beats the determinstic lower bound, and a deterministic algorithm for more than players with a cost well below n for a number of players roughly below square root of n. More precisely: If the messages are not delivered in the order they were sent (for example when the communication delay time is arbitrary) then two players require at least $n-1$ messages. In an asynchronous network, where the messages are delivered in the order they were sent, $0.88n$ messages suffice. In a synchronous network $0.586n$ messages suffice and $0.536n$ messages are required in the worst case. We exhibit a simple randomized algorithm with expected worst-case cost of $0.5n$ messages, and a deterministic algorithm for $k \geq 2$ players with a cost well below n for all $k = o(\sqrt{n})$.
The graph-theoretic framework they formulate for expressing and analyzing algorithms for this problem may be of independent interest.
Besides being a new type of search problem with potentially many applications, these results are bound to have an impact on the field of secure multi-party computation, where is typically assumed that the bad players already form a coalition that is fully coordinated. These results will be presented at SODA'98.
Vitányi serves in the program committee of the *Annual ACM Conference on Principles of Distributed Computing* 1998, to be held in Puerto Vallarta, Mexico.

Algorithms and Complexity

Buhrman and *L. Fortnow* (On sabbatical from Univ. of Chicago) studied resource bounded Kolmogorov Complexity. Most notably are two theorems in resource bounded Kolmogorov complexity that allow many applications in complexity theory. The results can be found in *Resource Bounded Kolmogorov Complexity Revisited* in the proceedings of the STACS'97, Germany.

They also obtained new results on the question whether 2 questions to Satisfiability yield more information than 1 question. The paper *Two Queries* has been accepted for CCC'98 in Buffalo, USA, and has been invited for the special issue of the 98 conference.

Buhrman, Beigel (Lehigh University), and *Fort-*

now created a relativized world where the Valiant-Vazirani isolation lemma does not hold deterministically. This proof answers several other open oracle questions such as giving a world where every exponential time set can be solved nondeterministically in polynomial-time yet there are no one way functions. This gives an easy construction of the Berman-Hartmanis isomorphism conjecture vastly simplifying earlier work of Fenner, Fortnow and Kurtz. Their paper *NP Might Not Be As Easy As Detecting Unique Solutions* was accepted for STOC'98 in Dallas.

Buhrman, *S. Fenner* (Univ. of Maine), and *L. Fortnow* studied resource bounded measure and obtained several results. These results can be found in *Results on Resource bounded Measure* in the proceedings of the ICALP'97 in Bologna, Italy.

Fortnow and *Rogers* (DePaul University) examined BQP, problems computed quickly by quantum computers, and found strong connections to earlier work in counting complexity due to Fenner, Fortnow, Kurtz and Li. These connections give strong simple new limitations on the power of quantum computation. Their paper *Complexity Limitations on Quantum Computation* was accepted for CCC'98 and was invited to the special issue.

Buhrman, *Fortnow*, and *Thierauf* (Ulm University) gave the first reasonable nonrelativizing separation result showing that the exponential variation of Merlin-Arthur games is not computable with polynomial-size circuits and gave a relativized world where it does. Their paper *Nonrelativizing Separations* was accepted for CCC'98, in Buffalo.

Buhrman, *Vitányi* and *M. Li*, later joined by *Tromp*, embarked on a systematic study to the properties of Kolmogorov Random Graphs. Old and several new properties are discovered. The theory of individual random graphs (Kolmogorov random graphs) was extended with close estimates of mean and variance of occurrence frequencies of all graphs of given size as subgraphs of an individual high-complexity graph. These new results imply that all subgraphs of appropriate given size occur with certainty. They gave an elementary proof using the incompressibility method (Kolmogorov complexity) for the asymptotic expression for the number of unlabeled graphs – a result due to Harary and Palmer in the seventies using sophisticated arguments. They investigated the similarity and differences between global form properties such as that some property occurs with high probability, and local properties such as that some property holds for every object of high Kolmogorov complexity. A difference is that in the latter case all properties which hold locally hold simultaneously for the local object, while this is not the case for high-probability local properties. These results can be found in *Kolmogorov Random Graphs and the Incompressibility Method* and was presented at the *IEEE Conf. on Compression and Complexity of sequences 1997*.

Fortnow, and *R. Downey* give some evidence that the tools used in Ladner's proof giving incomplete NP sets must create large easy gaps. These results are published in *Uniformly Hard Languages* and were accepted for CCC'98 in Buffalo.

