Overview Research Activities 2001

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CWI is the National Research Institute for Mathematics and Computer Science. It is sponsored by the Netherlands Organization for Scientific Research (NWO). CWI is a founding member of ERCIM, the European Research Consortium for Informatics and Mathematics. It participates in the Telematica Instituut and the Amsterdam Science Technology Centre (WTCW). CWI is a Member of the World Wide Web Consortium (W3C) and runs the W3C Office in The Netherlands.

General Director

G. van Oortmerssen

Colophon

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Centrum voor Wiskunde en Informatica

Visiting address	Kruislaan 413, 1098 SJ Amsterdam, The Netherlands
Postal address	P.O. Box 94079, 1090 GB Amsterdam, The Netherlands
Telephone	+31 20 592 9333
Telefax	+31 20 592 4199
Website	www.cwi.nl

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They can be ordered at:
Mrs. D.C.M. Amende (phone +31 20 592 4128; e-mail `Thea.Amende@cwi.nl`).

PREFACE

This Overview is a supplement to *CWI Annual Report 2001*, which highlights CWI research in 2001. It is a comprehensive report of the various activities in 2001 of CWI's four scientific clusters and their themes:

- **Probability, Networks and Algorithms – PNA**

  Themes:

  - Networks and Logic – Optimization and Programming – PNA1
  - Traffic and Communication – Performance and Control – PNA2
  - Stochastics – PNA3
  - Signals and Images – PNA4

- **Software Engineering – SEN**

  Themes:

  - Biography of Aad van Wijngaarden – SEN0
  - Interactive Software Development and Renovation – SEN1
  - Specification and Analysis of Embedded Systems – SEN2
  - Coordination Languages – SEN3
  - Evolutionary Systems and Applied Algorithmics – SEN4

- **Modelling, Analysis and Simulation – MAS**

  Themes:

  - Applied Analysis and Scientific Computing for PDEs – MAS1
  - Computational Fluid Dynamics – MAS2

- **Information Systems – INS**

  Themes:

  - Standardization and Knowledge Transfer – INS0
  - Data Mining and Knowledge Discovery – INS1
  - Multimedia and Human-Computer Interaction – INS2
  - Visualization – INS3
  - Quantum Computing and Advanced Systems Research – INS4

Per cluster the following items are addressed:

- General overview;
- Staff survey;
- Survey of CWI reports published by cluster.

Per theme the following items are addressed:

- Staff (+ affiliation of seconded staff);
- Scientific report: General part + report per subtheme/project;
- PhD theses;
- Knowledge transfer;
- Organization of conferences, workshops, courses, etc.;
- Visits to conferences, workshops, colloquia, etc., working visits;
- Memberships of committees and other professional activities;
- Visitors;
- Software developed;
- Books;
- Papers in journals and proceedings;
- CWI reports (only the report numbers);
- Other publications.

PROBABILITY, NETWORKS AND ALGORITHMS

General Overview

PNA focuses on discrete and probabilistic modeling, optimization and control (with control theory, discrete mathematics, logic, operations research, and stochastics as prime tools), and on their applications in technology, management, and life sciences, in particular (but not exclusively) in information and communication technology, operations management, and biology.

The first and foremost research objective of PNA is to make fundamental and applied contributions to problems and techniques in these areas. Testing and implementing the new techniques for practical use and developing algorithms also belong to the objectives, as exemplified by participation in several externally funded application-oriented projects and a considerable number of consultancies.

As for consultancies, it is PNA's policy not to compete with other parties in the service sector, but rather to supplement them by developing innovative scientific techniques and implementing and testing them in practice. Results of PNA's research are being used in transportation (Dutch Rail, State Highways), information technology (IBM, Hewlett Packard, Philips, Microsoft), communication (KPN Research, AT&T, Bell Communications Research), public health (hospitals), environment (RIVM, North Sea Directorate), seismology (Shell, KNMI), and finance (Limperg).

Much of PNA's research is on the borderline of mathematics and computer science. Examples are computational logic, computer-intensive methods in stochastics, computational complexity, fractal image coding and compression, wavelet transforms for signal analysis, morphological image processing, control of discrete-event systems and hybrid systems, performance and control of computer-communication networks, and the design of digital and VLSI-circuits.

PNA maintains strong ties with academia and other research institutions. Seven members hold a university professorship, while three others have other kinds of university associations. Members of PNA play an active role in several Dutch research schools, in graduate networks, and in the research institute EURANDOM. They present graduate courses and are involved in the organization of international conferences.

PNA receives financial support from NWO, STW, ERCIM, NATO, INTAS, and international programs of KNAW and NWO with Hungary and Indonesia, for several research positions for PhD students and postdocs.

In addition, the European Commission supports PNA through the Fifth Framework Program in the projects 'PHLUKES – Design and implementation of a database of photographical material of cetacaens that can be individually identified by visual features', 'FOUNDIT – Feedback-Operated User iNterfaces for Design and Image reTrieval', and 'MASCOT – Metadate for Advanced Scalable Video Compression Tools', the ESPRIT program in the project 'VHS – Verification of Hybrid Systems', the Training and Mobility of Researchers (TMR) Program in the projects 'SI – System Identification' (with CWI as coordinator) and 'DONET – Discrete Optimization Network', and the Research Training Networks (RTN) Program in the projects 'AMORE – Algorithmic Methods for Optimizing the Railways in Europe' and 'DYNSTOCH – Statistical Methods for Dynamical Stochastic Models'. Next to that, ERCIM supports PNA through the Fellowship program.

In 2001 preparations were made to start a new pilot-theme PNA2 'Advanced Communications Networks' in January 2002. Most researchers in the new pilot-theme were recruited from the former PNA2 'Traffic and Communication – Performance and Control'. The researchers of PNA2 working on traffic networks and systems and control will join theme MAS2, to form a new theme MAS2 'Computation and Control'.

Staff

- Networks and Logic – Optimization and Programming – PNA1

  - A.M.H. Gerards
  - K.R. Apt
  - S.Brand
  - L. Di Gaspero
  - M.H. van Emden
  - S. Etalle
  - S. Fiorini
  - R. Gennari
  - F. Goualard
  - J.Y. Halpern
  - W.J. van Hoeve
  - M. Laurent
  - S.G.E. Maróti
  - F. van Raamsdonk
  - A. Schrijver
  - J.G. Smaus
  - A.G. Steenbeek
  - L. Stougie
  - C.F.M. Vermeulen

- Traffic and Communication – Performance and Control – PNA2

  - J.H. van Schuppen
  - J. van den Berg
  - S.C. Borst
  - R.J. Boucherie
  - O.J. Boxma
  - K.G. Dębicki
  - L.C.G.J.M. Habets
  - B. Hanzon
  - D. Jibetean
  - J. Komenda
  - R. Litjens
  - M.R.H. Mandjes
  - R. Núñez Queija
  - W.R.W. Scheinhardt
  - M.J.G. van Uitert

- Stochastics – PNA3

  - J. van den Berg
  - T. Blomster
  - R.M. Brouwer
  - E. Capobianco
  - K.O. Dzhaparidze
  - J.A. Ferreira
  - R. Helmers
  - R. van der Horst
  - M.S. Keane
  - B. Lemmens
  - I W. Mangku
  - S.W.W. Rolles
  - P.J.C. Spreij
  - B. Tarigan
  - S.M. Verduyn Lunel
  - J.H. van Zanten

- Signals and Images – PNA4

  - H.J.A.M. Heijmans
  - M.J. Huiskes
  - L. Kamstra
  - A.A.M. Kuijk
  - A.J. Lenstra
  - M.N.M. van Lieshout
  - P.J. Oonincx
  - E.J.E.M. Pauwels
  - G. Piella Fenoy
  - B.A.M. Schouten
  - A.W.M. Smeulders
  - A.G. Steenbeek
  - R.S. Stoica
  - P.M. de Zeeuw
  - Y.-W. Zhan

- Secretaries:

  - L.M. Schultze (until September 1)
  - S.J. van Dam (from September 1)

CWI Reports

PNA-R0101. H.J.A.M. Heijmans, R. Keshet. *Inf-semilattice approach to self-dual morphology.*

PNA-R0102. R. Helmers, I W. Mangku, R. Zitikis. *Statistical properties of a kernel type estimator of the intensity function of a cyclic Poisson process.*

PNA-R0103. S.C. Borst, P.A. Whiting. *Dynamic rate control algorithms for HDR throughput optimization.*

PNA-R0104. G. Piella, H.J.A.M. Heijmans. *Adaptive lifting schemes with perfect reconstruction.*

PNA-R0105. K. Dębicki. *Generalized Pickands constants.*

PNA-R0106. S.C. Borst, M.R.H. Mandjes, M.J.G. van Uitert. *Generalized processor sharing queues with heterogeneous traffic classes.*

PNA-R0107. S.C. Borst, O.J. Boxma, M.J.G. van Uitert. *Two coupled queues with heterogeneous traffic.*

PNA-R0108. M. Laurent. *A comparison of the Sherali-Adams, Lovász-Schrijver and Lasserre relaxations for 0–1 programming.*

PNA-R0109. B. Hanzon, D. Jibetean. *Global minimization of a multivariate polynomial using matrix methods.*

PNA-R0110. J.A. Ferreira. *A note on inverses of non-decreasing Lévy processes.*

PNA-R0111. E. Capobianco. *Independent multiresolution component analysis and matching pursuit.*

PNA-R0112. L. Kamstra. *Discrete wavelet transforms over finite sets which are translation invariant.*

PNA-R0113. L. Kamstra. *Juggling polynomials.*

PNA-R0114. E. Capobianco. *Stochastic decomposition and approximation of stock index return volatility.*

PNA-R0115. M.N.M. van Lieshout, R.S. Stoica. *The Candy model revisited: Markov properties and inference.*

PNA-R0116. S. Jha, J.H. van Schuppen. *Modelling and control of cell reaction networks.*

PNA-R0117. M.N.M. van Lieshout, A.J. Baddeley. *Extrapolating and interpolating spatial patterns.*

PNA-R0118. E . Altman, T. Jiménez, R. Núñez-Queija. *Analysis of two competing TCP/IP connections.*

PNA-R0119. K.O. Dzhaparidze. *Note on randomized filtered experiments in presence of nuisance parameters.*

PNA-R0120. D. Jibetean. *Global optimization of rational multivariate functions.*

PNA-R0121. J. van den Berg, H. Kesten. *Randomly coalescing random walk in dimension* ≥ 3.

PNA-R0122. S.C. Borst, O.J. Boxma, J.F. Groote, S. Mauw. *Task allocation in a multi-server system.*

PNA-R0123. K.O. Dzhaparidze, J.A. Ferreira. *A frequency domain approach to some results on fractional Brownian motion.*

PNA-R0124. P.M. de Zeeuw, R.A. Zuidwijk. *Numerical methods for decomposition of 2D signals by rotation and wavelet techniques.*

PNA-R0125. K.O. Dzhaparidze, P.J.C. Spreij, E. Valkeila. *Information processes in filtered experiments.*

Networks and Logic – Optimization and Programming – PNA1

Staff

- Prof. dr. ir. A.M.H. Gerards, theme leader (0.8 PNA1, 0.2 Eindhoven University of Technology)
- Prof. dr. K.R. Apt, senior researcher (0.8 PNA1, 0.2 University of Amsterdam)
- S. Brand, MSc, PhD student
- L. Di Gaspero, MSc (Un. Udine), PhD student (until June 30)
- Prof. dr. M.H. van Emden, guest researcher (until September 30)
- Dr. S. Etalle (UM & UT), researcher (0.1)
- Dr. S. Fiorini, postdoc (as of August 15)
- R. Gennari (UvA), PhD student (0.4)
- Dr. F. Goualard, ERCIM Fellow (until May 31)
- J.Y. Halpern, guest researcher (as of August 15)
- Drs. W.J. van Hoeve, PhD student (0.8)
- Dr. M. Laurent (also Ecole Normale Supérieure, Paris), senior researcher (0.63)
- S.G.E. Maróti, MSc, PhD student (as of February 1)
- Dr. F. van Raamsdonk (Free University Amsterdam), senior researcher (0.2)
- Prof. dr. A. Schrijver, senior researcher (0.4 PNA1, 0.4 PNA, 0.2 University of Amsterdam)
- Dr. J.G. Smaus, ERCIM Fellow (until May 15)
- A.G. Steenbeek, programmer (0.9 PNA1, 0.1 PNA4)
- Dr. L. Stougie (TUE), senior researcher (0.2)
- Dr. C.F.M. Vermeulen, postdoc (as of June 1)

Scientific Report

PNA1 focuses on fundamental and applied research in the areas of mathematical logic, combinatorics (in particular networks), optimization, algorithmics, complexity, and transportation. The problems studied originate from fields like networks, combinatorial optimization, computational logic and computational complexity, and from practice, in particular from production and transportation planning, routing, scheduling, and timetabling, and the design of VLSI-circuits. The techniques make use of models and methods coming from mathematics (mathematical logic, geometry, topology, graph theory), operations research (linear and integer programming), and computer science (logic and constraint programming and complexity theory). One of the goals in this theme is to explore the possibilities of cross-fertilization between integer and constraint programming. A new development within PNA1 is the investigation of computational and combinatorial problems arising in molecular biology. As of January 1, the subtheme *Algorithmic*

and Combinatorial Methods for Molecular Biology (PNA1.3) has been founded. It is led by L. Stougie (Eindhoven University of Technology), member of PNA1 for 1 day per week. The first objective is to build up knowledge in this modern field, rich in potential applications of techniques from discrete mathematics and combinatorial optimization.

Networks & Optimization – PNA1.1

Combinatorial optimization – polyhedra and efficiency
A. Schrijver continued finishing the book *Combinatorial Optimization – Polyhedra and Efficiency*, which is expected to appear at the end of 2002.

Semidefinite relaxations for combinatorial optimization problems
M. Laurent has investigated some new semidefinite relaxations for 0/1 polytopes introduced by Lasserre (2000) and based on real algebraic results (representation of positive polynomials as sums of squares and moment theory). Lasserre showed that, for a 0/1 polytope lying in n-space, the hierarchy converges to it in n steps. M. Laurent gives a simple direct combinatorial proof for this result and she shows that the new hierarchy refines two other hierarchies obtained by applying the Lovász-Schrijver and the Sherali-Adams lift-and-project methods. A detailed study is made of the geometric properties of the new semidefinite relaxations for the cut polytope. For any integer $t \geq 1$, the class of graphs whose cut polytope is equal to the t-th relaxation in the hierarchy is shown to be closed under taking minors and some forbidden minors are identified.

M. Laurent is writing in collaboration with F. Rendl the survey article on 'Semidefinite programming and integer programming' to appear as chapter of the forthcoming handbook on Discrete Optimization edited by K. Aardal, G. Nemhauser and R. Weismantel.

Weakly bipartite graphs
A. Schrijver found a short proof for Guenin's characterization of weakly bipartite graphs. This proof will appear in *Journal of Combinatorial Theory, series B*.

With J.F. Geelen (University Waterloo, Canada), A.M.H. Gerards continued the work on decomposing weakly bipartite graphs.

Strong t-perfection
A. Schrijver showed that each graph containing no bad subdivision of K_4 as a subgraph, is strongly t-perfect. This implies a characterization of those graphs each subgraph of which is t-perfect, and gives a combinatorial min-max relation for the weighted stable set number of such graphs. The paper will appear in *SIAM Journal on Discrete Mathematics*.

Eigenvalues and embeddings
With L. Lovász (Microsoft Research, Redmond), A. Schrijver showed that corank 3 Colin de Verdière matrices correspond to 3-dimensional vector flows. This enbables to describe planarity by Colin de Verdière matrices, and might be extended to corank 4, in order to obtain a similar certificate for linkless embeddability.

Graphs on surfaces
With B. Mojar (Ljubljana), A. Schrijver proved a conjecture of Robertson and Thomas that the orientable genus of a graph G embedded in a nonorientable surface S with sufficiently large face-width is proportional to the minimum number of intersections of a blockage with the graph.

Matroids
J.F. Geelen (University of Waterloo, Canada), A.M.H. Gerards and G. Whittle (University of Victoria, Wellington, New Zealand) continued their work on branch-width and matroid minors. They finalized their paper on well-quasi-ordering of matroids representable over finite fields with bounded branch-width (which will appear in the *Journal on Combinatorial Theory, Series B*) and started to investigate the ones with large branch-width. They proved that matroids with high rank have either many disjoint cocircuits, or a large clique-minor, or a long line (a report is nearly finished). This extends the edge-disjoint version of the Erdös-Pósa theorem, which says that a graph has either many edge-disjoint circuits or a small set of edges intersecting each circuit. The research on matroid minors will be continued.

Together with J.F. Geelen, A.M.H. Gerards prepared a report with a new proof, in terms of signed graphs, of Seymour's forbidden minor characterization of matroids that are graphic or cographic, which is one of the two key parts of Seymour's Regular matroid decomposition theorem.

Railway optimization
S.G.E. Maróti worked in cooperation with L. Kroon (NS Reizigers & Erasmus University) and other researchers and planners at the Dutch Railways on the application of combinatorial and integer programming techniques for railway optimization problems, in particular maintenance routing. This research is part of the research training network AMORE of the European Union.

Partial ordering and polytopes
S. Fiorini and J.-P. Doignon (ULB, Brussels) characterized all facets and symmetries (i.e. combinatorial isomorphisms) of the approval-voting polytopes. The issue was raised by Doignon and Regenwetter, motivated by the characterization of the size-independent model for approval voting of Falmagne and Regenwetter (1996). S. Fiorini also showed that a 0/1-polytope can be affinely embedded as a face of some partial order polytopes if and only if it can be affinely embedded as a face of some 3-SAT polytope. On the other hand, Fiorini showed that many 0/1-polytopes are not affinely embeddable as a face of any l-SAT polytope. Intuitively, the two results give a lower bound and an upper bound on the 'facial complexity' of the partial order polytopes. The concept of a transitively orientable graph can be transposed to a similar concept for two-graphs. S. Fiorini showed that the list of minimal non-transitively orientable two-graphs is considerably shorter and simpler than Gallai's (1967) list of minimal non-transitively orientable graphs. This raises questions like: Is it possible to derive the minimal non-transitively orientable two-graphs directly and can one derive Gallai's result from that one? Answering these questions could yield new insights to the theory of comparability graphs.

Constraint and Integer Programming – PNA1.2

Constraint programming
K.R. Apt worked on a number of aspects of logic and constraint programming. In particular, he revised two journal papers that appeared in 2001. The first one concerned his joint work with E. Monfroy and dealt with an account of rule-based constraint programming. It appeared in *Theory and Practice of Logic Programming* (TPLP). The other one concerned the use of commutativity in the constraint propagation algorithms. The paper appeared in *ACM Transactions on Programming Languages and Systems* (TOPLAS).

K.R. Apt and J.G. Smaus worked on the correspondences between logic programming and other programming paradigms. The results of this work so far appeared in a special issue of the *Joint Bulletin of the Novosibirsk Computing Center and Institute of Informatics Systems* devoted to constraint programmig. This line of research is now pursued jointly with K. Vermeulen and deals with the interpretation of first-order logic as a constraint programming language. Finally, he collaborated with S. Brand on the subject of efficient schedulers for rule-based constraint programming. A paper on this subject is in preparation.

F. Goualard devised a framework for having heterogeneous constraint solvers cooperate. The framework uses *component programming* techniques: solvers, be they a piece of code, a library written in an unspecified language, or a complete application such as Maple, exchange information by sending signals to ports. The event-driven model allows to transparently use components that are running on the same computer or in a distributed environment. A C++ library, aLiX, implementing the framework has been developed and its versatility assessed in a paper presented at the Sixth Annual Workshop of the ERCIM Working Group on Constraints in Prague, Czech Republic, in June 2001.

M.H. van Emden worked with K.R. Apt on a generic framework for the branch-and-bound principle in optimization.

Interval arithmetic
Van Emden studied the relation between evaluation of expressions in interval arithmetic and the effect of constraint propagation on the interval constraint system corresponding to the expression. As a result of elucidating this relation, improvements were found to the Newton method for solving nonlinear equations. These results were reported in *Computing Functional and Relational Box Consistency by Structured Propagation in Atomic Constraint Systems*, Sixth Annual Workshop of the ERCIM Working Group on Constraints, June 18–20, 2001, Prague, Czech Republic.

Van Emden worked with T. Hickey of Brandeis University on revisions to 'Interval Arithmetic: From Principles to Implementation'. This paper was accepted by the *Journal of the ACM*.

Hickey and Van Emden started on a new topic: Global Sign Analysis, which makes it possible, given a real-valued function of a real, to determine for most of the real line the sign of that function. Typically at most small unclassifiable intervals remain. These can often be determined as being a zero or a singularity. This is done numerically and is correct in spite of rounding errors. A prototype program in CLIP, an interval constraint version of Prolog developed by Hickey, was completed. A draft version of a paper was written.

Flight simulation
Van Emden worked with Prof. J.A. Mulder at TU Delft on a problem in flight simulation. It requires the solving of nonlinear algebraic equations. The idea is to use interval methods. However, it turned out that obtaining the equations is a research topic in its own right. This project is still far from settled.

Logic programming
J. Smaus worked with P. Deransart and F. Fages (INRIA Rocquencourt) on type systems for logic programming, in particular the problem of ensuring absence of type errors at runtime. An article has been accepted by the *Journal of Functional and Logic Programming*. A further article with an emphasis on subtyping is planned.

J. Smaus and S. Etalle worked with A. Bossi and S. Rossi on termination of logic programs using a certain kind of execution mechanism, called input-consuming derivations. This work is published in the *Proceedings of the European Symposium on Programming*. An extended version has been submitted to a journal recently.

J. Smaus worked with D. Pedreschi and S. Ruggieri on a survey on termination of logic programs, studying the effect of various selection rules on termination. This work has been accepted for publication.

Reasoning about uncertainty
J. Halpern worked on various aspects of reasoning about uncertainty. He has almost completed work on his book 'Reasoning About Uncertainty'. In addition, he worked with his students in Cornell on finding logics appropriate for reasoning about security.

Term rewriting
F. van Raamsdonk worked on termination of higher-order term rewriting (leading to a publication in the proceedings of RTA 2001), on program extraction in type theory (jointly with P. Severi (University of Montevideo, Uruguay); a paper is now submitted) and on a book on term rewriting edited by J.W. Klop, R.C. de Vrijer, and M. Bezem.

Algorithmic and Combinatorial Methods for Molecular Biology – PNA1.3
L. Stougie organized, in cooperation with S. Verduyn Lunel (PNA3), the NWO Special Year on Mathematical Biology. Aim was to investigate the interfaces between biology and mathematics and to provide mathematicians with insight into the particular mathematical problems encountered by biologists, biochemists, and medical researchers. The program consisted of nine one-day symposia in different research institutes and a winterschool. The network built during this year will be further enhanced in the future.

Knowledge Transfer

K.R. Apt and A. Schrijver are part-time professor at the University of Amsterdam.

A.M.H. Gerards is part-time professor at the Eindhoven University of Technology.

J.Y. Halpern taught the course 'Reasoning about Uncertainty' at the University of Amsterdam.

M. Laurent taught 'Combinatorial Optimization I', a graduate course of the Landelijk Netwerk Mathematische Besliskunde.

A. Schrijver taught the EIDMA graduate course 'Advanced Graph Theory and Combinatorial Optimization'.

Organization of Conferences, Workshops, Courses, etc.

- PPDP2001 (Third International Conference on Principles and Practice of Declarative Programming), Firenze, Italy, September 5–7: S. Etalle, member Program Committee.
- LOPSTR 2001 (2001 International Workshop on Logic Program Synthesis and Transformation), Paphos, Cyprus, November 26 – December 1: S. Etalle, member Program Committee.
- NWO Special Year on Mathematical Biology: L. Stougie, organizer.
- Seminar Bio Informatics Pattern Analysis, NWO-Special Year Mathematics and Biology, CWI, Amsterdam, March 22 (an activity of the

NWO Special Year on Mathematical Biology): M. Laurent, L. Stougie, A. Schrijver, organizers.
- Dixièmes Journées Francophones de Programmation en Logique et de Programmation par Contraintes (JFPLC'2001), Paris, France, April: K.R. Apt, member Program Committee.
- Minisymposium Discrete Mathematics, Nederlands Mathematisch Congres, VU Amsterdam, April 19: A.M.H. Gerards, organizer.
- Cutting Planes and Integer Programming, Symposium in the honor of Ralph Gomory, Eindhoven University of Technology, April 26: A.M.H. Gerards, co-organizer.
- DONET Summerschool on Integer Programming and Combinatorial Optimization, Utrecht, The Netherlands, June 11–12: A.M.H. Gerards, member Organizing Committee.
- IPCO VIII, Eighth Conference on Integer Programming and Combinatorial Optimization, Utrecht, The Netherlands, June 13–15: A.M.H. Gerards, member Organizing Committee, chair Program Committee, M. Laurent, member Program Committee, L. Stougie, member Organizing Committee.
- Sixth Annual Workshop of the ERCIM Working Group on Constraints, Prague, Czech Republic, June 18–20: K.R. Apt, co-organizer.
- Seventeenth International Conference on Logic Programming (ICLP ' 01), Paphos, Cyprus, November 26 – December 1: K.R. Apt, member Program Committee.
- Seminar day From Chemistry to Life, Dutch Polymer Institute TU Eindhoven, Eindhoven, The Netherlands, November 30 (an activity of the NWO Special Year on Mathematical Biology): L. Stougie, organizer.
- ICLP workshop on Specification, Analysis and Validation for Emerging Technologies in Computational Logic (SAVE). Coral Beach Hotel and Resort, Paphos, Cyprus, December 1: S. Etalle, co-organizer.
- NWO/IOP-Gnomics Winterschool Mathematics and Biology, Wageningen, December 17–19 (an activity of the NWO Special Year on Mathematical Biology): L. Stougie, organizer.
- Tagung 'Geometric convex combinatorics' Mathematisches Forschungsinstitut Oberwolfach, Oberwolfach, Germany, June 16–22, 2002: A.M.H. Gerards, co-organizer.

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

- Twenty-Sixth Conference on the Mathematics of Operations Research, Lunteren, The Netherlands, January 16–18: A.M.H. Gerards, W.J. van Hoeve, A. Schrijver.
- Victoria University, Wellington, New Zealand, January 31 – February 24: A.M.H. Gerards (working visit).
- Logic & Constraints Seminars, Amsterdam, January 29 & February 12: R. Gennari (lecture: *Beyond hard constraints I-II*).
- Meeting of DEDUGIS (Working group on Deduction in Geographic Information Systems), Venice, Italy, February 13–16: K.R. Apt (lecture: *Constraint propagation revisited*).
- Theory Day of NVTI (Dutch Association for Theoretical Computer Science), Utrecht, March 23: K.R. Apt (lecture: *A primer on constraint programming*).
- Meeting of the ESPRIT Working Group on Concurrent Constraint Programming for Time Critical Applications, Nantes, France, February 19–20: F. Goualard (lecture: *Solving universally interval constraints*).
- Thirty-Second Southeastern International Conference on Combinatorics, Graph Theory and Computing, Baton Rouge, Louisiana, USA, February 26 – March 2: A. Schrijver (lectures: *Permanents and edge-colouring; Graph embedding and eigenvalues*).
- EIDMA Minicourse on matching theory, by Jim Geelen, Eindhoven University of Technology, Eindhoven, March 5–9: A.M.H. Gerards, W.J. van Hoeve, S.G.E. Maróti.
- Fifth International Symposium on Functional and Logic Programming, Tokyo, Japan, March 7–9: J. Smaus.
- CLLI Seminar, March 22, Amsterdam: R. Gennari (lecture: *Soft constraint frameworks*).
- Seminar Bio Informatics Pattern Analysis, NWO-Special Year Mathematics and Biology, CWI, Amsterdam, March 23: A.H.M. Gerards, M. Laurent, A. Schrijver, L. Stougie.
- ETAPS 2001, Joint European Conferences on Theory and Practice of Software, Genova, Italy, April 2–6: S. Etalle.

- AMORE Internal Meeting, Rome, Italy, April 2–4: S.G.E. Maróti.
- Third International workshop on Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (CP-AI-OR 2001), Wye, Kent, United Kingdom, April 8–10: L. Di Gaspero.
- Logic and constraints seminar, CWI, Amsterdam, April 9 & May 23: W.J. van Hoeve (lecture: *The alldifferent constraint: a survey, I & II*).
- International workshop on termination, May 20–21, Utrecht, The Netherlands: F. van Raamsdonk.
- 12th international conference on rewriting techniques and applications (RTA 2001), Utrecht, The Netherlands May 22–24: F. van Raamsdonk.
- EIDMA course Advanced Graph Theory and Combinatorial Optimization, by A. Schrijver, Amsterdam, April 11 – June 20: W.J. van Hoeve.
- Nederlands Mathematisch Congres, VU Amsterdam, April 19–20: A. Schrijver (lecture: *Graph embedding and eigenvalues*), A.H.M. Gerards, M. Laurent, W.J. van Hoeve.
- Meeting of the ACM Publications Board, New York, April 19–22: K.R. Apt.
- University La Sapienza of Rome, Rome, Italy, April 20 – May 3: L. Stougie (working visit).
- Cutting Planes and Integer Programming, Symposium in honor of Ralph E. Gomory, Eindhoven, April 26: A.M.H. Gerards (lecture: *On Gomory cuts and on Gomory-Hu trees*), W.J. van Hoeve, M. Laurent. L. Stougie, A. Schrijver (lecture: *Gomory cuts, Gomory-Hu trees, and the traveling salesman problem*).
- Department of Computer Science, University of Rome Tor Vergata, Rome, Italy, April 26: L. Stougie (lecture: *On-line routing problems*).
- University of Venezia Ca Foscari, Venice, Italy, May 7–9: J. Smaus (working visit).
- Merton College, Oxford, United Kingdom, May 14–21: A.M.H. Gerards (working visit).
- Department of Mathematics, Oxford University, Oxford, United Kingdom, May 15: A.M.H. Gerards (lecture: *Branch width and well-quasi-ordering in matroids and graphs*).
- One-day Combinatorics Colloquium, University of Reading, Reading, United Kingdom, May 16: A.M.H. Gerards (lecture: *Branch width and well-quasi-ordering in matroids and graphs*).
- London School of Economics, London, United Kingdom, May 17: A.M.H. Gerards (lecture: *Branch width and well-quasi-ordering in matroids and graphs*).
- Workshop on Stochastic Programming, Molde, Norway, 18–21 May: L. Stougie (lecture: *Online optimization*).
- SINTEF and Technical University of Norway, Trondheim, Norway, May 21–24: L. Stougie.
- University of Oxford, Oxford, United Kingdom, May 28–29: K.R. Apt (lecture: *A uniform framework for constraint propagation algorithms*).
- High Performance Optimization Techniques, Utrecht, June 6–8: M. Laurent.
- DONET Summer School on Integer Programming and Combinatorial Optimization, University of Utrecht, June 11–12: A.M.H. Gerards, W.J. van Hoeve, S.G.E. Maróti, M. Laurent, L. Stougie.
- Eighth Conference on Integer Programming and Combinatorial Optimization (IPCO 2001), Utrecht, June 13–15: A.M.H. Gerards, W.J. van Hoeve, G. Maróti, M. Laurent, L. Stougie.
- Konrad Zuse Zentrum, Berlin, Germany, June 17–19: L. Stougie (working visit).
- Sixth Annual Workshop of the ERCIM Working Group on Constraints, Prague, Czech Republic, June 18–20: K.R. Apt, S. Brand, W.J. van Hoeve (lecture: *The alldifferent constraint*).
- Summer School on Logical Methods at BRICS, Aarhus, Denmark, June 25 – July 6: R. Gennari.
- Yale University, New Haven, Connecticut, USA, June 23–28: L. Stougie (working visit).
- University of Waterloo, Waterloo, Ontario, Canada, July 1–21: A.M.H. Gerards (working visit).
- Fourth International Andrei Ershov Memorial Conference, Perspectives of System Informatics (PSI'2001), Novosibirsk, Akademgorodok, Russia, July 2–6: S. Brand.
- Institute of Informatics Systems of the Siberian Division of the Russian Academy of Sciences, Novosibirsk, Akademgorodok, Russia, July 2–14: S. Brand (working visit).
- University of Bologna, Bologna, Italy, July 3–25: W.J. van Hoeve (working visit).
- Brandeis University, Boston, USA, July 11–22: M. van Emden (working visit).
- Russian Research Institute of Artificial Intelligence (RRIAI), Moscow, Russia, August 22–27:

K.R. Apt (lectures: *A Uniform Framework for Constraint Propagation Algorithms and The Alma Project, or How logic can help us in imperative programming*).
- Workshop on Perfect Graphs, Princeton University, Princeton, N.J., USA, September 7–11: A.M.H. Gerards.
- Graph Drawing 2001, Vienna, Austria, September 23–26: A. Schrijver (lecture: *Graph drawing and eigenvalues*).
- SINTEF and Technical University of Norway, Trondheim, Norway, October 6–8: L. Stougie (working visit).
- CaberNet plenary workshop, 2001 Workshop of CaberNet, the Network of Excellence on Dependability, Pisa, Italy, October 10–11: S. Etalle.
- Workshop 'The sharpest cut' in honor of M. Padberg 60th birthday, Berlin, Germany, October 11–13: M. Laurent.
- Thirteenth Belgium-Netherlands Conference on Artificial Intelligence (BNAIC-01), Amsterdam, October 25–26: K.R. Apt.
- EIDMA Symposium 2001, Oostende, Belgium, October 25–26: A.M.H. Gerards (lecture: *Branch width and well-quasi-ordering in matroids and graphs*), S. Fiorini (lecture: *The facets and the symmetries of the approval-voting polytope*).
- Oxford University. Oxford, United Kingdom, October 26: J.Y. Halpern (lecture: *Reasoning about uncertainty*).
- 2nd AMORE Research Seminar, Patras, Greece, October 30 – November 3: G. Maróti.
- Microsoft Research, Redmond (WA), USA, October 21 – November 10: A. Schrijver (working visit, lecture: *Edge-Colouring, Dimers, and Scheduling*).
- Meeting of COTIC (Working group on Constraint programming for time critical applications), Amsterdam, November 16: K.R. Apt (lecture: *Constraint programming viewed as rule-based programming).*
- International Conference on Logic Programming, joint with the Conference on Principles and Practice of Constraint Programming. Paphos, Cyprus, November 26 – December 1: K.R. Apt (lecture: *How to write a good paper*), S. Brand, S. Etalle, R. Gennari (lecture: Constraint propagation from a mathematical perspective), W.J. van Hoeve, C. Vermeulen.
- Workshop Methods for modalities, Amsterdam, November 29: J.Y. Halpern (lecture: *Causes and explanations: a structural-model approach*).
- Seminar day From Chemistry to Life Dutch Polymer Institute TU Eindhoven, Eindhoven, 30 November: A.M.H. Gerards, L. Stougie.
- Weizmann Institute, Rehovot, Israel, December 3–6: K.R. Apt (working visit, lecture: *A uniform framework for constraint propagation algorithms*).
- Eindhoven University of Technology, Eindhoven, December 4: J.Y. Halpern (lecture: *Plausibility measures and default reasoning*).
- Pan-Dependability Workshop, Toulouse, France, December 10–12: S. Etalle.
- Consultation workshop on dependability research in preparation of the 6th Framework Programme, Toulouse, France, December 13–14: S. Etalle.
- NWO/IOP-Gnomics Winterschool Mathematics and Biology, Wageningen, December 17–19: A.M.H. Gerards, L. Stougie.
- Spinoza workshop, Amsterdam, December 20: J.Y. Halpern (lecture: *Causes and explanations: a structural-model approach*).

Memberships of Committees and Other Professional Activities

PhD Committees

- P. Schuurman, January 9, TUE: A.M.H. Gerards
- D. Kurowicka, January 22, Delft University: M. Laurent
- Honorary degree Ralph E. Gomory: April 27, TUE: A.M.H. Gerards (honorary supervisor)
- S. Seres, May 28, University of Oxford: K.R. Apt
- B. Lemmens, June 7, Free University Amsterdam: M. Laurent
- R. de Wolf, September 6, University of Amsterdam: A. Schrijver

Organizational Activities

- Association for Logic Programming: K.R. Apt, member of the Executive Committee
- EIDMA – Euler Institute for Discrete Mathematics and Its Applications: A. Schrijver, member Board
- ERCIM Working Group on Constraints: K.R. Apt, chairman
- European Commission in preparation of the 6th Framework Programme: S. Etalle, consultant

- KNAW Akademie Raad voor de Wiskunde: A. Schrijver, member
- Koninklijke Nederlandse Akademie van Wetenschappen: A. Schrijver, member
- Landelijk Netwerk Mathematische Besliskunde: A.M.H. Gerards, member board, A. Schrijver, member governing board
- Mathematical Programming Society: A. Schrijver, member Symposium Advisory Committee
- Nederlandse organisatie voor Wetenschappelijk Onderzoek (NWO): A. Schrijver, member Programma Commissie Netwerken
- Stieltjes Instituut voor Wiskunde: A. Schrijver, member Science Council
- Technische Universiteit Eindhoven: A. Schrijver, member Raad van advies voor de Wiskunde

Editorial Activities

- *ACM Transactions on Computational Logic*: K.R. Apt, editor-in-chief and founding editor
- *Artificial Intelligence*: J.Y. Halpern, member of editorial board
- *Chicago Journal of Theoretical Computer Science*: J.Y. Halpern, consulting editor
- *Combinatorica*: A. Schrijver, editor-in-chief
- *Computing Research Repository (CoRR)*: J.Y. Halpern, administrator (and founder)
- *CWI Tracts, CWI Syllabi*: A.M.H. Gerards, editor
- *Discrete Mathematics and Theoretical Computer Science*: A.M.H. Gerards, editor
- *Discrete Applied Mathematics*: A. Schrijver, 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, editor, J.Y Halpern, editor
- *Journal of the ACM*: J.Y. Halpern, editor-in-chief
- *Mathematics of Operations Research*: M. Laurent, associate editor, A. Schrijver, associate editor
- *Mathematical Programming, Series A*: A.M.H. Gerards, associate editor
- *Newsletter of the Association for Logic Programming*: S. Etalle, editor
- *North-Holland Mathematical Library*: A. Schrijver, advisory editor
- *SIAM Journal on Discrete Mathematics*: A.M.H. Gerards, editor, A. Schrijver, editor
- *SIAM Journal on Optimization*: M. Laurent, editor
- *SIAM Monographs on Discrete Mathematics and Applications*: A. Schrijver, member editorial board
- *Theory and Practice of Logic Programming*: K.R. Apt, editor

Visitors

- M. Conforti (University of Padova. Italy), January 9–18
- D. Bienstock (Columbia University, New York, NY, USA), January 14–15
- M. van Dongen (Computer Science Department, University College Cork, Ireland), April 2–3
- M.X. Goemans (MIT, Cambridge, Mass. USA), January 14–15
- I. Barany (Rényi Institute, Budapest, Hungary and University College, London, UK), January 14–15
- G. Woeginger, Technische Universität Graz, Graz, Austria), January 14–15
- J.F. Geelen (University of Waterloo, Canada), March 9–14
- Franz Rendl (University of Klagenfurt, Austria), March 28–31
- B. Guenin (University of Waterloo, Canada), May 7 – June 18
- A. Semenov (Institute of Informatics Systems Russian Academy of Sciences, Novosibirsk, Russia), May 12–20
- A.V. Karzanov (Moscow, Russia), May 13–21
- E. Monfroy (University of Nantes, France), October 28 – November 4

Books

K. Aardal, A.M.H. Gerards (eds.) (2001). *Integer programming and combinatorial optimization*, Proceedings 8th international IPCO conference, Utrecht, The Netherlands, June 13–15. Lecture Notes in Computer Science **2081**, Springer, Heidelberg.

K.R. Apt, R. Bartak, S. Brand, E. Monfroy, F. Rossi (eds.) (2001). *Proceedings of the 6th Annual Workshop of the ERCIM Working Group on Constraints.* (Available electronically from the Computing Research Repository (CoRR), as http://xxx.lanl.gov/abs/cs.PL/0110012).

A. Copestake, C. Vermeulen (eds.) (2001). *Algebras, Diagrams and Decisions in Language, Logic and Computation*, CSLI publishers.