Fortnow, inspired by his work on autoreducibility with Buhrman and Torenvliet, showed some work in the direction of separating the complexity classes NL and NP. Part of this work gives the first nontrivial machine-independent time-space trade-off for satisfiability. These results *Nondeterministic Polynomial Time versus Nondeterministic Logartithmic Space* were accepted and presented at Computational Complexity Theory 97

Fortnow is program committee member of 29th ACM Symposium on the Theory of Computing (1997).

Van Melkebeek was a Marie Curie Fellow from January till September, and a visiting Ph.D. student from The University of Chicago. He joined his adviser Lance Fortnow, who completed a sabbatical year at CWI.
Van Melkebeek spent most of his time on structural properties of complexity classes. A very promising one from the point of view of separating complexity classes is the autoreducibility of the complete sets. Buhrman, Fortnow and Torenvliet presented a paper on this topic at the 36th Symposium on Foundations of Computer Science in 1995. Together with Van Melkebeek, they refined and furthered this approach, and finished a paper *Separating Complexity Classes using Autoreducibility* to be submitted to SIAM Journal on Computing.

Buhrman and *Van Melkebeek* investigated another possible way of separating complexity classes. The idea is to show that one class has a lot of complete sets, and the other only has a few. Using Lutz's concept of resource bounded measure to formalize the notions of scarceness and abundance within complexity classes, they showed that complete sets for several complexity classes within exponential time and under various reducibilities are rare. These results were reported in *Hard Sets are Hard to Find*, and was accepted for CCC'98.

Buhrman, *van Melkebeek*, *Regan* (SUNY Buffalo, USA), *Sivakumar* (University of Texas), and *Straus*

(AT&T research) combined a new appraoch to resource bounded measure, betting games, with the aforementioned autoreducibility and the joint paper *A Generalization of Resource-Bounded Measure, with an Application* was presented at ATCS'98.

Van Melkebeek and *Zhou* (Bell Labs) also worked on pseudo-randomness and derandomization.

Buhrman, *Fortnow*, and *Torenvliet* wrote an overview paper *Six Hypotheses in Search of a Theorem*. This paper was presented as invited lecture by Buhrman at CCC'97 in Ulm.

Buhrman and *Torenvliet* extended earlier work of Buhrman with respect to the set of resource bounded kolomogorov random strings. They showed that various versions of this set are complete or hard for well studied complexity classes under *nondeterministic* reductions. Their paper *Randomness is Hard* was accepted for CCC'98

Cramer, *Schoenmaker*, and *Grennaro* working on electronic voting protocols revealed a secure and more efficient voting mechanism. The results will be published in the European Journal on Telecommunication and in Eurocrypt'97 as *Secure and Optimally Efficient Multi-Authority Election Scheme*.

Cramer and *Damgård* (Aarhus University, Denmark) paper *Linear zero-knowledge: A Note on Efficient Zero-Knowledge Proofs and Arguments* was presented at STOC'97. Their work on secure identification *Fast and secure immunization against man-in-the-middle impersonations* was presented at EUROCRYPT '97.

Cramer finished his Ph.D. thesis *Modular Design of Secure yet practical cryptographic protocols* and defended it with success on January 31, 1997.

Buhrman is program committee member of CCC'97 in Ulm, Germany.

Vitányi and M. Li continued with the theory of time-bounded universal distributions and their applications in 'simple pac-learning' and 'universal average case complexity.'

The 2nd revised and extended edition of *An Introduction to Kolmogorov Complexity and Its Applications*, Springer-Verlag, New York, was prepared and it appeared in 1997 (xx+637pp). The book was translated into Chinese (to appear with the *Chinese Science Press*, Beijing, China).

Vitányi was/is program committee member of COCOON'97 in Shanghai, WADS97 in Canada, LFCS'97 in Russia, IEEE Compression and Sequences Conf 97 in Italy, PODC98 in Mexico, ESA98 in Italy, and MFCS98 in the Slovak Republic, WDAS97 in Canada.

Organization of Conferences, Workshops, Courses, etc.

- *COLORET.* European HCM project in the area of Computation, Logic and recursion theory.
- *ESPRIT.* 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 plenary speaker at the ECML97 conference in Prague, Czech Republic, and program committee member of ALT97 in Japan, ECML97 in Czech Republic, The Fifth International Symposium on Artificial Intelligence and Mathematics 1998 in Fort Lauderdale, Florida, USA, and the School on Natural Computation (SNAC), 1997 in Finland.
  Partners in the ESPRIT Working Group are 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. EuroCOLT finished early 1997, was extended by the ESPRIT Commission to end 1997, and subsequently the follow-up EuroCOLT II was approved comprising a changed set of partners including CWI.

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

H. Buhrman:

- *CCC'97 PC meeting*, Barcelona, Spain, Universitat Polytecnica de Catalunya, February 17–24 (*Fast Longlived Renaming*)
- *STACS'97*, Lübeck, Germany, March 1–4 (*Resource bounded Kolmogorov Complexity Revisited*)
- Barcelona working visit Balcazar/Gavalda, Universitat Polytecnica de Catalunya, May 1–10 (*Substituting Quantum Entanglement for Communication*)
- *CCC'97*, University of Ulm, June 24–27 (*Six Hypothesis in Search of a Theorem*)

- Visit Garay, IBM Yorktown Heights/ Crypto group, August 7–8 (*Quantum Communication Complexity*)
- *DIMACS workshop on quantum computing* Princeton University, Princeton NJ, USA, August, 11–15
- *Workshop complexity theory*, Freeport Maine University of Southern Maine, Freeport MA, USA, August 17–22 (*Quantum Communication Complexity*)

P. Vitányi:

- *Conference on Simplicity in Economics: Theory and Applications*, CentER Institute, Faculty of Economics, Catholic University Brabant, Tilburg, January 9–11 (*Simplicity and the Quantity of Information: Kolmogorov Complexity*)
- *NeuroCOLT ESPRIT Working Group 8556 Workshop*, Les Menuires, France, February 16–21 (*Ideal MDL, Bayesianism and Kolmogorov Complexity in Induction and Learning*).
- *Amsterdam Logic Colloquim*, Institute for Logic, Language and Computation, University of Amsterdam, March 7 (*Physics of Computation and the Quantum Computing Challenge*)
- *European Conference on Machine Learning*, Prague, Czech Republic, April 22–26 (*Prediction by Data Compression*)
- *IEEE Conference on compression and complexity of sequences*, Positano, Italy, June 10–13 (*Kolmogorov Random Graphs*)
- Computer Science Department, City University of Hong Kong, Kowloon, Hong Kong, August 4–17 Host: Prof. M. Li. (*Mutual Search*)
- *3rd Annual International Computing and Combinatorics Conference (COCOON)*, Shanghai, Peoples Republic of China, August 18–22 (*Mutual Search*).

L. Fortnow:

- *ENS Paris*, visit Serge Vaudenay Paris, France, January 16–17 (*Nondeterministic Polynomial-Time versus Nondeterministic Polynomial Space*)
- Hebrew University visit Noam Nisan, Jerusalem Israel, January 16–19 (*Nondeterministic Polynomial-Time versus Nondeterministic Polynomial Space*)
- Weizmann Institute visit Uri Feige Israel, January 20–21
- *14th Symposium on Theoretical Aspects of Computer Science*, Lübeck, Germany, February 27–March 1
- *Dagstuhl Workshop on Circuit Complexity*, Dagstuhl, Germany, March 10–15 (*Nondeterministic Polynomial-Time versus Nondeterministic Polynomial Space*)
- Heidelberg University visit Klaus Ambos-Spies Germany, April 7–8 (*Results on Resource-bounded Measure*)
- Tübingen University visit Klaus-Jörn Lange Germany, April 7–8 (*Two Queries*)
- Stuttgart University visit Volker Diekert Germany, April 11 (*Nondeterministic Polynomial-Time versus Nondeterministic Polynomial Space*)
- *12th IEEE Conference on Computational Complexity*, Ulm, Germany, June 24–27 (*Nondeterministic Polynomial-Time versus Nondeterministic Polynomial Space*)
- *24th Iternational Colloquium on Automata, Languages and Programming*, Bologna, Italy, July 7–11 (*Results on Resource-bounded Measure*)

P. Grünwald:

- Dagstuhl meeting on *Theory and Praxis of Machine Learning*, Schloß Dagstuhl, Germany, January 6–10 (*The NEW Definition of Stochastic Complexity*)
- DGNMR '97 (1997 Dutch-German Workshop on Nonmonotonic Reasoning), Saarbrücken, Germany, February 19-21 (*Causation, Explanation and Persistence*.
- Working visit to the University of Helsinki (COSCO group, P. Myllymaki and H. Tirri), Helsinki, Finland, May 24–July
- Conference on *Methods for Model Selection*. Bloomington, Indiana, USA, August 3–4 (*The MDL Principle for Model Selection*)
- *IJCAI '97* (Fifteenth International Joint Conference on *Artificial Intelligence*). Nagoya, Japan, August 23–29 (1) (*The MDL Principle and Nondeductive Inference* during 'IJCAI Workshop on *Abduction and Induction in AI*'; (2) *Nonmonotonic Temporal Reasoning as a Search for Explanations* during '2nd IJCAI Workshop on *Nonmonotonic Reasoning, Action and Change*')
- *KI '97* (21st German conference on *Artificial Intelligence*), Freiburg, Germany, September 8–12 (*Causation and Nonmonotonic Temporal Reasoning*).
- *BeNeLearn '97* (1997 Belgium-Netherlands Conference on *Machine Learning*), Tilburg, October 21 (*On Predictive Distributions and Bayesian Networks*)
- One-Day visit to University of Tilburg, November 13 (*A Gentle Introduction to the MDL Principle*).
- One-Day visit to University of Amsterdam, Autonomous Systems Working Group. Amsterdam, November 18 (*A Gentle Introduction to the MDL Principle*)