Software Developed

- A meta-program implementing the proof system for the specification, simulation verification and analysis of security protocols (www.cs.utwente.nl/∼etalle/protocol_verification/index.html): S. Etalle.
- ADDL (a Discrete Domain Library) a fully templated C++ library to manipulate and compute with sets and intervals of discrete values. This library is used in the aLiX library: F. Goualard.
- aLiX (a Library for Constraint Solving), a C++ library for solving constraints by enforcing local consistencies. The library is fully component-oriented, and communications are all event-driven. This is the implementation of an open framework devised by the author to have heterogeneous solvers cooperate: F. Goualard.
- Software for scheduling internships of medical students at the University of Maastricht: A. Steenbeek.

Papers in Journals and Proceedings

K.R. Apt (2001). The role of commutativity in constraint propagation algorithms. *ACM Toplas* **22**(6), 1002–1036 (2000) (appeared in 2001).

K.R. Apt (2001). One more revolution to make: free scientific publishing. *Communications of ACM* **44**(5), 25–28.

K.R. Apt, E. Monfroy (2001). Constraint programming viewed as rule-based programming. *Theory and Practice of Logic Programming* **1**(6), 713–750.

K.R. Apt (2001). Towards free access to scientific literature. *Nieuw Archief voor Wiskunde* **5/2**(3), 251–255.

K.R. Apt, J. Smaus (2001). Rule-based versus procedure-based view of logic programming. *Computer Science* **16**, Joint Bulletin of of the Novosibirsk Computing Center and Institute of Informatics Systems, 75–97.

C. Areces, R. Gennari, J. Heguiabehere, M. de Rijke (2001). Tree-based heuristics for modal logic. *Proceedings BNAIC'01*, 31–32. (Publisher: University of Amsterdam).

G. Ausiello, E. Feuerstein, S. Leonardi, L. Stougie, M. Talamo (2001). Algorithms for the on-line travelling salesman. *Algorithmica* **29**, 560–581.

M. Blom, S.O. Krumke, W.E. de Paepe, L. Stougie (2001). The online-TSP against fair adversaries. *Informs Journal on Computing* **13**, 138–148.

A. Bossi, S. Etalle, S. Rossi (2001). Semantics of well-moded input-consuming programs. *Computer Languages* **26**(1), Elsevier, 1–25. (appeared in 2001).

A. Bossi, S. Etalle, S. Rossi, J.G. Smaus (2001). Semantics and termination of simply-moded logic programs with dynamic scheduling. D. Sands (ed.). *Proc. European Symposium on Programming*, LNCS **2028**, Springer-Verlag, 402–416.

S. Brand (2001). Constraint propagation in presence of arrays. K.R. Apt, R. Bartak, E. Monfroy, F. Rossi (eds.). *Proceedings of the 2001 ERCIM Workshop on Constraints*, Prague, Czech Republic.

S. Brand (2001). Constraint Propagation in Presence of Arrays. *Computer Science* **16**, Joint Bulletin of the Novosibirsk Computing Center and Institute of Informatics Systems, 99–110.

F. Chu, J.Y. Halpern (2001). On the NP-completeness of finding an optimal strategy in games with common payoff. *International Journal of Game Theory* **30**(1), 99–106.

P. Deransart, J.-G. Smaus (2001). Well-Typed Logic Programs Are not Wrong. H. Kuchen, K. Ueda (eds.). *Proceedings of the Fifth International Symposium on Functional and Logic Programming*, LNCS **2024**, Springer-Verlag, 280–295.

L. Di Gaspero, A. Schaerf (2001). Tabu search techniques for examination timetabling. E. Burke, W. Erben (eds.). *Proc.of the 3rd Int. Conf. on the Practice and Theory of Automated Timetabling*, LNCS **2079**, Springer-Verlag, Berlin-Heidelberg, 104–117.

L. Di Gaspero, A. Schaerf (2001). Writing local search algorithms using EasyLocal++. S. Voss, D.L. Woodruff (eds.). *Optimization Software Class Libraries, OR/CS*, Kluwer Academic Publishers, Boston, 155–176.

L. Di Gaspero, A. Schaerf (2001). EasyLocal++: an object-oriented framework for the flexible design of local search algorithms and

metaheuristics. *Proceedings of the 4th Metaheuristics International Conference (MIC'2001)*, Porto, Portugal, July 16–20, 287–292.

E. Feuerstein, L. Stougie (2001). On-line single-server dial-a-ride problems. *Theoretical Computer Science* **268**, 91–105.

R. Gennari (2001). Translations for comparing soft frameworks. T. Walsh (ed.), *LNCS Proceedings* **2239**, Springer, 764.

R. Gennari (2001). General schema for constraint propagation. *Series Computer Science* **16**, Joint Bulletin of of the Novosibirsk Computing Center and Institute of Informatics Systems, 25–40.

J.Y. Halpern, R. van der Meyden (2001). A logic for SDSI's linked local named spaces. *Journal of Computer Security* **9**(1,2), 47–74.

J.Y. Halpern (2001). Alternative semantics for unawareness. *Games and Economic Behavior* **37**, 321–339.

J.Y. Halpern (2001). Substantive rationality and backward induction. *Games and Economic Behavior* **37**, 425–435.

W.J. van Hoeve (2001). The alldifferent constraint: a survey. *Sixth Annual Workshop of the ERCIM Working Group on Constraints*, Prague, June 2001 (www.arxiv.org/html/cs.PL/0110012).

S.O. Krumke, W.E. de Paepe, L. Stougie, J. Rambau (2001). Online bincoloring. *Proceedings of the 9th Annual European Symposium on Algorithms*, Lecture Notes in Computer Science **2136**, Springer, 74–85.

S.O. Krumke, W.E. de Paepe, D. Poensgen, L. Stougie (2001). News from the online traveling repairman. *Proceedings of the 26th International Symposium on Mathematical Foundations of Computer Science*, LNCS **2136**, Springer, 487–499.

M. Laurent (2000). Polynomial instances of the positive semidefinite and Euclidean distance matrix completion problems. *SIAM Journal on Matrix Analysis and its Applications* **22**, 874–894. (issue appeared in 2001).

M. Laurent (2001). On the order of a graph and its deficiency in chordality. *Combinatorica* **21**, 543–570.

M. Laurent (2001). Tighter linear and semidefinite relaxations for max-cut based on the Lovász-Schrijver lift-and-project procedure. *SIAM Journal on Optimization* **12**, 345–375.

F. van Raamsdonk (2001). On termination of higher-order rewriting. A. Middeldorp (ed.). *Proceedings of the 12th International Conference on Rewriting Techniques and Applications (RTA 2001)*, LNCS **2051**, Utrecht, the Netherlands, 261–27.

A. Schaerf, L. Di Gaspero (2001). Local Search techniques for educational timetabling problems. *Proceedings of the 6th International Symposium on Operations Research in Slovenia*, Preddvor, Slovenia, 13–23.

A. Schrijver (2001). A short proof of Mader's $\mathcal{S}$-paths theorem. *Journal of Combinatorial Theory Series B* **82**, 319–321.

J.-G. Smaus, P.M. Hill, A.M. King (2001). Verifying termination and error-freedom of logic programs with `block` declarations. *Journal Theory and Practice of Logic Programming* **1**(4), 447–486.

C. Vermeulen (2001). A calculus of substitution for DPL. *Studia Logica* **68**, 357–387.

CWI Reports

The following CWI report was published by a member of theme PNA1. See page 6 for the complete title of the report.

PNA-R0108

Other Publications

K.R. Apt (2001). The Logic Programming Paradigm and Prolog. *The Computing Research Repository* (CoRR), (37 pages). http://xxx.lanl.gov/abs/cs.PL/0107013

K.R. Apt, A. Kakas, F. Sadri (eds.) (2001). *ACM Transactions on Computational Logic 2 (4)*. Special issue dedicated to R.A. Kowalski.

K.R. Apt, Y. Zagorulko (eds.) (2001). *Joint Bulletin of of the Novosibirsk Computing Center and Institute of Informatics Systems*, Series: Computer Science, **16**.

S. Etalle, G. Delzanno (2001). Transforming a Proof System into Prolog for Verifying Security Protocols Together. *Pre-proceedings LOPSTR 2001*, The Eleventh International Workshop on Logic-Based Program Synthesis and Transformation, Paphos, Cyprus.

S. Etalle (2001). *ALP newsletter editorials of the following issues*: May 2001, August 2001, November 2001.

S. Fiorini (2001). *Polyhedral Combinatorics of Order Polytopes* (PhD thesis).

S. Fiorini (2001). *A Combinatorial Study of Partial Order Polytopes* (preprint).

S. Fiorini, J.-P. Doignon (2001). *The Facets and the Symmetries of the Approval-Voting Polytope* (preprint).

J.F. Geelen, A.M.H. Gerards (2001). *Regular Matroid Decomposition via Signed Graphs* (preprint).

F. Goualard (2001). Component Programming and Interoperability in Constraint Solver Design. *Proceedings of the 6th Annual Workshop of the ERCIM Working Group on Constraints.* June 18–20, Prague, Czech Republic.

O. Mansour, S. Etalle, T. Krol (2001). Scheduling and Allocation of Non-Manifest Loops on Hardware Graph-Models. F. Karelse (ed.). *Proceedings PROGRESS workshop.*

Traffic and Communication – Performance and Control – PNA2

Staff

- Prof. dr. ir. J.H. van Schuppen (Theme leader and senior researcher; 0.8; 0.2 at VU)
- Dr. J. van den Berg (0.1; also Theme PNA3)
- Prof. dr. ir. S.C. Borst (0.4; 0.1 at TUE and 0.5 with Lucent Technologies; Till 1 May 2001 0.8 at CWI)
- Dr. R.J. Boucherie (0.4, funded by STW and affiliated with UT)
- Prof. dr. ir. O.J. Boxma (0.2 from TUE till 1 May 2001 and 0.1 since then)
- Dr. K.G. Dębicki (Since 1 April 2001)
- Dr. ir. L.C.G.J.M. Habets (0.2 from TUE)
- Dr. B. Hanzon (Advisor)
- Mr. Siddhartha Jha (May–July; internship from IIT Kanpur, India)
- Ms. D. Jibetean
- Dr. J. Komenda (Since 1 May 2001)
- Drs. R. Litjens (KPN; 0.2)
- Prof. dr. M.R.H. Mandjes (0.8; 0.2 at UT)
- Dr. R. Núñez Queija (0.5 and 0.5 at TUE)
- Dr. ir. W.R.W. Scheinhardt (0.2 from UT)
- Drs. M.J.G. van Uitert (0.8; 0.2 at KPN Research)

Scientific Report

General report

The research effort of the theme is directed to fundamental and applied research in performance of queueing systems and in control and system theory. Most of the research is motivated by various forms of traffic, communication, and other engineering problems.

Traffic and communication are undergoing rapid technological changes because of the demands of modern industrial societies and because of the availability and low cost of computers and communication hardware. The high performance standards motivate research on performance analysis and control synthesis. Motivating engineering problems include: Communication and computer networks (ATM, B-ISDN, IP, LANs, wireless); freeway traffic (ramp-metering, routing, network management); railway traffic; transportation of goods; manufacturing systems.

The research effort of 2001 in performance focused on the analysis of flow-control mechanisms, integrated-services networks, packet scheduling algorithms, queues with heavy-tailed traffic, and mobile communication networks.

The research effort of 2001 in control was directed to reachability and to realization of affine systems on polytopes and of hybrid systems, to modelling and control of biochemical cell reaction networks, to failure diagnosis of timed discrete-event systems, control of discrete-event systems with coalgebra, and to system identification with computer algebra.

Communication and Computer Networks – PNA2.1

Project FAST

K. Dębicki and *M. Mandjes* have started examining queues fed by many Gaussian sources. The class of Gaussian sources includes the, practically relevant, input models of fractional Brownian motion (used to model long-range dependence) and Ornstein-Uhlenbeck. After scaling buffer and bandwidth by the number of sources, asymptotically exact overflow asymptotics are derived, both in the transient and steady-state regime. The techniques used rely on earlier results by Piterbarg and Prisyazhnyuk (double sum method) and Dębicki and Rolski.

K. Kumaran (Bell Labs), M. Mandjes and *A.L. Stolyar (Bell Labs)* have considered the trade-off of buffer and link speed at a queueing resource, for a given (fixed) value of the loss probability. Efficient (i.e., economical) network design is enabled through insight into the shape of the resulting 'iso-performance curve'. We have proved that the fluid loss ratio function $\Phi(c, b)$ is jointly convex in link speed c and buffer b.

Loosely speaking, the analysis is based on the general principle that the loss ratio experienced when two flows share buffer and link rate (for instance in a FIFO manner) is always lower than in the situation where both resources are partitioned into two parts (each part dedicated to one of the flows). This result extends and simplifies earlier results by Kumaran and Mandjes, which assumed many i.i.d. flows.

Project FLOW

E. Altman (INRIA), K. Avrachenkov (INRIA), C. Barakat (INRIA) and *R. Núñez Queija* continued the investigation of the throughput capacity of TCP (Transmission Control Protocol) flows. TCP is the main end-to-end flow control protocol for data communications in the Internet. The protocol relies on feedback signals from the receiving party acknowledging proper receipt of data packets. Additionally, TCP uses a dynamically adjusted bound on the number of packet injected into the network, but not yet acknowledged by the receiver. This bound – the so-called congestion window – adapts to congestion experienced by previously transmitted packets. In absence of congestion signals, the congestion window (and, hence, the transmission rate) is increased until a certain maximum (imposed by the receiver) is reached. In previous analyses of TCP it was commonly assumed that the round-trip time (i.e., the time it takes for a packet to reach the destination and the corresponding acknowledgment to return to the source) is constant, independent of the source's congestion window. This assumption results in a linear increase of the window size and simplifies the analysis considerably. However, when a TCP source's contribution to congestion on the path traversed by its packets is non-negligible, assuming a linear window increase results in a significant overestimation of the achievable throughput. Typically, the round-trip time increases with the window size, leading to a sublinear window growth. E. Altman, K. Avrachenkov, C. Barakat and R. Núñez Queija developed a model for TCP that accounts for both sublinear window growth, limited by a fixed maximum window size. The stability conditions for this model were investigated and, under Markovian assumptions, the resulting Kolmogorov equations were solved analytically for some important particular cases. Comparison of the throughput predicted by the model and the throughput measured on real TCP connections showed a good match.

E. Altman (INRIA, ULA), T. Jiménez (ULA) and *R. Núñez Queija* analyzed two asymmetric competing TCP connections where loss probabilities are directly related to their instantaneous window size, and occur when the sum of throughputs attains a given level. Bounds for the stationary throughput of each connection were obtained, as well as an exact expression for symmetric connections. This allows to further study the fairness as a function of the different round-trip times. In related analyses it is commonly assumed that when losses occur, *both* connections suffer from it. This simplifying artificial synchronization assumption is avoided in this investigation. The results on two competing TCP connections complement those of the previous topic by E. Altman, K. Avrachenkov, C. Barakat and R. Núñez Queija, where the behaviour of TCP in a numerous competitive environment is described by assuming an exogenous loss process.

N.D. van Foreest (University of Twente), M. Mandjes, D. Mitra (Bell Labs) and *W.R.W. Scheinhardt* considered feedback (Markov) fluid models. These were used to analyze bandwidth sharing schemes for the access network. In their model sources are always allowed to send at a guaranteed rate r. If the number of active clients is low, they can send at a higher rate (where the bandwidth is shared according to a processor-sharing discipline), but their rate can never exceed the line speed p of their access link. The buffer content distribution follows from a system of (inhomogeneous) linear differential equations, together with a set of boundary conditions. Explicit approximations for the case of many clients are derived. Similar models developed for analyzing feedback-based congestion control schemes such as TCP. Particularly issues of 'unfairness' were studied: what is for instance the disadvantage of having a longer round-trip time than another user, or the disadvantage of lacking the ability to aggressively increase the window size.

Project LT

A.A. Borovkov (Sobolev Inst. of Mathematics, Novosibirsk) and *O.J. Boxma* have considered large-deviations probabilities for random walks with regularly varying tails. They have established first-order approximations and some refinements for the distribution of sums and maxima of sequential sums of heavy-tailed random variables. Similar results have been obtained for probabil-

ities of crossing arbitrary curvilinear boundaries in the large-deviations range by random walks generated by such sequential sums.

S.C. Borst and *A.P. Zwart (TUE)* have considered a fluid queue fed by several heterogeneous M/G/∞ input processes with regularly varying session lengths. Under fairly mild assumptions, they derived the exact asymptotic behaviour of the stationary workload distribution. As a by-product, they obtained asymptotically tight bounds for the transient workload distribution. The results are strongly inspired by the large-deviations idea that overflow is typically due to some minimal combination of extremely long concurrent sessions causing positive drift. The typical configuration of long sessions is identified through a simple integer program, which paved the way for the exact computation of the asymptotic workload behaviour. The calculations provide crucial insight in the typical overflow scenario.

Project QFN-IS

Ph. Nain (INRIA) and *R. Núñez Queija* continued their study of the exact computation of performance measures of an M/M/1 queue in a random environment exhibiting heavy-tailed traffic phenomena (see also Project LT above). The sojourn times in the two-state semi-Markovian environment may have heavy-tailed distributions. The state of the environment determines the load on the queue. Investigation of the case where the queue is stable (possibly with a load close to 1) for a 'heavy-tailed' state of the random environment was completed. The case where the queue may be unstable during periods with a heavy-tailed distribution is currently under investigation.

S.C. Borst, R. Núñez Queija and *M.J.G. van Uitert* have initiated the investigation of a system of two queues which are served according to the Generalized Processor Sharing (GPS) discipline, and customers of one class (for instance, those in queue 1) share the capacity available to them in a processor sharing fashion. That is, each customer in queue 1 receives an equal share of the total capacity available to queue 1. The performance measure of interest is the tail of the sojourn time distribution of customers at queue 1. Assuming that the tail of the service requirement distribution at queue 1 is regularly varying and that the GPS weights are chosen in such a way that the capacity guaranteed to queue 1 is sufficient for stability of that queue, it can be shown that the tail of the sojourn time distribution at queue 1 is also regularly varying with the same index as the service requirement distribution.

Project QFN-PS

S.C. Borst, M.R.H. Mandjes and *M.J.G. van Uitert* have continued their study of a queue fed by a mixture of light-tailed and heavy-tailed traffic. The two traffic flows are served in accordance with the GPS discipline. They derived the asymptotic workload behavior of the light-tailed traffic flow under the assumption that its GPS weight is larger than its traffic intensity. The GPS mechanism ensures that the workload is bounded above by that in an isolated system with the light-tailed flow served in isolation at a constant rate equal to its GPS weight. Using probabilistic bounds, they showed that the workload distribution is in fact asymptotically equivalent to that in the isolated system, multiplied with a certain pre-factor, which accounts for the interaction with the heavy-tailed flow. Specifically, the pre-factor represents the probability that the heavy-tailed flow is backlogged long enough for the light-tailed flow to reach overflow. The results provide crucial qualitative insight in the typical overflow scenario.

S.C. Borst, O.J. Boxma and *M.J.G. van Uitert* continued the study of two coupled M/G/1 queues. The queues are coupled in the sense that whenever both queues are non-empty, they are both served by their own servers at unit speed. However, if one of the servers has no work in its own queue, it assists the other working server, resulting in increased service speeds (r_1 for queue 1 and r_2 for queue 2). Note that this system is closely related to Generalized Processor Sharing. Not surprisingly, qualitatively similar results as mentioned under the previous item are obtained. They finished the study of the workload behaviour in this queue when the service request distribution at one queue is exponentially distributed and at the other queue is regularly varying. They have initiated extensions of this work in two directions. (i) They started the analysis of the workload behaviour when the service time distribution at one of the queues has a general, but lighter tail than the other queue. (ii) They begun the study of the workload behaviour in the limiting case when $\frac{1}{r_1} + \frac{1}{r_2} = 1$.

M.R.H. Mandjes and *M.J.G. van Uitert* initiated a study to compare different scheduling disciplines with regard to their efficiency in a net-

work under certain Quality-of-Service (QoS) criteria. Two types of traffic flows are assumed to feed a buffer, which serves these flows according to one of the following mechanisms: first in first out (FIFO), resource partitioning (RP), strict priority (SP) or generalised processor sharing (GPS). The maximum number of flows that can be admitted to the system, given that the loss probability for both types of flows does not exceed a threshold, is derived. The loss probabilities for both types of traffic, under all scheduling disciplines mentioned, are computed using large-deviations techniques, with the number of traffic flows growing large (so-called many-sources asymptotics).

Project MOBILECOM
R. Litjens and *R.J. Boucherie* finished a QoS differentiation study for an integrated services GSM/GPRS cell serving speech, video, high- and low-priority data calls. Closed-form expressions have been derived for (conditional) QoS measures, including service-specific call blocking probabilities, video throughput measures and data call access, transfer and sojourn times. A numerical study is included to demonstrate the strengths of the considered model and to indicate the impact of the various operator-controllable parameters on the performance.

R. Litjens and *R.J. Boucherie* finished a sensitivity study of a queueing system integrating prioritized stream and delay-tolerant elastic calls, which utilize the varying remaining capacity in a processor-sharing fashion. The remarkable phenomenon that the QoS of the elastic calls improves under an increased elastic call size variability is demonstrated and analytically supported.

R. Litjens and *R.J. Boucherie* continued a throughput analysis in processor-sharing models, concentrating on both video and data services. Various throughput measures are derived and compared.

Research not associated with any particular project within PNA2.1
S.C. Borst, O.J. Boxma, J.A. Morrison and *R. Núñez Queija* studied a useful equivalence relation for the delay distributions in the G/M/1 queue under two different service disciplines: (i) PS (Processor Sharing); and (ii) ROS (Random Order of Service). By means of direct probabilistic arguments it can be shown that the sojourn time under PS is equal (in distribution) to the waiting time under ROS of a customer arriving to a non-empty system. Consequently, the sojourn time distribution for ROS is related to the waiting-time distribution for PS through a simple multiplicative factor, which corresponds to the probability of a non-empty system at an arrival instant. The equivalence relation was shown to extend to the M/M/1/K queue and to $\cdot$/M/1 nodes in product-form networks.

S.C. Borst and *P.A. Whiting* have examined the capacity improvements from diversity antennas in multi-user scenarios. Although available single-user results yield valuable insight for voice, they do not directly translate to multi-user data systems. First of all, they showed that the use of diversity antennas has the effect of dampening the variations in the channel conditions. This reduces the scope for channel-aware scheduling mechanisms such as HDR to obtain capacity gains by exploiting fluctuations in the feasible transmission rates. Conversely, in the presence of scheduling, diversity antennas may produce substantially smaller gains, or even have a negative impact on capacity. Second, in heterogeneous scenarios, they found that the capacity improvements from diversity antennas may widely vary, depending on what fairness notion is adopted. If the proportion of time slots is used as fairness criterion, then the gains in total throughput tend to be significant, but the edge users only receive a marginal share. In case the fairness measure is defined in terms of throughput ratios, the gains tend to be limited population-wide.

S.C. Borst, O.J. Boxma, J.F. Groote and *S. Mauw* have considered a slotted queueing system with C servers (processors) that can handle tasks (jobs). Tasks arrive in batches of random size at the start of every slot. Any task can be executed by any server in one slot with success probability α. If a task execution fails, then the task must be handled in some later time slot until it has been completed successfully. Tasks may be processed by several servers simultaneously. In that case, the task is completed successfully if the task execution is successful on at least one of the servers. The distribution of the number of tasks in the system is determined for a broad class of task allocation strategies, and the impact of various allocation strategies on mean number of tasks in the system and mean task response time is examined.

O.J. Boxma, D. Denteneer (Philips Research) and *J.A.C. Resing (TUE)* have studied contention resolution in cable access networks. The

contention resolution of requests for network access is carried out by contention trees. The performance analysis of those contention trees is studied by means of a machine repair model with Random Order of Service.

O.J. Boxma, S. Schlegel (EURANDOM) and *U. Yechiali (Tel-Aviv University)* have analyzed two-queue polling models with the special feature of a timer mechanism at the first queue. They have derived waiting time and workload distributions, as well as the queue length distributions at polling instants.

K. Dębicki extended the definition of Pickands constants to the class of Gaussian processes with stationary increments. He gave a comparison criterion for the generalized Pickands constants and extended a result of Pickands for certain stationary Gaussian processes. As an application, he obtained the exact asymptotics of the supremum of an integrated stationary Gaussian process with linear drift.

K. Dębicki analyzed the problem of estimating the tail probability of supremum of scaled Brownian motion process with linear drift. Using the local-time technique he obtained asymptotics and bounds which are expressed in terms of the expected value of the local time of scaled Brownian motion with linear drift. As an application, he obtained bounds for the tail distribution of supremum for some Gaussian processes with stationary increments that play an important role in the theory of fluid models.

V. Espinosa, L. Jorguseski, R. Litjens, E.R. Fledderus and *R. Prasad* carried out a study called Downlink Radio Resource Estimation and Control in WCDMA Cellular System with Voice and Data Users, which concentrated on the dynamic estimation of free resources in an integrated voice/data WCDMA network, and the efficient utilization of these resources by enhancing the data performance.

R. Litjens initiated a study to determine the potential gains of efficient up- and downgrading of shared data transfer channels in an integrated speech/data UMTS network. Rate- and power-based scheduling schemes have been compared, while within each class fixed rate/power allocations have been set as default alternatives, that have been compared both with uniform up- and downgrading of bit rates / transmission powers, and with a so-called balanced scheme which shifts capacity towards data traffic hot spots.

Traffic Networks – PNA2.2

Project CONTROL

L.C.G.J.M. Habets and *J.H. van Schuppen.* A reachability problem was solved for an affine dynamic system on a simplex and on a general polytope. The problem is part of a project on control of hybrid systems. A paper was presented at a workshop. Another paper has been submitted to a journal. Lectures on this research were presented at meetings of the EU ESPRIT LTR Project Verification of Hybrid Systems (VHS). The research is financially supported by the EU ESPRIT LTR project Verification of Hybrid Systems (VHS). The research proposal *Control and Computation* was accepted for financial support by the European Commission in the program EU.IST.LTR and has started 1 January 2002.

With S. Hedlund realization problems for piecewise-affine systems were studied. A condition for reduction of such a system due to unobservability was formulated.

J.H. van Schuppen. With S.L. Ricker (Mount Allision University, Sackville, NB, Canada) research was continued on decentralized failure detection of timed discrete-event systems.

Control and System Theory – PNA2.3

Project RESI

J.H. van Schuppen. Research on a stochastic realization problem for a σ-algebra family was continued and a paper remains to be completed.

With Siddhartha Jha problems of modelling and control of biochemical reaction networks were studied and formulated. Contacts were established and maintained with Hans Westerhoff (Vrije Universiteit, Amsterdam). Major problems to be studied are realization of rational positive systems and decompositions of cell reaction networks by graph theoretic methods.

Project RESI is financially supported by the European Commission through the Program Training and Mobility of Researchers (TMR) and Project System Identification (SI). The financial support is primarily for visiting postdocs and PhD students.

Project SICA

D. Jibetean, B. Hanzon. Together with Dr. R.L.M. Peeters (University of Maastricht) we investigate applications of techniques from constructive and computer algebra to several problems in the area of system identification, includ-

ing optimal model order reduction, identifiability analysis and optimization problems arising in this field. Particular attention has been given to the H_2 model reduction problem.

Knowledge Transfer

- ICT Kenniscongres (Den Haag, September 6–7): M. Mandjes (demo and poster presentation), M.J.G. van Uitert (demo).
- CWI in Bedrijf (CWI, October 5): M. Mandjes (lecture and demo), M.J.G. van Uitert (demo).
- Working visit to KEMA, Arnhem, December 18: J.H. van Schuppen with J.G. Verwer and P.W. Hemker.

Organization of Conferences, Workshops, Courses, etc.

- Reading Seminar (CWI, monthly): R. Núñez Queija and M.J.G. van Uitert.
- BETA/EURANDOM workshop on Stochastic models of manufacturing and logistic systems (Eindhoven, April 24–26): W.H.M. Zijm, O.J. Boxma and A.G. de Kok.
- Queueing Colloquium (CWI, June 27): S.C. Borst, M. Mandjes and R. Núñez Queija.
- EURANDOM workshop on The mathematics of stochastic networks (Eindhoven, October 29 – November 2): F. Baccelli, O.J. Boxma, S.G. Foss and J.A.C. Resing.
- CWI Colloquium *Modeling, identification, and control in biology and medicine*, CWI, Amsterdam, November 9: J.H. van Schuppen.
- Queueing Colloquium (CWI, November 28): M. Mandjes and R. Núñez Queija.

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

- Twenty-Sixth Conference on the Mathematics of Operations Research (Lunteren, January 16–18): R.J. Boucherie, S.C. Borst, O.J. Boxma (lecture), M. Mandjes, R. Núñez Queija, M.J.G. van Uitert (lecture), W.R.W. Scheinhardt.
- Working visit Twente University (Enschede, The Netherlands, February): R. Litjens (lecture).
- Participation in TRAIL Seminar 'Advances and applications in dynamic traffic flow modeling', February 2, Delft: S. Hedlund, J.H. van Schuppen.
- Participation in TRAIL Colloquium Dynamic Traffic Control and work visit to Prof. H. van Zuijlen, February 9, Delft: J.H. van Schuppen
- Lecture by J.H. van Schuppen at Stieltjes Week Stochastic Differential Equations, February 22–23, Leiden University (*Optimal stochastic control*).
- Working visit NTT DoCoMo R&D Center, Yokosuka Research Park, Japan, March 1–May 31: R. Litjens (lectures).
- Benelux Meeting, Houffalize, Belgium, March 26–28: D. Jibetean. Lecture: *Global minimization of a polynomial using algebraic matrix methods.*
- Participation in Workshop Hybrid Systems – Computation and Control 2001, March 28–30, Rome, Italy: L.C.G.J.M. Habets, J.H. van Schuppen. Lecture L.C.G.J.M. Habets *Control of piecewise-linear hybrid systems on simplices and polytopes.*
- Participation in meeting of project VHS, March 31, Rome, Italy: L.C.G.J.M. Habets, J.H. van Schuppen. Lecture J.H. van Schuppen *Control and system theory of piecewise-linear hybrid systems.*
- University of Maastricht, April 15–18: D. Jibetean.
- Participation in Nederlands Mathematisch Congres 2001, April 19–20, VU, Amsterdam: D. Jibetean, L.C.G.J.M. Habets, B. Hanzon, S.C. Borst (lecture), J.H. van Schuppen. Lecture D. Jibetean *Global minimization of a polynomial using algebraic matrix methods.* Lecture L.C.G.J.M. Habets *A control problem for affine systems on a full-dimensional polytope.*
- Working visit to Program Bedrijfswiskunde en -informatica (Business Mathematics and Informatics), Vrije Universiteit, Amsterdam: J.H. van Schuppen. Lecture *Dynamic routing control of motorway networks.*
- Participation in TRAIL Colloquium Dynamic Traffic Management, 20 April, Trail, Delft: J.H. van Schuppen.
- IEEE INFOCOM 2001 Conference (Anchorage AK, USA, April 22–26): M. Mandjes (lecture), R. Núñez Queija, M.J.G. van Uitert (lecture; also attended tutorial on traffic engineering in IP/MPLS).
- BETA/EURANDOM workshop on Stochastic models of manufacturing and logistic systems (Eindhoven, April 24–26): S.C. Borst, K. Dębicki.

- 14th ITC-specialists seminar on access networks and systems, Girona, Spain, April 25–27: W.R.W. Scheinhardt (Presentation of *Analysis of feedback fluid queues*).
- VTC 2001 conference (Rhodos, Greece, May 2001): R. Litjens (lecture).
- University of Maastricht, May 16–23: Working visit D. Jibetean.
- Working visit to Faculteit Toegepaste Wetenschappen, Rijksuniversiteit Gent, Gent, Belgium, May 17–18: J.H. van Schuppen.
- EURANDOM course on Spin glasses (Eindhoven, June 4–8): K. Dębicki.
- Participation in Analysis Conference on Nonlinear Phenomena in Science, Vrije Universiteit, Amsterdam, June 7: J.H. van Schuppen.
- Participation in Biometris Conference – Qualitative methods for life and earth, Wageningen University, June 20: Siddhartha Jha and J.H. van Schuppen.
- Joint ACM SIGMETRICS 2001 & Performance 2001 Conference (Cambridge MA, USA, June 16–20): R. Núñez Queija (lecture).
- Workshop on Mathematical Performance Modeling and Analysis 2001 (Cambridge MA, USA, June 20–21): S.C. Borst (lecture), R. Núñez Queija.
- Queueing Colloquium (CWI, June 27): R.J. Boucherie, K. Dębicki, M. Mandjes, R. Núñez Queija, M.J.G. van Uitert, W.R.W. Scheinhardt.
- Stochastic Processes and Applications (Cambridge, UK, July 9–13, 2001): K. Dębicki (lecture), M. Mandjes (invited lecture).
- EURO 2001 Conference (Rotterdam, The Netherlands, July 2001): R. Litjens (lecture).
- Participation in SCODES'01, Paris, July 23.
- Working visit Bell Laboratories (Murray Hill NJ, USA, July 23–24): M.J.G. van Uitert, J. Komenda.
- 11th INFORMS Applied Probability Conference (New York NY, USA, July 25–27): S.C. Borst (lecture), R.J. Boucherie (lecture), O.J. Boxma (session organizer; lecture), K. Dębicki (lecture), M. Mandjes (lecture), M.J.G. van Uitert (lecture), W.R.W. Scheinhardt (lecture *Feedback fluid queues and TCP*).
- Working visit INRIA (Sophia Antipolis, France, August 1–31): R. Núñez Queija.
- Participation in the Workshop on Maxplus algebras, Prague, Czech Republic, August 27–29: J. Komenda.
- Working visit (to V. Piterbarg) Erasmus University of Rotterdam (Rotterdam, The Netherlands, September 6): K. Dębicki.
- Participation in European Control Conference, Porto, Portugal, September 4–7: B. Hanzon, J.H. van Schuppen. Lecture J.H. van Schuppen *A controllability result for piecewise-linear hybrid systems.*
- Participation in ERNSI Workshop System Identification, Cambridge, United Kingdom, September 17–19: L.C.G.J.M. Habets, B. Hanzon, D. Jibetean, J.H. van Schuppen. Lecture J.H. van Schuppen *Problems of control and system theory of cell reaction networks.* D. Jibetean poster: *Global Identifiability Analysis using Algorithms for Detecting Connected Semi-Algebraic Components.*
- Participation in the DFG-NWO meeting in cell biology, Egmond aan Zee, September 28–30: J.H. van Schuppen.
- PNA Colloquium (CWI, September 10): S.C. Borst, K. Dębicki (lecture), M. Mandjes, R. Núñez Queija.
- XXX Conference on Applications of Mathematics (Zakopane, Poland, September 18–25): K. Dębicki (lecture).
- Workshop on Computer Algebra for Geometric Computing, Leiden, October 1,3: D. Jibetean.
- Workshop on Model Reduction, Eindhoven, October 8–9: D. Jibetean.
- Workshop on TCP (KPN Research, Leidschendam, October 9): M. Mandjes, R. Núñez Queija, M.J.G. van Uitert.
- COST 279 Meeting (Lisbon, Portugal, October): R. Litjens (lecture).
- Participation in Systems Theory Day, University of Groningen, Groningen, October 19: J.H. van Schuppen.
- Working visit to Faculteit Toegepaste Wetenschappen, Universiteit Gent, Gent, Belgium, October 22–23: J.H. van Schuppen. Lecture *Problems of control and system theory of cell reaction networks.*
- EURANDOM workshop on The mathematics of stochastic networks (Eindhoven, October 29 – November 2): O.J. Boxma, K. Dębicki (lecture), M. Mandjes (lecture), R. Núñez Queija, M.J.G. van Uitert, W.R.W. Scheinhardt.
- Participation in Colloquium *Modeling, identification, and control in biology and medicine*, CWI, Amsterdam, November 9: D. Jibetean, B. Hanzon, and J.H. van Schuppen.
- Working visit to the University of Maastricht, November 13–22: D. Jibetean.

- Queueing Colloquium (CWI, November 28): R. Bekker, S.C. Borst, R.J. Boucherie, O.J. Boxma (lecture), K. Dębicki, M. Mandjes, R. Núñez Queija, D. van Ooteghem, W.R.W. Scheinhardt (lecture *Decay rate behaviour for a quasi birth-death process with infinitely many phases*), M.J.G. van Uitert.
- Participation in TRAIL Colloquium Dynamic Traffic Management, Delft, December 3: J.H. van Schuppen.
- CDC 2001, Orlando, Florida, USA, December 4–7: D. Jibetean (lecture): *Global Identifiability Analysis using Algorithms for Detecting Connected Semi-Algebraic Components*.
- ITC-17 Conference (Salvador de Bahia, Brazil, December 3–7): O.J. Boxma (lecture).
- STW Meeting (Utrecht, The Netherlands, December 4): R. Litjens (lecture).

Memberships of Committees and Other Professional Activities

B. Hanzon:
- Associate professor of Applied Analysis at the Vrije Universiteit.

J.H. van Schuppen:
- Professor of Applied Anasysis at the Vrij Universiteit (part-time).
- Editor-in-Chief of the journal *Mathematics of Control, Signals, and Systems* since 1994.
- Associate Editor-at-Large of the journal *IEEE Transactions Automatic Control* since 1998.
- Coordinator of the Project System Identification (SI) that is financially supported by the European Commission through the Program Training and Mobility of Researchers (TMR), since 1998.
- Chairman of the Steering Committee of the ERCIM Working Group Control and System Theory, since 1995.
- Member of the PhD committees for:
  - Dr. B. Haverkamp, Delft University of Technology, February 13.
  - Dr. ir. P.P.M.M. Philips Eindhoven University of Technology, April 23.
- Member of the Users Committee of the NWO-STW Project Stochastic network analysis for the design of self optimising cellular mobile communication systems (AEC.4412). Meeting December 4.
- Member of the Steering Committee, of the International Symposia on the Mathematical Theory of Networks and Systems since 1989.
- Member of IFAC Technical Committee on Stochastic Systems since 1994.
- Member of Scientific Committee of the Workshop on Discrete Event Systems 2002 (WODES2002).
- Member of Program Committee of the Workshop Hybrid Systems – Computation and Control 2002.
- Member of the Dutch Institute of Systems and Control (DISC), since September 1995.
- Member of the Stieltjes Institute since January 2001.

S.C. Borst:
- Professor of Stochastic Operations Research (part time), Eindhoven University of Technology.
- Member of Technical Staff (part time), Bell Laboratories, Lucent Technologies, Murray Hill, USA.
- Associate editor of the journal *Operations Research Letters*.
- Associate editor of the journal *Performance Evaluation*.
- Member of the program committee of the joint ACM SIGMETRICS 2001 & Performance 2001 Conference (Cambridge MA, USA, June 2001).
- Member of IFIP Working Group 7.3.
- Second PhD thesis advisor of Q. Deng.
- Second PhD thesis advisor of A.P. Zwart.

O.J. Boxma:
- Professor of Stochastic Operations Research, Eindhoven University of Technology.
- Area editor of the journal *Operations Research Letters*.
- Associate editor of the journals *Applied Stochastic Models in Business and Industry; Markov Processes and Related Fields; Mathematics of Operations Research; Queueing Systems*.
- Member of the program committee of the ITC-17 Conference.
- Member of IFIP Working Group 7.3 (also of its membership election committee).
- Member of the International Advisory Committee of the International Teletraffic Congresses.
- Project leader INTAS project The mathematics of stochastic networks.
- Project leader SWON project Regular variation in broadband ISDN.
- One of the leaders of the SWON groot project Stochastic networks.
- Coordinator of the EURANDOM project Stochastic networks.
- Member of the Scientific (daily) board of research school Stieltjes.

- Member of the Management Team of research school BETA.
- PhD thesis advisor of Q. Deng (TUE) and A.P. Zwart (TUE), and member of the PhD committee of B.E. Sarroukh (TUE).
- Member of the NWO Gebiedsbestuur Exacte Wetenschappen.

K.S. Dębicki:

- Assistant professor in Department of Stochastic Processes, Mathematical Institute, University of Wrocław, Wrocław, Poland.
- Member of Polish Association of Mathematicians.
- Project leader 5 P03A 021 20 project Analysis of stochastic characteristics in the extreme value theory of stochastic processes.

R. Litjens:

- Member of Technical Staff, KPN Research, Leidschendam.

M.R.H. Mandjes:

- Professor of Stochastic Operations Research (part-time), University of Twente.
- Member of Technical Staff (part-time; till September 1, 2001), Bell Laboratories, Lucent Technologies, Murray Hill, USA.
- Member of the program committee of the ITC-17 Conference.
- Member PhD committee Q. Deng (thesis advisor: O.J. Boxma, second thesis advisor: S.C. Borst), Eindhoven University of Technology, September 5, 2001.
- Member PhD committee P.E. Lassila (thesis advisor: J. Virtamo), Helsinki University of Technology, October 12, 2001.