J. Tromp:

- Third European Conference on *Computational Learning Theory*, Jerusalem, Israel, March 17–19

- Hong Kong University, visit Ming Li, Hong Kong June 12–28

D. van Melkebeek:

- 14th Symposium on *Theoretical Aspects of Computer Science*, Lübeck, Germany, February 27–March 1
- 12th Annual IEEE Conference on *Computational Complexity*, Ulm, Germany, June 24–27 (*Complete Sets under Non-Adaptive Reductions are Scarce*)
- 24th International Colloquium on *Automata Languages and Programming*, Bologna, Italy, July 7–11
- University of Heidelberg (Prof. Klaus Ambos-Spies), Heidelberg, Germany, June 27–30 (*Complete Sets under Non-Adaptive Reductions are Scarce*)
- University of Tübingen (Prof. Klaus-Jörn Lange), Tübingen, Germany, July 1–2
- University of Stuttgart (Prof. Ulrich Hertrampf), Stuttgart, Germany, July 3 (*The Sparse Hard Set Problem for P*)
- University of Würzburg (Prof. Klaus Wagner), Würzbrug, Germany, July 4–6 (*Resource Bounded Measure and the Frequency of Complete Sets*)
- Colloquium: Amsterdam Complexity Theory Workshop, University of Amsterdam, January 29 (*SL is Contained in* $L^{4/3}$)
- Colloquium: Amsterdam Complexity Theory Workshop, CWI, May 14 (*Complete Sets under Non-Adaptive Reductions are Scarce*)

B. Terhal:

- IBM T.J. Watson Research Center (C.H.Bennett), Yorktown Heights, NY, USA, March 1–June 1
- IBM T.J. Watson Research Center (C.H.Bennett) Yorktown Heights, NY, USA, July 16–December 1
- First Killam Workshop on *Quantum Information Theory*, Montréal, Canada, May 27–29 (*Superfast Quantum Algorithms for Binary Search and Coin Weighing Problems*)
- Workshop on *Quantum Computation*, Villa Gualino, Turin, Italy, July 6–13 (*Superfast Quantum Algorithms Bor binary Search and Coin Weighing Problems*)
- DIMACS *Quantum Computing Tutorial and Workshop*, Princeton, NJ, USA, August 11–15 and June 15 (*Superfast Quantum Algorithms for Binary Search and Coin Weighing Problems*)
- Lunchseminarium, January 29 (*Quantum Computation*)
- IPA dagen, Veldhoven, April 15 (*Quantum Entanglement and the Teleportation of a Qubit*)

W. van Dam:

- Quantum Transport group, Delft University of Technology, working visit C. van der Wal, March 12 and June 2
- Quantum Computation Group, University of Oxford, working visit A. Ekert, Oxford, United Kingdom, March 16–March 23 (*Accessible Information in Identical Quantum States*)
- ISI Quantum Computation Workshop, Institute for Scientific Interchange Foundation at Villa Gualino, Turin, Italy, June 29–July 11 (*Quantum Communication Complexity of the Inner Product Function*)
- Krasnoyarsk Summer School'97, Krasnoyarsk University, Moscow Institute of Physics and Technology, Moscow State University, and Novosibirsk State University) Krasnoyarsk, Russia, July 24–August 13 (3-week course *Introduction to Computability Theory*)
- Mini-course on Quantum Computing, Department of Computer Science at the University of Helsinki, Helsinki, Finland, September 17–19 (3-day minicourse *Introduction to Quantum Computing*)
- *Quantum Computation Group*, University of Oxford long term working visit A. Ekert, Oxford, UK, September 29–December 17
- *Quantum Computation: Theory and Experiment*, Meeting of The Royal Society, London, UK, November 5–6
- *Issues in Quantum Computation and Information* Novartis Foundation Discussion Meeting, London, UK, November 7
- Department of History and Foundations of Mathematics and the Natural Sciences at the University of Utrecht, January 17 (*Goulash, Soufflés, and Other Recipes for Quantum Communication*)
- Department of Mathematics and Computer Science at the University of Amsterdam, March 7 (*Quantum Superdense Coding and Teleportation*)

R. Cramer:

- Working visit to Ueli Maurer, ETH, Zürich, Switzerland, January
- 29th ACM Symp. on Theory of Computing, El Paso, Texas, USA, May (*Linear zero Knowledge*)
- *EUROCRYPT '97*, Konstanz, Germany, May (*Fast and Secure Immunization against Man-in-the-middle Impersonations*).
- IFIP CWI (Vitányi) is member of the IFIP Special Interest Working Group on *Descriptional Complexity* now IFIP WG 1.2, and cochair of IFIP Special Interest Working Group on *Computational Machine Learning* IFIP WG 1.4.

A.E. Brouwer:

- Zsolt Baranyai meeting, Hungarian Academy of Sciences, Budapest, December 18 (*Around Baranyai's theorem*)

- Minisymposium Combinatorics, Barcelona, Spain, October 2–7 (*Model theory and Generalized Quadrangles*)
- European conference on Combinatorics, San Feliu de Guixols, Spain, September 29–October 7 (*The classification of distance-regular graphs of valency four*)
- Seminar Fort Collins, Colorado, USA, September 12 (*Model theory and Generalized Quadrangles*)
- Seminar Laramie, Wyoming, USA, September 7 (*Buildings and strongly regular graphs*)
- Finite Geometries, Deinze, Belgium, May 18–23 (*Linear spaces of quadrics*)
- 32e Ned. Math. Congres, Wageningen, April 3–4 (*De Klassificatie van Afstandsreguliere Grafen van Valentie 4*)

F. Gruau:

- INRIA, Nancy, France, December 10–12 (*Cellular encoding for interactive evolutionary robotics*)
- CWI Seminar, December 16 (*A New Model of Massive Parallelism*)

Memberships of Committees and Other Professional Activities

P.M.B. Vitányi:

- Professor of Computer Science, University of 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 Verlag, 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
- Invited Plenary Speaker at the *Conference on Simplicity in Economics: Theory and Applications*, Senter Institute, Faculty of Economics, Catholic University Brabant, Tilburg, January 1997
- Invited Plenary Speaker at the *European Conference on Machine Learning*, Prague, Czech Republic, May 1997
- Invited Plenary Speaker at the *IEEE Conference on Compression and Complexity of Sequences*, Positano, Italy, June 1997
- Invited Plenary Speaker at the *3rd Annual International Computing and Combinatorics Conference (COCOON)*, Shanghai, Peoples Republic of China, August 1997
- Program Committee, *23th International Symposium on Mathematical Foundations of Computer Science*, 1998, Brno, Slovak Republic
- Program Committee, *ACM Conference on Principles of Distributed Computing (PODC 98)*, Puerto Vallarta, Mexico
- Program Committee, *European Symposium on Algorithms ESA'98*, Venice, Italy, August 1998
- Program Committee, *The Fifth International Symposium on Artificial Intelligence and Mathematics*, January 4–6, 1998, Ft. Lauderdale, Florida
- Program Committee, *11th International Workshop on Distributed Algorithms, WDAG-11*, Saarbrücken, Germany
- Program Committee, *Compression and Complexity of SEQUENCES 1997*, in cooperation with the IEEE Data Compression Conference Positano (Amalfitan Coast) – Salerno, Italy, June 11–13
- Program Committee, *School on Natural Computation (SNAC)*, August 25–29: Turku, Finland
- Program Committee, *Algorithmic Learning Theory Conference*, Hong Kong
- Program Committee, *5th bi-annual Workshop on Algorithms and Data Structures*, WADS'97, Halifax, Canada, in August
- Program Committee, *10th European Conference on Machine Learning*, Prague, Czech Republic
- Program Committee, *Fourth International Conference on Logical Foundations of Computer Science* (LFCS'97) on July 6–12: in Yaroslavl, Russia
- Program Committee, *Third Annual International Computing and Combinatorics Conference* (COCOON'97), August: Shanghai, China
- 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 (EuroCOLT)*
- Member IFIP WG 1.2 on *Descriptive Complexity and Applications*, since 1991; co-chair of IFIP WG 1.4 on *Computational Machine Learning*