R. Núñez Queija:

- Assistant professor of Stochastic Operations Research, Eindhoven University of Technology (part-time).
- Member of the research schools Stieltjes and BETA.

M.J.G. van Uitert:

- Member of Technical Staff (part-time), KPN Research, Leidschendam.

W.R.W. Scheinhardt:

- Assistant professor of Stochastic Operations Research, University of Twente.

Visitors

- S. Hedlund (Lund Institute of Technology, Lund, Sweden), January 8–March 10. Lecture February 27, *Optimal control of hybrid systems via convex dynamic programming.*
- R. Kumar (University of Kentucky, Lexington, KY, USA), May 4. Lecture *Control of discrete-event systems with temporal logic specifications.*
- G. Pappas (University of Pennsylvania, Philadelphia, PN, USA), June 27. Lecture *Hierarchies of consistent control abstractions.*
- S.L. Ricker (Mount Allison University, Sackville, NB, Canada), July 10–31. Lecture *Decentralized control of discrete-event systems with communication between supervisors.*
- Y. Yamamoto (Kyoto University, Kyoto, Japan), August 31. Lecture *Digital signal processing via sampled-data control theory.*
- Ph. Nain (INRIA Sophia Antipolis, France), September 26.
- J.-L. Gouzé (INRIA Sophia Antipolis, France) November 8–9. Lecture at Colloquium on November 9.

Papers in Journals and Proceedings

I.J.B.F. Adan, O.J. Boxma, J.A.C. Resing (2001). Queueing models with multiple waiting lines. *Queueing Systems* **37**, 65–98.

E. Altman, K. Avrachenkov, C. Barakat, R. Núñez Queija (2001). State-dependent M/G/1 type queueing analysis for congestion control. *Proc. INFOCOM 2001*, Anchorage AK, USA, 1350–1359.

E. Altman, K. Avrachenkov, C. Barakat, R. Núñez Queija (2001). TCP modeling in the presence of nonlinear window growth. *Proc. ITC-17*, 883–894.

S.C. Borst, O.J. Boxma, M.J.G. Van Uitert (2001). Two coupled queues with heterogeneous traffic. *Proc. ITC-17*, 1003–1014.

S.C. Borst, E.G. Coffman Jr., E.N. Gilbert, P.A. Whiting, P.M. Winkler (2001). Optimal carrier sharing in wireless TDMA. *Journal of Interconnection Networks.*

S.C. Borst, P.A. Whiting (2001). Dynamic rate control algorithms for HDR throughput optimization. *Proc. INFOCOM 2001*, Anchorage AK, USA, 976–985.

O.J. Boxma, D. Perry (2001). A queueing model with dependence between service and interarrival times. *Eur. J. Oper. Res.* **128**, 611–624.

O.J. Boxma (2001). Files van files – WWW en de wondere wereld van de wachtrij. *Kwantitatieve Methoden* **67**, 81–95.

O.J. Boxma, Q. Deng, J.A.C. Resing (2001). Polling systems with regularly varying

service and/or switchover times. *Advances in Performance Analysis* **3**, 71–107.

O.J. Boxma, O. Kella, D. Perry (2001). An intermittent fluid system with exponential on-times and semi-Markov input rates. *Probability in the Engineering and Informational Sciences* **15**, 189–198.

O.J. Boxma, I.A. Kurkova (2001). The M/G/1 queue with two service speeds. *Advances in Applied Probability* **33**, 520–540.

O.J. Boxma, D. Perry, W. Stadje (2001). Clearing models for M/G/1 queues. *Queueing Systems* **38**, 287–306.

O.J. Boxma, R. Syski (2001). Obituary: Jacob Willem Cohen. *Journal of Applied Probability* **38**, 604–608.

K. Dębicki (2001). Asymptotics of the supremum of scaled Brownian motion. *Probability and Mathematical Statistics* **21**, 199–212.

K. Dębicki (2001). Uogolnione stale Pickands'a. *Materialy konferencyjne XXX Konferencji Zastosowan Matematyki*, Zakopane, 7.

V. Espinosa, L. Jorguseski, R. Litjens, E.R. Fledderus, R. Prasad (2001). Downlink radio resource estimation and control in WCDMA cellular system with voice and data users. *Proc. WPMC'01*, Aalborg, Denmark.

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M. Mandjes, J.-H. Kim (2001). An analysis of the phase transition phenomenon in packet networks. *Advances in Applied Probability* **33**, 260–280.

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CWI Reports

The following CWI reports were published by members of theme PNA2. See page 6 for the complete titles of the reports.

PNA-R0103	PNA-R0105	PNA-R0106
PNA-R0107	PNA-R0109	PNA-R0116
PNA-R0118	PNA-R0120	PNA-R0122

Other Publications

E. Altman, K. Avrachenkov, C. Barakat, R. Núñez Queija (2001). *TCP Modeling in the Presence of Nonlinear Window Growth.* INRIA Research Report RR–4312.

A.A. Borovkov, O.J. Boxma (2001). *On Large Deviation Probabilities for Random Walks with Heavy Tails.* EURANDOM Report 2001–027.

S.C. Borst, P.A. Whiting (2001). *The use of Diversity Antennas in High-Speed Wireless Systems: Capacity Gains, Fairness Issues, Multi-User Scheduling.*

S.C. Borst, A.P. Zwart (2001). *Fluid Queues with Heavy-Tailed $M/G/\infty$ Input.* SPOR Report 2001–02, Eindhoven University of Technology.

O.J. Boxma (2001). In memoriam Wim Cohen. *Nieuw Archief voor Wiskunde* **5**, 21.

O.J. Boxma, S. Schlegel, U. Yechiali (2001). *Two-Queue Polling Models with a Patient Server.* EURANDOM Report 2001–029.

O.J. Boxma, D. Denteneer, J.A.C. Resing (2001). *Some Models for Contention Resolution in Cable Networks.* EURANDOM Report 2001–037.

K. Dębicki, A. Raczynski (eds.) (2001). *Informator Instytutu Matematycznego Uniwersytetu Wrocławskiego.* University of Wrocław Press, Poland.

N. Van Foreest, M.R.H. Mandjes, W.R.W. Scheinhardt (2001). *Performance Analysis of Heterogeneous Interacting TCP Sources.* Memorandum 1607, Faculty of Mathematical Sciences, University of Twente.

N. Van Foreest, M.R.H. Mandjes, W.R.W. Scheinhardt (2001). *Analysis of a Feedback Fluid Model for Heterogeneous TCP Sources.* Memorandum 1608, Faculty of Mathematical Sciences, University of Twente.

M.R.H. Mandjes, D. Mitra, W.R.W. Scheinhardt (2001). *Models of Network Access Using Feedback Fluid Queues.* Memorandum 1612, Faculty of Mathematical Sciences, University of Twente.

W.R.W. Scheinhardt, A.P. Zwart (2001). *A Tandem Fluid Queue with Gradual Input.* Memorandum 1563, Faculty of Mathematical Sciences, University of Twente.

Stochastics – PNA3

Staff

- Dr. J. van den Berg, theme leader (0.9 fte)
- T. Blomster, visiting PhD student (February – June)
- Drs. R.M. Brouwer, PhD student (since February)
- Dr. E. Capobianco, postdoc (ERCIM fellow; since April)
- Dr. K.O. Dzhaparidze, senior researcher
- Dr. J.A. Ferreira, postdoc (EU project DYNSTOCH; since March)
- Dr. R. Helmers, senior researcher
- R. van der Horst, programmer (0.75 fte)
- Prof. dr. M.S. Keane, senior researcher (0.8 fte)
- Drs. B. Lemmens (UvA), PhD student (NWO, 0.2 fte; until June)
- I W. Mangku, PhD student (Indonesian cooperation; until February)
- Dipl.-math. S.W.W. Rolles, PhD student (EURANDOM, 0.2 fte)
- Dr. P.J.C. Spreij (UvA), senior researcher (0.2 fte)
- B. Tarigan, PhD student (Indonesian Cooperation project)
- Prof. dr. S.M. Verduyn Lunel (UL), advisor (0.2 fte)
- Drs. J.H. van Zanten, PhD student (NWO, until September)

Scientific Report

Highlights

This year has shown a dynamic movement of young researchers in PNA3: Mangku, Lemmens and Van Zanten defended their PhD theses successfully and had no difficulty to find jobs. One

new PhD student (Brouwer) and two postdocs (Capobianco and Ferreira) started in our theme.

The research proposal *Dynamic Percolation Phenomena near Criticality* by Van den Berg, involving a 2-year postdoc position, has been accepted by NWO. The postdoc will start in 2002.

Probability – PNA 3.1

In the first quarter of 2001 Van den Berg participated one month in the programme on Random Walks at the Erwin Schrödinger Institute in Vienna. Much time during this visit was used to work out in more detail some of the ideas and results about Coalescing Random Walks mentioned in the Overview 2000, and to write the first version of a (quite long and technical) paper. This is joint work with Harry Kesten. The final version was completed and submitted in May and has been accepted for publication.

Much time in Vienna was also used to study and discuss with other participants, a spectacular new result by Stanislav Smirnov about conformal invariance and Cardy's formula for 2D critical percolation.

With Antal Járai (UBC, Vancouver) Van den Berg has studied the lowest crossing in 2D critical percolation. Their result gives, up to a constant factor, the probability that this crossing comes within a certain distance from the 'bottom'. This problem arose originally as a side issue in their study of D. Aldous 'frozen percolation' model, but other (more recent) motivations are possible interesting implications for and relations with Stochastic Loewner Evolutions. These processes, which were introduced by O. Schramm a few years ago, have recently proved to be extremely useful and interesting.

A problem posed by Tom Liggett concerning the correlations in symmetric exclusion models has been studied. Although Van den Berg strongly believes that Reimer's generalized BK inequality can be used here, no solution has been found yet.

R. Brouwer (PhD student) has started in February. With Van den Berg she studies a class of percolation-like problems which are motivated by certain forest-fire, neuron and epidemics models. It is expected that these models have a kind of self-organized critical behaviour. Several explicit calculations have been done for the case where the underlying medium has a regular tree structure. For the square lattice simulations have been done and preliminary theoretical results have been obtained. Further progress is expected soon.

Keane and Rolles have prepared a paper entitled *Tubular Recurrence*. It gives the first proof of recurrence of directionally reinforced random walks on tube-like graphs, and has been accepted for publication in *Acta Mathematica Hungarica*. It will also appear as one of the five articles of Rolles' dissertation, to be defended on March 20, 2002, at the University of Amsterdam, under Keane's supervision.

Statistics – PNA 3.2

I W. Mangku received his PhD degree in Mathematics at the University of Amsterdam on January 22; R. Helmers was co-advisor and M.S. Keane thesis advisor.

A paper on consistent estimation of a cyclic Poisson intensity function by R. Helmers, I W. Mangku and R. Zitikis was accepted for publication by the *Journal of Multivariate Analysis*. A follow-up paper on statistical properties of a kernel type estimator of the intensity function of a cyclic Poisson process appeared as CWI report and was submitted for publication. A paper by Helmers and Mangku on nonparametric estimation of the period of a cyclic Poisson process – a revised version of part of chapter 5 of Mangku's thesis – is in preparation and will be submitted for publication to a book in honour of Constance van Eeden. R. Helmers intends to participate (invited speaker) in a conference celebrating van Eeden's 75th birthday, to be held in Montréal, Canada, May 24–25, 2002.

Helmers gave talks on his joint work with Mangku and Zitikis in Yogyakarta, Bandung, Singapore and also in Hong Kong, where he stayed two weeks in December, visiting Hong Kong University of Science and Technology (HKUST).

The collaboration by Helmers with B.Y. Jing and W. Zhao, both at HKUST, on saddlepoint approximation for studentized trimmed means was continued. With N. Gribkova (St. Petersburg) Helmers established the (empirical) Edgeworth expansion for a studentized trimmed mean under minimal conditions.

With R. Zitikis (London, Ont.) Helmers is in the process of obtaining Edgeworth and bootstrap approximations for a class of Gini type indices, with applications to economic inequality.

Helmers made contributions to Chapter 7 and 8 of *Regression Periods in Human Infancy* (with A.J. van Es, F.X. Plooij), a book to appear

in 2002.

With K.P. Choi (Singapore) a study of bounds for the median of the Poisson distribution and related objects was started.

Tarigan continued her PhD research with Helmers. She worked on the statistical estimation of ruin probabilities in the Poisson risk model. For the special case that the claim size distribution is assumed to be exponential, some preliminary results were obtained. She gave lectures on her research in Marseille and Amsterdam.

Consultation: With R. van der Horst, Helmers continued work on a consultation project for the Dutch Ministry of Transport and Public works (RWS) – estimating the intensity of oil pollution in the Dutch part of the North Sea in various years – and also made some progress with a project supported by the Limperg Institute: the aim is to validate a bootstrap calibrated Stringer bound, for practical use in monetary audit populations, when dollar unit sampling is appropriate.

Stochastic Analysis – PNA 3.3

One of the highlights of this year was the completion by J.H. van Zanten of his PhD thesis *Martingales and Diffusions, limit theory and statistical inference*. The defence took place at UvA, October 24.

Another remarkable event took place on September 6–8 at the University of Helsinki. E. Valkeila (together with K.O. Dzhaparidze and P.J.C. Spreij) organized the workshop on *Hellinger Integrals and Hellinger Processes* in the framework of the TMR project DYNSTOCH. In some of the lectures (e.g. the opening lecture by B. Grigelionis) the possibilities were pointed out for further developments of the general theory. This theory took its present form in the work by K. Dzhaparidze, P.J.C. Spreij and E. Valkeila which is up to now available only in the form of two preprints (University of Helsinki, Department of Mathematics, reports 264 and 265) of Mathematics Department of Helsinki University, but will soon appear as one paper in *Annals of Probability* (for its tentative version see CWI report PNA-R0125). CWI report PNA-R0119 is a small note on this subject.

On Februari 1, T. Blomster (Helsinki) joined our DYNSTOCH project to work at CWI till June 31. Blomster is a PhD student of E. Nummelin, studying Stochastic models of exchange economies. Blomster gave a talk on this subject in our Spatial Stochastics Seminar. His cooperation with K. Dzhaparidze resulted in Preprint 303 of the Department of Mathematics at the University of Helsinki. This paper, entitled On Cobb-Douglas dynamical exchange economies has been submitted to *Journal of Economic Dynamics and Control* (sec. B). Dzhaparidze has been invited to present these results in the Helsinki Workshop. Blomster gave a series of lectures in the seminar of the Department of Mathematics, University of Helsinki.

On March 1, J.A. Ferreira joined Dzhaparidze in his study of fractional Brownian motion. Some of the results obtained were presented at the Dynstoch 2001 workshop, Paris, as well as at the International Meeting of Statisticians, Funchal. CWI report PNA-R0123, *A frequency domain approach to some results on fractional Brownian motion* contains current results that are intended for submission to a probabilistic journal. A follow-up report with the tentative title *On orthogonal functions and reproducing kernels associated with the spectrum of fractional Brownian motion* is in preparation.

In his research and studies on Levy processes, Ferreira partly collaborates with A. Kyprianou (Utrecht). CWI report PNA-R0110 by Ferreira contains a note on a special property of non-decreasing Levy processes. The material is worked out as a paper submitted to *Statistics and Probability Letters*.

Ferreira's talk in the Spatial Stochastics Seminar on *Characterizations in probability and statistics: an example of application to goodness of fit*, reflected another area of his interests.

Another subject of interest within our subtheme is *Stochastic volatility*. The paper on this subject Nonparametric volatility density estimation by A.J. van Es, P.J.C. Spreij and J.H. van Zanten, is submitted to *Bernoulli*.

The above mentioned area is also of interests for E. Capobianco, ERCIM fellow since April 1. His ideas and results in this direction were presented in our Spatial Stochastics Seminar, with the title *Multi-resolution properties of semiparametric volatility models*. Some of these results are already published; the paper *Independent Component Analysis and Resolution Pursuit with Wavelet and Cosine Packets*, by Capobianco, is accepted for publication in *Neurocomputing*, and the paper *Multi-resolution Approximations for Volatility Processes* is currently under second revision for *Quantitative Finance*. Closely related

were the lectures *Wavelet-based Local Volatility Approximation* and *Computational Learning for Non-stationary Systems*, which Capobianco has presented in June at the conference *Applied Inverse Problems* in Montecatini and at the DYNSTOCH Workshop in Paris.

Capobianco contributed also to the ENUMATH conference in Ischia with the paper *Functional Approximation and Estimation for Latent Variable Systems*, which will appear in 2002 in the Proceedings by Springer-Verlag, and to the APFA3 conference in London with the paper *Hammerstein System and Independent Components for Representing and Decomposing Volatility Processes*. The latter will be submitted for publication in a special issue of either *Quantitative Finance* or *European Physical Journal B*.

Ergodic Theory and Dynamical Systems – PNA 3.4

The article entitled *Generators* (by Keane and J. Serafin of Wrocław Institute of Technology), which contains a simple new construction of a finite generator for an ergodic transformation of finite entropy, has been accepted for publication in *Periodica Mathematica*. It is available in preprint form electronically.

Knowledge Transfer

- M.S. Keane: Advisor, Philips Research Laboratories, Eindhoven (1 day per week).
- M.S. Keane: Advisor, 3rd UK-Japan Winter School, Bury St Edmunds, UK, January 11–16.
- M.S. Keane: Advisor, Hewlett-Packard Laboratories, Bristol, UK (1 month).
- M.S. Keane: Advisor and member of the International Panel, Eurandom, Eindhoven.
- Van den Berg gave a course on Markov random fields in Utrecht at the MRI Spring School.

PhD Theses

- I Wayan Mangku, January 22, University of Amsterdam (thesis advisor M. Keane, co-advisor R. Helmers): *Estimating the Intensity of a Cyclic Poisson Process.*
- B. Lemmens, June 7, Free University of Amsterdam (thesis advisors M. Keane and S.M. Verduyn Lunel): *Iteration of nonexpansive maps under the 1-norm.*
- B.A.M. Schouten, March 23, University of Amsterdam (thesis advisor M. Keane): *Giving Eyes to ICT! or How Does a Computer Recognize a Cow?*
- J.H. van Zanten, *Martingales and Diffusions, limit theory and statistical inference*, October 24, University of Amsterdam (thesis advisor M Keane, Co-advisors K. Dzhaparidze and P.J.C. Spreij).

Organization of Conferences, Workshops, Courses, etc.

- Chairman, Committee of Conferences on Stochastic Processes. (M.S. Keane).
- J. van den Berg: Co-organiser (with O. Häggström (Gothenburg) of a workshop on Discrete Probability, to be held in June 2002 at Eurandom (Eindhoven).
- J. van den Berg: Co-organiser (with M. Dekking, F. den Hollander and R. Meester) of a probability lecture day in March 2002.
- J. van den Berg: Co-organiser (with Marie-Colette van Lieshout) of the Spatial Stochastics Seminar at CWI.
- M.S. Keane: Co-organizer, Workshop Dynamical Systems and Related Fields, Budapest, Hungary, August 21–25.
- Organizer, Bijeenkomst Stochastici, Lunteren, November 11–14: M. Keane.
- Co-organizers of Workshop on Hellinger Integrals and Hellinger Processes, Helsinki University, September 6–8: (Dzhaparidze and Spreij).
- Helmers made preliminary arrangements for a KNAW research workshop on Statistics to be held in June 2002 in Bandung.

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

- Invited lecture, Colloquium Probability Theory, Statistics and Financial Mathematics, University of Amsterdam, January 8: I W. Mangku.
- Working visit, Wesleyan University, January 23–29: Lecture on *Random Coin Tossing*, Departmental Colloquium, January 24: M. Keane.
- XXI International Seminar on Stability Problems for Stochastic Models, Eger, Hungary, January 28 – February 3. Closing lecture delivered on *Reinforced Random Walks*, February 2: M. Keane.
- Working visit, Budapest University of Technology, February 4–9. Lecture on *Generators*, Staff Colloquium, February 8: M. Keane.

- Conference *Systèmes Dynamiques 2001*, Luminy, France, February 11–17: M. Keane.
- Participant (and invited speaker) in the programme on Random Walks at the Erwin Schrödinger Institute in Vienna: February 19–March 21: J. van den Berg.
- April 2001 : Spring School Stochastics, Utrecht R. Brouwer.
- Working visit, Erwin Schrödinger Institute, Vienna, Austria, February 19–March 16 and June 8–July 5. Lecture on *Generators*, July 4: M. Keane.
- South West Probability Seminar, Bristol, UK, April 3. Lecture on *Generators*: M. Keane.
- Ergodic Theory and Number Theory Seminar, University of Utrecht. Lecture on *Finitary Codes*, April 6: M. Keane.
- Working visit (+ two invited lectures), Department of Mathematics, Gadjah Mada University, Yogyakarta, Indonesia, May 15–17: R. Helmers.
- Working visit, University of Strasbourg, May 20–25. Lecture on *Generators*, May 21: M. Keane.
- Working visit (+ invited lecture), Institute of Technology, Bandung, Indonesia, May 22: R. Helmers.
- Working visit (+ invited lecture), Department of Applied Probability and Statistics, National University of Singapore, May 30: R. Helmers.
- Working visits to LADSEB, Padova, May 26–June 5: P. Spreij.
- T. Blomster:
  Summer school of Finish statisticians, Lahti, June 4–9.
- DYNSTOCH Workshop, June 13–16: H. Poincaré Inst., Paris. K. Dzhaparidze, T. Blomster, P.J.C. Spreij, J.H. van Zanten (lecture: *Uniform limit theorems for regular diffusion processes with finite speed measure*), E. Capobianco (lecture: *Computational Learning for Non-stationary Systems*) and J.A. Ferreira (lecture: *A frequency domain approach to some results on fractional Brownian motion*).
- E. Capobianco: Conference on Applied Inverse Problems, Montecatini, Italy, June 19–21. Lecture: *Wavelet-based Local Volatility Approximation.*
- Participant in the programme on Random Walks at the Erwin Schrödinger Institute in Vienna, June 16–23: Van den Berg.
- Conference on Stochastic Processes and their Applications, Cambridge, July 9–12: Van den Berg and Keane.
- Working visit, University of Warwick, July 13–17. Lecture on *Reinforced Random Walk* on July 16: M. Keane.
- E. Capobianco: Conference 'European Numerical Mathematics and Advanced Applications' (ENUMATH), Ischia, Italy, July 23–28. Lecture: *Functional Approximation and Estimation for Latent Variable Systems.*
- International Meeting of Statisticians, August 13–18, Funchal: Dzhaparidze, Ferreira and Spreij; lectures on *On spectral analysis of fractional Brownian motions* and *Vandermonde matrices and time series analysis.*
- Workshop Dynamical Systems and Related Fields, Budapest, Hungary, August 21–25. Opening lecture on *Ergodic Theory from the Random Walker's Viewpoint* by M. Keane; also lecture by Van den Berg.
- Workshop on Hellinger Integrals and Hellinger Processes, Helsinki, September 6–8. Lecture *On the dynamic Cobb-Douglas model for exchange economies* by Dzhaparidze and *Information processes in filtered experiments* by Spreij.
- Joint meeting of DMV and ÖMG, Vienna, Austria, September 17–21. Special lecture delivered on *Spontaneous Emergence of Opinions*, September 18: Keane.
- Spatial Stochastics Seminar, CWI. Lecture on *Once Reinforced Random Walk*, September 25: Keane.
- Working visit, Tel-Aviv University, October 4–11: Keane.
- Invited lecture at Scientific Meeting for Indonesian Students in Europe, Université Aix-Marseille III, October 12: Tarigan.
- Workshop on Percolation, Particle Systems and other Stochastic Processes, October 29–31, Milano (minicourse on 'The BKR inequality, with applications to percolation and particle systems' by Van den Berg).
- Annual Lunteren Stochastics meeting, November 12–14: van den Berg, Dzhaparidze, Ferreira, Brouwer, Keane.
- Invited lecture at 'Friday Afternoon Colloquium', University of Amsterdam, November 30: Tarigan.
- Workshop on Long-Range Stochastic Dynamics, Eurandom, Eindhoven, December 3–5: Van den Berg (lecture) and Brouwer.
- Conference: Applications of Physics in Financial Analysis (APFA3), London, December 5–7. Lecture *Hammerstein System and Independent*

Components for Representing and Decomposing Voaltility Processes by Copabianco.
- Working visit (+ invited lecture), Department of Mathematics, Hong Kong University of Science and Technology, December 6–20: Helmers.
- One day visit to the University of Hong Kong, Department of Statistics and Actuarial Science, (with invited lecture), December 16: Helmers.
- Staff Colloquium, Free University of Amsterdam. Lecture on *Commutative and Noncommutative Bernoulli Schemes*, December 10: Keane.
- Basic Notions Series, Staff Colloquium University of Utrecht. Lecture on *Entropy*, December 20: Keane.
- Regular visits to the Mark Kac seminar Van den Berg, Brouwer, Keane.

Memberships of Committees and Other Professional Activities

- M.S. Keane: member of governing board and secretary, *Compositio Mathematica*.
- M.S. Keane: Coordinating editor, *Indagationes Mathematicae*.
- M.S. Keane: Member of board, Akademie Raad voor de Wiskunde.
- M.S. Keane: Member of several other editorial boards of mathematics journals.
- M.S. Keane: Radio interview in *De Avonden*, September 2001; subject: sealed letter of Wolfgang Doeblin.
- Helmers acted as a reviewer for the National Research Foundation of South Africa.
- M.S. Keane: Member of the PhD thesis committee for R. Ion (December 11, UvA).
- J. van den Berg: Member of the PhD thesis committee for Bas Lemmens (VU, June 7).
- R. Helmers: projectleader 'Probability and Mathematical Statistics' of the 'Extended Programme Applied Mathematics' 2000–2005, a cooperation project of KNAW between the Netherlands and Indonesia.
- R. Helmers: member Steering committee Research Statistical Auditing of the Limperg Institute, the Inter University Research Institute for Accountancy in The Netherlands.

Visitors

- M. Yuri (Sapporo)
- D. Saupe (Leipzig)
- M. Brin (College Park, Maryland)
- K. Simon (Budapest)
- T. Liggett (Los Angeles)
- J. Propp (Madison)
- J. Fill (Baltimore)
- J. Serafin (Wroclaw)
- B. Tóth (Budapest)
- R. Cerf (Orsay)
- N. O'Connell (Bristol)
- H. Kesten (Cornell)
- J. Memin (Rennes), October 21–25.
- M. Yor (Paris), October 22–24.
- Subanar (Yogyakarta), January 15–30.
- R. Zitikis (Winnipeg), January 14–February 14.
- R.K. Sembiring (Bandung), June 16.

Papers in Journals and Proceedings

J. van den Berg, J. Kahn (2001). A correlation inequality for connection events in percolation. *Ann. Probab.* **29**, 123–126 (2001).

J. van den Berg, B. Tóth (2001). A signal-recovery system: asymptotic properties, and construction of an infinite-volume process. *Stoch. Proc. Appl.* **96**, 177–190.

E. Capobianco (2001). Robust Control Methods for on-line Statistical Learning. *EURASIP Journal on Applied Signal Processing* **2**, 1–7.

K. Dzhaparidze (2001). On Interpolation Series Related to the Abel-Goncharov Problem. *Indag. Mathem., N.S.* **12**(1), 55–72.

K. Dzhaparidze, J.H. van Zanten (2001). On Bernstein-type inequalities for martingales. *Stochastic Processes and their Applications* **93**(1), 109–117.

B. Lemmens, R.D. Nussbaum, S.M. Verduyn Lunel (2001). Lower and upper bounds for omega-limit sets of nonexpansive maps. *Indag. Mathem., N.S.* **12**(2), 191–211.

J.H. van Zanten (2001). A note on consistent estimation of multivariate parameters in ergodic diffusion models. *Scandinavian Journal of Statistics* **28**(4), 617–623.

CWI Reports

The following CWI reports were published by members of theme PNA3. See page 6 for the complete titles of the reports.

PNA-R0102	PNA-R0110	PNA-R0111
PNA-R0114	PNA-R0119	PNA-R0121
PNA-R0123	PNA-R0125	

Other Publications

M. Löwe, F. Merkl, S.W.W. Rolles (2001). *Moderate Deviations for Longest Increasing Subsequences: The lower tail.* EURANDOM Report 2001–008. Accepted for publication in *Journal of Theoretical Probability.*

J. van den Berg, H. Kesten (2001). *Randomly Coalescing Random Walk in Dimension* ≥ 3. Preprint 1051 of the Erwin Schrödinger Institute.

B. Lemmens (2001). *Iteration of Linear p-Norm Nonexpansive Maps.* Report Vrije Universiteit WS-553 February (with O.W. van Gaans), submitted.

B. Lemmens (2001). *Periods of Periodic Points of 1-Norm Nonexpansive Maps.* Report EURANDOM 2001–028 September.

B. Lemmens (2001). *Periodic Points of Nonexpansive Maps: a Survey.*

T. Blomster, K. Dzhaparidze (2001). *On Cobb-Douglas Dynamical Exchange Economies. Preprint* 303. Reports of the Department of Mathematics University of Helsinki.

M.S. Keane, S.W.W. Rolles (2001). Tubular recurrence. EURANDOM Report 2000–035.

A.J. van Es, P.J.C. Spreij, J.H. van Zanten (2001). Nonparametric Volatility Density Estimation. *Mathematics ArXiv* PR/0107135.

P.J.C. Spreij (2001). Book review: Introduction to option pricing in a securities market, by K. Dzhaparidze, *Nieuw Archief voor Wiskunde* **5/2**(2), 181.

R. Helmers (2001). Review of 'Bootstrap methods'. M.R. Chernick (ed.). A practioner's guide. *Statistics in Medicine* **20**(8), 1303–1304.

Signals and Images – PNA4

Staff

- H.J.A.M. Heijmans , theme leader
- M.J. Huiskes, researcher (since August 1)
- L. Kamstra, PhD student
- A.A.M. Kuijk, researcher (till April 30)
- A.J. Lenstra, researcher (0.1–Eurandom)
- M.N.M. van Lieshout, researcher
- P.J. Oonincx, researcher
- E.J.E.M. Pauwels, researcher
- G. Piella Fenoy, PhD student
- B.A.M. Schouten, PhD student (till September 1)
- A.W.M. Smeulders, advisor (UvA)
- A.G. Steenbeek, programmer
- R.S. Stoica, researcher
- P.M. de Zeeuw, programmer
- Y.-W. Zhan, researcher (since November 1)

Scientific Report

General

The proliferation of the internet in modern day society is arguably driving research in the field of image and video processing. Images are abundant and become an integral part of everyday life. Economies of scale produce necessary computational power and bandwidth at ever decreasing prices.

As a result, there is an ever increasing need for tools to code, transmit, store, index, search, and protect visual information. Digital image processing is a multidisciplinary science that borrows principles from diverse fields such as optics, surface physics, visual psychophysics, computer science and mathematics. The many applications of image processing include: astronomy, ultrasonic imaging, remote sensing, video communications and microscopy, among innumerable others. It is being increasingly recognized that many of the problems encountered in the field of image and video processing and computer vision research cannot be 'solved' only through the development of faster hardware or more efficient algorithms, but that they require a deeper understanding of the intrinsic difficulties. This has resulted in a growing demand for sophisticated mathematical models and theories, and one of the major goals of the 'Signals and Images' research theme PNA4 is to fall in with these demands.

The research in this theme is subdivided into three subthemes. The subtheme 'Content-Based Coding, Indexing, and Retrieval' (PNA4.1) is concerned with research issues in the area of interpretation and retrieval of visual information. In particular, it is directed towards the development of mathematical methodologies that enable the generation of content-based description and intelligent retrieval of images. The subtheme 'Wavelets and Morphology' (PNA4.2) deals with various multiresolution techniques in signal and image processing, such as wavelet analysis, mathematical morphology, and image scale-spaces, as well as with specific applications such as image and video coding and compression, data fusion and image analysis. The third subtheme 'Stochastic Geometry' (PNA4.3) is concerned

with modelling and analysis of random geometric structures using techniques from spatial statistics and stochastic and integral geometry. Extensive cooperations and contacts are maintained with researchers from the academic world as well as researchers from other national institutes (NLR, TNO) and industry. External financing comes from the Dutch NWO and STW programme, the EU 5th Framework Programme, and NATO.

Research Highlights

- Start of three European projects
- Construction of a scheme for image retrieval by means of adaptive wavelet lifting
- Development of principled clustering algorithm based on distribution-free statistics, with applications in image segmentation
- Construction of adaptive wavelets by update lifting schemes that do not require bookkeeping
- New compression algorithms using nonlinear binary wavelets
- Investigation of a new 3D wavelet-based video codec using temporal motion-compensated lifting schemes
- Design of a region-based image fusion scheme
- New constructions of locally isotropic point processes
- New results on spatial interpolation
- Introduction of a new class of models for inhomogeneous spatial point processes
- Organization of national seminar 'Wavelets and their Applications'
- Completion of PhD theses by B.A.M. Schouten and R.S. Stoica

Content-Based Coding, Indexing, and Retrieval – PNA4.1

The ubiquity and rapid growth of digital multimedia databases has spawned a number of challenging problems regarding the indexing, storage and retrieval of information. These problems are particularly acute for image databases as there is no general set of canonical features that adequately captures the variety and wealth of visual information.

Content-Based Image Retrieval (CBIR) aims at designing algorithms and interfaces that will assist the user in this task. Research conducted within PNA4.1 addresses a number of CBIR-related problems, such as image-segmentation, interfaces and theoretical models for user-feedback, feature extraction and indexing. In addition, the proposed methodologies are being tested in projects addressing a number of concrete applications.

With regard to image segmentation, *Pauwels*, in collaboration with G. Frederix from K.U. Leuven (Belgium), has investigated a statistically principled approach based on clustering. The idea is to use linear or non-linear functions that map pixels into low-dimensional numerical feature-spaces. Clusters in these spaces are indicative of perceptually salient regions in the original image. The research focused on methods for reliably extracting clusters using distribution-free statistics (such as Kolmogorov-Smirnov or Cramer-von Mises) for 1-dimensional, and the Rosenblatt transformation for higher-dimensional feature-spaces. The image-segmentations thus obtained yield important information for further content-extraction.

A second CBIR-related research theme is the development of a search engine for images that learns from observing examples and counter-examples supplied by the user. The actual learning is achieved by gradually refining a probabilistic model that predicts the relevance of each image in terms of its features. By comparing these predictions to the positive and negative feedback obtained from the user, the model parameters can be tuned resulting in an enhanced performance. This work has been the basis for the EC-project FOUNDIT that aims at developing a CBIR-search engine for the retrieval of textile patterns and designs. The research in the project is coordinated by Pauwels and Huiskes, in collaboration with G. Caenen at K.U. Leuven (Belgium). Among the FOUNDIT partners are an Italian designer with a database of approximately half a million images, and a developer of CAD-CAM systems for fashion designs.

A related problem is addressed in EUROPHLUKES, an EC 5th Framework Programme Concerted Action, that kicked off in December 2001, and focuses on photo-identification of whales and dolphins. Here the first challenge is to robustly extract and mathematically describe physical characteristics that can be used to identify individual animals. Secondly, these mathematical features will be the key to retrieve from a large database (collected by a substantial number of individual observers) all other sightings of the same animal. This research is being done by Oonincx in collaboration with Steenbeek, under the supervision of Heijmans and Pauwels.

Oonincx and *De Zeeuw* extended their scheme for image retrieval based on the wavelet lifting scheme and the computation of moments by using

different wavelet filters for smooth and unsmooth parts of an image. Results show that the adaptive approach performs better than non-adaptive approaches.

Wavelets and Morphology – PNA4.2

On May 1, a new European project (MASCOT) coordinated by Heijmans with seven other European partners has been started. The goal of MASCOT is to improve the quality and efficiency of video coding systems by exploiting metadata information. Furthermore it seeks to design an intrinsically scalable video coding scheme providing fully progressive bitstreams by exploiting novel morphological and adaptive wavelet decomposition methods, and by the development and optimisation of advanced and dedicated prediction schemes. In this respect an extensive collaboration with B. Pesquet-Popescu from ENST in Paris have been initiated. This collaboration concerns, at the one hand, the development of adaptive lifting schemes (see description below), and at the other the investigation of temporal lifting schemes using motion compensation to be used for 3D wavelet coding.

Zhan is currently implementing this scheme. In the near future several tests will be performed to evaluate and improve the scheme.

Piella and *Heijmans*, in collaboration with B. Pesquet-Popescu (ENST) continued their investigation of the adaptive lifting scheme for the construction of nonlinear wavelets. Many signals (and images) in real life are non-stationary, with the structure varying significantly within each scale. In order to overcome this problem, local adaptivity is needed. Our strategy consists of either making the prediction coefficient vary with time or space so that the prediction error (or other parameter) is minimized, or switching between different filters according to some criterion. The latter seems the most suitable in practice, but it requires a bookkeeping of the filters which have been used at the analysis step in order to be able to reconstruct the signal at the synthesis step. The ongoing research within PNA4 has shown that such bookkeeping is not always necessary: in a number of cases it is possible to recover the decisions at the synthesis step. Various interesting results have been obtained. A first paper has been accepted by the *IEEE Transactions on Signal Processing*. Various other papers are in preparation. The next steps will consist in demonstrating the potential of these results in the context of two different applications, image denoising and image and video compression.

Piella, with assistance of De Zeeuw, has continued her research on image fusion. The goal of this work is to develop an effective MR technique for merging different images in order to improve the visual interpretation process. To this end, an algorithm has been proposed which combines aspects of both object and pixel-level fusion. The basic idea is to exploit the information provided by the different input images to identify the regions of interest, and to use these regions to guide the fusion process. The approach uses multiresolution decompositions to model information at different scales, and multiresolution/multimodal segmentation to identify, also at different scales, the important regions in the real scene. The corresponding regions in the inputs to be combined are evaluated for their saliency in terms of both structural (local, low-level) and semantic (contextual, more abstract) features. All this information is integrated to yield a decision map which reveals, at each position, which of the input images contains a better description of the real scene. Some very promising results have been obtained. Next steps concern the development of appropriate assessment procedures and the fine-tuning of the algorithm.

The research of *Kamstra* is focused on multiresolution decompositions of signals with function values in a finite set that is not necessarily a ring. He has defined a discrete wavelet transform of such finite valued signals and derived strong necessary conditions on such transforms. This makes it possible to give explicit examples of linear and nonlinear discrete wavelet transforms of binary signals without using the so-called lifting scheme. Current research aims at the development of wavelets with larger support and the application of the theory in the field of lossless compression of binary signals and images.

The work of Heijmans with Kresch (HP Laboratories, Haifa) on the construction of self-dual morphological operators using complete inf-semilattices was finished. A major paper has been accepted by the *Journal of Mathematical Imaging and Vision*. Currently they are considering the application in the area of curve evolution and scale-spaces. A first (conference) paper has appeared.

In 2001, only a limited amount of time resources were spent on the ongoing efforts (sponsored by a NATO Collaborative Research Grant)

of Heijmans and J. Goutsias (Johns Hopkins University, Baltimore) to develop a general theory on morphological multiresolution decompositions of images. One additional paper was written.

During the period May–July, two students from the Indian Institute of Technology in New Delhi fulfilled internship within PNA4. Mukul Chhabra worked on a project concerning the implementation of morphological granulometries using line segments and Ankur Mani made an implementation of so-called 'stabilized inverse diffusion equations' (SIDEs).

Stochastic Geometry – PNA4.3

Hess, Van Lieshout, Payne and *Stein* studied the spread of striga (witchweed), arguably one of the major biological threats to cereal crops in many African countries. They compared a range of well-known models, and performed a case study using quadrat count data collected at a test field in Niger from 1985 until 1991. A Bayesian approach was adopted with independent Poisson counts and a prior auto regression term for enforcing spatial coherence. The smoothed fields showed the presence of a seed bank, while the estimated model parameters indicated a decay in the striga numbers over time, as well as a clear correlation with the amount of rainfall just after sowing. Such results are helpful in precision agriculture as a guide to more cost-effective striga control strategies.

Hahn, Jensen, Van Lieshout and *Nielsen* introduced and studied a new class of models for inhomogeneous spatial point processes that can be thought of as modifications of homogeneous templates such that regions with different intensity differ only by a scale factor. If the density of the point process can be defined in terms of interpoint distances only, one could simply replace this distance by a locally scaled analogue. Alternatively, and more generally, the interaction functions or conditional intensity might be subjected to local scaling, the latter recipe yielding a sequential process that has the same local geometry as the template. Particular attention was paid to distance interaction and shot noise models, and to the effect of local scaling on the interaction structure of the point process.