- Publiciteitscommissie van het Wiskundig Genootschap (Publicity Committee Dutch Mathematical Society), since 1989
- Ph.D. Supervisor in 1997 of B. Terhal, R. Cramer, H.H. Ehrenburg, P. Grünwald, W. van Dam, R. de Wolf, University of Amsterdam
- Ph.D. Committee (M. Wiering), University of Amsterdam, 1997–
- Licentiate Thesis Outside Examiner (M. Hirvensalo), University of Turku, Finland, 1997–
- Ph.D. Committee (B. Terwijn), University of Amsterdam, 1997–
- Advisor *Monash Key Centre for Computational Data Analysis*, Monah University, Clayton Campus, Melbourne, Australia
- 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 of the board)
- Dutch *Institute for Programming and Algorithmics (IPA)* (member)
- *Onderzoeksschool Logica (OzL)* (member)
- Project leader various SION projects in Machine Learning, Multiple Computing Agents, Cryptography and Randomness, Quantum Computing

A.E. Brouwer:
- Member of Ph.D. committee for Mario de Boer (970321), Willem de Graaf (970610), Marten van Dijk (971208)
- Editor of *European J. Combinatorics*
- Editor of *J. Algebraic Combinatorics*

F. Gruau:
- Organizer of the *First Autonomous Football Tournament* during ECAL '97
- Program committee member of *First European Conference on Genetic Programming*, March 1997
- Program committee member of *First European Conference on Evolutionary Robotics*, April 1998
- Program committee member of *Genetic Programming conference* '97 and '98

H. Buhrman:
- Member of the porgram committee for *12th annual conference on Computational Complexity*, Ulm
- Member of the program committee of *RANDOM'98*
- Member of Program committee of *SIROCCO'98*

L. Fortnow:
- Editor, *Information and Computation*
- Editor, *Chicago Journal of Theoretical Computer Science*
- Member, *IEEE Conference on Computation Complexity Conference Committee*
- Member, *29th ACM Symposium on the Theory of Computing*, Program Committee

D. van Melkebeek:
- Organizer bi-weekly *Seminar on Computational Complexity Theory*

P. Grünwald:
- ESPRIT Working Group 8556: *Neural and Computational Learning (NeuroCOLT)*
- The Dutch 'computer science research schools' *IPA 'Instituut voor Programmatuur en Apparatuur*) and OzsL (*Onderzoekschool voor Logica*)
- Throughout 1997 member of the IPA *Promovendiraad*.
- Member of the organizing committee of the conference *Methods for Model Selection* (see under 'Memberships of committees').
- Member of Organizing Committee of *Methods for Model Selection Conference*, August 3–4, Bloomington, Indiana, USA

W. van Dam:
- In the Summer of 1997 invited lecturer at the Krasnoyarsk Summer School. This school is organized each year by members of several Russian universities and hosts around 200 Russian high-school students who are selected by a highly competitive admission procedure. He gave at this summer school a three weeks course on computatibility theory.
- The Department of Computer Science at the University of Helsinki invited him give a three day mini-course on quantum computation. This was part of a seminar on quantum computation organized by Henri Tirri of the Complex Systems Computation Group in Helsinki (September 17–19).
- Together with Hoi-Kwong Lo of the Hewlett-Packard Laboratory in Bristol (U.K.), he is responsible for the organization of the bi-monthly 'HP/Oxford Seminar on Quantum Information and Computation'.

Awards

L. Fortnow:
- Fulbright Scholar Award
- NWO grant

P. Vitányi:
- SION Projects, ESPRIT BRA 4 Project

Visitors

- Eric Allender (Rutgers University, USA)
- Nick Chater (University of Warwick, UK)
- Richard Cleve (University of Calgary, Canada)
- Joan Feigenbaum (AT&T Research, USA)
- Jack Lutz (Iowa state University, USA)

- Mike Mosca (Oxford University, UK)
- Petri Myllymaki (University of Helsinki, Finland)
- Walter Savitch (University California, San Diego, USA)
- Marcus Scheafer (University of Chicago, USA)
- John Smolin (IBM research, USA)
- Thomas Thierauf (Ulm University, Germany)
- Moti Yung (Columbia University, USA)
- Shiyu Zhou (AT&T Research, USA)

Papers in Journals and Proceedings

A. BLOKHUIS, A.E. BROUWER (1997). Determination of the distance-regular graphs without 3-claws. *Discrete Math.* **163**(3), 225–227.

A.E. BROUWER, W.H. HAEMERS, V.D. TONCHEV (1997). Embedding partial geometries in steiner designs. *Proceedings of the First Pythagorean Conference*, Cambridge University Press, 33–41.

A.E. BROUWER, H.M. MULDER (1997). The vertex connectivity of a $\{0, 2\}$-graph equals its degree. *Discrete Math.* **169**(1–3), 153–155.