Baddeley and *Van Lieshout* investigated issues arising when a spatial pattern is observed within some bounded region of space, and one wishes to predict the process outside of this region (extrapolation) as well as to perform inference on features of the pattern that cannot be observed (interpolation). They focused on spatial cluster analysis, where the interpolation stems from the fact that the centres of clustering are not observed. In the Bayesian paradigm, they advocated using repulsive Markov priors. Doing so, they investigated which properties of the prior are inherited by the posterior distribution of the complete data, i.e. cluster centres with associated offspring marks, and proposed an adaptive coupling from the past algorithm to sample from this posterior. The approach was illustrated by means of the well-known redwood data set (Ripley, 1977).

Stoica continued his studies into the properties of the Candy model, a line segment process designed for the high-level vision task of extracting linear features from a given image. In collaboration with Van Lieshout, he proved Ruelle and local stability, investigated its Markov properties, and developed simulation algorithms for the model. Estimation of the model parameters was tackled as well. In a joint project with Descombes and Zerubia, they carried out case studies concerning the detection of roads in a countryside region close to the city of Muar in Malaysia, the extraction of tracks in between crop fields in an agricultural region of Ukraine, and on summarising the Nile delta, its branches and adjacent irrigation channels, in Egypt.

The line segment process served to control the geometry of the network, while the goodness-of-fit was taken care of by a term relative to the data. The results were a clear indication that marked point processes are efficient tools for handling image analysis problems.

PhD Theses

B.A.M. Schouten (2001). *Giving eyes to ICT! Or: how does a computer recognize a cow?* University of Amsterdam, March 23.

R.S. Stoica (2001). *Processus ponctuels pour l'extraction de réseaux linéiques dans les images satellitaires et aériennes.* University of Nice-Sophia Antipolis.

Knowledge Transfer

- June 19: Senter-workshop Imaging meets business, Bussum, Poster + Demonstration CBIR-engine Pariss: E. Pauwels.
- September 6–7 ICT Kennis congres, Den Haag. Demonstration Image Retrieval Engine Pariss:

E. Pauwels and M. Huiskes.
- Coordination of EU-Project FOUNDIT: Feedback-Operated User Interface for Design and Image Retrieval: E. Pauwels.
- Coordination of EU-Project MASCOT Metadata for Advanced Scalable Video Coding Tools: H.J.A.M. Heijmans.
- September 3–5 Poster presentation at International Workshop on Catchment-Scale Hydrological Modelling and Data Assimilation, Wageningen: M. Huiskes.
- Course Fourier Analysis University of Amsterdam, January–February: P.J. Oonincx.
- Advisor of trainees from University of Amsterdam: P.J. Oonincx.
- Supervision of trainees from IIT New Delhi: E. Pauwels and H.J.A.M. Heijmans.

Organization of Conferences, Workshops, Courses, etc.

- CWI in Bedrijf: E. Pauwels.
- Co-organization Wavelets IX, SPIE 46th annual meeting, San Diego: P.J. Oonincx.
- Dutch Wavelet Seminar: Lute Kamstra November 23, TU Eindhoven.
  Main speaker: Wolfgang Dahmen (RWTH Aachen).
- Signals and Images Seminar (bi-weekly): P.J. Oonincx.
  Speakers from outside CWI: H. Feichtinger, J. Barrera, N. Hieu, F. Mindru, I. Sluimer, K. Urban.
- Organiser of the Spatial Stochastics Seminar (bi-weekly) and the PNA colloquium (bi-monthly): M.N.M. van Lieshout.
- Member programme committee on behalf of the Institute of Mathematical Statistics of the Joint Statistical Meeting held in Atlanta, August 5–9. Organiser of a session on 'Spatial statistics': M.N.M. van Lieshout.

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

- WIC Midwintermeeting: Content Protection and Watermarking, January 12: H.J.A.M. Heijmans.
- Spatial Stochastics Seminar, CWI Amsterdam, February 13: R.S. Stoica (+ lecture).
- A Forum of Methodology, Wageningen University, February 15: M.N.M. van Lieshout (+ invited lecture).
- Working visit B. Pesquet-Popescu, ENST Paris, March 6–9: H.J.A.M Heijmans (+ lecture).
- Statistische Dag VVS, Utrecht, April 9: M.N.M. van Lieshout.
- MASCOT kick-off meeting, June 7–8, CWI Amsterdam: H.J.A.M Heijmans.
- SPIE International Symposium on Optical Science and Technology, San Diego, USA, July 29–August 3: L. Kamstra (+ lecture), P.J. Oonincx (+ lecture).
- ICT Kennis Congres, Den Haag, September 6–7: G. Piella.
- MASCOT 2nd meeting, September 10–11, ENST Paris: H.J.A.M Heijmans.
- Working visit B. Pesquet-Popescu, ENST Paris, September 11–12: H.J.A.M Heijmans.
- Woudschoten Conferentie van de Werkgemeenschap Numerieke Wiskunde, Zeist, September 12–14: P.M. de Zeeuw.
- INRIA/IBM/Berkeley Workshop on Multimedia and Content-Based Image Retrieval. Paris, September 24–25: E. Pauwels (+ lecture).
- International Conference on Image Processing ICIP, Thessaloniki, Greece, October 7–10: E. Pauwels (+ lecture).
- IEEE International Conference on Image Processing (ICIP 2001), Thessaloniki, Greece, October 7–10: G. Piella (+ poster, joint work with H.J.A.M Heijmans).
- Lecture at CWI Scientific meeting, October 26: H.J.A.M Heijmans.
- FOUNDIT-kick-off meeting at Pianezza, Milan, Italy, October 28–29: E. Pauwels and M. Huiskes.
- Invited lecture at Philips Natlab, November 5: H.J.A.M Heijmans.
- Workshop 'Vision, an inspiration for science', NWO Themajaar 'Mathematische Biologie', November 6: (M. Huiskes).
- Workshop 'Who swims there?' Kickoff meeting EUROPHLUKES, CML Universiteit Leiden, December 7–9: H.J.A.M. Heijmans (+ lecture), E. Pauwels (+ lecture), P.J. Oonincx, A. Steenbeek.
- Working visit to Philips Research, Eindhoven, November 9: G. Piella and L. Kamstra.
- Wavelet seminar, Eindhoven, November 23: G. Piella (+lecture).
- Working visit X. Descombes and J. Zerubia on the occasion of the PhD defence of R.S. Stoica, INRIA Sophia Antipolis, France, February 8–11: M.N.M. van Lieshout.

- Working visit X. Descombes and J. Zerubia, INRIA Sophia Antipolis, France, February 5–9: R.S. Stoica.
- 37e Nederlands Mathematisch Congres, Vrije Universiteit Amsterdam, April 19–20: H.J.A.M Heijmans and M.N.M. van Lieshout.
- PNA Colloquium, CWI Amsterdam, May 28: M.N.M. van Lieshout (+lecture).
- Working visit X. Descombes and J. Zerubia, INRIA Sophia Antipolis, France, June 25–July 1: M.N.M. van Lieshout.
- Joint Statistical Meeting, Atlanta, August 5–9: M.N.M. van Lieshout (+ invited lecture).
- Bijeenkomst Stochastici, Lunteren, November 12–14: M.N.M. van Lieshout and R.S. Stoica.
- 11th International Workshop on Stereology, Stochastic Geometry and Related Fields, Perth, Western Australia, December 10–14: M.N.M. van Lieshout (+ invited lecture).
- Working visit A.J. Baddeley, University of Western Australia, December 15–23: M.N.M. van Lieshout.
- Working visit M. Sigelle, Ecole Nationale Supérieure des Télécommunications, Paris, France, March 30: R.S. Stoica (+ lecture).
- 11th IEEE Workshop on Statistical Signal Processing, Singapore, August 6–8: R.S. Stoica (+ poster).
- Summer school 'Spatial Statistics and Computational Methods', TMR (Training and Mobility of Researchers, EU) network, Aalborg, Denmark, August 19–23: R.S. Stoica.
- Working visit X. Descombes and J. Zerubia, INRIA Sophia Antipolis, France, October 22–26: R.S. Stoica.

Memberships of Committees and Other Professional Activities

H.J.A.M. Heijmans:
- Member of editorial board *Journal of Mathematical Imaging and Vision*.
- Editor of electronic newsletter *Morphology Digest*.
- Coordinator of MASCOT project (EU 5th FP, May 2001–April 2003)
- Coordinator of large NWO projects Wavelets and their Applications; partners: CWI, RUG, TUE, UT.
- Member of Programme Committee of IEEE Workshop on Scale-Space and Morphology in Computer Vision, Vancouver, July 7–8.
- Member of Technical Committee of IEEE Conference on Image Processing, (ICIP 2001), Thessaloniki, Greece, October 7–10.
- Member of Technical Committee of Sixth International Symposium on Mathematical Morphology (ISMM2002), Sydney, Australia, April 3–5 2002.
- Member of PhD Committee of Marcos d'Ornellas, University of Amsterdam, March 27.
- Member of PhD Committee of Hieu Nguyen, University of Amsterdam, March 27.

M.N.M. van Lieshout:
- Secretary/treasurer of the VVS (Vereniging Voor Statistiek en Operationele Research).
- Member steering committee Complex stochastic models, Eurandom.
- Member reading and promotion committee R.S. Stoica, University of Nice-Sophia Antipolis, France; 'Processus ponctuels pour l'extraction de réseaux linéiques dans les images satellitaires et aériennes'.
- Member reading committee PhD thesis I. Taskinen, University of Jyväskylä, Finland; *Cluster priors in the Bayesian modelling of fMRI data*.
- Host editorial meeting Highly Structured Stochastics Systems, November 8–9.
- Maintainer of catalogue of research expertise within the framework of the ERCIM Vital Statistics project.

E.J.E.M. Pauwels:
- Coordinator of FOUNDIT project (EU, 5th FP, September 2001–August 2003).
- Course 'Technologie en Economische Sectoren' at Katholieke Universiteit Brussel, Belgium.

P.M. de Zeeuw:
- Secretary of the Dutch-Flemish Numerical Analysis Society.

Visitors

- H.G. Feichtinger, University of Vienna, January 14–16 .
- J. Barrera, Universidade de São Paulo, March 28–29.
- I.S. Molchanov, University of Glasgow, UK, April 18.
- B. Pesquet-Posecu, ENST Paris, June 5–8.
- D. Keren, Dept. of Computer Science, Haifa, Israel, October 1–2. Talk: *Anti-faces for detection* .
- B. Pesquet-Posecu, ENST Paris, November 5–8.
- P.J. Green, University of Bristol, UK, November 8–9.

- N.L. Hjort, University of Oslo, Norway, November 8–9.
- S. Richardson, Imperial College, UK, November 8–9.
- K. Urban, RWTH Aachen, November 28.
- M. Ortner, INRIA Sophia Antipolis, France, December 3–7.

Software Developed

- *Fracfeat:* a textural image feature extractor: B.A.M. Schouten and P.M. de Zeeuw.
- *PARISS:* Panoramic, Adaptive, Reconfigurable Interface for Similarity Search: E. Pauwels and M. Huiskes in collaboration with G. Caenen, K.U. Leuven .
- *Matlab Fusion Toolbox:* under development: G. Piella and P.M. de Zeeuw.
- *LISQ:* the wavelet lifting scheme on quincunx grids in Matlab: P.M. de Zeeuw.

Books

P.J. Oonincx (2001). *Mathematical Signal Analysis: Wavelets, Wigner Distribution and a Seismic Application*, CWI Tract 130 (ISBN: 90 6196 499 7).

Papers in Journals and Proceedings

P.J. Oonincx, P.M. de Zeeuw (2001). Adaptive wavelet lifting for image retrieval. *Proceedings SPIE, Wavelets IX* **4478**, San Diego, 2001, 75–86.

L. Kamstra (2001). Discrete wavelet transforms over finite sets: a general approach. *Proc. SPIE, Wavelets IX* **4478**, San Diego.

P.J. Oonincx (2001). Wavelets: een hype of toch meer? *Nieuw Archief voor Wiskunde* **5**(2), 120–126.

G. Frederix, E.J. Pauwels (2001). Segmentation based on Distribution-free Statistics: Wielding Occam's Razor. R. Veltkamp, H. Burkhardt, H.-P. Kriegel (eds.). State-of-the-Art in Content-Based Image and Video Retrieval. *Computational Imaging and Vision* **22**, 165–190.

E.J. Pauwels, G. Frederix, G. Caenen (2001). Image Segmentation based on Statistically Principled Clustering. *Proceedings of International Conference on Image Processing* **III**, 66–69.

G. Caenen, E.J. Pauwels (2001). Intelligent Interfaces for Content-Based Retrieval of Images and Designs from Digital Databases. *Proceedings DPP2001: International Conference on Digital Production Printing and Industrial Applications*, Antwerp, 322–326.

R. Kresch, H.J.A.M. Heijmans (2001). Morphological adjunctions, pyramid decisions, and curve evolution. M. Kerckhove (ed.). *Proceedings of Third International Conference on Scale-Space and Morphology*, Springer, Berlin.

H.J.A.M. Heijmans (2001). Scale-spaces, PDE's, and scale-invariance. M. Kerckhove (ed.). *Proceedings of Third International Conference on Scale-Space and Morphology*, Springer, Berlin, 215–226.

G. Piella, H.J.A.M. Heijmans (2001). An adaptive update lifting scheme with perfect reconstruction. *Proceedings of International Conference on Image Processing 2001.*

X. Descombes, R.S. Stoica, L. Garcin, J. Zerubia (2001). A RJMCMC algorithm for object processes in image processing. *Monte Carlo Methods and Applications* **7**, 149–156.

A. Stein, M.N.M. van Lieshout, H.W.G. Booltink (2001). Spatial interaction of methylene-blue stained soil pores. *Geoderma* **102**, 101–121.

M.N.M. van Lieshout, E.W. van Zwet (2001). Exact sampling from conditional Boolean models with applications to maximum likelihood inference. *Advances in Applied Probability (SGSA)* **33**, 339–353.

X. Descombes, M.N.M. van Lieshout, R.S. Stoica, J. Zerubia (2001). Parameter estimation by a Markov chain Monte Carlo technique for the Candy model. *Proceedings of 11th IEEE Workshop on Statistical Signal Processing* held August 6–8, Orchid Country Club, Singapore, 22–25.

M.N.M. van Lieshout, I.S. Molchanov, S.A. Zuyev (2001). Clustering methods based on variational analysis in the space of measures. *Biometrika* **88**, 1021–1033.

D.E. Hess, M.N.M. van Lieshout, W.A. Payne, A. Stein (2001). A review of spatio-temporal modelling of quadrat count data with application to striga occurrence in a pearl millet field. *International Journal of Applied Earth Observation and Geoinformation* **3**, 133–138.

M.N.M. van Lieshout (2001). An introduction to stochastic geometry. A. Stein, T.H. Jetten, A.G.T. Schut (eds). *Quantitative*

Approaches to System Analysis **23**, *Proceedings Forum of Methodology*, Wageningen University, 63–71.

CWI Reports

The following CWI reports were published by members of theme PNA4. See page 6 for the complete titles of the reports.

PNA-R0101 PNA-R0104 PNA-R0112
PNA-R0113 PNA-R0115 PNA-R0117
PNA-R0124

Other Publications

P.J. Oonincx, R. Sleeman, T. Van Eck (2001). An application of the DWT in seismic data analysis. A. Petrosian, F. Meyer (eds.). *Wavelets in Signal and Image Analysis.*

U. Hahn, E.B.V. Jensen, M.N.M. van Lieshout, L.S. Nielsen (2001). *Inhomogeneous Spatial Point Processes by Location Dependent Scaling.* Research Report 16, Laboratory for Computational Stochastics, University of Aarhus.

H.J.A.M. Heijmans, L. Kamstra, G. Piella, J. Goutsias (2001). Building nonlinear wavelets. A.M. Vossepoel, F.M. Vos (eds.). *Fourth Quinquennial Review 1996–2001*, Dutch Society for Pattern Recognition and Image Processing.

H.J.A.M. Heijmans, J. Goutsias (2001). *Morphological Decomposition Systems with Perfect Reconstruction: From Pyramids to Wavelets.* (To appear in volume dedicated to the memory of Georges Mathéron) (Invited Paper)

SOFTWARE ENGINEERING

General Overview

Software Engineering (SEN) is a cluster of four related themes:

SEN1	Interactive Software Development and Renovation
SEN2	Specification and Analysis of Embedded Systems
SEN3	Coordination Languages
SEN4	Evolutionary Systems and Applied Algorithmics

The research activities in this cluster are focused on various aspects of software engineering. Our ambition was and is to cover the whole range of activities from fundamental concepts and prototype implementations to the application of these concepts in practice. For fundamental research, cooperations have been continued and further extended with Dutch universities and international partners. Applications and technology transfer have been realized in cooperation with external partners and via the creation of spin-off companies.

In addition to scientific publications, demonstrations and prototype systems are important outcomes of the research in this cluster. These prototypes find their way to researchers worldwide. Our policy is to develop them to the point that real-life applications can be tested and then transfer exploitation to industrial partners. The close interactions with the Software Improvement Group assure knowledge transfer in the area of software renovation. The creation of spin-offs in other areas is under discussion.

The activities in SEN1 are dominated by the question how techniques like parsing, rewriting and component-based software engineering can be applied to the development and renovation of large software systems. Its research was concentrated in three areas: software renovation, domain-specific languages, and generic language technology.

SEN2 addresses the question how the quality of software in embedded systems (telecommunications, communication protocols) can be improved. Techniques like process algebra, timed automata, and modal logics are used for proof checking, state-space analysis and reduction, simulation and testing of processes and data. Research has focused on four areas: μCRL language and tool set, process theory, distributed shared dataspaces and security.

SEN3 concentrates on the specification, interaction and dynamic composition of components. Research was focused on three areas: formal models for coordination languages, coordination and component-based architectures, and coalgebraic models of computation.

SEN4 aims at the further development of intelligent computation techniques (evolutionary and multi-agent systems, adaptive algorithms, neural networks) and their applications (e-commerce, auctions, optimization, mathematical finance). Research was done in four areas: evolutionary algorithms, neural networks, discrete algorithms, and trade agents.

Highlights

- After many years successfully leading the cluster SEN and its predecessors, J.W. de Bakker stepped down as cluster leader. In 2002, P. Klint will succeed him in this function. J.W. de Bakker also retired as part-time full professor at VUA.
- W.J. Fokkink and J.J.M.M. Rutten were both appointed as part-time full professor at VUA. J.A. La Poutré was appointed as part-time full professor at TUE. Together with the existing part-time positions of P. Klint (UvA) and J.W. Klop (VUA) the links between SEN and Dutch universities have hence been further strengthened.
- Two Phd theses were successfully defended by (former) SEN members:
  - S.C.C. Blom (2001). *Term Graph Rewriting–Syntax and Semantics* (VUA, Thesis advisor: J.W. Klop)

- R. van Liere (2001). *Studies in Interactive Visualization* (UvA, Thesis advisor: P. Klint)

- SEN members have acted as editors in the editorial boards of the following journals: e-JEMED, Electronic Notes in Computer Science, Fundamenta Informaticae, Information Processing Letters, Journal of Computer and System Sciences, Netnomics, Science of Computer Programming, and Theoretical Computer Science.
- SEN members have participated in the PCs of the following conferences: CMCS 2001, CoCoord 01, CONCUR 2001, CSMR 2001, DMTCS 2001, EXPRESS 01, FMICS 01, HICCS-35, LDTA 2001, PDPTA 2001, ParCo 01, PaCt 01, RULE 2001, SWARM 2001, WCI 2001, and WCRE 2001.
- SEN has cooperations with the following companies: ABN AMRO, Adaptive Planet, Ericsson (Sweden), First Result, France Telecom, ING, KPN, NLR, Ordina, Software Improvement Group, Thales, and Verimag (France).

Staff

- Biography of Aad van Wijngaarden – SEN0

  - G. Alberts

- Interactive Software Development and Renovation – SEN1

  - P. Klint
  - J.A. Bergstra
  - M.G.J. van den Brand
  - A. van Deursen
  - E.G. van Emden
  - J. Heering
  - H.A. de Jong
  - M. de Jonge
  - R. Lämmel
  - L.M.F. Moonen
  - P.A. Olivier
  - J.J. Vinju
  - J.M.W. Visser

- Specification and Analysis of Embedded Systems – SEN2

  - W.J. Fokkink
  - B. Badban
  - J.A. Bergstra
  - S.C.C. Blom
  - C. Daws
  - H.J.M. Goeman
  - J.F. Groote
  - J.J.M. Hooman
  - N. Ioustinova
  - J.W. Klop
  - I.A. van Langevelde
  - B. Lisser
  - S.P. Luttik
  - S. Mauw
  - V. van Oostrom
  - S.M. Orzan
  - J. Pang
  - J.C. van de Pol
  - A. Ponse
  - Y.S. Usenko
  - J.A. Valero Espada
  - A.G. Wouters
  - M.B. van der Zwaag

- Coordination Languages – SEN3

  - J.J.M.M. Rutten
  - F. Arbab
  - J.W. de Bakker
  - A. Baltag
  - F. Bartels
  - C.L. Blom
  - F.S. de Boer
  - M.M. Bonsangue
  - F.J. Burger
  - C.T.H. Everaars
  - J.V. Guillen Scholten
  - J.J. van der Ham
  - J. den Hartog
  - J.N. Kok
  - A. Kurz
  - W.P. de Roever
  - P. Zoeteweij

- Evolutionary Computation and Applied Algorithms – SEN4

  - J.A. La Poutré
  - F. Alkemade
  - S.M. Bohté
  - D.D.B. van Bragt
  - E.H. Gerding
  - P.J. 't Hoen
  - J.K. Hoogland
  - M.B. de Jong
  - J.N. Kok
  - E. Kutschinski
  - C.D.D. Neumann
  - D.J.A. Somefun
  - Drs. R. van Stee

- Secretary:

  - J.J. Bruné-Streefkerk

CWI Reports

SEN-R0101. S.M. Orzan. *Distributing requirements specifications on Basic Splice.*

SEN-R0102. I.A. van Langevelde. *A compact file format for labeled transition systems.*

SEN-R0103. L. Epstein, R. van Stee. *Lower bounds for on-line single-machine scheduling.*

SEN-R0104. L. Epstein, S. Seiden, R. van Stee. *On the fractal beauty of bin packing.*

SEN-R0105. J. van de Pol. *Just-in-time: on strategy annotations.*

SEN-R0106. J.C. van de Pol. *A prover for the μCRL toolset with applications – Version 0.1.*

SEN-R0107. A. Ponse, Y.S. Usenko. *Equivalence of recursive specifications in process algebra.*

SEN-R0108. J.K. Hoogland, C.D.D. Neumann, D. Bloch. *Converting the reset.*

SEN-R0109. J.M.W. Visser. *Visitor combination and traversal control.*

SEN-R0110. A. van Deursen. *Program comprehension risks and opportunities in extreme programming.*

SEN-R0111. J.F. Groote, J. Pang, A.G. Wouters. *Analysis of a distributed system for lifting trucks.*

SEN-R0112. M. de Jonge, J.M.W. Visser. *Grammars as contracts.*

SEN-R0113. M. de Jonge, E. Visser, J.M.W. Visser. *Collaborative software development.*

SEN-R0114. M. de Jonge, E. Visser, J.M.W. Visser. *XT: a bundle of program transformation tools; system description.*

SEN-R0115. M. de Jonge. *A pretty-printer for every occasion.*

SEN-R0116. M. de Jonge, R. Monajemi. *Cost-effective maintenance tools for proprietary languages.*

SEN-R0117. J.F. Groote, B. Lisser. *Computer assisted manipulation of algebraic process specifications.*

SEN-R0118. L.M.F. Moonen. *Generating robust parsers using island grammars.*

SEN-R0119. A. van Deursen, L.M.F. Moonen, A. van den Bergh, G. Kok. *Refactoring test code.*

SEN-R0120. J.J.M.M. Rutten. *Elements of stream calculus (an extensive exercise in coinduction).*

SEN-R0121. M.G.J. van den Brand, P. Klint, J.J. Vinju. *Term rewriting with traversal functions.*

SEN-R0122. R. Lämmel. *Typed generic traversals in S'_γ.*

SEN-R0123. S.C.C Blom. *Partial τ-confluence for efficient state space generation.*

SEN-R0124. R. Lämmel, J.M.W. Visser. *Typed combinators for generic traversal.*

SEN-R0125. M.G.J. van den Brand, J. Scheerder, J.J. Vinju, E. Visser. *Disambiguation filters for scannerless generalized LR parsers.*

SEN-R0126. A. van Deursen, P. Klint. *Domain-specific language design requires feature descriptions.*

SEN-R0127. F. Arbab, F.S. de Boer, M.M. Bonsangue, J.V. Guillen Scholten. *A channel-based coordination model for components.*

SEN-R0128. F. Arbab, F.S. de Boer, M.M. Bonsangue, J.V. Guillen Scholten. *MoCha: a framework for coordination using mobile channels.*

SEN-R0129. J.J.M.M. Rutten. *Coinductive counting: bisimulation in enumerative combinatorics (extended abstract).*

SEN-R0130. A.G. Wouters. *Manual for the μCRL tool set (version 2.8.2).*

SEN-R0131. S.M. Bohté, E.H. Gerding, J.A. La Poutré. *Competitive market-based allocation of consumer attention space.*

SEN-R0132. S. Seiden, R. van Stee. *New bounds for multi-dimensional packing.*

SEN-R0133. L. Epstein, R. van Stee. *Minimizing the maximum starting time on-line.*

Biography of Aad van Wijngaarden – SEN0

Aad van Wijngaarden (1916–1987), founding father of computer science in The Netherlands and former director of CWI, is the subject of a historical research project. The leading theme in the composition of a scientific biography is Mathematical beauty and a taste for language. In his scholarship Van Wijngaarden, engineer by training, was strongly guided by mathematical beauty. It made him consider scientific computing in its own right (1946), made him turn towards programming languages (1958) and reared his preferences in the design of ALGOL 68. In 2001 research was continued by archival searches and

interviews in The Netherlands, the US (Boston, Washington and Princeton) and the UK (Oxford and Cambridge).

Organization of Conferences, Workshops, Courses, etc.

- GMFW symposium about Dirk Struik at the 37th Nederlands Mathematisch Congres, Amsterdam, April 19–20: Gerard Alberts and Teun Koetsier (organization, chair)

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

G. Alberts:
- Amherst. Workshop organized by CRA, Using History to Improve Undergraduatie Teaching of Computer Science, August 5–7, in Amherst (Massachussetts) contribution by G. Alberts: *From arrangement of work to programming: numerical analysis.*
- KNAW. Wetenschap in de Tweede Gouden Eeuw, symposium KNAW, September 19.
- BSHM. From Sumer to Spreadsheet – The History of Mathematical Table Making BSHM-conference, September 22–23, Oxford. G. Alberts chair in a session.
- Science for Sustainability congress Nijmegen, November 28, contribution by G. Alberts on mathematics and sustainability: *Do not disturb my circles, or Why the soldier was sent for Archimedes in the first place.*
- Logic in Action. A Farewell to the Spinoza Project 'Logic in Action', Amsterdam, December 20.

Memberships of Committees and Other Professional Activities

G. Alberts:
- Editor *Nieuw Archief voor Wiskunde*
- Secretary GMFW, landelijk werkcontact Geschiedenis en Maatschappelijke Functie van de Wiskunde
- Member of Werkgroep Verzamelbeleid Computerhistorie
- Member of the Archives Committee of the Wiskundig Genootschap, CPAW, Commissie Persoonlijke Archieven van Wiskundigen
- Member PhD committee Danny Beckers, University of Nijmegen (*Propaedeutic mathematics and the rise of pure mathemtics in The Netherlands around 1800*)
- Coordinator of the Science and Society research programme, University of Nijmegen

Papers in Journals and Proceedings

Behoud de keuzevrijheid. Wiskunde en politiek bij G. Zoutendijk, interview door Gerard Alberts, Ger Koole. *Nieuw Archief voor Wiskunde – Vijfde Serie* **2**(1) (maart 2001), 36–41.

G. Alberts (2001). Dirk Struik 1894–2000. Waarom Struiks geschiedenis van de wiskunde in het Nederlands niet beknopt was. *Euclides* **76**(6), 218–222.

K. Vreugdenhil, G. Alberts, P. van Gelder (2001). Waterloopkunde. Een eeuw wiskunde en werkelijkheid. *Nieuw Archief voor Wiskunde* **5**(2–3), 266–276.

G. Alberts, B. Zwaneveld (2001). Alle dagen eindexamen; interview met Henk Schuring. *Nieuw Archief voor Wiskunde* **5**(2–3), 262–265.

G. Alberts (ed.) (2001). Afscheid van Dirk Struik. *Nieuw Archief voor Wiskunde* **5**(2–3), 226–250.

G. Alberts (2001). Historicus voor groot publiek en vakgenoten. *Nieuw Archief voor Wiskunde* **5**(2–3), 248–250.

H. Oud, G. Alberts (2001). Van de buitenwereld heb ik me nooit veel aangetrokken. Interview met Constance van Eeden. *STAtOR* 1–4 (April 2001), 5–8.

G. Alberts (2001). Wiskunde en wederopbouw; deskundigen en hun Prometheïsche huiver. GEWINA (December 2001; to appear)

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 leader
- Dr. A. van Deursen, project leader
- E.G. van Emden, trainee (from October 1)
- J. Heering, project leader
- Drs. H.A. de Jong, project member
- Drs. M. de Jonge, project member
- Dr. R. Lämmel, postdoc (seconded)
- Drs. L.M.F. Moonen, project member
- Dr. P.A. Olivier, PhD student/postdoc
- Drs. J.J. Vinju, project member
- Drs. J.M.W. Visser, project member

Scientific Report

The research was concentrated in three areas: software renovation (SEN1.1), domain-specific languages (SEN1.2), and generic language technology (SEN1.3). The latter is mainly 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 domain-specific languages as well as tools for software renovation.

Software Renovation – SEN1.1

The objective of the Software Renovation Group is to develop tools and methods for dealing with existing software systems.

One of the directions pursued by the Software Renovation Group deals with legacy systems. Tools and techniques for extracting, querying, and presenting *source models* for such systems are being investigated. This has resulted in, for example, the notion of *island grammars*, which aim at making the extraction phase flexible as well as robust. An application of the source model extraction paradigm is in *software architecture* recovery. In this area, the Software Renovation Group has organized the Software Architecture Recovery and Modeling (SWARM) forum during the IEEE Working Conference on Reverse Engineering (WCRE) in October 2001. The successful SWARM event will be continued as a Dagstuhl seminar in February 2003.

A second direction investigated by the Software Renovation Group takes the *software process* as its starting point, with special attention being paid to light-weight methodologies such as *extreme programming*. The Software Renovation Group has published results on *testing*, *customer involvement*, and the role of *program understanding* in extreme programming.

Domain-Specific Languages – SEN1.2

The aims of this subtheme are:

- Develop methods for selecting suitable DSL domains, and for capturing domain knowledge into a DSL and its compiler;
- Develop metatools for the rapid prototyping of domain-specific languages;
- Gain more experience, via case studies, with the use of domain-specific languages in a commercial setting.

Van Deursen/Klint. A DSL can be viewed as a way of configuring a family of systems for a certain application domain. Its design thus requires an analysis of the underlying domain. One of the ways this can be done is by means of feature diagrams in which the dependencies between features are described (SEN-R0126).

Heering. The work on Language Design Assistants (LDAs) incorporating significantly more knowledge about programming and domain-specific languages than current language development systems was continued. A meeting with the Action Semantics people at Aarhus University (J. Iversen, P.D. Mosses) was organized to discuss the various issues involved, in particular modular language definitions. Imposing a type discipline on language building blocks was studied (report in preparation). The SAGA cooperation with Bergen University has resulted in the publication of a special issue of *Scientific Programming* on coordinate-free numerics.

De Jonge. In cooperation with R. Monajemi and R. van Halen (Lucent Technologies, Enschede) the SEN1 generic language technology was applied to SDL, a specification language for telecommunication software. An environment for SDL code browsing and visualization at different levels of abstraction was developed very quickly once the SDL grammar had been specified (SEN-R0116). Apart from this, a tool for automated source tree composition called Autobundle was developed. Among other things, this involved the design of a DSL for package definition. It defines parameters such as package dependencies and package configuration. Autobundle was applied to the distribution process of the ASF+SDF Meta-Environment, JJForester, XT, the Stratego compiler, and the Elan compiler.

Lämmel (seconded at CWI from VU for 1 day/week)/Visser. With Lämmel's move to the VU, the NWO project 'Generation of Program Transformation Systems' was transferred from CWI to the VU as well. His earlier work at CWI on Grammar Engineering in the context of this project (with C. Verhoef) has led to several journal publications in 2001. His work with J. Visser at CWI focused on generic programming technology as needed for program transformation systems, and in particular on the typing of generic traversals (SEN-R0122, SEN-R0124).

Generic Language Technology – SEN1.3
One of the objectives of the GLT group is to realize a redesign and reimplementation of the ASF+SDF Meta-Environment. This is an interactive development environment for the automatic generation of interactive systems for manipulating programs, specifications, or other texts written in a formal language. Over the years, this system has been used in a variety of academic and commercial projects ranging from formal program manipulation to conversion of COBOL systems.

The parser was further improved, in particular, its disambiguation capabilities (SEN-R0125). In the realm of software renovation it is necessary that layout and especially comments are maintained during program transformation. The ASF+SDF interpreter was extended to maintain and restore layout during rewriting. Furthermore, both the ASF+SDF interpreter and ASF+SDF compiler were extended with tree traversal functions needed for program transformation (SEN-R0121). In cooperation with the Software Improvement Group BV both rewriting with layout and traversal functions were used to develop a transformation tool for COBOL software in a proof of concept project for ABN AMRO.

After decorating SDF definitions with labels and constructors, it is possible to generate an API on top of the C version of the ATerm library to manipulate ATerms in a type safe manner. This approach has been used to generate APIs for plain parse trees, SDF itself, the fixed part of ASF, and other frequently used data structures. These APIs have been used to improve the code of various components in the ASF+SDF Meta-Environment. A report describing this technique and its benefits is in preparation.

Some of the components of the ASF+SDF Meta-Environment are also used in the XT-toolkit, a bundle of program transformation tools. This toolkit allows the construction/generation of program transformation tools in a fast and flexible manner (SEN-R0114). It uses among others the SDF parsing technology, and the generic pretty-printing technology (SEN-R0115). The XT bundle also contains the GrammarBase, a collection of reusable SDF grammars that is available on-line. XT has been used to develop tools for e.g. COBOL renovation, SDL analysis (SEN-R0116), and collaborative software development (SEN-R0113).

To connect the parse tools (parse table generator and generic parser) of the ASF+SDF Meta-Environment to the main-stream object-oriented programming language JAVA, the generator JJForester was developed. To support processing of parse trees, the visitor combinator framework/library JJTraveler was developed (SEN-R0109). Visitor combinators enable fully programmable, generic tree and graph traversal in JAVA. JJForester provides automatic instantiation of the JJTraveler framework for a given SDF grammar. The JAVA version of the ATerm library has been adapted to allow the use of JJTraveler for ATerm traveral.

To support generic traversal of parse trees in the higher-order lazy functional programming language HASKELL, a generic programming bundle has been developed, named Strafunski (SEN-R0124). Strafunski consists of StrategyLib, a library of functional strategy combinators, and DrIFT-Strafunski, a precompiler that automatically instantiates the generic term interface of StrategyLib for a given signature.

PhD Thesis

R. van Liere (2001). *Studies in Interactive Visualization*, University of Amsterdam, March 4. Thesis advisor: P. Klint.

Knowledge Transfer

During August 2001, J. Visser and S. Klusener (SIG BV) conducted the technology transfer project Account number conversion and transformation infrastructure, in which a program transformation infrastructure based on SEN1.1 tools was set up at SIG.

The ASF+SDF Meta-Environment has been installed at FirstResult (Amsterdam) under Windows using CygWin (J.J. Vinju).

Organization of Conferences, Workshops, Courses, etc.

- XP2001 Workshop on Customer Involvement (WCI 2001) and WCRE 2001 Forum on Software Architecture Recovery and Modelling (SWARM 2001) (A. van Deursen).
- HICCS-35 Minitrack Domain-Specific Languages in Software Engineering (J. Heering).
- Meeting on Language Design Assistants (J. Heering).

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

- *IFIP WG2.1 Meeting*, Cochabamba, Bolivia, January 15–25: R. Lämmel.
- *PC POPL 2001*, London,UK, January 16–19: P. Klint.
- *Interoperability of Reengineering Tools*, Dagstuhl, Germany, January 21–26: A. van Deursen and L. Moonen (*From research to startup: Experiences in interoperability*).
- *Science Foundation Ireland*, Dublin, February 15–16: P. Klint.
- *Second Stratego Users Day*, Utrecht, February 8: J. Visser (XT capita selecta).
- *SAGA Project Meeting*, Utrecht: J. Heering
- *INRIA Scientific Council*, Rocquencourt, February 22: P. Klint.
- *OOTI Formal Methods Course*, Technische Universiteit Eindhoven, March 19: A. van Deursen (*Formal methods for program understanding*).
- *DSL Project Review Meeting*, Telematica Instituut, Enschede, March 20: M.G.J. van den Brand (Demo), A. van Deursen (*DSL project outlook*), M. de Jonge (SDL: A DSL case study), and P. Klint (*The DSL project: Progress and perspective*).
- *Working visit Lucent*, Enschede, March 20: A. van Deursen, M. de Jonge, and P. Klint.
- *ETAPS/CC/LDTA 2001*, Genova, Italy, April 2–8: M.G.J. van den Brand (*Demo of ASF+SDF Meta-Environment*), P. Klint (*Collaborative development of language processing tools*), M. de Jonge (*XT: A bundle of program transformation*), L. Moonen (*The ASF+SDF Meta-Environment*), J.J. Vinju (*Demo of ASF+SDF Meta-Environment*), J. Visser (*Object-oriented tree traversal and XT: A bundle of program transformation*).
- *Working visit LORIA*, Nancy, France, April 16–18: M.G.J. van den Brand.
- *ASF+SDF ELAN Workshop*, Thionville, France, April 18–20: M.G.J. van den Brand (*ASF+SDF demo*), H.A. de Jong (*Generation of API's*), P. Klint (*Future development of the ASF+SDF Meta-Environment*), M. de Jonge (*Software systems meaning software bundles*), P. Olivier (TIDE), J.J. Vinju (*Rewriting with traversal functions*), (J. Visser) JJForester.
- *Software Generation Course*, Universiteit Utrecht, May 15: A. van Deursen (*Domain engineering; A domain-specific language for financial products*).
- *XP 2001*, Cagliari, Italy, May 20–24: A. van Deursen (*Refactoring test code and customer involvement*), L. Moonen (*Refactoring test code*).
- *RTA 2001/WRS 2001*, Utrecht, May 23: P. Klint (*Is strategic programming a viable paradigm?*).
- *IPA Basic Course on Software Technology*, Universiteit Utrecht, May 28: M.G.J. van den Brand, H.A. de Jong, P. Klint, P.A. Olivier, and J.J. Vinju (*Generic language technology course*).
- *IPA review*, Eindhoven, June 11: P. Klint (*A picture of software engineering in IPA*).
- *Conseil Scientifique INRIA*, Paris, France, June 13: P. Klint.
- *Working visit BRICS*, Aarhus, Denmark, June 16–22: M.G.J. van den Brand.
- *Meeting on Language Design Assistants*, Amsterdam, August 24: M.G.J. van den Brand (*The current status of the ASF+SDF Meta-Environment*), A. van Deursen and Leon Moonen (*Language design assistants and program understanding*), J. Heering (*Language design assistants as knowledge-based systems*), P. Klint (*Domain-specific language design requires feature descriptions*), R. Lämmel (*Towards generic refactoring*).
- *IEEE/IFIP Working Conference on Software Architecture (WICSA 2001)*, Amsterdam, August 29–30: A. van Deursen, L. Moonen.
- *WICSA Workshop on Architecture Reconstruction and Software Product Lines*, Amsterdam, August 31: A. van Deursen, L. Moonen.
- *MicroSoft First .Net Crash Course*, Cambridge, September 2–6: P. Klint, H.A. de Jong, J.J. Vinju.
- *NWO ICT Kenniscongres*, Den Haag, September 6–7: P. Klint (*Assemble-to-order product configuration*).
- *Software Engineering Course*, Universiteit van Amsterdam, September–November: A. van Deursen (10 lectures).
- *PLI/RULE 2001*, Florence, Italy, September 4: M.G.J. van den Brand.
- *WCRE 2001*, Stuttgart, Germany, October 2–5: A. van Deursen (*Software architecture modelling; Program comprehension risks and opportunities in XP*), L. Moonen (*Generating robust parsers using island grammars*).
- *OOPSLA 2001*, Tampa Bay, USA, October 14–17: J. Visser (*Visitor combination and traversal control*).

- *International Conference on Software Maintenance*, Florence, Italy, November 6–11: M. de Jonge (*Cost-effective maintenance tools for proprietary language*).
- *Software Engineering Course*, Universiteit van Amsterdam, November 8: L. Moonen (*Exploring sofware systems*).
- *Invited lecture*, Technische Universiteit Eindhoven, November 13: A. van Deursen (*Software architecture reconstruction*).
- *Visiting researcher LORIA*, Nancy, France, November 19–(ongoing): M.G.J. van den Brand.
- *INRIA Scientific Council*, Rocquencourt, November 20: P. Klint.
- *Landelijk Architectuur Congres*, Zeist, November 28–29: A. van Deursen (*Understanding legacy architectures*).

Memberships of Committees and Other Professional Activities

M.G.J. van den Brand:
- PC member LDTA 2001, CSMR 2001, RULE 2001.

A. van Deursen:
- Organizer XP2001 Workshop on Customer Involvement (WCI 2001) and WCRE 2001 Forum on Software Architecture Recovery and Modelling (SWARM 2001).
- PC member International Conference on Reverse Engineering for Information Systems and IEEE Working Conference on Reverse Engeering (WCRE).
- Program co-chair WCRE 2002.

J. Heering:
- Co-organizer HICCS-35 Minitrack Domain-Specific Languages in Software Engineering (with M. Mernik).
- Organizer Meeting on Language Design Assistants.
- PC member LDTA 2001.

P. Klint:
- European Association for Programming Languages and Systems (EAPLS): P. Klint (President).
- Member INRIA Scientific Council.
- Member Steering Committee ETAPS.
- Member Adviescommissie Informatica (ACI, NWO).
- Member Jacquard Programme Committee (NWO).
- Member PhD committee F.J. Meijer (UvA).
- Editor *Science of Computer Programming.*

Visitors

- R. van Halen, Lucent, June 7.
- M. Schrage and J. Jeuring, University of Utrecht, June 28.
- P.D. Mosses, Aarhus University, August 23–24.
- J. Iversen,Aarhus University, August 23–24.
- E. Meijer, Microsoft, September 7.
- R. Monajemi, Lucent/Bell Labs, September 21.
- T.B. Dinesh, Servelots Inc., October 9.
- P.D. Mosses, Aarhus University, November 15–16.
- S. Hille, Telematica Instituut, December 6.

Software Developed

- ASF+SDF Meta-Environment releases 0.7.3, . . ., 1.0.1 (M.G.J. van den Brand et al.).
- Autobuild releases 0.4.8, . . ., 0.4.10 (M. de Jonge).
- Autobundle releases 0.1, . . ., 0.4 (M. de Jonge).
- APIGen: An API generator for abstract data types (P.A. Olivier).
- JJForester releases 0.3, . . ., 0.8 (J. Visser).
- JJTraveler: Framework and library supporting visitor combinators for Java (J. Visser).
- Mangrove: A generator for source model extractors based on island grammars (L. Moonen).
- Strafunski: Generic programming bundle for Java supporting functional strategies (J. Visser).
- XT releases 0.6, . . ., 0.9 (M. de Jonge).

Books

A. van Deursen (ed.) (2001). *Proceedings of the WCRE 2001 Software Architecture Recovery and Modeling Forum (SWARM 2001)*, CWI.

A. van Deursen (ed.) (2001). *Proceedings of the XP2001 Workshop on Customer Involvement (WCI2001)*, CWI.

A. van Deursen (2001). Recovering rationale. *Proceedings of the WCRE 2001 Discussion Forum on Software Architecture Recovery and Modeling (SWARM 2001)*, CWI.

Papers in Journals and Proceedings

M.G.J. van den Brand, H.A. de Jong, P. Klint, P.A. Olivier (2001). Annotated terms for efficient data exchange. *Xootic Magazine* **9**(2).

M.G.J. van den Brand, A. van Deursen, J. Heering, H.A. de Jong, M. de Jonge, T. Kuipers,P. Klint, L. Moonen, P.A. Olivier, J. Scheerder, J.J. Vinju, E. Visser, J. Visser (2001). The ASF+SDF Meta-Environment: A component-based language development environment. R. Wilhelm (ed.). *Compiler Construction (CC 2001)*, LNCS **2027**, Springer-Verlag, 365–370.

A. van Deursen, L. Moonen (2001). An empirical study into Cobol type inferencing. *Science of Computer Programming* **40**(2/3), 189–211.

A. van Deursen (2001). Program comprehension risks and opportunities in extreme programming. E. Burd, P. Aiken, R. Koschke (eds.). *Proceedings 8th Working Conference on Reverse Engineering, (WCRE 2001)*, IEEE Computer Society, 176–185.

A. van Deursen, L. Moonen, A. van den Bergh, G. Kok (2001). Refactoring test code. M. Marchesi (ed.). *Proceedings of the 2nd International Conference on Extreme Programming and Flexible Processes in Software Engineering (XP2001)*, University of Cagliary, 92–95.

A. van Deursen, L. Moonen, T. Kuipers (2001). Legacy to the extreme. M. Marchesi, G. Succi (eds.). *eXtreme Programming Examined*, Addison-Wesley, 501–514.

T.B. Dinesh, M. Haveraaen, J. Heering (2001). An algebraic programming style for numerical software and its optimization. *Scientific Programming* **8**(4), (September/October 2001) 247–259 (Special issue on Coordinate-Free Numerics).

M. de Jonge, R. Monajemi (2001). Cost-effective maintenance tools for proprietary languages. *Proceedings International Conference on Software Maintenance (ICSM 2001)*, IEEE Computer Society.

M. de Jonge, E. Visser, J. Visser (2001). XT: A bundle of program transformation tools – system description. M.G.J. van den Brand, D. Parigot (eds.). *Proceedings Workshop on Language Descriptions, Tools and Applications (LDTA 2001)*, *Electronic Notes in Theoretical Computer Science* **44**(2).

P. Klint (2001). Is strategic programming a viable paradigm? B. Gramlich, S. Lucas (eds.). *Proceedings Workshop on Reduction Strategies in Rewriting and Programming (WRS '01)*, *Electronic Notes in Theoretical Computer Science* **57**.

T. Kuipers, J. Visser (2001). Object-oriented tree traversal with J.J. Forester. M.G.J. van den Brand, D. Parigot (eds.). *Proceedings Workshop on Language Descriptions, Tools and Applications (LDTA 2001)*, *Electronic Notes in Theoretical Computer Science* **44**(2).

R. Lämmel, G. Riedewald (2001). Prological language processing. M.G.J. van den Brand, D. Parigot (eds.). *Proceedings Workshop on Language Descriptions, Tools and Applications (LDTA 2001)*, *Electronic Notes in Theoretical Computer Science* **44**(2).

R. Lämmel, C. Verhoef (2001). Cracking the 500-language problem. *IEEE Software*, 78–88.

R. Lämmel, C. Verhoef (2001). Semi-automatic grammar recovery. *Software–Practice & Experience* **31**(15), 1395–1438.

J. Visser (2001). Visitor combination and traversal control. *OOPSLA 2001 Conference Proceedings*, *ACM SIGPLAN Notices* **36**(11), 270–282.

CWI Reports

The following CWI reports were published by members of theme SEN1. See page 43 for the complete titles of the reports.

SEN-R0109	SEN-R0110	SEN-R0112
SEN-R0114	SEN-R0116	SEN-R0118
SEN-R0119	SEN-R0121	SEN-R0122
SEN-R0124	SEN-R0125	SEN-R0126

Other Publications

J. Boef, A. van Deursen, P. Klint (2001). Goede softwarelogistiek basis voor snelle aanpassingen. *Automatisering Gids*.

M.G.J. van den Brand (ed.) (2001). *Proceedings RULE 2001*, *Electronic Notes in Theoretical Computer Science* **59**(4).

M.G.J. van den Brand, D. Parigot (eds.) (2001). *Proceedings Workshop on Language Descriptions, Tools and Applications (LDTA 2001)*, *Electronic Notes in Theoretical Computer Science* **44**(2).

A. van Deursen (2001). Customer involvement experiences in a software product line. *Proceedings of the XP2001 Workshop on Customer Involvement (WCI2001)*, CWI.

A. van Deursen (2001). Customer involvement in Extreme Programming – XP2001 workshop report. *ACM SIGSOFT Software Engineering Notes* **26**(6).

P. Klint (2001). Collaborative development of language processing tools (abstract). M. van den Brand, D. Parigot (eds.). *Proceedings First Workshop on Language Descriptions, Tools and Applications (LDTA'01)*, *Electronic Notes in Theoretical Computer Science* **44**(2).

Specification and Analysis of Embedded Systems – SEN2

Staff

- Prof. dr. W.J. Fokkink, theme leader
- Drs. B. Badban, PhD student (from October 15)
- Prof. dr. J.A. Bergstra, advisor
- Dr. S.C.C. Blom, project member
- Dr. C. Daws, ERCIM fellow (from December 1)
- Drs. H.J.M. Goeman, senior researcher (seconded)
- Prof. dr. ir. J.F. Groote (seconded TUE)
- Dr. J.J.M. Hooman, project member (seconded)
- Dipl. Ing. N. Ioustinova (from October 15)
- Prof. dr. J.W. Klop, project leader
- Drs. I.A. van Langevelde, project member
- Drs. B. Lisser, programmer
- Drs. S.P. Luttik, PhD student (NWO-EW) (until September 15)
- Dr. S. Mauw, project member (seconded TUE)
- Dr. V. van Oostrom, project member (seconded TUE) (from February 1)
- Drs. S.M. Orzan, PhD student
- Drs. J. Pang, PhD student
- Dr. J.C. van de Pol, project leader
- Dr. A. Ponse, project member (seconded)
- Drs. Y.S. Usenko, project member
- Drs. J.A. Valero Espada, PhD student (from March 1)
- Dr. A.G. Wouters, project member (until January 31)
- Drs. M.B. van der Zwaag, PhD student (NWO-EW)

Scientific Report

μCRL Language and Toolset

Jaco van de Pol implemented strategy annotations in term rewrite systems, a theorem prover for μCRL data types, and several reduction algorithms for linear processes based on data flow analysis and theorem proving techniques. Stefan Blom and Simona Orzan designed and implemented distributed bisimulation reduction algorithms for a cluster of computers using message passing communication. They obtained some speedup compared to the sequential algorithms, but the most important gain is in the size of the state spaces that can be processed. Bert Lisser implemented reduction and comparison algorithms for bisimulation. Furthermore, he worked on a graphical user interface for the μCRL toolkit. Stefan Blom and Bert Lisser prepared integration of the μCRL toolset with parallel and distributed tools. Stefan Blom implemented and maintained his tau-confluence reduction method in the instantiator. Yaroslav Usenko, Alban Ponse and Jan Friso Groote worked on a linearization procedure for μCRL, which consisted of two parts: adaptation of an existing pCRL algorithm to the μCRL setting and defining a new data type to represent combinations of parallel and sequential compositions with renaming operations. Pang Jun and Wan Fokkink analyzed a cache coherence protocol devised at the Vrije Universiteit Amsterdam. Izak van Langevelde continued his investigation of symmetry of state spaces. This research aims at formulating conditions under which operations like bisimulation reduction and model checking can be performed on one 'mirroring half', after which the result is 'mirrored' to obtain the full result. Stefan Blom worked out his novel theory for tau-confluence that supports the tau-confluence reduction in the μCRL toolset. Bas Luttik completed his PhD thesis on choice quantification in μCRL.

Process Theory

Izak van Langevelde analyzed the P1394.1 Standard for High Performance Serial Bus Bridges by means of the model checker SPIN. Natalia Ioustinova introduced a transformation of SDL timers aimed at the reduction of the infinite domain of timer values to a finite one while preserving the behaviour of a system. The proposed transformation of SDL-timers is a simple and inexpensive step that can be considered as a zero-

phase of the translation of SDL-specifications to a model-checker input language. She also proposed a timer abstraction to further reduce the state space. Henk Goeman studied various models of concurrency and notions of bisimulation, to relate these to his calculus of communicating processes. This (pi-like) calculus involves a direct combination of the lambda-calculus with concepts from concurrency. It maintains as primitive constructs the notions of abstraction and (self)application from the lambda-calculus, but it incorporates also notions of (non)deterministic choice, concurrent and sequential composition, communication, encapsulation and hiding. It generalizes the notion of function application to that of process application, taking lambda as just an arbitrary port name among many others. The calculus has great expressive power, recursive constructs appear through self application, and the usual dichotomy between data objects and program structures is totally absent. Bahareh Badban started working on integrating techniques for the verification of distributed systems. Sjouke Mauw introduced the 'impossible futures' preorder, which is the weakest preorder that allows one to reason about deadlock, lifelock and recursion. Alban Ponse and Mark van der Zwaag worked on a combination of four-valued logic and process algebra.

Distributed Shared Data Spaces

Miguel Valero and Jaco van de Pol studied the verification of distributed applications built under the JavaSpaces architecture. This technology provides a virtual space with which external processes coordinate by sharing objects. They specified a formal model in μCRL of the main features of JavaSpaces and implemented and model checked some interesting applications. They are currently comparing their proposal with other approaches. Jaco van de Pol and Jozef Hooman worked on formal verification of replication on a distributed data space architecture. Simona Orzan and Michel Chaudron worked on a framework for describing distributed shared dataspaces, i.e. global storages of information that coordinate processes by letting them read/write/delete pieces of data (e.g. Splice, Linda, JavaSpaces). The framework allows reasoning about properties of distributed dataspace architectures, by means of equivalence and refinement relations.

Security. Wan Fokkink initiated the CWI Security Platform, which combines a number of research groups within CWI that are interested in and perform research on security related issues. Pang Jun analyzed the Needham-Schroeder public-key protocol using the μCRL toolset. Sjouke Mauw started the development of a security model for internet applications, and of a formal framework for studying the security of mobile code. He co-founded the Eindhoven Computer Science Security Group.

Miscellaneous

Sujith Vijay, Wan Fokkink and Jaco van de Pol studied the axiomatizability of mixed algebras of booleans and naturals. Stefan Blom continued his work at the Eindhoven Embedded Systems Institute on the design and implementation of a Java package for accessing sensors and actuators with drivers for the Lego Dacta and Fischer Technik interfaces. Jan Friso Groote worked on a stochastic approach towards dividing tasks over a huge number of processors. He worked on a first design of a specification language GenSpect and spent time on building a symbolic modal formula checker. Alban Ponse worked in unit operators in program algebra.

PhD Thesis

S.C.C. Blom (2001). *Term Graph Rewriting – Syntax and Semantics.* Thesis advisor J.W. Klop, March 4, Vrije Universiteit Amsterdam.

Knowledge Transfer

- W.J. Fokkink acted as advisor on the use of formal methods in the development of interlocking systems for the Euro-Interlocking consortium in Zürich.
- I.A. van Langevelde joined the 'IEEE P1394.1 Reflector Discussion List', evangelizing the need for formal methods in standardization and pointing out weak points in the Draft Standard.
- J.C. van de Pol, I.A. van Langevelde and S.C.C. Blom collaborated with Ericsson Sweden on the use of the μCRL toolset for the verification of locker algorithms.
- J.C. van de Pol, S. Orzan and M. Valero Espada collaborated with Thales in Enschede in the context of a PROGRESS project.
- W.J. Fokkink and J. Pang collaborated with Add-Controls in Amersfoort in the context of a PROGRESS project.

Organization of Conferences, Workshops, Courses, etc.

- W.J. Fokkink gave a course on μCRL at the Vrije Universiteit Amsterdam.
- J.F. Groote gave a course on μCRL at the Technische Universiteit Eindhoven.
- J.W. Klop gave a course on process algebra at the Katholieke Universiteit Nijmegen.
- A. Ponse gave a course on process algebra at the Universiteit van Amsterdam.
- S.P. Luttik and I.A. van Langevelde organized a weekly seminar (PAM) on process theory, protocol verification, term rewriting and theorem proving at CWI.

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

- *2nd Dutch Model Checking Day*, Enschede, January 30: S.C.C. Blom (*The μCRL Toolset*), W.J. Fokkink, J.C. van de Pol, I.A. van Langevelde.
- *Computational Logic Seminar*, ILLC, Amsterdam, February 16: J.C. van de Pol (*Equational Binary Decision Diagrams*).
- *Applications of Kleene Algebra*, Dagstuhl, Germany, February 18–23: A. Ponse (*Iteration in Process Algebra*).
- *IPA Spring Days on Security*, Heeze, April 18–20: S. Orzan, J. Pang, M. Valero Espada.
- *Working visit University of Augsburg*, Augsburg, Germany, May 9–11: A. Ponse (*ACP-style Process Algebra*), M.B. van der Zwaag.
- *Summer School ELBA*, Elba, Italy, May 21–26: M. Valero Espada.
- *12th Conference on Rewriting Techniques and Applications*, Utrecht, May 22–24: S.C.C. Blom.
- *1st Workshop on Reduction Strategies in Rewriting and Programming*, Utrecht, May 26: J.C. van de Pol (*Just-in-time: On Strategy Annotations*).
- *IPA Basic Course on Software Technology*, Utrecht, May 28–June 1: J. Pang, M. Valero Espada.
- *13th EUROMICRO Conference on Real Time Systems*, Delft, June 13–15: J. Pang, M. Valero Espada.
- *Summer School on WAN*, Lipari, Italy, July 1–14: S. Orzan.
- *Perspectives of System Informatics*, Novosibirsk, Russia, July 4: J.F. Groote (*Resolution and BDDs cannot Simulate each other Polynomially*).
- *6th International Workshop on Formal Methods for Industrial Critical Systems*, Paris, France, July 16–18: J. Pang (*A Balancing Act: Analyzing a Distributed Lift System*).
- *13th International Conference on Computer Aided Verification*, Paris, France, July 19–23: S.C.C. Blom and B. Lisser (*μCRL: A Toolset for Analysing Algebraic Specifications*).
- *International Summer School on Formal Methods*, Bologna, Italy, July 22–29: J. Pang and Y.S. Usenko (*μCRL Toolset Demo*), M.B. van der Zwaag.
- *ICT Kenniscongres*, The Hague, September 6–7: B. Lisser (*μCRL Toolset Demo*), W.J. Fokkink, S.C.C. Blom.
- *CWI in Bedrijf*, Amsterdam, October 5: J.C. van de Pol (*Gedistribueerde Architectuur onder Vuur*).
- *Proof Theory in Computer Science*, Dagstuhl, Germany, October 8–13: J.C. van de Pol (*Equational Binary Decision Diagram*).
- *2nd Workshop on Embedded System and Software*, Veldhoven, October 18: W.J. Fokkink, J.C. van de Pol (*Verifying Replication on a Distributed Shared Data Space with Time Stamps*), J. Pang (*A Balancing Act: Analyzing a Distributed Lift System*).
- *3rd Dutch Model Checking Day*, Eindhoven, November 7: S.C.C. Blom, W.J. Fokkink, N. Ioustinova, I.A. van Langevelde, J. Pang, Y.S. Usenko, M. Valero Espada.
- *7th Dutch Testing Day*, Eindhoven, November 8: I.A. van Langevelde.
- *2nd EIFFRA Meeting at Euro-Interlocking*, Zürich, Switzerland, November 8: W.J. Fokkink.
- *Electronic Tool Integration Workshop*, Dortmund, Germany, November 23–24: J.C. van de Pol (*The μCRL Toolset*).
- *IPA Fall Days on Timed Systems*, Vught, November 26-30: J.C. van de Pol (*Verifying Replication in Distributed Data Spaces with Time Stamps*), M.B. van der Zwaag (*Examples of Timed Verification in Untimed Settings*), B. Badban, S. Orzan, J. Pang, M. Valero Espada, Y.S. Usenko.
- *Seminar on Mathematical Logic*, Utrecht, November 30: J.C. van de Pol (*Equational Binary Decision Diagrams*).

Memberships of Committees and Other Professional Activities

W.J. Fokkink:
- Professor of Computer Science at the Vrije Universiteit Amsterdam.
- Project manager Systems Validation Centre.
- Coordinator CWI Security Platform.
- Member Steering Committee SAFE-NL.
- Member Program Committee CONCUR'01, University of Aalborg, August 2001.
- Member Program Committee 7th Dutch Testing Day, EESI, Eindhoven, November 2001.
- Guest editor *Information Processing Letters*, special issue on process algebra, October 2001.

J.F. Groote:
- Professor of Computer Science at the TU Eindhoven.
- Member Program Committee FMICS'01, Paris, July 2001.
- Member Program Committee EXPRESS'01, University of Aalborg, August 2001.

J.W. Klop:
- Professor of Computer Science at the Vrije Universiteit Amsterdam.
- Head of Department Theoretical Computer Science, Vrije Universiteit Amsterdam.
- Member editorial board CWI Tracts and Syllabi.
- Member of IFIP WG 1.6 on Term Rewriting.
- Member Science Committee IPA.
- Chairman Dutch Association for Theoretical Computer Science (NVTI).
- Editor of NVTI Nieuwsbrief.
- Member habilitation committee Ian Mackie, École Polytechnique, Paris, March 2001.
- Member habilitation committee Delia Kesner, Université Orsay, November 2001.

Visitors

- Olga Tveretina, Bilkent University, Ankara, Turkey, January 17–22 (*Entropy-Based Design of Low Power FSM's*).
- Thomas Arts, Ericsson Computer Science Laboratory, Älvsjö, Sweden, February 14 (*Verification of Distributed Locker Algorithms*).
- Tomas Krilavicius, Kaunas, Litouwen, April 4–6 (*Aggregate Model Verification*).
- Bahareh Badban, Teheran, Iran, May 8–14 (*Fragments of Heyting Arithmetic*).
- Sujith Vijay, IIT Delhi, India, May 11–July 17 (*Finite Omega-Complete Axiomatisations for* $(0, S, T, F, <=, /)$ *and Related Algebras*).
- Martin Leucker, University of Technology, Aachen, Germany, November 26–December 2 (*Distributed Model Checking*).

Developed Software

- The SVC library: implementation of a compact file format for labeled transition systems.
- Theorem prover for μCRL.
- Parallelization of the instantiator of μCRL.
- Reduction of state spaces based on confluence.
- Maintenance of the μCRL toolkit.
- Compiler of EURIS into μCRL.

Papers in Journals and Proceedings

L. Aceto, W.J. Fokkink, A. Ingólfsdóttir (2001). 2-nested simulation is not finitely equationally axiomatizable. *Proceedings 18th Symposium on Theoretical Aspects of Computer Science (STACS'01)*, Dresden, LNCS **2010**, Springer-Verlag, 39–50.

L. Aceto, W.J. Fokkink, C. Verhoef (2001). Structural operational semantics. *Handbook of Process Algebra*, Elsevier, 197–292.

L. Aceto, W.J. Fokkink, C. Verhoef (2001). Conservative extension in structural operational semantics. *Current Trends in Theoretical Computer Science – Entering the 21st Century*, World Scientific, 504–524.

Th. Arts, I.A. van Langevelde (2001). Correct performance of transaction capabilities. *Proceedings 2nd IEEE Conference on Application of Concurrency to System Design (ICACSD'01)*, IEEE Computer Society, Newcastle upon Tyne, 35–42.

J.C.M. Baeten, H.M.A. van Beek, S. Mauw (2001). Specifying Internet applications with DiCons. *Proceedings 16th ACM Symposium on Applied Computing (SAC 2001)*, ACM, Las Vegas, USA, 576–584.

J.C.M. Baeten, H.M.A. van Beek, S. Mauw (2001). An MSC based representation of DiCons. *Proceedings 10th SDL Forum (SDL'01)*, Copenhagen, 328–347.

J.A. Bergstra, W.J. Fokkink, A. Ponse (2001). Process algebra with recursive operations. *Handbook of Process Algebra*, Elsevier, 333–389.

J.A. Bergstra, A. Ponse (2001). Non-regular iterators in process algebra. *Theoretical Computer Science* **269**(1-2), 203–229.

J.A. Bergstra, A. Ponse (2001). Process algebra and conditional composition. *Information Processing Letters* **80**(1), 41–49.

J.A. Bergstra, A. Ponse (2001). Register-machine based processes. *Journal of the ACM*.

S.C.C. Blom, W.J. Fokkink, J.F. Groote, I.A. van Langevelde, B. Lisser, J.C. van de Pol (2001). μCRL: a toolset for analysing algebraic specifications. *Proceedings 13th Conference on Computer Aided Verification (CAV'01)*, LNCS **2102**, Springer-Verlag, Paris, France, 250–254.

C.H. Cap, N. Ioustinova (2001). Algebraic and transitional techniques for requirements specification of distributed systems. *Proceedings IEEE TC ECBS and IFIP WG10.1 2nd Joint Workshop on Formal Specification of Computer-Based Systems (FSCBS'01)*, IEEE Computer Society Press, Washington DC, USA.

W.J. Fokkink, I.A. van Langevelde, S.P. Luttik, Y.S. Usenko (2001). How can I be sure that my DVD player understands my TV? *ERCIM News* **47**, 34–35.

J.F. Groote, W.H. Hesselink, S. Mauw, R. Vermeulen (2001). An algorithm for the asynchronous Write-All problem based on process collision. *Distributed Computing* **14**, 75–81.

J.F Groote, J. Pang, A.G. Wouters (2001). A balancing act: Analyzing a distributed lift system. *Proceeding 6th Workshop on Formal Methods for Industrial Critical Systems (FMICS'01)*, Paris, France, 1–12.

J.F. Groote, A. Ponse, Y.S. Usenko (2001). Linearization in parallel pCRL. *Journal of Logic and Algebraic Programming* **48**(1–2), 39–72.

J.F. Groote, M. Reniers (2001). Algebraic process verification. *Handbook of Process Algebra*, Elsevier, 1151–1208.

J.F. Groote, J. Springintveld (2001). Focus points and convergent process operators: a proof strategy for protocol verification. *Journal of Logic and Algebraic Programming* **49**, 31–60.

J.F. Groote, J.J. van Wamel (2001). Analysis of three hybrid systems in timed μCRL. *Science of Computer Programming* **39**, 215–247.

J.F. Groote, J.J. van Wamel (2001). The parallel composition of uniform processes with data. *Theoretical Computer Science* **266**, 631–652.

J.F. Groote, H. Zantema (2001). Resolution and Binary Decision Diagrams cannot simulate each other polynomially. *Proceedings 4th Conference on Perspectives of System Informatics (PSI'01)*, LNCS **2244**, Springer-Verlag, Novosibirsk, 33–38.

U. Hannemann, Jozef Hooman (2001). Formal design of real-time components on a shared data space architecture. *Proceedings 25th Computer Software and Applications Conference (COMPSAC'01)*, IEEE Computer Society Press, 143–150.

W.H. Hesselink, J.F. Groote (2001). Wait-free concurrent memory management by Create and Read until Deletion (CaRuD). *Distributed Computing* **14**, 31–39.

J. Hooman, J.C. van de Pol (2001). Verifying replication on a distributed shared data space with time stamps. *Proceedings 2nd Progress Workshop on Embedded Systems*, Veldhoven, 107–120.

N. Ioustinova, N. Sidorova (2001). Transformation of SDL specifications - a step towards the verification. *Proceedings 4th Conference on Perspectives of System Informatics (PSI'01)*, LNCS **2244**, Springer-Verlag, Novosibirsk, 64–78.

Z. Khasidashvili, M. Ogawa, V. van Oostrom (2001). Uniform normalisation beyond orthogonality. *Proceedings 12th Conference on Rewriting Techniques and Applications (RTA'01)*, LNCS **2051**, Springer-Verlag, Utrecht, 122–136.

Z. Khasidashvili, M. Ogawa, V. van Oostrom (2001). Perpetuality and uniform normalization in orthogonal rewrite systems. *Information and Computation* **164**(1), 118–151.

S. Mauw, M.A. Reniers (2001). A process algebra for Interworkings. *Handbook of Process Algebra*, Elsevier, 1269–1327.

S. Mauw, M.A. Reniers, T.A.C. Willemse (2001). Message Sequence Charts in the software engineering process. S. Kang (ed.). *Handbook of Software Engineering and Knowledge Engineering*, World Scientific.

J.C. van de Pol (2001). Just-in-time: On strategy annotations. *Proceedings 2nd Workshop on Reduction Strategies*, Utrecht. (To appear in a special issue of *Electronic Notes in TCS*.)

A. Ponse, Y.S. Usenko (2001). Equivalence of recursive specifications in process algebra. *Information Processing Letters* **80**(1), 59–65.

J. Tretmans, K. Wijbrans, M.R.V. Chaudron (2001). Software engineering with

formal methods: The development of a storm surge barrier control system revisiting seven myths of formal methods. *Formal Methods in System Design* **19**(2), 195–215.

M. VOORHOEVE, S. MAUW (2001). Impossible futures and determinism. *Information Processing Letters* **80**(1), 51–58.

H. ZANTEMA, J.C. VAN DE POL (2001). A rewriting approach to Binary Decision Diagrams. *Journal of Logic and Algebraic Programming* **49**(1–2), 61–86.

M.B. VAN DER ZWAAG (2001). The cones and foci technique for timed transition systems. *Information Processing Letters* **80**(1), 33–40.

CWI Reports

The following CWI reports were published by members of SEN2. See page 43 for the complete titles of the reports.

SEN-R0101	SEN-R0102	SEN-R0105
SEN-R0106	SEN-R0107	SEN-R0111
SEN-R0117	SEN-R0123	SEN-R0130

Coordination Languages – SEN3

Staff

- Prof. dr. J.J.M.M. Rutten, theme leader
- Dr. F. Arbab, senior researcher
- Prof. dr. J.W. de Bakker, cluster head and researcher
- Dr. A. Baltag, NWO/GE postdoc (until June 30)
- Drs. F. Bartels, NWO/GE PhD student
- Drs. C.L. Blom, programmer
- Dr. F.S. de Boer, senior researcher (seconded from Utrecht University)
- Dr. M.M. Bonsangue, postdoc (until March 30, from April 1 seconded from the University of Leiden)
- F.J. Burger, programmer
- Drs. C.T.H. Everaars, programmer
- Drs. J.V. Guillen Scholten, PhD student
- J.J. van der Ham, trainee (from August 16 until November 15)
- Drs. J. den Hartog, NWO/GE PhD student (until August 31)
- Prof. dr. J.N. Kok, advisor (University of Leiden)
- Dr. A. Kurz, postdoc (until May 1 and from September 15)
- Prof. dr. W.P. de Roever, senior researcher (on sabbatical from the University of Kiel, from March 1 until October 15)
- Drs. P. Zoeteweij, researcher (from April 1)

Scientific Report

Coordination models and languages focus on such key issues in Component Based Software Engineering as specification, interaction, and dynamic composition of components. In particular, the research of this theme has concentrated on:

- development of formal models for coordination, components, and component based software;
- study of the foundations of computation, notably operational semantics and coalgebraic methods;
- development of and experiments with the coordination language 'Manifold' and its visual programming and debugging environment;
- using the Manifold system to work on real applications of coordination programming in numerical computing.

The theme has cooperated with many internal and external partners, including MAS2 (Piet Hemker and Barry Koren), PNA1 (Krzysztof Apt), PNA2 (Jan van Schuppen), UU, UL (Joost Kok), UvA (Yde Venema, Johan van Benthem), KUN (Bart Jacobs), and many universities abroad. The year 2001 has been particularly successful regarding external activities: The European Union project Omega, the Telematics Institute pre-phase of the project ArchiMate, the NWO bilateral project Mobi-J, and an NCF project were all funded. Manifold has been picked up by the software company Adaptive Planet, who is building a product based on this software. By the end of 2001 (December), Jan Rutten was appointed professor (bijzonder hoogleraar) at the VUA, in the subject of foundations of computer science, esp. coalgebra.

Formal methods for coordination languages – SEN3.1

Within this subtheme, *F. Arbab* and *M. Bonsangue* have continued their collaboration with F. de Boer on studies of component-based systems, both from the formal and engineering points of view. The aim is to develop a programming environment to support component-based design and compositional verification of large applications. More specifically, a Java implementation of a communication middleware for components,

supporting both distribution and mobility, has been started by Juan Scholten as part of his masters thesis. Furthermore, a proposal for joint research and collaboration among CWI, Utrecht University, and University of Kiel on components for Java has been awarded by NWO and DFG.

Preliminary studies were undertaken in order to provide the formal underpinnings of a development process for component-based systems based on visual languages like UML (Unified Modeling Language). Work in this direction involves the definition of a component model within UML and semantical and type theoretical studies of the UML Object Constraint Language.On this topic an EU research project, Omega, in collaboration with Verimag, University of Kiel, Weizmann Institute, KUN, NLR, France Telecom, IAI, and Oldenburg University was submitted and awarded.

F. de Boer worked on the development of a Hybrid Modal logic for reasoning about navigation in object-structures, formal models of components, real-time programming (e.g. Timed Linda and real-time extensions of Concurrent Constraint Programming), and, finally, formal models of agent communication. In the context of the NWO project 'A Methodology for the Design of Agent-Based Architectures' Frank de Boer has been working on the implementation in Java of the agent-oriented programming language 3APL.

F. Arbab continued his work on a new family of general Distributed Termination Detection Algorithms, called Back To The Future (BTTF), with significantly improved performance. These algorithms take advantage of system-wide apparent causal relationships that can be established among messages exchanged in a distributed system, using only the externally observable behaviour of each of its components. This work includes the underlying formalism for the BTTF algorithms, an outline of their correctness proofs, and a detailed analysis of their performance. C. Blom and F. Arbab completed a full Java implementation of these algorithms.

During his visit at the CWI W.P. de Roever has been working together with F.S. de Boer on an assertional method for reasoning about the correctness of multi-threaded Java programs (this joint work with the PhD student Erika Abraham-Mumm resulted in a publication at the international conference FOSSACS 2002). Furthermore, W.P. de Roever and F.S. de Boer have been involved in the preparation of the European project OMEGA (which started January 1, 2002).

Coordination and component-based software architectures – SEN3.2

The Manifold system is now stable and further work on its maintenance and enhancements continued in 2001 as a small activity in this subtheme. A software company expressed interest in Manifold and started a joint project with CWI to produce a coordination layer on top of their existing software product, based on Manifold.

The work on the application of Manifold in parallelization and distribution of numerical computation (with MAS2) under a new NCF project (Everaars, Arbab, and Koren) was funded and started in 2001. A new OIO (P. Zoeteweij) was appointed to work on the NWO project with PNA1 on coordination of distributed constraint systems (K. Apt, C. Blom, P. Zoeteweij, and F. Arbab). P. Zoeteweij with F. Arbab and C. Blom developed a framework for configuring parallel constraint solvers from components in four categories: variable domains, solvers, splitting schemes and search strategies. The framework is based on earlier results on a coordination-based algorithm for constraint propagation and on a mechanism for the distributed splitting of variable domains to facilitate search. This work has advanced to the stage where the framework can be used as a testbed for strategies to solve constraint satisfaction problems by the coordination of solvers.

F. Arbab developed a new channel-based exogenous coordination model called Reo. Complex coordinators, called connectors, are compositionally constructed in Reo out of simpler ones, the simplest connectors being a set of basic channels provided by users. Reo connectors are ideal as glue code that composes and coordinates the dynamic behaviour of components in a component based system. Preliminary results show Reo to be very powerful and expressive, and it has been well received by our international colleagues as well as some industrial contacts. Reo is now adopted as the coordination framework for our ongoing research on component based software, and its realization in Java is under way. A formal semantics for Reo, based on the coalgebraic methodology developed in subtheme SEN3.3, is being developed by J. Rutten.

J. Scholten finished his Masters thesis on a Java implementation of mobile channels, at Lei-

den University, and was appointed as an OIO to continue his work on coordination of component interactions through mobile channels at CWI.

F. Arbab and M. Bonsangue, in collaboration with the Ordina Institute, Telematics Institute, and KUN, prepared and submitted a proposal for the Telematics Institute project ArchiMate: Visualizing architectures in an integrated semantic framework. The pre-phase study part of this project was funded and started in 2001. The state of the art study activity within this project started by J. Scholten and F. Arbab in November.

Under the supervision of F. de Boer and J. Scholten, the CKI (UU) student Jeroen van der Ham investigated as part of his graduation for a period of 2 months the state of the art of querying heterogenous distributed information sources.

Exploratory research: Coalgebraic models of computation – SEN3.3

The theory of coinduction and coalgebra was studied and applied to various topics in computer science and mathematics, including specification, modal logic, and control theory. First applications have been developed of coalgebra and coinductive reasoning to the system of component connectors developed in subtheme SEN3.1. Our participation in two recently granted NWO projects has continued, together with UvA (Venema, Van Benthem) and KUN (Jacobs), on coalgebra and modal logic, and together with PNA2 (Van Schuppen), on coalgebra and control. The coalgebra group of CWI continues to play an active role in the further development of coalgebra as a discipline worldwide, amongst others by the involvement of various members of SEN3 in the CMCS workshop series.

The research of Falk Bartels, in the context of NWO project Promacs in which also TUE (S. Andova, J. Baeten) participates, concentrated on generalized definition and proof principles for coalgebras, now also including the translation of previous results into dual algebraic schemata. Furthermore, SOS style rule formats for the specification of operators on probabilistic systems were studied. Baltag, another member of the Promacs project, continued to work on modal logics for coalgebras and on dynamic-epistemic logic and its various applications to game theory, communication, and control theory.

The research of Alexander Kurz dealt with the following topics: he worked on logics for coalgebras, with special emphasis on logics for final semantic, and modal predicates and coequations (jointly with Jiri Rosicky, Brno). Furthermore he worked on the definability, canonical models, and compactness for finitary coalgebraic modal logic (jointly with Dirk Pattinson, LMU Munich). Kurz started to work on coalgebras and control theory in close collaboration with Jan Komenda and Jan van Schuppen (PNA2), in the context of the NWO project Cocon. He moreover taught courses on 'Coalgebras and Modal Logic' at the Masaryk University, Brno, June 2001 and at the European Summerschool in Logic, Language, and Information, Helsinki, August 2001.

Jerry den Hartog was given an extension of his contract at CWI until August 31st, in order to finish the write-up of his thesis. Also after he started working at the TUE, he has continued to have regular meetings at CWI, under the guidance of De Bakker and Rutten, to discuss the progress of his thesis. The subject of his research has been various probabilistic extensions of semantical models and verification methods, including a probabilistic Hoare-style logic that was developed jointly with De Vink (formerly VUA, now TUE and UL). At the end of 2001, the thesis was next to finished and was about to be formally submitted to the VUA.

As part of a continuing effort to study 'concrete coalgebra and coinduction at work', Jan Rutten constructed a coalgebraic calculus of streams, in which coinduction is the central reasoning principle. A number of applications was studied, including difference and differential equations, and probabilistic transition systems. Another extensive case study concerned the use of weighted automata and coinduction to various counting problems from enumerative combinatorics. Most recently, the coinductive stream machinery has been put to work to construct a formal model for the component connector model Reo of Farhad Arbab (mentioned under subtheme SEN3.1 above), allowing formal reasoning about connector equivalence and optimization. This has led to further plans for joint research between subthemes 3.1 and 3.3 (including the submission of a joint NWO/EW research proposal).

Organization of Conferences, Workshops, Courses, etc.