A.E. BROUWER, M. VAN EUPEN (1997). The correspondence between projective codes and 2-weight codes. *Des. Codes Cryptography* **11**(3), 261–266.

H. BUHRMAN, S. FENNER, L. FORTNOW (1997). Results on resource-bounded measure. *Proceedings of the 24th International Colloquium on Automata, Languages and Programming*, Lecture Notes in Computer Science **1256**, Springer-Verlag, 188–194.

H. BUHRMAN, L. FORTNOW (1997). Resource-bounded kolmogorov complexity revisited. *Proceedings of the 14th Symposium on Theoretical Aspects of Computer Science*, Lecture Notes in Computer Science **1200**, Springer, Berlin, 105–116.

H. BUHRMAN, L. FORTNOW, L. TORENVLIET (1997). Six hypotheses in search of a theorem. *Proceedings of the 12th IEEE Conference on Computational Complexity*, IEEE, New York, 2–12.

H. BUHRMAN, M. LI, P. VITÁNYI (1997). Kolmogorov random graphs and the incompressibility method. *Proceedings of Conference on Compression and Complexity of Sequences (SEQUENCES'97)*, IEEE Computer Society Press, Positano, Italy.

R. CLEVE, H. BUHRMAN (1997). Substituting quantum entanglement for communication complexity. *Physical Review A* **56**(2), 1201–1204.

R. CRAMER, I. DAMGÅRD (1997). Fast and secure immunization against man-in-the-middle impersonations. W. FUMY (ed.). *Advances in Cryptology–EUROCRYPT '97*, Lecture Notes in Computer Science **1233**, Springer-Verlag, Berlin.

R. CRAMER, I. DAMGÅRD (1997). Linear zero-knowledge: A note on efficient zero-knowledge proofs and arguments. *29th ACM Symposium on Theory of Computing (STOC '97)*, New York, 436–445.

R. CRAMER, R. GENNARO, B. SCHOENMAKERS (1997). A secure and optimally efficient multi-authority election scheme. W. FUMY (ed.). *Advances in Cryptology—EUROCRYPT '97*, Lecture Notes in Computer Science **1233**, Springer-Verlag, Berlin, 103–118.

R. CRAMER, R. GENNARO, B. SCHOENMAKERS (1997). A secure and optimally efficient multi-authority election scheme. *European Transactions on Telecommunications* **8**(5), 481–490.

L. FORTNOW (1997). Counting complexity. L. HEMASPAANDRA, A. SELMAN (eds.). *Complexity Theory Retrospective II*, Springer, 81–107.

L. FORTNOW (1997). Nondeterministic polynomial time versus nondeterministic logartithmic space: Time-space tradeoffs for satisfiability. *Proceedings of the 12th IEEE Conference on Computational Complexity*, IEEE, New York, 52–60.

F. GRUAU (1997). Cellular encoding for interactive evolutionary robotic. P. HUSBANDS, I. HARVEY (eds.). *European Conference on Artificial Life*, MIT Press.

P. D. GRÜNWALD (1997). Causation and nonmonotonic temporal reasoning. G. BREWKA, C. HABEL, B. NEBEL (eds.). *KI-97: Advances in Artifical Intelligence*, Lecture Notes in Artifical Intelligence **1303**, Springer-Verlag, 159–170.

P. D. GRÜNWALD (1997). Causation, explanation and persistence. *Proceedings 1997 Dutch German Workshop on Nonmonotonic Reasoning*, Saarbrücken, 149–158.

P. D. GRÜNWALD (1997). The minimum description length principle and non-deductive inference. P. FLACH (ed.). *Proceedings IJCAI-97 Workshop on abduction and induction in AI*, Nagoya, Japan, 19–24.

P. D. GRÜNWALD (1997). Nonmonotonic temporal reasoning as a search for explanations. *Proceedings NRAC '97 (Second IJCAI Workshop on Nonmonotonic Reasoning, Action and Change)*, Nagoya, Japan, 91–102.

T. JIANG, J. SEIFERAS, P.M.B. VITÁNYI (1997). Two heads are better than two tapes. *J. Assoc. Comput. Mach.* **44**(2), 237–256.

J. KECECIOGLU, M. LI, J. TROMP (1997). Inferring a DNA sequence from erroneous copies. *Theoretical Computer Science* **185**(1), 3–13.

W.W. KIRCHHERR, M. LI, P.M.B. VITÁNYI

(1997). The miraculous universal distribution. *Mathematical Intelligencer* **19**(4), 7–15.

P. KONTKANEN, P. MYLLYMÄKI, T. SILANDER, H. TIRRI, P. GRÜNWALD (1997). Comparing predictive inference methods for discrete domains. *Proceedings AISTATS-97*, Ft. Lauderdale, USA, 311–318.