ACG, the Amsterdam Coordination Group. ACG is an – on average biweekly – seminar, chaired by Jaco de Bakker, in which ongoing re-

search on coordination languages and models, and on coalgebra, is discussed by members and former members of SEN3, and invited visitors. The following presentations were given:

- January 16: *Modelling decentralized Control Problems using the Logic of Epistemic Actions*, Alexandru Baltag.
- January 30: *Generalised Coinduction*, Falk Bartels.
- February 13: *Implementation of Mobile Channels*, Juan Guillen Scholten.
- February 27: *Elements of stream calculus*, Jan Rutten.
- March 27: *Reasoning about probability and nondeterminism*, Jerry den Hartog.
- April 10: *Coordination and component based software architecture*, Michel Chaudron.
- April 24: *Shared Data Space Systems: Verification and Expressiveness Results*, Jaco van de Pol.
- May 8: *Rho: A Channel-based Coordination Paradigm for Mobile Components*, Farhad Arbab.
- June 12: *Axiomatizing GSOS with termination*, Erik de Vink.
- July 10: *Recent trends in object oriented verification*, Frank de Boer.
- September 4: *Coordination of Mobile Components*, Farhad Arbab.
- September 11: *Coinductive counting with weighted automata and continued fractions*, Jan Rutten.
- September 25: *Beyond Mu-Calculus: strong logics for strong bisimulation*, Alexandru Baltag.
- October 9: *Modeling infinite probabilistic choices using an ultrametric version of kernels*, Jerry den Hartog.
- November 6: *A proof theory for the multi-threaded flow of control in Java*, Frank de Boer.
- November 20: *Modal Properties as Natural Transformations*, Alexander Kurz.
- November 27: *Automatic generation of proof-outlines for Java*, Marcel Kyias.
- December 4: *Towards a Formal Specification of Rew*, Farhad Arbab.
- December 11: *Coalgebraic Modalities and Logics for Process Transformations*, Alexandru Baltag.
- December 18: *Verification of security protocols using Casper and FDR*, Erik de Vink.
- *ProMACS project meetings. Three ProMACS project meetings were held in 2001*, two of them organized by CWI.
  - January 26: S. Andova (TUE, *Abstraction in Probabilistic Process Algebra*), J. Baeten (TUE), A. Baltag (CWI, *Applying a logic of epistemic actions to control theory*), F. Bartels (CWI, *On Turi/Plotkin's Categorical Treatment of SOS Definition Formats*), J.J.M.M. Rutten (CWI).
  - September 12: S. Andova (TUE, An *algebraic verification of probabilistic Concurrent Alternating Bit Protocol*), J. Baeten (TUE), A. Baltag (CWI, *Beyond Mu-Calculus: strong logics for strong bisimulation*), F. Bartels (CWI, *Distributive laws and operators on probabilistic systems*), J.J.M.M. Rutten (CWI).

Further events were:

- March 15–16 , Mobi-J meeting with F. Arbab, M. Bonsangue, F. de Boer, W.P. de Roever (Kiel University), E. Abraham-Mumm (Kiel University), and Marcel Kias (Kiel University).
- F. Arbab and M. Bonsangue organized the CWI Component Based Software day, April 27. Speakers: F. Arbab, M. Broy (Technical University of München), H. Bossenbroek (Escador), M. Aksit (UT), E. Proper (Ordina Institute, KUN), B. Watson (TUE), O. Nierstrasz (University of Berne), and P. Klint. Organizing commitee: F. Arbab, M. Bonsangue and E. Proper (Ordina Institute, KUN).
- *Coalgebra meeting on October 25.* Again there was a working meeting between the coalgebra groups of the University of Nijmegen and SEN3, this time held at CWI. The following presentations were given:

  Falk Bartels (*GSOS for probabilistic systems*),
  Jesse Hughes (KUN, *Horn coequations*),
  Bart Jacobs (KUN, *From coalgebras to (labeled) transition systems*),
  Alexander Kurz (*On Coequations*),
  Jan Rutten (*Coinductive counting with weighted automata and continued fractions*),
  Hiroshi Watanabe (AIST, Japan, invited speaker, *Operationally conservative extension/translation and morphism between distributive laws*).

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

- *Omega meeting*, March 19 and 20, NLR, Amsterdam: F. Arbab, F.S. de Boer, M.M. Bonsangue.
- *Theoriedag NVTI 2001*, March 23: F. Arbab, J.W. de Bakker, F. Bartels, A. Baltag, M.M. Bonsangue, J.J.M.M. Rutten.
- *ETAPS 2001*, Genoa, Italy, April 4–7: A. Kurz (*On the Dualtity between Observability and Reachability*).
- *CMCS 2001*, Genoa, Italy, April 6–7: A. Baltag, F. Bartels (*Generalized Coinduction*), A. Kurz (*Modal Rules are Coimplications*), J.J.M.M. Rutten.
- *W3C NL Master Class on XML*, Den Haag, April 12: F. Arbab.
- *IPA Spring days on Security*, Heeze, April 18–20: F. Bartels.
- *MFPS XVII*, Aarhus, Denmark, May 23–27: J.J.M.M. Rutten (*Elements of stream calculus*, invited talk).
- *Seminar of the LFE 'Programming and Software Engineering'*, Institute of Computer Science of LMU, Munich, April 26: A. Kurz (*Logics for Coalgebras*, invited talk).
- *ProMACS project meeting*, Eindhoven, June 5: A. Baltag, F. Bartels (*Lambda Iteration*), J.J.M.M. Rutten.
- *Course on coalgebra and modal logic*, Masaryk University, Brno, June: A. Kurz.
- *Working visit University of Stanford*, Stanford, USA: June 18 (Carolyn Talcott) and June 19 (Ptolemy Group): F. Arbab.
- *PDPTA 01*, Las Vegas, USA, June 25–28: F. Arbab.
- *Foundations of Wide Area Network Programming*, Lipari, Italy, July 1–14: P. Zoeteweij.
- *ConCoord 01*, Lipari, Italy, July 4–9: F. Arbab.
- *Meeting GI 1.0.6*, Munich, Germany, July 6: J.J.M.M. Rutten (*Elements of stream calculus*, invited talk).
- *PhD defense Pattinson*, Munich, Germany, July 7: J.J.M.M. Rutten.
- *TARK 2001*, Siena, Italy, July 7–11: A. Baltag (*Logics for Insecure Communications*).
- *PhD Programme Dresden*, July 17: A. Kurz (*Semantische Klassifizierung von Logiken FCr Koalgebren*, invited talk).
- *Course on coalgebra and modal logic*, European Summerschool in Logic, Language, and Information, Helsinki, August: A. Kurz.
- *PODC 2001*, Providence, USA, August 26–29: W.P. de Roever.
- *Nederlands ICT-Kenniscongres*, Den Haag, 6–7 September: F. Arbab (*Coordination of Mobile Components*).
- *CWI visit to Philips Nat Lab*, Eindhoven, the Netherlands, September 26: F. Arbab.
- *ICSM 2001*, Florence, Italy November 6–9: C.T.H. Everaars (*Using Coordination to Restructure Sequential Programs*).
- *PhD defense Z. Barbosa*, Universidade do Minho, Portugal, November 22–24 and December 13–16: J.J.M.M. Rutten.
- *PROLE 2001: Primeras Jornadas sobre Programacién y Lenguajes*, Almagro (Ciudad Real), Spain, November 23–24: F. Arbab (Panta Rei (Everything Flows): *A Calculus of Channels*, invited talk).
- *Colloquium of the PhD Programme Logic in Computer Science*, LMU Munich, November 30: A. Kurz (*Modale Eigenschaften als natürliche Transformationen*, invited talk).
- *KIT (INCO-DC) project meeting*, Cyprus, December 6–11: F. Arbab.

Memberships of Committees and Other Professional Activities

F. Arbab:

- Member IPA, Dutch Graduate School Institute for Programming and Algorithmics.
- Track Chair, Coordination Models and languages, PDPTA 2001: International Conference on Parallel and Distributed Processing Techniques and Applications, Las Vegas, Nevada, USA, June 25–28.
- Associate Editor, *Proceedings of the International Conference on Parallel and Distributed Processing Techniques and Applications*, Las Vegas, Nevada, USA, June 25–28.
- Co-organizer of the *Component Based Software Day*, CWI, Amsterdam, April 27.
- Coordinator, ESPRIT INCO-DC EC project 962144.
- Program Committee member, *ParCo 01*, Parallel Computing 2001, Naples, Italy, September 4–7.
- Program Committee member, *PaCt 01: Sixth International Conference on Parallel Computing Technologies*, Novosibirsk, Russia, September 3–7.
- Program Committee member, *ConCoord 01: International Workshop on Concurrency and Coordination*, Lipari Island, Italy, July 6–8.

- Expert evaluator, The European Commission, the Community Research 5th Framework IST Programme, Brussels, May 14–18.

J.W. de Bakker:
- Professor of Computer Science, Vrije Universiteit Amsterdam (till August 1).
- Member Koninklijke Nederlandse Akademie van Wetenschappen.
- Member Academia Europaea (AE).
- Member AE committee on Mathematics and Informatics.
- Editor Cambridge University Press Tracts in Theoretical Computer Science.
- Editor *Theoretical Computer Science*.
- Editor *Fundamenta Informaticae*.
- Associate editor *Journal of Computer and System Sciences*.
- Member emeritus IFIP Working Group 2.2 on Formal Description of Programming Concepts.
- Board member IPA, Dutch Graduate School Institute for Programming and Algorithmics (till August 1).
- Member steering Committee European Educational Forum (IPA, BRICS, TUCS and four further consortia).
- Member of IFIP Technical Committee 1 on Foundations of Computer Science.
- Member selection committee:
  - Special Chair (bijzonder hoogleraar) Foundations of Computer Science, esp. Coalgebra, VUA.
  - Personal Chair Security and correctness of software, KUN.
  - Associate Professorship Structure analysis of computer controlled systems, TUE.
- Member Board of Curators Special Chair on Foundations of Computer Science, esp. Coalgebra, VUA.
- Member VSNU National Visiting Committee on Education in Computer Science.
- (Co)project leader NWO/EW project Biography of Aad van Wijngaarden.

A. Baltag:
- Member of the LIC group (Logic in Communication), ILLC, UvA.
- Member of the program committee of CMCS'01 (the fourth international workshop on 'Coalgebraic Methods in Computer Science').
- Member of the SION project 'ProMACS: Probabilistic Methods for the Analysis of Continuous Systems'.

F. Bartels:
- Member IPA, Dutch Graduate School Institute for Programming and Algorithmics.

F.S. de Boer:
- Member, IPA, Dutch Graduate School Institute for Programming and Algorithmics.
- Member, SIKS.
- Member, IFIP Working Group 2.2 Formal Description of Programming Concepts.
- Program Committee Member, International Conference on Concurrency Theory (CONCUR), Aalborg, Denmark, 2001.
- Program Committee Member, Workshop on Models for Time-Critical Systems (CONCUR 2001), Aalborg, Denmark, 2001.
- Coordinator, ESPRIT Working Group Concurrent Constraint Programming for Time Critical Applications, 1997–2001 (Utrecht University).
- Principal Investigator, NOAG-i project: A Methodology for the Design of Agent-Based Architectures (Utrecht University).
- Partner, European IST project (Fifth RTD Framework Program) Omega on correct development of Real-Time Embedded Systems in UML.
- Partner of the bilateral NWO/DFG project Mobi-J (German partner: Willem-Paul de Roever, University of Kiel).

M.M. Bonsangue:
- Member IPA, Dutch Graduate School Institute for Programming and Algorithmics.
- Co-organizer of the *Component Based Software Day*, CWI, April 27, 2001, Amsterdam.
- Supervisor of master thesis of Juan Scholten from Leiden University.
- Supervisor of master thesis of Henk-Jan van der Wijk from Leiden University.
- Lecturer of a course on Software Architecture at LIACS, University of Leiden (from January to April).

J.J.M.M. Rutten:
- Professor of Theoretical Computer Science (from December 1), Vrije Universiteit Amsterdam.
- (Co)project leader of the NWO/EW projects 'ProMACS: Probabilistic Methods for the Analysis of Continuous Systems', 'Cocon: coalgebra and control', and 'Comolo: Coalgebraic modal logic'.
- Editor of Elseviers 'Electronic Notes in Theoretical Computer Science'.
- Editor of Book Series 'Semantic Structures in Computation', Kluwer Academic Press Publishers.
- Board member of the 'NVTI' (Dutch Association of Theoretical Computer Science). Editor of NVTI's newsletter.

- Member of Research Schools IPA and OzsL.
- Member of the programme committees of DMTCS 2001 and CMCS 2001.
- External examiner PhD theses of D. Pattinson, Ludwig-Maximilians University Munich; L. Barbosa, Universidade do Minho, Portugal.

Visitors

- Dr. D. Pattinson, University of Munich, March 3–12.
- Dr. M. Steffen, Germany, March 14–16.
- Dr. M. Rössiger, University of Dresden, March 28.
- Prof. dr. P. Panangaden, McGill University, Montréal, May 27–29.
- Dr. H. Watanabe, University of Edinburgh, October 25.
- Dr. A. Baltag, University of Oxford, December 10–12.
- Drs. E. Abraham-Mumm, University of Kiel, March 15 and 16.
- Drs. M. Kias, University of Kiel, March 15–20.
- Prof. dr. W.P. de Roever, University of Kiel, March–October.

Papers in Journals and Proceedings

K. Everaars, F. Arbab, B. Koren (2001). Using Coordination to Restructure Sequential SourceCode into a Concurrent Program. *Proceedings of the IEEE International Conference on Software Maintenance (ICSM 2001)*, Florence, Italy, 342–351.

G.A. Papadopoulos, F. Arbab (2001). Configuration and Dynamic Reconfiguration of Components Using the Coordination Paradigm. *Future Generation Computer Systems* **17**(8), Elsevier Science, 1023–1038.

E. Monfroy, F. Arbab (2001). Constraints Solving as the Coordination of Inference Engines. A. Omicini, F. Zambonelli, M. Klusch, R. Tolksdorf (eds.). *Coordination of Internet Agents: Models, Technologies, and Applications*, Springer, 399–422.

F. Arbab (2001). Coordination of Mobile Components. *Electronic Notes in Theoretical Computer Science* **54**, Elsevier Science, 1–16.

F. Arbab (2001). Apparent Causality for Distributed Termination Detection. *Proceedings of the Fifth International Workshop on Termination (WST '01)*, Utrecht, The Netherlands.

W.P.de Roever, F.S. de Boer et. al. (2001). State-Based Proof Theory of Concurrency: from Noncompositional to Compositional Methods. Cambridge University Press Tracts in Theoretical Computer Science,.

R.M. van Eijk, F.S. de Boer, W. van der Hoek, J.-J.Ch. Meyer (2001). On Dynamically Generated Ontology Translators in Agent Communication. *International Journal of Intelligent Systems* **16**(5).

R.M. van Eijk, F.S. de Boer, W. van der Hoek, J.-J.Ch. Meyer (2001). Modal Logic with Bounded Quantification over Worlds. *Journal of Logic and Computation*, Special Issue on Hybrid Logics.

F.S. de Boer, M. Gabbrielli, M.C. Meo (2001). A Denotational Semantics for Timed Linda. *Proceedings of the Third International Conference on Principles and Practice of Declarative Programming (PPDP 2001)*, ACM Press.

F.S. de Boer, M. Gabbrielli, M.C. Meo (2001). A Temporal Logic for reasoning about Timed Concurrent Constraint Programs. *Proceedings of The Eighth International Symposium on Temporal Representation and Reasoning (TIME-01)*, IEEE Computer Society Press.

F.S. de Boer, R. van Eijk (2001). Decidable Navigation Logics for Object Structures. *Proceedings of CSL01*, LNCS.

W. de Vries, F.S. de Boer, W. van der Hoek, J.-J.Ch. Meyer (2001). A Truly Concurrent Model for Interacting Agents. *Proceedings of the 4th Pacific Rim International Workshop on Multi-Agents (PRIMA 2001)*, LNAI **2132**.

J.I. den Hartog, E.P. de Vink, J.W. de Bakker (2001). Metric semantics and full abstractness for action refinement and probabilistic choice. *Proceedings MFCSIT 2000, ENTCS* **40**.

F. Bartels (2001). Generalised Coinduction. A. Corradini, M. Lenisa, U. Montanari (eds.). *Proceedings of Fourth Workshop on Coalgebraic Methods in Computer Science CMCS'01*, Genova, Italy, *ENTCS* **44**(1), Elsevier Science B.V.

A. Kurz (2001). Modal Rules are Co-Implications. A. Corradini, M. Lenisa,U. Montanari (eds.). *Proceedings of Fourth Workshop on Coalgebraic Methods in Computer Science CMCS'01*, Genova, Italy, *ENTCS* **44**(1), Elsevier Science B.V.

M. Bidoit, R. Hennicker, A. Kurz (2001). On the Duality between Observability and Reach-

ability. *Proceedings of Fossacs*.

J.J.M.M. Rutten (2001). Elements of stream calculus (an extensive exercise in coinduction). *Proceedings of the 17th Annual Conference on Mathematical Foundations of Programming Semantics (MFPS '01), ENTCS* **45**, Aarhus, Denmark, Elsevier Science B.V., 1–66. Invited paper.

B. Jacobs, L. Moss, H. Reichel, J. Rutten (eds.) (2001). Coalgebraic methods in computer science. *Theoretical Computer Science* **260**(1-2), Special issue including selected papers from the First International Workshop on Coalgebraic Methods in Computer Science (CMCS '98).

CWI Reports

The following CWI reports were published by members of theme SEN3. See page 43 for the complete titles of the reports.

SEN-R0120 SEN-R0127 SEN-R0128 SEN-R0129

Other Publications

J.V. Guillen Scholten (2001). *MoCha: A Model for Distributed Mobile Channels*, Masters thesis, Leiden University.

Evolutionary Systems and Applied Algorithmics – SEN4

Staff

- Prof. dr. ir. J.A. La Poutré, theme leader
- Drs. F. Alkemade, PhD student
- Drs. S.M. Bohté, PhD student
- Dr. ir. D.D.B. van Bragt, researcher
- Drs. E.H. Gerding, PhD student
- Dr. P.J. 't Hoen, postdoc (from March 1)
- Dr. J.K. Hoogland, postdoc (till September 30)
- Drs. M.B. de Jong, PhD student
- Prof. dr. J.N. Kok, advisor
- Drs. E. Kutschinski, PhD student
- Dr. C.D.D. Neumann, postdoc
- Dr. D.J.A. Somefun, postdoc
- Drs. R. van Stee, PhD student (till August 31)

Scientific Report

The theme group SEN4 focused on evolutionary algorithms (SEN4.1), neural networks (SEN4.2), and discrete algorithms (SEN4.3), especially for problems related to management, economics, and e-commerce. In addition, research was performed on the topic of mathematical finance. Specific activities in these areas are selected and stated below.

Evolutionary Algorithms – SEN4.1

An important topic in the field of agent-based computational economics is the relationship between the evolutionary technique that is used and the economic problem that is modelled. We assessed this fundamental problem by considering learning processes in a multi-agent Cournot model, where the trading rules of the agents are adapted by an evolutionary algorithm (EA). Results obtained with this model show that the economic model and the settings of the EA must be sufficiently decoupled. Otherwise, the robustness and performance of the EA may deteriorate. In addition, we also developed alternative evolutionary techniques which yield more robust results in comparison with previous studies. This work was performed within the framework of the NWO-EW project 'Evolutionary Exploration Systems for Electronic Markets'. (F. Alkemade, J.A. La Poutré, H.M. Amman (Eindhoven University of Technology))

We also started to develop a model of network economics in which adaptive agents buy and sell goods. Transactions can only take place in this model if there is a link (network connection) between the two parties. Our goal is to investigate the role of intermediaries in such a setting. Because the complexity of our model is significant we use genetic algorithms to determine highly efficient outcomes. We use these outcomes as a benchmark to evaluate the performance of agent-based models. A specific contribution of this work is the application of genetic algorithms to network structures. (F. Alkemade, J.A. La Poutré)

Real-life negotiations typically involve multiple parties with different preferences and bargaining strategies which change over time. Such a dynamic environment has been studied with a multi-population EA, where each population represents an evolving collection of bargaining strategies. The bargaining strategies are rep-

resented by a special kind of finite automata, which require only two transitions per state. We show that such automata (with a limited complexity) are a suitable choice in a computational setting. We furthermore describe an EA which generates highly-efficient bargaining automata in the course of time. A series of computational experiments shows that co-evolving automata are able to discriminate successfully between different opponents, although they receive no explicit information about the identity or preferences of their opponents. These results are important for the further development of evolving automata for real-life (agent system) applications. (D.D.B. van Bragt, J.A. La Poutré)

Most of today's (prototype) systems for automated negotiations, like Kasbah or Tête-à-Tête, use simple and static negotiation rules. We were able to show, however, that such 'fixed' bidding agents can be exploited by more sophisticated 'adaptive' software agents (based upon evolving automata). These adaptive agents are able to learn strategies which perform (almost) optimally against a variety of fixed opponents. Furthermore, they are able to adapt their strategies online to deal with changing opponents and open environments. This implies that fixed bargaining strategies should not be used for bounded environments (like specific business-to-business markets) with only a limited number of participants and agent types. (D.D.B. van Bragt, J.A. La Poutré)

Previous research on the development of efficient bargaining strategies with EAs was also extended. In particular, we studied a negotiation game with 'outside opportunities" for the players. In this model, players can negotiate with other opponents if negotiations with the current opponent are not successful. The emergent behaviour in this model was studied by evolutionary simulation. These experiments show that 'fair' agreements can evolve if the players have the opportunity to negotiate at a low cost with multiple opponents. (E.H. Gerding, J.A. La Poutré, D.D.B. van Bragt)

The amount of attention space available for recommending suppliers to consumers on e-commerce sites is typically limited. Within the Trade Agents project, we therefore further developed a competitive distributed recommendation mechanism (based on adaptive software agents) for efficiently allocating the 'consumer attention space', or banners. A patent application was filed (together with KPN Research) for this system. In our approach, each agent bids in an auction for the momentary attention of each consumer. Successive auctions allow agents to rapidly adapt their bidding strategy to focus on consumers interested in their offerings. The feasibility of this system, for a variety of customer behaviour models, was demonstrated by evolutionary simulation. (S. Bohté, E.H. Gerding, J.A. La Poutré)

A scalable and extensible agent architecture was developed for the above-described system. This architecture supports agents in a distributed bidding application, where the agents run on dedicated machines for maximum computational resources. Furthermore, as an extension, the agents can operate in multiple independent markets concurrently. (P.J. 't Hoen, S. Bohté, E.H. Gerding, J.A. La Poutré)

Neural Networks – SEN4.2

The research on spiking neural networks continued to explore supervised and unsupervised algorithms for classification problems. In particular, research was performed on the applicability of spiking neurons for the problem of dynamic feature binding in visual 'retina'-like settings. This problem extends to the representation and manipulation of symbols in neural network architectures. (S. Bohté, J.A. La Poutré, J.N. Kok)

Neural networks were also used in a learning agent-system, where the neural network calculates the monetary bid in an auction given a set of attributes for the items that is being auctioned off. Experiments show that the neural network effectively learns the profitable bidding policy. (S. Bohté, E.H. Gerding, J.A. La Poutré)

Some other work in SEN4.2 concerns financial systems. Earlier work on pricing of complex financial derivatives has been extended. The use of certain techniques from high energy physics, in particular the formulation of pricing problems in such a way that numeraire invariance becomes manifest, has led to significant simplifications in the theory. (J.K. Hoogland, C.D.D. Neumann)

In collaboration with researchers from Dresdner Kleinwort Wasserstein, a specific financial instrument, the resetable convertible bond, has been analyzed. We were able to reduce the dimensionality of the problem, compared to results known from the literature, resulting in faster and more accurate pricing of the product. (J.K. Hoogland, C.D.D. Neumann, D. Bloch (Dresdner Kleinwort Wasserstein))

Another extension of the theory is the incorporation of jumps in the stochastic modelling of asset prices, so-called jump diffusion models. This makes it possible to use our formalism for pricing of derivatives subject to e.g. credit risk or sudden price moves such as crashes. One of the results is a very clear description of hedging strategies for such instruments, in contrast with the standard approach. Another result is a unified picture of several known, but scattered, models for pricing stock options when option prices are driven by Levy-processes. (J.K. Hoogland, C.D.D. Neumann, M.H. Vellekoop (University of Twente))

Discrete Algorithms – SEN4.3

In the NWO-EW project 'Dynamic Algorithms for On-Line Optimization', research on online bin packing continued. New upper and lower bounds were presented for a multi-dimensional generalization of bin packing, called box packing. Several variants of this problem, including bounded space box packing, square packing, variable sized box packing and resource augmented box packing are also studied. The main results, stated for two dimensions, are as follows: A new upper bound of 2.66013 for online box packing, a new $14/9 + \varepsilon$ polynomial time offline approximation algorithm for square packing, a new upper bound of 2.43828 for online square packing, a new lower bound of 1.62176 for online square packing, a new lower bound of 2.28229 for bounded space online square packing and a new upper bound of 2.32571 for online two-sized box packing. (R. van Stee, S. Seiden (Louisiana State University))

Furthermore, work was done on on-line scheduling. The scheduling problem of minimizing the maximum starting time on m parallel identical machines on-line was studied. The goal is to minimize the last time that a job starts. We show that while the greedy algorithm has a competitive ratio of $\Theta(\log m)$, we can give a constant competitive algorithm for this problem. We also show that the greedy algorithm is optimal for resource augmentation in the sense that it requires $2m - 1$ machines to have a competitive ratio of 1, whereas no algorithm can achieve this with $2m-2$ machines. (R. van Stee, L. Epstein (The Interdisciplinary Center, Herzliya, Israel))

We also developed an algorithm to minimize the total completion time on-line on a single machine, using restarts, with a competitive ratio of 3/2. The optimal competitive ratio without using restarts is 2 for deterministic algorithms and $e/(e-1)$ for randomized algorithms. This is the first restarting algorithm to minimize the total completion time that has a better competitive ratio than an algorithm that does not restart. (J.A. La Poutré, R. van Stee)

In the NWO-EW project 'Quality of Service for Multimedia Systems', research on the concept of pricelist propagation as a solution for quality-of-service routing was finished. In addition, research was performed on reinforcement learning with multiple objectives. (M.B. de Jong, J.A. La Poutré) In cooperation with researchers from Philips research, work was also performed on scheduling strategies for near video-on-demand. (M.B. de Jong, J. Aerts, W. Michiels, J. Korst (Philips NatLab Laboratories))

In the Trade Agents project, we further studied the problem of applying price discrimination with an online adaptive algorithm. In particular, we considered the case where the seller of a product or service applies price discrimination by distinguishing between different delivery times. For this situation, we developed an efficient and robust algorithm which dynamically adjusts both the price and the size of the discount for delayed delivery of the product. The algorithm consists of a (multi-variable) derivative follower algorithm with an adaptive step-size. We show that this algorithm has attractive (convergence) properties when operating in static and dynamic profit landscapes (unlike previously proposed algorithms). Computational experiments show that the algorithm is able to generate high profit levels in a dynamic pricing setup with price discrimination. (D.D.B. van Bragt, D.J.A. Somefun, E. Kutschinski, J.A. La Poutré)

A start has also been made in the investigation of the 3SAT problem. The aim of this research is to see whether some recent theoretical results (found using techniques from statistical mechanics) can help to solve such problems more efficiently. (C.D.D. Neumann, J.A. La Poutré)

Trade Agents Project

A large body of research has been performed within the project 'Autonomous Systems of Trade Agents in E-Commerce' ('Trade Agents'), a project funded by the Telematics Institute, and with project partners TNO, ING, and KPN. Several of the research activities described above and several of the publications stated below were (also) part of this project.

In addition, research into information retrieval methods and information filtering was performed. A survey discussing filtering and user profiling techniques as well as commercial information filtering applications was compiled. Even though prominent in on-line retail shopping, personalization and efficient interactive user profiling were found not to have grown to their full potential in that domain. (E. Kutschinski, J.A. La Poutré)

To explore the potential of active profiling by example in information filtering, selective sampling for text classification was further investigated. This work focused on so-called 'committee-based' sampling methods. In particular, a technique to create more robust homogeneous committees was developed, and a novel approach of using several different classifier types within one committee for selective sampling was examined. These mixed committees perform significantly better in terms of learning speed and classification performance than any of the individual classifiers. (E. Kutschinski, J.A. La Poutré)

In addition, research started on the problem of how economical principles, in combination with certain machine learning techniques, can facilitate the sales of information goods. (D.J.A. Somefun, J.A. La Poutré, D.D.B. van Bragt)

Other Activities

Based on the above research activities, the theme group also participates (as coordinator/initiator) in the ICES/KIS-III expression of interest 'Adaptive Intelligent Systems for Health Care (I-CARE)', for designing agent systems and intelligent systems for e-health applications; and it furthermore became a member of the foundation SNN (Stichting Neurale Netwerken).

PhD Thesis

P.J. 'T HOEN (2001). *Towards Distributed Development of Large Object-Oriented Models. Views of Packages as Classes.* October 25 at Leiden University. Thesis advisor: Prof. dr. G. Engels.

Knowledge Transfer

- Participation in the Trade Agents project (Autonomous Systems of Trade Agents in E-Commerce), a project together with TNO, and with the companies ING and KPN, funded by the Telematics Institute.
- The Trade Agents project was represented at the Dutch ICT knowledge congress, The Hague, September 6–7.
- J.A. La Poutré gave a lecture on trading agents and innovative concepts in e-commerce at the Dutch ICT knowledge congress, The Hague, September 6–7.
- D.D.B. van Bragt gave a lecture at 'CWI in Bedrijf' on research performed within the Trade Agents project, CWI, Amsterdam, October 5.

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

- *2nd Workshop on Economic Dynamics (CeNDEF '2001)*, Amsterdam, January 4–6: D.D.B. van Bragt (*Evolving Automata Negotiate with a Variety of Opponents*), J.A. La Poutré (*The Influence of Fairness in Multi-Issue and Multi-Stage Bargaining: An Evolutionary Simulation*).
- *Working visit Dresdner Kleinwort Wasserstein*, London, UK, February 26–March 3 and October 1-5: J.K. Hoogland, C.D.D. Neumann.
- *Brussels Evolutionary Algorithms Day 2001, the 2nd Belgian/Dutch PhD workshop on EAs*, Free University Brussels, Brussels, Belgium, May 28: F. Alkemade (*Agent-based Computational Economics*), M.B. de Jong (*Multi-objective Coordination Between Quality-of-Service Management Agents*), J.A. La Poutré.
- *Working visit KPN Research*, Leidschendam, 15 March: J.K. Hoogland, C.D.D. Neumann.
- *International Conference on Cognitive and Neural Systems*, Boston, USA, May 30–June 2: S. Bohté (*Learning in Spike-Time Encoded Neural Networks*).
- *Working visit Brandeis University*, Boston, USA (E.D. de Jong), June 3: S. Bohté (*Neural Information Processing with Spiking neurons*).
- *Workshop on Economics with Heterogeneous Interacting Agents (WEHIA '2001)*, Maastricht, June 7–9: F. Alkemade (*Heterogeneous, Boundedly Rational Agents in the Cournot Duopoly*), J.A. La Poutré.
- *Workshop on Evolutionary and Computational Ideas in Economics and Organizations*, Odense, Denmark, June 8: D.J.A. Somefun (*Posted Offer versus Bargaining – An Example of how Institutions can Facilitate Learning*).

- *Working visit Ecole Polytechnique*, Paris, France, June 18–19: J.K. Hoogland, C.D.D. Neumann (*Converting the Reset*).
- *7th International Conference on Computing in Economics and Finance (CEF '2001)*, New Haven, USA, June 28–30: D.D.B. van Bragt (*Evolving Automata Negotiate with a Variety of Opponents*), D.J.A. Somefun (*Posted Offer versus Bargaining – An Example of how Institutions can Facilitate Learning*).
- *Genetic and Evolutionary Computation Conference (GECCO '2001)*, San Francisco, USA, July 7–11: D.D.B. van Bragt (*Generating Efficient Automata for Negotiations – An Exploration with Evolutionary Algorithms*).
- *Infonomics Workshop on Electronic Market Design*, Maastricht, July 11–13: E.H. Gerding, J.A. La Poutré.
- *1st Workshop on Efficient Algorithms*, Riga, Latvia, August 24–25: R. van Stee (*Optimal On-line Flow Time with Resource Augmentation*).
- *26th International Symposium on Mathematical Foundations of Computer Science (MFCS '2001)*, Mariánské Lázně, Czech Republic, August 26–31: R. van Stee (*Lower Bounds for Online Single-Machine Scheduling Problems*).
- *Working visit Leiden University*, Leiden (B. Bakker), September 24: S. Bohté (*Neural Information Processing with Spiking Neurons: Counting on the Single Spike*).
- *ERCIM E-Commerce Workshop*, Zurich, Switzerland, October 3: J.A. La Poutré.
- *Adaptive Agents, Intelligence and Emergent Human Organization: Capturing Complexity through Agent-Based Modeling*, Arthur M. Sackler Colloquium of the National Academy of Sciences, Irvine, CA, October 4–6: F. Alkemade, D.J.A. Somefun.
- *Working visit Dresdner Bank*, London, UK, October 5–10: C.D.D. Neumann.
- *5th European Workshop on Reinforcement Learning (EWRL-5)*, Utrecht, October 5–6: M.B. de Jong.
- *Working visit University of Colorado*, Boulder, USA, October 12: S. Bohté (*Neural Information Processing with Spiking Neurons: Counting on the Single Spike*).
- *3rd ACM Conference on Electronic Commerce (EC '01)*, Tampa, USA, October 15–17: S. Bohté (*Competitive Market-Based Allocation of Consumer Attention Space*), E.H. Gerding, J.A. La Poutré.
- *13th Belgium-Dutch Artificial Intelligence Conference (BNAIC '2001)*, Amsterdam, October 25–26: F. Alkemade (*Heterogeneous, Boundedly Rational Agents in the Cournot Duopoly*), J.A. La Poutré.
- *Working visit University of Nijmegen*, Nijmegen, November 21: S. Bohté (*Neural Information Processing with Spiking Neurons: Counting on the Single Spike*).
- *Digitisation of Commerce: e-Intermediation (DoC:e-I)*, Infonomics/Merit Workshop, Maastricht, November 23–24: F. Alkemade.
- *Working visit University of Twente*, Enschede, December 3: C.D.D. Neumann.
- *Winterschool on Mathematical Finance*, Oegstgeest, December 17–19: J.K. Hoogland (*Symmetries in Jump-Diffusion Models with Applications in Option Pricing and Credit Risk*).
- *Working visit Italian National Research Concil (CNR)*, Rome, Italy, December 18–21 (R. Conte, M. Missikoff): E.H. Gerding (*Market-Based Allocation of Attention Space*).
- *11th Belgian-Dutch Conference on Machine Learning (BENELEARN '2001)*, Antwerp, Belgium, December 21: D.D.B. van Bragt (*Coevolving Automata Negotiate with a Variety of Opponents*).

Memberships of Committees and Other Professional Activities

J.A. La Poutré:
- Appointed as part-time professor at the School of Technology Management (Capacity Group Information and Technology), Eindhoven University of Technology, Eindhoven.
- Member of the Editorial Board of *Netnomics*, Journal for internet economics and e-commerce; Kluwer Academic Publishers.
- Member of the Editorial Board of *e-JEMED*, the Electronic Journal of Evolutionary Modeling and Economic Dynamics, a new electronic journal (http://www.e-jemed.org/).
- Member of PhD thesis committee of B.H.P.J. Vermeer, Eindhoven University of Technology, April 9.

Visitors

- Dr. L. Epstein, The Interdisciplinary Center, Herzliya, Israel, March 1.
- Drs. B. Bakker, Leiden University, Leiden, March 22.

- The researchers of the CeNDEF centre (Prof. dr. C. Hommes), Faculty of Economics and Econometrics, University of Amsterdam, April 12. (CeNDEF: Centre for Non-linear Dynamics in Economics and Finance.)
- Dr. W.B. Langdon, University College, London, UK, May 17–18.
- Dr. S. Seiden, Louisiana State University, Baton Rouge, USA, June 12.
- K.N. Kannan, MSc, Carnegie Mellon University, Pittsburgh, USA, November 22.
- Dr. C. Jonker, Free University, Amsterdam, November 26.

Software Developed

- Within the Trade Agents project, a demonstrator/visualisor for competitive market-based distribution of consumer attention space (KPN business case) was developed. Also, a prototype agent system was implemented for this case.
- A new website for the Trade Agents has been constructed (http://www.cwi.nl/projects/ASTA/).
- Java software for evolutionary computing and dynamic pricing.

Papers in Journals and Proceedings

F. Alkemade, J.A. La Poutré (2001). Heterogeneous, Boundedly Rational Agents in the Cournot Duopoly. *Proceedings of the 13th Belgian-Dutch Conference on Artificial Intelligence* (BNAIC '2001), Amsterdam, 21–22.

S.M. Bohté, J.A. La Poutré, J.N. Kok (2001). Learning in Spike-Time Encoded Neural Networks. *Proceedings of the 5th International Conference on Cognitive and Neural Systems*, Boston, USA.

S.M. Bohté, E.H. Gerding, J.A. La Poutré (2001). Competitive Market-Based Allocation of Consumer Attention Space. *Proceedings of the 3rd ACM Conference on Electronic Commerce (EC '01)*, Tampa, USA, 202–205.

D.D.B. van Bragt, J.A. La Poutré (2001). Generating Efficient Automata for Negotiations – An Exploration with Evolutionary Algorithms. *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO '2001)*, San Francisco, USA, Morgan Kaufmann Publishers, 1093.

D.D.B. van Bragt, C.H.M. van Kemenade, J.A. La Poutré (2001). The Influence of Evolutionary Selection Schemes on the Iterated Prisoner's Dilemma. *Computational Economics* **17**(2/3), 253–263.

D.D.B. van Bragt, J.A. La Poutré (2001). Co-evolving Automata Negotiate with a Variety of Opponents. *Proceedings of the 11th Belgian-Dutch Conference on Machine Learning (BENELEARN '2001)*, Antwerp, Belgium, 77–84.

L. Epstein, R. van Stee (2001). Lower Bounds for On-Line Single-Machine Scheduling. *Proceedings of the 26th International Symposium on Mathematical Foundations of Computer Science (MFCS '2001)*, Mariánské Lázně, Czech Republic, Lecture Notes in Computer Science, LNCS **2136**, Springer Verlag, 338–350.

L. Epstein, R. van Stee (2001). Optimal On-Line Flow Time with Resource Augmentation. *Proceedings of the 13th International Symposium on the Fundamentals of Computation Theory (FCT '2001)*, Riga, Latvia, Lecture Notes in Computer Science, LNCS **2138**, Springer Verlag, 472–482.

J.K. Hoogland, C.D.D. Neumann (2001), Local Scale Invariance and Contingent Claim Pricing. *International Journal of Theoretical and Applied Finance* **4**(1), 1–21.

J.K. Hoogland, C.D.D. Neumann (2001), Local Scale Invariance and Contingent Claim Pricing II: Path-Dependent Contingent Claims. *International Journal of Theoretical and Applied Finance* **4**(1), 23–43.

R. van Stee, J.A. La Poutré (2001). Running a Job on a Collection of Dynamic Machines, with On-Line Restarts. *Acta Informatica* **37**(10), 727–742.

R. van Stee, J.A. La Poutré (2001). Partial Servicing of On-Line Jobs. *Journal of Scheduling* **4**(6), 379–396.

CWI Reports

The following CWI reports were published by members of theme SEN4. See page 43 for the complete titles of the reports.

SEN-R0103	SEN-R0104	SEN-R0108
SEN-R0131	SEN-R0132	SEN-R0133

Other Publications

For the Trade Agents project, a sequence of deliverables was produced. Several of these are alrea-

dy occurring in the above publication list and in the software list below. We mention some of the other deliverables next.

A patent request was submitted (for CWI and KPN) at the European Patent Office, for a patent on 'Competitive Market-Based Allocation of Consumer Attention Space.'
Resulting from work in the Trade Agents project.

E. Kutschinski, J.A. La Poutré (2001). *Scientific Techniques for Interactive Profiling.* Deliverable for the Trade Agents project.

D.D.B. van Bragt, D.J.A. Somefun (2001). *A Robust Dynamic Pricing Algorithm: The Adaptive Step-Size Derivative Follower.* Deliverable for the Trade Agents project.

D.D.B. van Bragt, J.A. La Poutré (2001). *Evolving Automata Negotiate with a Variety of Opponents – II.* Deliverable for the Trade Agents project.

P.J. 't Hoen, S. Bohté, E. Gerding, H. La Poutré (2001). *Implementation of a Competitive Market-based Allocation of Consumer Attention Space.* Deliverable for the Trade Agents project.

MODELLING, ANALYSIS AND SIMULATION

General Overview

Modelling, analysis and simulation are the three pillars of the contemporary exact sciences. Cluster MAS concentrates on Partial Differential Equations (PDEs). In 2001, our research was organized in two related themes:

- MAS1 - Applied Analysis and Scientific Computing for PDEs
- MAS2 - Computational Fluid Dynamics

The expertise includes applied analysis, fluid dynamics, numerical analysis and scientific computing. Two small-sized activities concern asymptotics and special functions and computational number theory.

The ongoing trends in computer hardware have brought desktop performance in the gigaflop range, which will further increase the demand for advanced modelling, analysis and simulation with applied and computational mathematics at the centre of interest. Our aim is to hold a strong position in these rapid 'computational science' developments. This requires a balance between long lasting discipline oriented research and an enduring attention for applications. For that purpose a considerable part of our research is application driven. Applications for MAS research are numerous and are found everywhere in physics, life-, geo- and environmental sciences, in engineering and in many industrial and technological fields. The theme reports below give many interesting examples.