P. KONTKANEN, P. MYLLYMÄKI, T. SILANDER, H. TIRRI, P. GRÜNWALD (1997). On predictive distributions and Bayesian networks. *Proceedings BeNeLearn '97 (Belgium-Netherlands Conference on Machine Learning)*, Tilburg, 59–68.

M. LI, P.M.B. VITÁNYI (1997). Average-case analysis via incompressibility. *Proc. 11th Conference on Fundamentals of Computation Theory*, Lecture Notes in Comuter Science **1279**, Springer-Verlag, Heidelberg, 38–50.

M. LI, P.M.B. VITÁNYI (1997). Average-case analysis using Kolmogorov complexity. *Advances in Algorithms, Languages, and Complexity*, Kluwer Academic Publishers, Dordrecht, 157–169.

P.M.B. VITÁNYI, M. LI (1997). On prediction by data compression. *Proc. 9th European Conference on Machine Learning*, Lecture Notes in Artificial Intelligence **1224**, Springer-Verlag, Heidelberg, 14–30.

CWI Reports

INS-R9701. P.D. GRÜNWALD. *Causation, explanation and nonmonotonic temporal reasoning*. Available at ftp://ftp.cwi.nl/pub/pdg/R9701.ps.Z .

INS-R9709. P.D. GRÜNWALD. *The sufficient cause principle and reasoning about action*. Available at ftp://ftp.cwi.nl/pub/pdg/R9709.ps.Z .

Other Publications

R. CRAMER (1997). *Modular design of practical and provably secure cryptographic protocols*, Ph.D. thesis, University of Amsterdam.

R. BEIGEL, H. BUHRMAN, L. FORTNOW (1997). *NP Might not be as Easy as Detecting Unique Solutions*, Technical Report CS 97-02, University of Chicago Department of Computer Science.

H. BUHRMAN, L. FORTNOW, T. THIERAUF (1997). *Nonrelativizing Separations*, Technical Report CS 97-11, University of Chicago Department of Computer Science.

H. BUHRMAN, D. VAN MELKEBEEK (1997). *Complete Sets under Non-adaptive Reductions are Scarce*, Technical Report TR-97-04, The University of Chicago.

H. BUHRMAN, D. VAN MELKEBEEK (1997). *Hard Sets are Hard to Find*, Technical Report TR-97-12, The University of Chicago, 1997. Accepted for the *13th Annual IEEE Conference on Computational Complexity*.

H. BUHRMAN, R. CLEVE, W. VAN DAM (1997). *Quantum Entanglement and Communication Complexity*, Technical report, BRICS. Also as e-print on the Los Alamos archive (quant-ph/9705033).

H. BUHRMAN, W. VAN DAM, P. HØYER, A. TAPP (1997). *Multiparty Quantum Communication Complexity*, e-print quant-ph/9710054, Los Alamos archive. Accepted as Rapid Communication for Physical Review A.

L. FORTNOW, J. ROGERS (1997). *Complexity Limitations on Quantum Computation*, Technical Report 97-003, DePaul University School of Computer Science, Telecommunications and Information Systems.

P. KONTKANEN, P. MYLLYMÄKI, T. SILANDER, H. TIRRI, P. GRÜNWALD (1997). *Predictive Distributions and Bayesian Networks*, Technical Report NC-TR-97-032, Neurocolt Technical Report Series. Available at www.cs.rhbnc.ac.uk/ research/ compint/ neurocolt/.

M. LI, P.M.B. VITÁNYI (1997). *An Introduction to Kolmogorov Complexity and its Applications* , Second Edition, Springer-Verlag, New York (xx + 637 pp).

M. LI, P.M.B. VITÁNYI (1997). *Reversibility and Adiabatic Computation: Trading Time and Space for Energy*, Technical Report quant-ph/9703022. Also published in *Proc. Royal Soc. London, Series A*, 452(1996), 769–789.

M. LI, J. TROMP, P.M.B. VITÁNYI (1997). *Reversible Simulation of Irreversible Computation by Pebble Games*, Technical Report quant-ph/9703009. To appear in *Physica D*.

S.H. NIENHUYS-CHENG, R. DE WOLF (1997). *Foundations of Inductive Logic Programming*, Lecture Notes in Artificial Intelligence **1228**, Springer-Verlag, Berlin.

B.M. TERHAL (1997). Quantum informatie theorie bij IBM. *WINS faculteitsblad 'De Afleiding'*.

P.M.B. VITÁNYI (1997). Physics of Computation and the quantum computing challenge. *NVTI Bulletin*.