Application driven mathematical research requires extensive contacts with technological institutes, government laboratories and industry. The theme reports list a wide variety of specific contacts and funded projects. For the greater part, our external financial support is obtained from ICES-KIS2, different NWO programs such as Computational Science, STW, 'Wiskunde Toegepast', NCF and FOM, and different EU projects.

Discipline oriented research requires extensive contacts and joint work with university researchers. These are also found in the theme reports. Furthermore, Profs. P.W. Hemker and J.G. Verwer hold a part-time position as professor of numerical analysis at the UvA, Dr. B. Koren holds a part-time position as associate professor (UHD) at the Faculty of Aerospace Engineering of TU-Delft, and Dr. M.A. Peletier holds a part-time position as associate professor (UHD) in applied analysis at the TUE. Advisers to MAS from universities are Prof. J. Hulshof (VU) for mathematical analysis, Profs. O. Diekmann (UU) and H.V. Westerhoff (VU) for life-science applications, and Profs. P. Wesseling (TUD) and B. van Leer (University of Michigan) for computational fluid dynamics.

End of 2001, Prof. P.W. Hemker has got the honorary status of CWI fellow. As of 2002 he will be succeeded as theme leader for MAS2 by Dr. B. Koren. End of 2001 it has also been decided to promote the subtheme MAS1.4 on 'Pattern Formation and Low Temperature Plasmas' to a pilot theme MAS3 beginning in 2002. This new pilot theme has been named 'Nonlinear dynamics and complex systems' and will be headed by Prof. dr. U.M. Ebert.

N.M. Temme (0.2 fte) has served as CWI contact person for Dutch Research Schools and has organized the general CWI Scientific Meetings.

J. Kok (0.4 fte) has provided general computer support within MAS and has acted as CST contact person. He has also been the organizing secretary of the Annual Dutch Numerical Mathematics (Woudschoten) Conference.

P.M. de Zeeuw (0.1 fte) has served as secretary for the 'Werkgemeenschap Numerieke Wiskunde'.

J. de Vries (0.4 fte) has done library work for MAS and has pursued research on linearization of G-spaces and dynamical systems. He has submitted his introductory book (Dutch) on dynamical systems to Epsilon Uitgaven. For 0.6 fte he was seconded at the VU for giving courses on linear algebra and dynamical systems.

Staff

- Staff directly managed by cluster leader

  - N.M. Temme (0.2 fte; 0.8 at MAS1)
  - J. de Vries (0.4 fte; 0.6 at VU)
  - P.M. de Zeeuw (0.1 fte; 0.9 at PNA4)

- Applied Analysis and Scientific Computing for PDEs – MAS1

  - J.G. Verwer
  - M. Arrayás Chazeta
  - P.J.F. Berkvens
  - J.G. Blom
  - M.A. Botchev
  - C.M Cuesta
  - O. Diekmann
  - C.J. van Duijn
  - U.M. Ebert
  - J.E. Frank
  - I.A. Guerra Benavente
  - J. Hulshof
  - W.H. Hundsdorfer
  - J. Kok
  - J.K. Krottje
  - D. Lanser
  - B. Lastdrager
  - B.J. Meulenbroek
  - C.S. Montijn
  - M.A. Peletier
  - R. Planqué
  - A. Rocco
  - P.B. Rodin
  - D. Sijacic
  - B.P. Sommeijer
  - N.M. Temme
  - R. Vidunas
  - J. Wensch
  - H.V. Westerhoff

- Computational Fluid Dynamics – MAS2

  - P.W. Hemker
  - D.P.L.D. Benden
  - E.H. van Brummelen
  - S. Cavallar
  - G.F. Duivesteijn
  - M. Genseberger
  - J. Kok
  - B. Koren
  - B. Lastdrager
  - M.R. Lewis
  - W.A. Mulder
  - M. Nool
  - D.E.A. van Odyck
  - M.H. van Raalte
  - H.J.J. te Riele
  - L. Voort
  - P. Wesseling

- Secretaries:

  - N. Mitrovic (until September)
  - S.J. van Dam (from September)

CWI Reports

MAS-R0101. P.W. Hemker, G.I. Shishkin, L.P. Shishkina. *High-order time-accurate schemes for parabolic singular perturbation problems with convection.*

MAS-R0102. J.E. Frank, S. Reich. *A particle-mesh method for the shallow water equations near geostrophic balance.*

MAS-R0103. E.H. van Brummelen, H.C. Raven, B. Koren. *Efficient numerical solution of steady free-surface Navier-Stokes flow.*

MAS-R0104. C. Cuesta, J. Hulshof. *A model problem for unsaturated porous media flow with dynamic capillary pressure.*

MAS-R0105. J. Huisman, M. Arrayás, U.M. Ebert, B.P. Sommeijer. *How do sinking phytoplankton species manage to persist?*

MAS-R0106. H.J.J. te Riele. *On the size of solutions of the inequality* $\phi(ax+b) < \phi\,(ax)$.

MAS-R0107. R.P. Brent, P.L. Montgomery, H.J.J. te Riele. *Factorizations of Cunningham numbers with bases 13 to 99: millennium edition.*

MAS-R0108. U.M. Ebert, M. Arrayás, N.M. Temme, B.P. Sommeijer, J. Huisman. *Critical conditions for phytoplankton blooms.*

MAS-R0109. A. Rocco, J. Casademunt, U.M. Ebert, W. van Saarloos. *The diffusion coefficient of propagating fronts with multiplicative noise.*

MAS-R0110. P.B. Rodin, U.M. Ebert, W.H. Hundsdorfer, I.V. Grekhov. *Superfast fronts of impact ionization in initially unbiased layered semiconductor structures.*

MAS-R0111. J.E. Frank, S. Reich. *Conservation properties of smoothed particle hydrodynamics applied to the shallow water equations.*

MAS-R0112. B. Koren, M.R. Lewis, E.H. van Brummelen, B. van Leer. *Riemann-problem and level-set approaches for two-fluid flow computations; I. Linearized Godunov scheme.*

MAS-R0113. B. Koren, M.R. Lewis, E.H. van Brummelen, B. van Leer. *Riemann-problem and level-set approaches for two-fluid*

flow computations; II. Fixes for solution errors near interfaces.

MAS-R0114. A. Gil, J. Segura, N.M. Temme. *Evaluation of the modified Bessel function of the third kind of imaginary orders.*

MAS-R0115. D. Lanser. *A comparison of operator splitting and approximate matrix factorization for the shallow water equations in spherical geometry.*

MAS-R0116. R. Vidunas, N.M. Temme. *Symbolic evaluation of coefficients in Airy-type asymptotic expansions.*

MAS-R0117. A. Gil, J. Segura, N.M. Temme. *Computing complex Airy functions by numerical quadrature.*

MAS-R0118. W.H. Hundsdorfer, J.G. Verwer. *On the convergence analysis of advection-diffusion schemes on non-uniform grids.*

MAS-R0119. C.J. van Duijn, I.A. Guerra, M.A. Peletier. *Global existence conditions for a non-local problem arising in statistical mechanics.*

MAS-R0120. M. Arrayás, U.M. Ebert, W.H. Hundsdorfer. *Spontaneous branching of anode-directed streamers between planar electrodes.*

MAS-R0121. P.B. Rodin, U.M. Ebert, W.H. Hundsdorfer, I.V. Grekhov. *Tunneling-assisted impact ionization fronts in semiconductors.*

Applied Analysis and Scientific Computing for PDEs – MAS1

Staff

- Prof. dr. J.G. Verwer, cluster and theme leader
- Dr. M. Arrayás Chazeta, until August 31, postdoc (EU)
- Dr. P.J.F. Berkvens, postdoc (NWO)
- Drs. J.G. Blom, researcher
- Dr. M.A. Botchev, until January 14, postdoc (NWO)
- C.M. Cuesta MSc, until October 31, PhD student (NWO)
- Prof. dr. O. Diekmann, advisor (UU)
- Prof. dr. ir. C.J. van Duijn, PhD supervisor (TUE)
- Prof. dr. U.M. Ebert, researcher, subtheme leader
- Dr. J.E. Frank, postdoc (CWI/GMD)
- I.A. Guerra Benavente MSc, PhD student
- Prof. dr. J. Hulshof, advisor and PhD supervisor (VU)
- Dr. W.H. Hundsdorfer, researcher
- Drs. J. Kok, programmer and general support
- Ir. J.K. Krottje, from April 1, PhD student (NWO)
- Ir. D. Lanser, PhD student, until November 30 (NWO)
- Drs. B. Lastdrager, PhD student (NWO)
- Drs. B.J. Meulenbroek, from November 1, PhD student
- Ir. C.S. Montijn, from October 1, PhD student (NWO)
- Dr. M.A. Peletier, researcher
- Drs. R. Planqué, PhD student
- Dr. A. Rocco, from September 1, Postdoc (CWI/FOM)
- Dr. P.B. Rodin, 5-month guest researcher (CWI/FOM)
- D. Sijacic MSc, PhD student (FOM)
- Dr. B.P. Sommeijer, researcher
- Dr. N.M. Temme, researcher
- Dr. R. Vidunas, until October 31, postdoc (NWO)
- Dr. J. Wensch, 3-month guest researcher
- Prof. dr. H.V. Westerhoff, advisor (VU)

Scientific Report

The mathematical research within this theme deals with partial differential equations, applied and numerical analysis, modelling and scientific computing. An activity of limited size is asymptotics for special functions. The nature of the projects ranges from fundamental to practical with a considerable part application driven. In 2001 the research was organized in four subthemes:

Atmospheric flow and transport problems – MAS1.1

This subtheme is entirely numerical and concerns the development of new, tailored algorithms for large-scale PDEs from atmospheric air pollution modelling and circulation. In previous years substantial effort has been devoted to these subjects. With the completion of the PhD thesis of Lanser, the expiration of the joint CWI-GMD project of Frank, and the expiration of the joint CWI-IMAU project of Botchev and Berkvens (March 1, 2002), it has been decided to terminate our atmospheric activities beginning 2002. During 2001 we have

still worked on four projects and Verwer, Hundsdorfer and Blom have published a long survey paper in *Surveys on Mathematics for Industry* on numerical time integration for air pollution models (preprint is report MAS-R9825). Lanser and Botchev both succeeded in getting a position (Universitair Docent) at the University of Twente.

(1) Transport modelling
In this 'NWO Wiskunde Toegepast' project we have developed advection and zooming algorithms (local refinement) for TM3 and its successor TM5. These are global atmospheric dispersion models in use by KNMI and IMAU and other European atmospheric institutes. The expiration date of this project is March 1, 2002. The final part of the work, parallelization on the SARA computer, will be completed by IMAU (Institute for Marine and Atmospheric Research, University of Utrecht), partner in this project. The report MAS-R0023 by Berkvens, Botchev, Krol, Peters and Verwer presenting an algorithm for the columnwise solution of vertical transport and chemistry has been accepted for publication in a *Proceedings of the IMA*, Minneapolis. The report MAS–R0031 by Botchev and Verwer on approximate matrix factorization has been revised for the *Journal of Computational and Applied Mathematics*.

(2) Circulation modelling
The second project concerns atmospheric circulation and is the PhD project of Lanser. The focus was on grid-point models using grid resolutions far beyond existing ones used in spectral models. This activity has been terminated December 1 at the departure of Lanser to the University of Twente (PhD defense at the University of Amsterdam, March 7, 2002). In 2001, Lanser has finished Report MAS-R0115 on operator splitting and approximate matrix factorization for the shallow water equations in spherical geometry. A report handling similar issues for a more realistic 3D model will be finished in Twente. She published, with Blom and Verwer, her report MAS-R0021 on time stepping issues for shallow water problems in the *Journal of Computational Physics*. Co-operative contacts were maintained with KNMI and NCAR (Boulder).

(3) Numerical atmospheric dynamics
The CWI/GMD joint research on numerical atmospheric dynamics was concluded in 2001. The research was carried out by Frank in co-operation with Imperial College of London. Three publications considering geometric properties of Lagrangian and semi-Lagrangian methods were prepared. The first of these considered a particle-mesh method for balanced atmospheric flows, incorporating advection field smoothing, and appeared as Report MAS-R0102. In the second publication (MAS-R0111) a circulation theorem for the smooth particle hydrodynamics (SPH) method was proven. In the third publication, a grid was used to effect global basis functions for the SPH method such that the resulting scheme preserved the Hamiltonian structure of the shallow water equations (submitted to the proceedings of the *International Workshop Meshfree Methods for Partial Differential Equations*, held in Bonn, September 11–14). The research on geometric methods and PDEs will be continued by Frank in 2002, amongst others in connection with biological problems.

Analysis, Asymptotics and Computing – MAS1.2
This subtheme has a strong applied analysis bias. Two PhD projects, from Cuesta and Guerra, still emanate from the subtheme 'PDEs in Porous Media Research' that was terminated August 2000. Both projects will be finished in 2002.

(1) Interacting stellar structures
A new topic as part of the PhD research of Guerra concerns the evolution of the density and temperature of a three-dimensional cloud of self-interacting particles. This phenomenon is modelled by a parabolic equation for the density distribution combining temperature-dependent diffusion and convection driven by the gradient of the gravitational potential. This equation is coupled with Poisson's equation for the potential generated by the density distribution. The system preserves mass by imposing a zero-flux boundary condition. Finally the temperature is fixed by energy conservation, that is, the sum of kinetic energy (temperature) and gravitational energy remains constant in time. This model is thermodynamically consistent, obeying the first and the second law of thermodynamics. Van Duijn, Guerra, and Peletier have proved (MAS-R0119) local existence and uniqueness of weak solutions for the system, using a Schauder fixed-point theorem. In addition, sufficient conditions were derived for global in time existence and

blow-up for radially symmetric solutions, using a comparison principle for an equation for the accumulated radial mass.

(2) Groundwater flow with dynamic capillary pressure
Modelling vertical non-steady groundwater flow with dynamic capillary pressure, leads to a peculiar nonlinear diffusion-convection equation, viz., one extended with a nonlinear third order term with two space derivatives and one time derivative. Cuesta (PhD research) and Hulshof (supervisor, VU) have considered the special case in which the original equation is the Burgers' equation and the third order term is linear. They have investigated stability of travelling wave solutions of the resulting pseudo-parabolic Burgers' equation, first by integral estimates and then by linear stability analysis. This study is extended with numerical analysis with special emphasis on the large time behaviour of the Cauchy problem. Depending on the initial data the solution converges to a self-similar source type solution, a rarefaction wave or a travelling wave. Results are found in MAS-R0104. Currently Cuesta is finishing her PhD research at the VU under supervision of Prof. Hulshof.

(3) Asymptotics and special functions
Vidunas and Temme examined error bounds for remainders in asymptotic expansions of parabolic cylinder functions (MAS-R0116). Temme and López (Pamplona) submitted a paper on expanding analytic functions in a two-point Taylor series. The methods will be used in a new type of asymptotic expansion of certain orthogonal polynomials. With Gil and Segura (Madrid) Temme wrote a report on the numerical aspects of modified Bessel functions with purely imaginary order and on complex Airy functions (MAS-R0114). Also new activities started on numerical computations of complex inhomogeneous Airy functions. Furthermore, Temme wrote revisions of three chapters for the new edition of the *Handbook of Mathematical Functions* (Abramowitz and Stegun) and participated in the editorial board of this international project.

(4) Numerical integration
The main activity on this topic has been the progress on the book 'Numerical Solution of Advection-Diffusion-Reaction Equations' by Hundsdorfer and Verwer. Completion is expected in 2003. In collaboration with Ruuth and Spiteri (Vancouver), monotonicity properties of multistep schemes have been studied by Hundsdorfer. Results for nonlinear problems were obtained for methods of BDF and Adams type, which were thus far not covered by a proper monotonicity theory. This research will be reported in 2002. Hundsdorfer and Verwer studied basic properties of spatial discretizations for advection-diffusion problems on nonuniform grids (MAS-R0118). New results were obtained on supra-convergence of numerical schemes with vertex-centered and cell-centered formulations.

Applications from the life sciences – MAS1.3
This topic is still relatively new within MAS. It was started in the course of 1999 and has now reached a reasonable size. Here the emphasis is on analytical and numerical analysis of PDEs from biology.

(1) Neurobiology: modelling of axon growth
In collaboration with NIH (Netherlands Institute for Brain Research, KNAW), we started in April of 2001 with an 'NWO Wiskunde Toegepast' PhD project on this subject. The new PhD student is J.K. Krottje. Within this project, Krottje will continue and extend earlier work of Lastdrager, see Item 7 of MAS1.3 below. The research concerns a mathematical model for outgrowth of axons from neurons in the nervous system and focuses on numerical methods for this model. The model in use at this moment comprises a set of parabolic PDEs coupled with gradient equations. First investigations of Krottje deal with maintenance of important analytical solution properties (bundling and debundling) in a numerical discretization. A first report by Krottje is in preparation.

(2) Cell biology: the ICES project
Within the framework of the ICES-KIS2 programme, Blom and Peletier have examined a mathematical model that measures the influence of spatial effects on the metabolism of a cell. Mathematically this leads to a system of PDEs of the reaction-diffusion type. In collaboration with molecular cell biologists from SILS (the Swammerdam Institute for Life Sciences, Univ. of Amsterdam) and IMBW (the Institute for Molecular Biological Sciences of the Vrije Universiteit), extensive numerical experiments have been done for the phosphotransferase system (PTS). Two joint papers for submission to biochemistry journals are in preparation.

(3) Cell biology: the silicon cell
This project is related to the above ICES project. Here the research is conducted within the framework of the Silicon Cell Consortium, which is a joint effort of research groups from IMBW, SILS, IvI (Institute for Informatics, Univ. of Amsterdam) and CWI. The long-term goal of the Consortium is the computation of Life at the cellular level. In 2001, Blom and Peletier started at CWI the investigation of a class of continuum models of lipid bilayers. Models of this type will be essential parts of the envisaged complete-cell simulation. These models are based on equations for block copolymer melts, and more specifically on the mesoscopic dynamics framework of Fraaije and co-workers from the University of Leiden. The idea is that the state of the system is given by the densities of specific parts of the lipids and of the solvent. The evolution of the system is driven by an advection field which is determined by solving a minimization problem involving the probability densities of the microscopic components. The model takes the form of a parabolic system of PDEs with a computationally expensive nonlocal component involving integrals of high dimension. For the one-dimensional simplification, numerical and analytical results have been derived. A publication is in preparation.

(4) Cell biology: rods and DNA
In bacteria, DNA is present in closed loops with a torsional loading (the link number is non-zero). As a result these loops twist into the knot-like structures that are well known from telephone cords. Various numerical simulations have provided insight in the relationship between the imposed link number and the resulting three-dimensional form; eventually we will investigate this analytically. In preparation of the full three-dimensional problem, Peletier and Planqué (PhD research) are concentrating on a model problem of lower dimension: a twisted rod that is forced to lie on a cylinder. Planqué has also spent part of his time on revising a manuscript from his master thesis on defence strategies against cuckoo parasitism. This manuscript, joint with Britton, Franks and Peletier, has been submitted to the *Bulletin of Mathematical Biology*.

(5) Aqueous biology: biofilm problems
An EU-funded project called BIOFILMS started in 2000 and will last until 2003. In this project, co-ordinated by the Aquatic Ecology and Ecotoxicology-group of the Univ. of Amsterdam, several European partners study different aspects of biofilms. A biofilm is a thin layer composed of micro-algae, bacteria and their mucus and occur in all natural rivers and lakes. There is a major interest from drinking-water companies, since they have to prepare drinking water from surface water, which is often of moderate quality. Biofilms upstream the water plant can be exploited to regulate organic matter content in the water. The study of this aspect is the main object of the project. The participation of CWI (Peletier and Sommeijer) concerns the mathematical modelling of biofilms. For that purpose, an existing software package (AQUASIM) has been used and adapted so as to simulate the growth of a biofilm composed of multiple algae compartments together with bacteria.

(6) Microbiology: phytoplankton models
In 2000, joint research was started with J. Huisman of the research group Aquatic Microbiology from the Institute of Biodiversity and Ecosystems Dynamics, Univ. of Amsterdam. This collaboration was extended in 2001 and will be continued in the coming years through a PhD project granted by the Computational Science Program (NWO). In this joint research, the dynamics of phytoplankton species is studied. Special emphasis is placed on the role that mixing rates (diffusion), vertical velocity (advection by sinking or buoyancy), and water column depth play in the model. It turns out that some parameter combinations yield a vanishing population, whereas relatively small changes in these values lead to a situation where a population can be sustained (so-called bloom). In MAS-R0108 (published in *Bulletin of Mathematical Biology*), Ebert, Arrayás, Temme, Sommeijer, and Huisman derive analytical expressions for the critical values that separate the bloom/no-bloom regions in the parameter space. The special role of sinking phytoplankton species and their ability to persist, is described in MAS-R0105 (to appear in *The American Naturalist*). Sinking phytoplankton take up CO_2 from the atmosphere, transfer it into the deep ocean (the so-called 'export production'), and hence play a vital role for the greenhouse effect. A further study by Huisman and Sommeijer concerns the influence of the turbidity on the export production in stratified waters. It is shown that the maximal vertical velocity that can be sustained is inversely proportional to the turbidity of the water. Results have been submitted to

Limnology and Oceanography and will also appear in a MAS report in 2002. Finally, we started to consider competition models. First results were presented at the NIOZ-conference and submitted to *J. Sea Research* (also to appear as MAS-R0201).

(7) Sparse grid methods
This subject concerns the PhD research of Lastdrager on 'Sparse Grid Methods and Time Integration' and is in the final stage (PhD defense at the University of Amsterdam early 2002). In 2001, Lastdrager has applied the sparse-grid technique to a set of parabolic PDEs coupled with gradient equations, which is a simple model for axon growth in brain tissue. He concluded that sparse grid methods offer no significant improvement over single grid methods. Thereafter he has continued his investigations on this axon growth model with a study on time integration by means of a linearly implicit Rosenbrock method. This work has resulted in a very insightful treatment of sources with very small support, close to point sources. A MAS report is in preparation. It has also delivered instructive comparison results with the explicit Runge-Kutta-Chebyshev method examined for this model by Verwer and Sommeijer in MAS-R0001. These results will be used to advantage in subsequent work by Krottje, see the first item of MAS1.3. This year, Lastdrager has also published his joint reports MAS-R9930/R0025 with Koren and Verwer in the journals *Appl. Numer. Math.* and *J. of Comp. Meth. in Appl. Math.*, respectively.

(8) NCF project
During his 3-month visit to CWI, Dr. J. Wensch (Univ. of Halle) studied with Sommeijer a parallel numerical implementation of the mixed parabolic-gradient system mentioned in the first item of MAS1.3 (the axon model). The research was carried out as part of an NCF funded project. The parallel computer has been the SARA Terasmachine. The numerical algorithms were based on J.G. Verwer and B.P. Sommeijer, A numerical study of mixed parabolic-gradient systems, *J. Comp. Appl. Math.* 132, 191–210, 2001. A report on this NCF project is in progress and will appear early 2002.

Pattern formation and low temperature plasmas – MAS1.4
The subtheme MAS1.4 started in 2000. It continued to grow in 2001, and will be continued as the new pilot theme MAS3 'Nonlinear Analysis and Complex Systems' in 2002 and headed by Dr. U. Ebert. The first postdoc of the group, Dr. Manuel Arrayás, finished his contract and succeeded in finding a tenure track position as assistant professor at University Juan Carlos II in Madrid. A new postdoc Dr. Andrea Rocco and two PhD students, Carolynne Montijn and Bernard Meulenbroek have joined. Danijela Sijacic has continued her PhD work, and Dr. Pavel Rodin stayed as a guest for a total of 5 months in 2001. Ebert and Arrayás contributed to the phytoplankton modelling project of subtheme MAS1.3 discussed above. Within MAS1.4 the following investigations were continued or started:

(1) Pulled fronts: a basic issue in nonlinear analysis
The research on pulled fronts of the past years found recognition by a number of invitations of Ebert, including an invited talk at the Sixth SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah in May. Another form of recognition was the granting of a related research proposal of Hundsdorfer and Ebert on numerical techniques for pulled fronts by the FOM/NWO-program on Computational Science. Meanwhile, Carolynne Montijn started on Oct. 1 as a PhD student on this project. The results of the project will be used directly for the numerical study of streamer discharges, see below. Research papers of the group during the past year dealt with the influence of noise on pulled fronts, see CWI report MAS-R0109 by Rocco, Casademunt, Ebert and van Saarloos (accepted for publication in *Phys. Rev. E*). A related paper by Tripathy, Rocco, Casademunt and van Saarloos on a universality class of fluctuating pulled fronts was published this year in *Phys. Rev. Lett.* **86**, 5215. Dr. A. Rocco meanwhile has joined CWI as a postdoc, and now mainly concentrates on streamer discharges. Finally, report MAS-R0011 by Ebert, van Saarloos and Peletier (Univ. of Leiden) discussing universal algebraic convergence in time of pulled fronts as a common mechanism for difference-differential and partial differential equations, was revised and accepted in 2001 for publication in *Eur. J. Appl. Math.* in 2002.

(2) Discharges in general
The new research activities at CWI on pattern formation in electric discharges found broad

recognition: in the course of the year, Ebert presented the subject at three international and one national conference or workshop, in seminars at two German universities, at the Natuurkundig Colloquium in Eindhoven, and at CWI in Bedrijf. A popular paper on the subject appeared in *ERCIM News* **44**, 56–57.

(3) Streamers in gas discharges
The understanding of streamers in gas discharges based on own analysis and on simulations from the literature was published by Ebert and Arrayás as Pattern formation in Electric Discharges in Lecture Notes in Physics, Vol. 567, pp. 270–282 (preprint is CWI report MAS-R0028). The investigation got a new turn by an own simulation program that was written by Hundsdorfer, tested and evaluated by Arrayás, and further improved by Rocco and Meulenbroek. The simulations performed with higher electric fields than all previous ones in the literature showed a completely new transition: the streamer branched. This finding led to the CWI report MAS-R0120 by Arrayás, Ebert and Hundsdorfer (Spontaneous Branching of Anode-Directed Streamers between Planar Electrodes), and to a new set of analytical questions presently investigated by Rocco and Meulenbroek: can criteria for the onset of branching be given? What are the properties (width, degree of ionization etc.) of the newly emerging branches? Will streamers branch repeatedly? But streamer branching forms a challenge not only to analysis, but also to simulations and experiments: the present simulations assume cylindrical symmetry and hence are effectively 2-dimensional. However, the description of streamer branching requires truly 3-dimensional simulations. At the TU Eindhoven, a temporal resolution below 1 nanosecond can be reached for streamer photography. Experimental tests of the predictions are presently being planned.

(4) Streamer-like fronts in semiconductor switches
Fast high power semiconductor switches from the group of I. Grekhov at the Ioffe-Institute in St. Petersburg are widely used in power electro-engineering. Their mode of operation is streamer-like. The theoretical and simulational investigation of these switches has led to two preprints by Rodin, Ebert, Hundsdorfer and Grekhov. In CWI report MAS-R0110 (Superfast fronts of impact ionization in initially unbiased layered semiconductor structures), the presently available switches are described and an improvement is suggested. In the second preprint (Tunneling-assisted impact ionization fronts in semiconductors), a new type of faster switches based on an additional interaction is suggested. P. Rodin also presented the results in a talk at the Dynamics Days Europe 2001 in Dresden.

(5) Spontaneous pattern formation in DC 'barrier' discharges
In 2001, Sijacic and Ebert gained a thorough understanding of the stationary homogeneous solutions of the system, and set a start to the analysis of spontaneous homogeneous oscillations. The analysis of stationary self-sustained gas discharges in the range from Townsend to abnormal glow discharge in the full parameter space was missing in the literature. It will serve as a starting point for the analysis of the patterns. A first paper will be submitted in February 2002. Sijacic presented her results in four posters and two talks in 2001.

(6) Polymer dynamics
In the model of polymer reptation suggested and evaluated by Schäfer, Ebert and Baumgärtner in previous years, an essential step was still missing, namely the evaluation of the coherent scattering function, a standard observable in neutron scattering experiments. The calculation was performed in 2001. It can be found in the preprint *The coherent scattering function in the reptation model: analysis beyond asymptotic limits*, by L. Schäfer, U. Ebert, and A. Baumgärtner, submitted on January 5, 2002.

Organization of Conferences, Workshops, Courses, etc.

- P.M. de Zeeuw organized the minisymposium 'Numerieke Analyse' at the 37ste Nederlands Mathematisch Congres, VU, April 19–20.
- B.P. Sommeijer was involved in the course Parallel Scientific Computing & Simulation (UvA).
- M.A. Peletier organized the colloquium series 'Crossroads of Mathematics, Informatics and Life Sciences'.
- W. Hundsdorfer and J.G. Verwer organized the minisymposium 'Numerical Solution of Advection-Diffusion-Reaction Equations', SCICADE Conference, Vancouver, July 30 – August 3.
- W. Hundsdorfer and U. Ebert organized the MAS1-seminars.

- M.A. Peletier and U. Ebert are co-organizers of the seminar series 'Nonlinearity in Amsterdam' (UvA, VU, CWI), see `http://turing.wins.uva.nl/~alejan/nia.html`
- M.A. Peletier is co-organizer of the 42nd Europese Studiegroep Wiskunde met de Industrie (CWI and UvA).
- M.A. Peletier is co-organizer of Eurodiffusie (with Natuur & Techniek), see `http://www.wiskgenoot.nl/eurodiffusie/`
- M. Arrayás continued to organize the Capitán Araña Sessions aimed to stimulate scientific discussions and exchange between OIO's and postdocs at CWI until the end of his contract in August.
- Woudschoten Conference on Numerical Analysis. J. Kok is secretary of the organizing committee and actual organizer. J.G. Verwer is member of the organizing committee of the 2002 meeting.
- J.E. Frank is involved in the setup of an international working group for collective research in geometric integration (CoRGI), whose goal is to organize an annual conference, workshops and funding of PhD students and postdocs.

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

- Working visit to Université Paris-Sud, January 22–26: I.A. Guerra (*Asymptotic results for injection of reactive solutes from a three-dimensional well*).
- Seminarium natuurkunde, Univ. Bayreuth, Germany, January 30: U. Ebert (*Pattern Formation in Electric Discharges*).
- Wetenschappelijke vergaderingen Statistische Fysica, Lunteren, February 1–2: and Plasma Fysica, Lunteren, February 14–15: U. Ebert, D. Sijacic, M. Arrayás (posters by Arrayás/Ebert and Sijacic/Ebert).
- CPS Today, Lunteren, February 13: U. Ebert (*Pattern formation in electric discharges*), D. Sijacic.
- Algemeen Wiskunde Colloquium, Univ. Leiden, February 15: W. Hundsdorfer (*Implicit and Explicit Time Stepping for Convection Problems*).
- APP Spring Meeting 'Diagnostics of Non-Equilibrium High Pressure Plasmas', Bad Honnef, February 18–21: U. Ebert, D. Sijacic, M. Arrayás (posters by Arrayás/Ebert and Sijacic/Ebert).
- Workshop on Singular limits of reaction-diffusion systems: Interfaces and spikes, Lorentz Center, Leiden, March 12–23: I. Guerra (poster: Asymptotic results for injection of reactive solutes from a three-dimensional well), R. Planqué, U. Ebert, invited talk (*Interface motion in electric discharges*).
- Colloquium at Mathematical Modelling Centre, University of Leicester, UK, March 16: J. Frank (*A potential vorticity-conserving particle-mesh method for the shallow water equations*).
- Seminarium Theoretische Natuurkunde, Universiteit van Amsterdam, March 29: U. Ebert, (*Pulled fronts propagating into unstable states: unconventional and universal*).
- Editorial Board meeting of the Digital Library Mathematical Functions, NIST, Washington (USA), April 4–5: N.M. Temme (*Update of the Handbook of Mathematical Functions*, Abramowitz and Stegun).
- 2nd International Conference on Air Pollution Modelling and Simulation '01, Champs-sur-Marne, France, April 9–12: P.J.F. Berkvens (*Parallel Processing and Non-Uniform Grids in Global Air Quality Modelling*).
- Fifth Symposium Wiskunde Toegepast, Maastricht, April 19: P.J.F. Berkvens (*Parallel Processing and Non-Uniform Grids in Global Air Quality Modelling*).
- Nederlands Mathematisch Congres, April 19–20: B.P. Sommeijer (session chairman), C. Cuesta (*A model problem of groundwater flow with dynamic capillary pressure: stability of travelling waves*), D. Lanser (*Time integration of prototype atmospheric circulation models in spherical geometry*).
- Fundacion Camara, Facultada de Fisica, Sevilla, April 26: M. Arrayás (*Quantum Computing: Alicia y Benito's stories*).
- Natuurkundig colloquium TU Eindhoven, April 26: U. Ebert (*Pattern formation in electric discharges*).
- Seminar 'Computational Neuroscience', NIH Amsterdam, April 27: B.P. Sommeijer, B. Lastdrager (*Modeling axonal guidance*).
- Universidad Carlos III de Madrid (Spain), Working visit, April 30–May 4: N.M. Temme (*From here to infinity*).
- OIO school Condensed Matter and Statistical Physics, Nijmegen, May 7–11: D. Sijacic (*Pattern formation in DC driven 'barrier' discharges*).

- PDEs on the sphere, Montréal, May 17: D. Lanser (*Time Integration of prototype atmospheric circulation models in spherical geometry*).
- 13th International Conference on Parallel CFD '01, Egmond aan Zee, May 21–23: P.J.F. Berkvens (*Global Air Quality Modelling Enhanced with Nesting and Parallel Processing*).
- Minisymposium 'Fronts, pulses and waves in nonlinear PDEs', Sixth SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah, May 24: U. Ebert (*Pulled fronts propagating into unstable states: unconventional and universal*).
- IFIP Workshop 'Scientific Computing and the Computational Sciences', CWI and UvA, May 28–29: J.G. Verwer, invited lecture (*New numerical PDE problems from computational biology*), B.P. Sommeijer, J.G. Blom.
- Université de Genève, Mathematical Institute, May 30–June 1: J.G. Verwer (*New numerical PDE problems from computational biology*).
- Seminar 'Nonlinearity in Amsterdam', CWI, June 1: P. Rodin (*Pattern formation in semiconductor devices*).
- EUPLASIMO Workshop, TU Eindhoven, July 5: W. Hundsdorfer (*Numerical Simulation of Negative Streamers*).
- International Symposium 'Dynamics Days Europe 2001', Dresden, Germany, June 5–8: P. Rodin, invited talk (*Superfast ionization fronts in semiconductors: pattern formation in power electronics*), U. Ebert , W. Hundsdorfer.
- Working visit to James P Keener, Utah, June 9–16: M.A. Peletier.
- Workshop EU-BIOFILM project, June 11–13, Academy of Sciences of the Czech Republic, Brno, B.P. Sommeijer (*Preliminary results with AQUASIM*).
- Summer School Hamiltonian Systems and Homoclinic Bifurcations, Universiteit Twente, June 11–15: R. Planqué.
- Fourth European Conference on Elliptic & Parabolic Problems, Rolduc, June 18–22: M.A. Peletier, I. Guerra.
- Sixth International Symposium on Orthogonal Polynomials, Special Functions and Applications (Roma), June 18–22: N.M. Temme, invited lecture (*Large parameter cases of the Gauss hypergeometric function, in particular in connection with orthogonal polynomials*).
- 19th Biennial Conference on Numerical Analysis, Dundee, Scotland, June 26–29: J. Frank.
- SCICADE Conference, Vancouver, Canada, July 30–August 3: W. Hundsdorfer. (*IMEX Time Stepping with Spatial Discontinuous Finite Elements*).
- University of Hong Kong, Working visit and PhD thesis committee, August 20–24: N.M. Temme.
- Workshop Patterns and Waves — Mathematics and Nonlinear Chemistry, Lorentz Center, Leiden, August 30–September 7: U. Ebert (poster), D. Sijacic (poster).
- Summer school in Laredo organized by University of Cantabria, September 3–7: C. Cuesta (*Escuela retrospectiva de matematica aplicada*).
- Prospective school in Applied Mathematics, Laredo, Spain, September 3–7: R. Planqué.
- International Workshop Meshfree Methods for Partial Differential Equations, Bonn, Germany, September 11–14: J. Frank (*Particle-mesh methods for the rotating shallow water equations*), J.G. Blom.
- First DFG/NWO meeting on 'Entering the Living Cell', Egmond aan Zee, September 28–30: J.G. Blom (*Posterpresentaties Silicon Cell / CWI research in the Life Sciences*).
- International Conference on Numerical Algorithms, Marrakesh, Morocco, October 1–5: N.M. Temme (*Computing special functions by using quadrature rules*).
- CWI in Bedrijf, October 5: U. Ebert (*Electrische ontladingen — patroonformatie tussen esthetiek en toepassingen*), J.G. Blom (*De Silicon Cell*).
- IMA Workshop Dynamical Systems in Celestial Mechanics and Climate Dynamics, Minneapolis, Minnesota, October 29–November 2: J. Frank.
- Genomics Impulse 2001, Den Haag, November 6: J.G. Blom (*Posterpresentatie The Silicon Cell: Towards computing a living cell*).
- Algemeen Wiskunde Colloquium, UvA, November 21: D. Lanser (*Efficient Numerical Methods for Atmospheric Flow Problems*).
- 4th EUregional WELT-PP (*Workshop on the Exploration of Low Temperature Plasma Physics*) in Kerkrade, November 22–23: U. Ebert (*Tip splitting in streamer discharges*), D. Sijacic (poster), A. Rocco, C. Montijn, B. Meulenbroek.
- Universität Hamburg, Fachbereich Mathematik, November 22–23: J.G. Verwer (*Numerical time integration of air pollution models*).

- Mathematisches Forschungsinstitut Oberwolfach, Meeting 'Modellierung, Simulation und Optimierung integrierter Schaltkreise', November 25–December 1: J.G. Verwer (*Splitting methods for advection-diffusion-reaction problems*).
- Symposium 'Structuring Factors of Shallow Marine Coastal Communities', NIOZ, Texel, November 29–30: B.P. Sommeijer (*Simulation techniques for the population dynamics of sinking phytoplankton in light-limited environments*).
- Nichtlinearitätsseminar, Univ. Magdeburg, December 3: U. Ebert (*Streamers – Laplace-Wachstum in elektrischen Entladungen*).
- Scientific Meeting CWI, December 14: B.P. Sommeijer (*Numerical simulation of phytoplankton dynamics*).
- Winterschool Mathematics and Biology, Wageningen, December 17–21: R. Planqué.

Memberships of Committees and Other Professional Activities

J.G. Verwer:
- Professor of Numerical Analysis, Korteweg-de Vries Institute, University of Amsterdam.
- Senior Editor *APNUM* (*Applied Numerical Mathematics*).
- Co-editor special *APNUM* issue devoted to proceedings of the 9th NUMDIFF Seminar, 4–8 Sept., Halle, 2000.
- Member advisory committee of CMUC (The Centre for Mathematics of the University of Coimbra, Portugal).
- Member scientific committee APMS'2001 – 2nd International Conference on Air Pollution Modelling and Simulation, April 9–13, Paris, organized by ENPC and INRIA.
- CWI contact for the Flemish Research Network on Advanced Numerical Methods for Mathematical Modelling (WOG).
- Committee member PhD thesis N. Borovykh, May 16, University of Leiden (*Stability estimates and resolvent conditions in the numerical solution of initial value problems*).
- Committee member PhD thesis W. Bomhof, May 23, University of Utrecht (*Iterative and parallel methods for linear systems with application in circuit simulation*).
- Committee member PhD thesis A. Abdulle, May 31, Université de Genève (*Chebyshev methods based on orthogonal polynomials*).
- Gutachter and committee member PhD thesis A. Gerisch, Aug. 23, Martin-Luther-Universität Halle-Wittenberg (*Numerical methods for the simulation of taxis-diffusion-reaction systems*).

B.P. Sommeijer:
- Managing editor Letter Section *Journal Computational and Applied Mathematics (JCAM).*

N.M. Temme:
- Editor *ZAMP.*
- Editor *Mathematics of Computation.*
- Editor Update *Handbook of Mathematical Functions* ('Abramowitz and Stegun').
- Member of the governing board of the Stieltjes Institute for Mathematics and CWI-coordinator for the Dutch research schools in mathematics and computer science.
- Organizer of the CWI monthly seminar 'CWI Scientific Meetings'.
- Member of PhD thesis committee Yang Heping, City University of Hong Kong.

M.A. Peletier:
- Secretary of the Wiskundig Genootschap.

U.M. Ebert:
- Leader of the FOM-workgroup TF–CWI under the Special Commission for Technical Physics.
- Leader of the CWI–group of the research school Centrum voor Plasmafysica en Stralingstechnologie.
- Member of the committee for the PhD thesis defense of C. Storm, Univ. Leiden, June 16.

Visitors

- S. Angenent (J.G. Verwer), Univ. of Madison and UL, January 10–11.
- B. Sandstede (J.G. Verwer), Ohio State Univ., January 14–18.
- G. Stelling (J.G. Verwer), Delft Hydraulics and TU-Delft, January 24.
- A. Ostermann (W. Hundsdorfer), Univ. of Innsbruck, February 19–23.
- C. Strümpel (U. Ebert), Univ. Münster, Germany, March 8.
- C. Budd (M.A. Peletier), Univ. of Bath, April 23–27.
- J. Eggers (U. Ebert), Univ. of Essen, May 7–8.
- S. Hilgenfeldt (U. Ebert), Univ. Twente, June 1.
- F. Otto (U. Ebert), Univ. Bonn, Germany, June 1.
- I. Grekhov (U. Ebert), Ioffe-Inst. St. Petersburg, Russia, June 11–15.
- S. Reich (J. Frank), Imperial College, London, July.

- J.L. Lopez (N.M. Temme), Univ. of Pamplona, July 2–28.
- A. Rocco (U. Ebert), Univ. La Sapienzia, Rome, July 9–11.
- J. Wensch (B.P. Sommeijer), Univ. of Halle, September 1–November 30.
- G. Lord (M.A. Peletier), Heriot-Watt University, October 22–November 1, December 17–21.

Papers in Journals and Proceedings

A. Gil, J. Segura, N.M. Temme (2001). On non-oscillating integrals for computing inhomogeneous Airy functions. *Math. Comput.***70**, 1183–1194.

M.A. Botchev, H.A. van der Vorst (2001). A parallel nearly implicit time-stepping scheme. *J. Comp. Appl. Math.* **137**, 229–243.

C.J. van Duijn, G. Galiano, M.A. Peletier (2001). How mangroves salinize the soil. *Interfaces and Free Boundaries* **3**,15–44.

C.J. van Duijn, I.A. Guerra, M.A. Peletier (2001). Asymptotic Results for Injection of Reactive Solutes from a Three-Dimensional Well. *Journal of Mathematical Analysis and Applications* **260**, 367–383.

U. Ebert, M. Arrayás (2001). Pattern formation in electric discharges. *Coherent Structures in Complex Systems*, D. Reguera et al. (eds.). Lecture Notes in Physics **567**, Springer, Berlin, 270–282.

U. Ebert, M. Arrayás, N. Temme, B. Sommeijer, J. Huisman (2001). Critical conditions for phytoplankton blooms. *Bull. Math. Biol.* **63**, 1095–1124.

J.E. Frank, P.J. van der Houwen (2001). Parallel iteration of extended backward differentiation formulas. *IMA J. Numer. Anal.* **21**, 367–385.

J.E. Frank, C. Vuik (2001). On the construction of deflation-based preconditioners. *SIAM J. Sci. Comput.* **23**, 442–462.

P.J. van der Houwen, B.P. Sommeijer (2001). Approximate factorization for time-dependent partial differential equations. *J. Comp. Appl. Math.* **128**, 447–466.

P.J. van der Houwen, B.P. Sommeijer (2001). Factorization in block-triangularly implicit methods for shallow water applications. *Appl. Numer. Math.* **36**, 113–128.

W. Hundsdorfer (2001). Partially implicit BDF2 blends for convection dominated flows. *SIAM J. Num. Anal.* **38**, 1763–1783.

M. Kirkilionis, O. Diekmann, B. Lisser, M. Nool, B.P. Sommeijer, A. de Roos (2001). Numerical continuation of equilibria of physiologically structured population models, Part I: Theory. *Math. Models and Methods in Appl. Sciences* **11**, 1101–1127.

T. Lachand-Robert, M.A. Peletier (2001). Newton's Problem of the Body of Minimal Resistance in the Class of Convex Developable Functions. *Mathematische Nachrichten,* **226**, 153–176.

T. Lachand-Robert, M.A. Peletier (2001). An Example of Non-convex Minimization and an Application to Newton's Problem of the Body of Least Resistance. *Annales de l'Institut Henri Poincaré, Analyse Nonlinéaire* **18**, 179–198.

J. Lang, J.G. Verwer (2001). ROS3P – An accurate third order Rosenbrock solver designed for parabolic problems. *BIT* **41**, 731–738.

D. Lanser, J.G. Blom, J.G. Verwer (2001). Time integration of the shallow water equations in spherical geometry. *J. Comput. Phys.* **171**, 1–21.

B. Lastdrager, B. Koren, J.G. Verwer (2001). Solution of time-dependent advection-diffusion problems with the sparse-grid combination technique a Rosenbrock solver. *Computational Methods in Applied Mathematics* **1**(2), 86–98.

B. Lastdrager, B. Koren, J.G. Verwer (2001). The sparse-grid combination technique applied to time-dependent advection problems. *Appl. Numer. Math.* **38**, 377–402.

M.A. Peletier (2001). Generalized Monotonicity from Global Minimization in Fourth-Order ODE's. *Nonlinearity* **14**, 1221–1238.

M.A. Peletier (2001). Sequential Buckling: A Variational Analysis. *SIAM Journal on Mathematical Analysis* **32**, 1142–1168.

F. Plenge, P. Rodin, E. Schöll, K. Krischer (2001). Breathing current domains in globally coupled electrochemical systems: A comparison with a semiconductor model. *Phys. Rev. E* **64**, 056229.

S.M. Soskin, V.I. Sheka, T.L. Linnik, M. Arrayás, I.Kh. Kaufman, D.G. Luchinsky, P.V.E. McClintock, R. Mannella (2001). Noise-induced escape on time-scales preceding quasi-stationarity: New developments in the Kramers problem. *Chaos* **11**, 595–604.

S.M. Soskin, R. Mannella, M. Arrayás, A.N. Silchenko (2001). Strong enhancement

of noise-induced escape by nonadiabatic periodic driving due to transient chaos. *Phys. Rev. E* **63**, 051111.

S.M. Stojković, D.Lj. Mirjanić, J.P. Šetrajčić, D.D. Šijačić, I.K. Junger (2001). Spectra and states of electrons in surfaces perturbed quantum wires. *Surface Science* **477**, 235.

N.M. Temme, J.L. López (2001). The Askey scheme for hypergeometric orthogonal polynomials viewed from asymptotic analysis. *J. Comp. Appl. Math.,* **133**, 623–633.

G. Tripathy, A. Rocco, J. Casademunt, W. van Saarloos (2001). Universality class of fluctuating pulled fronts. *Phys. Rev. Lett.* **86**, 5215–5218.

J.G. Verwer, B.P. Sommeijer (2001). A numerical study of mixed parabolic-gradient systems. *J. Comp. Appl. Math.* **132**, 191–210.

C. Vuik, J.E. Frank (2001). Coarse grid acceleration of a parallel block preconditioner. *Future Generation Computing Systems* **17**, 933–940.

C. Vuik, J.E. Frank, A. Segal (2001). A parallel block-preconditioned GCR method for incompressible flow problems. *Future Generation Computing Systems* **18**, 31–40.

CWI Reports

The following CWI reports were published by members of theme MAS1. See page 70 for the complete titles of the reports.

MAS-R0102	MAS-R0104	MAS-R0105
MAS-R0108	MAS-R0109	MAS-R0110
MAS-R0111	MAS-R0114	MAS-R0115
MAS-R0116	MAS-R0117	MAS-R0118
MAS-R0119	MAS-R0120	MAS-R0121

Other Publications

U. Ebert (2001). Pattern Formation in Electric Discharges. *ERCIM News* **44**, 56–57.

P.M. de Zeeuw (ed.) (2001). *Het Nummer, Nieuwsbrief van de Werkgemeenschap Numerieke Wiskunde* **44**–**45**. CWI, Amsterdam.

Computational Fluid Dynamics – MAS2

In 2001 the MAS2 subthemes were:

MAS2.1 Computational Fluid Dynamics (Koren)

MAS2.2 Computational Number Theory and Data Security (Te Riele)

Staff

- Prof. dr. P.W. Hemker, theme leader
- D.P.L.D. Benden, trainee (seconded by University of Amsterdam, until December 31)
- Ir. E.H. van Brummelen, PhD student (until August 31)
- Drs. S. Cavallar, PhD student (until February 28)
- G.F. Duivesteijn, trainee (seconded by Delft University of Technology, until March 31)
- Drs. M. Genseberger, PhD student (joint with Utrecht University, until January 31)
- Drs. J. Kok, general support (joint with MAS1)
- Dr. ir. B. Koren, project leader
- Drs. B. Lastdrager, PhD student (joint with MAS1)
- Ir. M.R. Lewis, PhD student
- Dr. W.A. Mulder, researcher (seconded by Shell Rijswijk, since April 1)
- Drs. M. Nool, scientific programmer
- Dr. D.E.A. van Odyck, postdoc (since October 1)
- Ir. M.H. van Raalte, PhD Student (seconded by University of Amsterdam)
- Dr. ir. H.J.J. te Riele, project leader
- L. Voort, trainee (seconded by Delft University of Technology, until June 30)
- Prof. dr. ir. P. Wesseling, advisor (Delft University of Technology)

Changes

A major change, by the end of the year (formally per January 1, 2002), was that Prof. dr. ir. J.H. van Schuppen joined MAS2 with co-workers from Theme PNA2 (Dr. ir. L.C.G.J.M. Habets, Dr. B. Hanzon, Dr. J. Komenda and Mrs. D. Jibetean, MSc.). Because of this merger, per January 1, 2002, MAS2 was renamed *Computing and Control*.

Also by the end of the year (per January 1, 2002, formally), Koren took over Hemker's position as theme leader, and Hemker was appointed CWI Fellow.

Award

During the *Seventh ICFD Conference on Numerical Methods for Fluid Dynamics*, March 26–29, University of Oxford, Harald van Brummelen was awarded the *Bill Morton Prize* for his paper 'Adjoint shape optimization for steady free-surface flows'.

Scientific Report

Computational Fluid Dynamics – MAS2.1

MARIN
In the framework of the joint CWI/MARIN project *Robustness Improvement and Extension of PARNASSOS*, Van Brummelen finished his work on the development of an efficient numerical method for steady viscous free-surface flows, and its 2D implementation. The results of the investigation were published in the *Journal of Computational Physics*.

The investigation of adjoint shape-optimization techniques for solving steady free-surface flows established that mesh-width independent convergence behaviour of the adjoint method can be obtained by suitable preconditioning. However, it was also proven that in most practically relevant cases, the adjoint shape-optimization method does not offer an essential improvement in computational efficiency over the usual time integration method. Preliminary results were published in a paper presented at a ICFD-conference at the University of Oxford. The paper was awarded the *Bill Morton Prize*. Details on the research will appear in forthcoming publications.

In the context of interface-capturing methods, Van Brummelen and Koren developed a pressure-invariant conservative discretization for two-fluid flows. It was shown that the pressure oscillations that are commonly incurred by conservative discretizations of two-fluid flow problems, are caused by a loss of invariance properties of the continuum equations under discretization. A pressure-invariance condition for two-fluid flow discretizations was formulated and a non-oscillatory conservative discretization was set up for two-fluids with a barotropic equation of state. Numerical experiments with the new method are currently in progress.

NCF0
In the framework of the NCF-project *Parallel Adaptive Mesh Refinement for Computational Magneto-Fluid Dynamics*, Nool, in close cooperation with Dr. R. Keppens of FOM-Rijnhuizen, analyzed the efficiency of using Adaptive Mesh Refinement for Magneto-HydroDynamic problems in one, two and three dimensions for a variety of model problems. Execution times were reduced by factors up to 20. The overhead caused by regridding appears to be very small. The advantages of using different (conservative) discretizations on each level have been shown for hydro- and magnetohydrodynamic problems.

NCF1
In the framework of the NCF-project *Parallel Implementation of a State-of-the-Art, Incompressible Navier-Stokes Method*, Nool redesigned the implementation of a least-squares spectral element method. Least-squares methods lead to symmetric and positive definite algebraic systems. At the moment, these symmetric algebraic systems are solved in parallel by the Conjugate Gradient method. The least-squares spectral element approach desires an element-by-element parallelization, whereas an efficient solution of the algebraic systems requires a row-wise distribution of a large global system. Favourable results of an MPI-implementation are already obtained on a distributed memory machine (Cray T3E) and on a virtual shared memory machine (SGI Origin 3800). The parallelization of the element-by-element calculation of the grid and the switch from an element numbering to a global numbering are currently in progress.

NCF2
On December 1, the NCF-project *Parallel Implementation of a Sparse-Grid Method for Time-Dependent Advection-Diffusion-Reaction Problems* started. Lastdrager and Everaars (SEN3) selected pure advection and mixed advection-diffusion model problems to tackle with a parallelized sparse-grid method. Previous investigations of these model problems by Lastdrager et al. revealed that they can be solved with a sparse-grid method but without significant gains in efficiency on sequential computers. It is expected that due to the inherent parallelizability of the sparse-grid method parallelization does yield a significant gain in efficiency.

NWO1
In the framework of the NWO-project *Domain-Decomposition-based Preconditioning Techniques for Large Sparse Linear Systems of Equations and Linear Eigenproblems*, Genseberger adapted a preconditioner for use within the Jacobi-Davidson method. The preconditioner, based on domain decomposition, was incorporated to compute solutions of the correction equation, which causes most of the computational work in Jacobi-Davidson. The construction of the preconditioner needed special care. For a two-dimensional advection-diffusion model problem, with constant coefficients, an analysis of the error amplification was performed which makes it possible to determine optimal coupling parameters. It turned out that from this also coupling parameters for variable-coefficient problems can be estimated. With the same preconditioner, even better performance is obtained by application on the eigenvalue problem level instead of on the correction equation level. Numerical experiments showed that the differences between these two approaches become significantly larger when the number of subdomains increases.

NWO2
In the framework of the (joint MAS1-MAS2) NWO-project *Sparse Grid Methods for Transport Problems*, Lastdrager continued to work on the gradient-diffusion problem from neurobiology. The initial method has been improved, stability analysis for a model problem has been made and the proposed model was shown to explain the processes of bundling and debundling observed in biological experiments. Further, the model itself was modified; instead of considering axons as point sources they are now considered as sources with finite physical dimensions.

NWO3
October 1, a start was made with the project *Computational Magnetohydrodynamics in Special Relativity*, in the framework of the larger NWO-project *Rapid Changes in Complex Flows*. As a first step to the final goal of developing a numerical method for solving the special relativistic magneto-hydrodynamic (SRMHD) equations, Van Odyck started implementing a numerical method to solve a one-dimensional special relativistic hydrodynamics problem. A spherical gas explosion is used as a model problem. This problem has been proposed by the Astro-Plasma physics group at the University of Utrecht and it can be seen as a simplification of a Gamma Ray Burst (GRB). These are not yet fully understood high-energy explosions in the universe. It is hoped that eventually an SRMHD calculation can shed light on this topic.

NWO4
This year the NWO project *Efficient and Robust Numerical Methods for Differential Equations with Singularities* in cooperation with the Institute of Mathematics and Mechanics, (Ural Branch, Russian Academy of Sciences, Prof. G.I. Shishkin) could be continued. In this project the research on development of efficient numerical methods for singularly perturbed boundary value problems was extended. Special numerical methods which converge ε-uniformly have been considered for parabolic and elliptic singularly perturbed equations. On the basis of a defect-correction technique or Richardson's extrapolation, high-order accurate methods were developed that allow to improve the ε-uniform accuracy with respect to the time variable. In view of possible parallelization, also domain decomposition methods were studied.

This activity is part of a Dutch-Russian cooperation, supported by NWO (EB 047.008.007). The Dutch groups in this cooperation involve KUN (Prof. dr. A.O.H. Axelsson, general coordinator) and CWI (Hemker). The cooperating Russian groups are: Moscow State University (Prof. G. Kobelkov and Prof. N.S. Bakhvalov, MSU), the Computing Center of the Russian Academy of Sciences, Moscow, (Dr. I.E. Kaporin and Dr. V. Konshin, RAS), the Institute of Mathematics and Mechanics, Ural branch RAS, Ekaterinburg, (Prof. G.I. Shishkin, IMM), the Institute of Computational Mathematics, Siberian branch RAS, Novosibirsk (Prof. V.P. Il'in, ICM), the Steklov Institute of Mathematics, RAS, St. Petersburg (Dr. L.Y. Kolotilina and Dr. A. Yeremin) and the Department of Applied Mathematics, Kuban State University, Krasnodar (Prof. E. Glushkov).

STW
In the framework of the STW-project *Development of a State-of-the-Art Navier-Stokes Solver for Water Flows around Moving Ships*, Lewis continued the implementation of an efficient solution method for steady free-surface Navier-Stokes flow problems, as proposed by Van Brummelen, for actual 3D ship hydrodynamics computation. Here, several 3D numerical experiments, with

varying degree of complexity, were considered. Primary interest was focussed on the convergence behaviour of the solution method. A theoretical analysis was also initiated to understand this behaviour.

Lewis and Koren also worked on the numerical simulation of inviscid, compressible and immiscible liquid-gas (water-air) flows in a gravitational field. The flows were described by the Euler equations of fluid dynamics with a source term due to gravity. The specific form of the source term allowed an elegant numerical treatment. The numerical method was derived by means of a transformation which converts the continuous, non-homogeneous system of conservation laws into a homogeneous system. The transformation was demonstrated for the 1D case, and can be easily extended to multiple spatial dimensions. Strang splitting method was used as a solution method. Numerical results were presented for a tube filled with (compressible) water and air. The water-air interface was captured. For this, use was made of the ghost-fluid method. For computing the separate water and air fluxes, a linearized Godunov scheme was applied and for accurately distinguishing water and air a level-set technique was used. Comparisons with exact analytical solutions were very good.

UvA

In this project, in cooperation with the University of Amsterdam, we investigate the use of high-order discontinuous Galerkin methods for the construction of a hierarchical self-adaptive solver for convection dominated flows in three dimensions. The work is based on recent achievements in the fields of: hierarchical approximation (wavelets, nested spaces); discrete system solvers with optimal complexity (multigrid); self-adaptive finite-element methods; affordable approximation in more dimensions (sparse grids); defect correction and a-posteriori error estimators. The aim is to combine several of these aspects in a general adaptive algorithm that is able to solve automaticly and efficiently hard convection-diffusion problems that –thus far– can only be solved if a substantial amount of a-priori knowledge is used.

During 2001 the emphasis of the research was on the weak formulation of the problem, the choice of a proper base for the test and trial spaces, and on the choice of a relaxation algorithm in a suitable multigrid method. D. Benden received his masters degree (drs.) from the University of Amsterdam (masters thesis: *A discontinuous Galerkin method applied to one-dimensional singularly perturbed convection-diffusion problems*). Starting February 2002, he will be the second PhD student in the project.

Computational Number Theory and Data Security – MAS2.2

Computational number theory studies problems from elementary, algebraic and analytic number theory which require the help of fast computers. This enlarges our 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 suitable for parallelization, and can be used as test-cases for parallel computing techniques. For example, some algorithms for factoring large numbers can be carried out on a grid of heterogeneous computers where the number of computers in the grid is allowed to vary in a dynamical way.

The main purpose of this project is to study fast factoring algorithms, and to factor the largest possible numbers in order to test the security of RSA cryptosystems. Stefania Cavallar, who left CWI in March to start as a postdoc at Eindhoven University, finished the chapter of her doctor's thesis where she studies a variant of the number field sieve in which three large primes are allowed in the relations, collected during the sieve part of this algorithm. Stefania's thesis defense is expected in 2002. Various numbers from the Cunningham table were factored by Peter Montgomery. No new world records were established, but preparations were made to start a new record attempt early 2002. An update report on the factorization of numbers of the form $a^n \pm 1$, $13 \leq a < 100$, which extends the original Cunningham table, appeared (report MAS-R0107).

The study of the size of the solutions of the inequality $\phi(an + b) < \phi(an), \gcd(a, n) = 1$, was finished (report MAS-R0106, appeared in a conference proceedings, see list of publications).

In cooperation with Hugh C. Williams, Herman te Riele carried out a computational study concerning the distribution of class numbers of real quadratic fields and he considerably extended an earlier verification of a conjecture of Cohen and Lenstra on this distribution. A report will appear in 2002.

The group had access to the idle cycles of

about 50 workstations and PCs at CWI and to the 1024 processor SGI Origin 3800 (called TERAS) at SARA.

Scientific collaboration was continued with (the groups of) Prof. R.P. Brent (Oxford University Computing Laboratory, Oxford, England), Prof. M. García (New York, USA), Prof. A.K. Lenstra (TU Eindhoven and Citibank, New York and Parsippany, USA), Drs. W.M. Lioen (Data Distilleries, Amsterdam), Dr. P.L. Montgomery (San Rafael, CA, USA), J.M. Pedersen (Vejle Business College, Vejle, Denmark), Prof. R. Tijdeman (Leiden University), and Prof. H.C. Williams (University of Manitoba, Canada).

Knowledge Transfer

P.W. Hemker:

- Capita course at University of Amsterdam 'Advanced Scientific Computing' (Sept. 13 – Dec. 13).
- Course at University of Amsterdam 'Numerical Hydrodynamics' (Feb. 3 – March 16).

B. Koren:

- Course at Delft University of Technology: Numerical Aircraft Aerodynamics II (February 2 – March 16 and November 16 – December 21).

P.L. Montgomery, H.J.J. te Riele:

- CWI has several source code license agreements with companies in The Netherlands, USA, Germany and France which allows them to use the Number Field Sieve factorization code as this was and is being developed by P.L. Montgomery, A.K. Lenstra, M. Elkenbracht-Huizing, S. Cavallar and B. Dodson.
  On a non-commercial basis, the NFS source code has also been made available for research purposes to other cooperating groups.

M.H. van Raalte

- Numerieke Wiskunde/Matlab, University of Amsterdam.

PhD Thesis

M. Genseberger (2001). *Domain Decomposition in the Jacobi-Davidson Method for Eigenproblems*, PhD thesis, Utrecht University, September 2001, ISBN 90 6196 507 1. Thesis advisor: Prof. dr. H.A. van der Vorst.

Organization of Conferences, Workshops, Courses, etc.

P.W. Hemker:

- Oberwolfach Meeting on 'Numerical Methods for Singular Perturbation Problems', April 9–14 (organizer).
- IFIP - WG 2.5 Business Meeting Amsterdam, May 26–27 (organizer, vice-chair).
- IFIP - WG 2.5 Workshop 'Scientific Computing and the Computational Sciences', Amsterdam, May 28–29 (organizer).
  Lecturers: Frenkel (ACCS, Amsterdam), *Numerical Simulation of Rare Events.* Langer (University Linz), *Scientific Computing Tools in Computational Science and Engineering.* Cohen (University Eindhoven), *From Routines to Internet Mathematical Services.* Boisvert (NIST, USA), *NIST Digital Library of Mathematical Functions.* Van de Weygaert (University Groningen), *The Computational Impact on Astronomy: Experiments in Cosmic Evolution.* Pool (Caltech, USA), *Report on DOE's ASCI.* Veldman (University Groningen), *Unraveling Turbulence by Means of Direct Numerical Simulation?* Goedbloed and Keppens (FOM Rijnhuizen), *Computational Magneto-Fluid Dynamics: Describing the Plasma Universe.* Einarsson (University Linköping, Sweden), *White paper on Accuracy and Reliability in Scientific Computing.* Nieuwstadt (University Delft), *Numerical Simulation of Turbulent Flows: a Challenge for Numerical Analysts and Computer Scientists.* Maubach (University Eindhoven), *A Rapid Development Environment for Scientific Computations.* Derksen and Van den Akker (University Delft), *Lattice-Boltzmann Simulations of Turbulent Flows with Industrial Applications.* Smit (ACCS, Amsterdam University), *Simulating the Behaviour of Hydrocarbons in Zeolites.* Verwer (CWI), *New Numerical PDE Problems from Biology.*

B. Koren:

- CFD-meetings, CWI, January 16–30, February 20, March 6, April 3–17, May 15, June 19, September 3–24, October 23, November 27, December 18. Guest lecturers: B. van Leer (University of Michigan, Ann Arbor), J. Müller (University of Leiden), A. van der Ploeg (MARIN), M.M.J. Proot (Delft University of Technology) and G.I. Shishkin (IMM, Ekaterinburg).
- Meeting NWO3-project, CWI, October 17.
- Meeting Users Committee STW-project, CWI, December 4.

M.R. Lewis:

- Organization of the PhDays 2001, Meeting for Dutch and Flemish PhD students in Numerical Mathematics, Belgium, May 25–27.

H.J.J. te Riele:

- 37e Nederlands Mathematisch Congres, Vrije Universiteit Amsterdam, April 19–20. Jointly organized by CWI and the Vrije Universiteit Amsterdam under the auspices of the Dutch Mathematical Society. Organization Committee: H.J.J. te Riele (chairman), André Ran (secretary, VUA), Rien van Veldhuizen (treasurer, VUA), Nada Mitrovic, Wilmy van Ojik, Mark Peletier, Maryke Titawano (VUA), Marcel van de Vel (VUA). Keynote speakers: Eric Verheul (PricewaterhouseCoopers), Lex Schrijver (CWI and UvA), Joost Hulshof (VUA), Aad van der Vaart (VUA).

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

- Working visits Faculty of Aerospace Engineering, Delft University of Technology, February 2, August 24: Nool.
- EIDMA Cryptography Working Group, Utrecht, February 9, December 7: Te Riele.
- ERCIM Meeting, ETH Zürich, February 12: Koren.
- NWO-MPR-meeting, University of Utrecht, February 21: Nool.
- 50th Meeting Kontaktgroep Numerieke Stromingsleer, Delft University of Technology, February 23: Van Brummelen, Hemker, Koren, Lewis.
- Global Grid Forum and Datagrid Seminar, WCW Amsterdam, March 5–9: Te Riele.
- ICFD Conference on Numerical Methods for Fluid Dynamics, University of Oxford, March 26–29: Van Brummelen (*Adjoint shape optimization for steady free-surface flows*).
- 37e Nederlands Mathematisch Congres, VU Amsterdam, April 19–20: Koren, Lewis (*Berekening van water-lucht stroming onder invloed van de zwaartekracht*), Nool, Te Riele.
- Meeting STW-project, MARIN, April 24: Koren and Lewis (*Berekening van water-lucht stroming onder invloed van de zwaartekracht*).
- Dagstuhl Seminar on Algorithms and Number Theory, Dagstuhl, Germany, May 13–18: Te Riele (*New computations concerning the Cohen-Lenstra class number heuristics*).
- IFIP working group, CWI Amsterdam, May 28-29: Hemker, Nool, Van Raalte.
- ERCIM Meeting, SISC, Stockholm, May 30–31: Koren (*ERCIM Vital Statistics*).
- 31st AIAA Fluid Dynamics Conference and Exhibit, Anaheim, CA, USA, June 11–14: Van Raalte (*An analytical model to describe the Reynolds number effects in supersonic base flow*).
- Universiteit Twente, June 14: Hemker (*On discontinuous Galerkin methods for elliptic problems*).
- Kick-off Meeting NWO3-project, FOM-Rijnhuizen, Nieuwegein, August 28: Hemker, Koren.
- ECCOMAS CFD 2001 conference, Wales, September 4–7: Lewis (*Computation of compressible, immiscible water-air flows under the action of gravity*).
- Working visit FOM-Rijnhuizen, September 5: Nool.
- ERCIM Meeting, CRCIM, Prague, September 10: Koren.
- 26e Conferentie van Numeriek Wiskundigen, Woudschoten, September 12–14: Benden, Hemker, Koren, Van Raalte.
- Staff Colloquium, Department of Mathematics, University of Groningen, September 25: Te Riele (*On the distribution of class numbers of real quadratic number fields*).
- Conference IOP EMVT, Golden Tulip Schiphol, September 26: Hemker.
- IOP EMVT Meeting, NIMAC, Ede, September 27: Hemker, Koren.
- MPI course, SARA Amsterdam, September 27–28: Nool, Te Riele.
- CWI in Bedrijf, CWI, October 5: Hemker, Lewis, Nool, Van Raalte, Te Riele.
- Meeting NWO3-project, CWI, Amsterdam, October 17: Hemker, Koren, Van Odyck.
- Algemeen Wiskunde Colloquium, Korteweg-de Vries Institute for Mathematics, University of Amsterdam, October 17: Te Riele (*On the distribution of class numbers of real quadratic number fields*).
- VGWM cursus, Bureau Zuidema, Beekbergen, October 18–19: Nool.
- Workshop on effective methods for Diophantine equations, Debrecen, Hungary, October 21–26: Te Riele (*Diophantine equations arising in searches for amicable pairs*).
- MARIN wetenschapsdag, Wageningen, November 8: Hemker (*Numerical techniques and free surface Navier-Stokes flows*).
- NWO Workshop, KU Nijmegen, November 29: Hemker (*Two approaches for discontinuous Galerkin discretisation*).

- Working visit MARIN, Wageningen, November 29: Hemker, Koren.
- Meeting STW-project, MARIN, December 4: Koren (*Riemann problem and level-set approaches for two-fluid flow computations, fixes for solution errors near interfaces*) and Lewis (*Uitbreiding PARNASSOS met vrije-randbehandeling*).
- Inaugural speech Prof. Verwer, University of Amsterdam, December 7: Hemker, Koren, Lastdrager, Lewis, Nool, Te Riele.
- Meeting NWO3-project, University of Utrecht, December 11: Hemker, Koren (*Fixes for zeroth-order solution errors near two-fluid interfaces*).
- Workshop Mathematics Institute, University of Utrecht, December 12: Benden, Hemker (*Discontinuous Galerkin methods*), Van Raalte.
- KEMA, Arnhem, December 18: Hemker.

Memberships of Committees and Other Professional Activities

M. Genseberger:
- Representative of BAU (Union for PhD students of Utrecht University) in LAIOO (Union for PhD students in The Netherlands, until April 30).

P.W. Hemker:
- Professor Scientific Computing, University of Amsterdam.
- Working Group 2.5 on Numerical Software, IFIP, vice-chair.
- Member NWO Programmacommissie Computational Science.
- Member steering group Amsterdam Centre for Computational Science (ACCS).
- Member Numerical Algorithms Group, NAG Inc.
- Associate editor *Computational Methods in Applied Mathematics*.
- Member Users Committee STW-project 'Development of a state-of-the-art Navier-Stokes solver for water flows around moving ships'.
- Referee of papers for various scientific journals and projects.
- Member PhD committee L. Vijfvinkel, KU Nijmegen, March 5 (*Automatic mesh domain partitioning for adaptively refined grids*).
- Member PhD committee M. Genseberger, University of Utrecht, September 10 (*Domain decomposition in the Jacobi-Davidson method for eigenproblems*).

B. Koren:
- Associate professor Computational Fluid Dynamics, Faculty of Aerospace Engineering, Delft University of Technology.
- CWI-representative in ERCIM Executive Committee.
- Member Users Committee STW-project 'Smering van ruwe oppervlakken'.
- Member MSc-committees A.H. van Zuijlen (July 5) and J. van Os (December 21), Faculty of Aerospace Engineering, Delft University of Technology.
- Referee of project proposals and journal papers.

M.R. Lewis:
- Member organizing Committee PhDays 2001, Meeting for Dutch and Flemish PhD students in Numerical Mathematics, Belgium, May 25–27.

M. Nool:
- Member of the CWI Works Council (until April 26).
- Chairman of the CWI Works Council-committee VGWM (since April 26).

H.J.J. te Riele
- Chairman of the Organizing Committee of the 37th Nederlands Mathematisch Congres (Free University, Amsterdam, April 19–20, 2001).
- Secretary of the Beeger Committee which biennially selects the Beeger Lecturer and organizes the Beeger Lecture during the Nederlands Mathematisch Congres.
- Member of the Committee which will make a bid to organize ECM2008 (the fifth European Congress of Mathematicians) in Amsterdam.
- Member of the Board of the *Mathematisch Research Instituut* onderzoekschool, on behalf of CWI.
- Reviewer for Mathematical Reviews and the Zentralblatt für Mathematik.
- Referee of papers for various scientific journals.
- Chairman of the CWI - Bibliotheekcommissie.
- Treasurer of the CWI Staff Club.

Visitors

- Dr. ir. P. Boerstoel and Drs. Ph. Simons (TNO, Technisch Physische Dienst, Delft), January 23.
- Prof. dr. ir. B. van den Brule and Dr. W.A. Mulder (Shell Rijswijk), January 23.
- Dr. ir. M.I. Gerritsma and Ir. M.M.J. Proot (Delft University of Technology), February 20.
- Dr. A. van der Ploeg (MARIN), March 6.

- Prof. dr. E. Turkel (Tel Aviv University), March 19 (*Robust low speed preconditioning for time-dependent and viscous flows*).
- G.W. Stewart (Berkeley, USA), April 4 (*Eigenvalue problems*).
- Prof. R.P. Brent (Computing Laboratory, Oxford University), April 6 (*Uniform random number generators and primitive trinomials*).
- Prof. Mark van Hoey (Florida State University), April 19 (*Factoring polynomials and 0-1 vectors*).
- Dr. J. Müller (University of Leiden), May 15 (*Study of stress-induced morphological instabilities via a phase field model approach*).
- U. Langer (University Linz), May 28–29 (*Scientific computing tools in computational science and engineering*).
- R. Boisvert (NIST, USA), May 28–29 (*NIST Digital Library of Mathematical Functions*).
- J. Pool (Caltech, USA), May 28–29 (*Report on DOE's ASCI*).
- B. Einarsson (University Linköping, Sweden), May 28–29 (*White paper on accuracy and reliability in scientific computing*).
- Dr. M. Olsson and colleague (Comsol, Stockholm), September 5 (*FEMLab demonstration*).
- Ir. P. Vaessen and colleagues (KEMA, Arnhem), October 16.
- Prof. dr. B. van Leer (University of Michigan, Ann Arbor), October 18–31 (*Optimal multigrid convergence by elliptic/hyperbolic splitting* and *Introduction to KGS stability theory*).
- G.I. Shishkin (IMM RAS Ural Branch, Ekaterinburg, Russia), November 1–30 (*Grid approximation of a singularly perturbed parabolic reaction-diffusion equation with a fast moving source* and *High-order accurate decomposition methods based on Richardson's extrapolation for a singularly perturbed elliptic reaction-diffusion equation on a strip*).
- L.P. Shishkina (IMM RAS Ural Branch, Ekaterinburg, Russia), November 1–30 (*High-order time-accurate schemes for parabolic singular perturbation convection-diffusion problems with Robin boundary conditions*).
- Dr. Peter Arbenz (Institute of Scientific Computing, ETH Zürich), November 21.
- R. Blaheta (IGAS, Ostrava, Czech Republic), November 23 (*Iterative methods based on space decomposition*).
- V.P. Il'in (Computing Center, Novosibirsk, Russia), November 23 (*Modified finite volume approximation for singular perturbation problems*).
- O. Axelsson and S.V. Gololobov (KU Nijmegen), November 23 (*A combined method of local Green's functions and central difference method for convection diffusion problems*).

Papers in Journals and Proceedings

E.H. van Brummelen, B. Koren (2001). A Godunov-type scheme for capturing water waves. E.F. Toro (ed.). *Proceedings of Godunov Methods, Theory and Applications*, Oxford, 1999, Kluwer, Dordrecht, 949–968.

E.H. van Brummelen, H.C. Raven, B. Koren (2001). Efficient numerical solution of steady free-surface Navier-Stokes flow. *Journal of Computational Physics* **174**, 120–137.

E.H. van Brummelen, H.C. Raven, B. Koren (2001). Numerical solution of steady free-surface Navier-Stokes flow. N. Satofuka (ed.). *Proceedings of the First International Conference on Computational Fluid Dynamics*, Kyoto, Springer, Berlin, 305–310.

E.H. van Brummelen, A. Segal (2001). Adjoint shape optimization for steady free-surface flows. M.J. Baines (ed.). *Proceedings of the Seventh ICFD Conference on Numerical Methods for Fluid Dynamics*, Oxford, Oxford University Press, Oxford, 549–556.

P.W. Hemker, G.I. Shishkin, L.P. Shishkina (2001). High-order time-accurate parallel schemes for parabolic singularly perturbed problems with convection. *Computing* **66**, 139–161.

P.W. Hemker, G.I. Shishkin, L.P. Shishkina (2001). Acceleration by parallel computations of solving high-order time-accurate difference schemes for singularly perturbed convection-diffusion problems. L. Vulkov, J. Wasniewski, P. Yalamov (eds.). *Numerical Analysis and Its Applications: Second International Conference, NAA 2000*, Rousse, Bulgaria, June 2000; Revised Papers, LNCS 1988. Springer, Berlin, 393–401.

P.W. Hemker, F. Sprengel (2001). Experience with the solution of a finite difference discretization on sparse grids. L. Vulkov, J. Wasniewski, P. Yalamov (eds.) (2001). *Lecture Notes in Computer Science* **1988**, Numerical Analysis and Its Applications: Second International Conference, NAA 2000, Rousse, Bulgaria, June 2000; Revised Papers, LNCS 1988. Springer, Berlin, 402–413.

M.A. Kirklionis, O. Diekmann, B. Lisser, Margreet Nool, Ben Sommeijer,

ANDRÉ M. DE ROOS (2001). Numerical continuation of equilibria of physiologically structured population models, I. Theory. *Math. Models Methods Appl. Sci.* **11**, 1101–1127.

B. KOREN, M.R. LEWIS (2001). Computation of compressible, immiscible water-air flows under the action of gravity. *Proceedings of the ECCOMAS Computational Fluid Dynamics Conference (ECCOMAS CFD 2001)*, CD-ROM, European Community on Computational Methods in Applied Sciences, Swansea.

B. LASTDRAGER, B. KOREN, J.G. VERWER (2001). Solution of time-dependent advection-diffusion problems with the sparse-grid combination technique and a Rosenbrock solver. *Computational Methods in Applied Mathematics* **1**, 86–98.

B. LASTDRAGER, B. KOREN, J.G. VERWER (2001). The sparse-grid combination technique applied to time-dependent advection problems. *Applied Numerical Mathematics* **38**, 377–401.

A.J. VAN DER POORTEN, H.J.J. TE RIELE, H.C. WILLIAMS (2001). Computer verification of the Ankeny-Artin-Chowla conjecture for all primes less than 100 000 000 000. *Mathematics of Computation* **70**, 1311–1328. (also issued as Report MAS-R9905, March 1999).

M.H. VAN RAALTE, B.W. VAN OUDHEUSDEN (2001). An analytical model to describe the Reynolds number effects in supersonic base flow. *AIAA-paper 2001–2785.*

H.J.J. TE RIELE (2001). On the size of solutions of the inequality $\phi(ax + b) < \phi(ax)$. K. ALSTER, J. URBANOWICZ, H.C. WILLIAMS (eds.). *Public-Key Cryptography and Computational Number Theory*, Warsaw, September 11–15, 2000, Walter de Gruyter, Berlin - New York, 249–255. (also issued as Report MAS-R0106, July 2001).

CWI Reports

The following CWI reports were published by members of theme MAS2. See page 43 or 70 for the complete titles of the reports.

MAS-R0101	MAS-R0103	MAS-R0106
MAS-R0107	MAS-R0112	MAS-R0113
SEN-R0039		

Other Publications

P.W. HEMKER, G.I. SHISHKIN, L.P. SHISHKINA (2001). Higher-order time-accurate schemes for parabolic convection-diffusion equations with boundary layers. Optimization of Finite Element Approximations & Splines and Wavelets (OFEA'2001), Abstracts of the International Conference June 25–29, St. Petersburg, Russia, 31–32.

B. KOREN (2001). Promoveren, waarom? *PhDays 2001*, 7–8.

E. LOOTS, M.R. LEWIS (eds.) (2001). *PhDays 2001.*

INFORMATION SYSTEMS

General Overview

Information Systems is a cluster of five related themes:

INS0	Standardization and Knowledge Transfer
INS1	Data Mining and Knowledge Discovery
INS2	Multimedia and Human-Computer Interaction
INS3	Visualization
INS4	Quantum Computing and Advanced Systems Research

The research activities are focused in this cluster on various aspects of information systems.

The activities in theme INS1 are dominated by large-scale activities in the area of multimedia databases and supporting database architectures, while investments in data mining techniques are maintained.

Much of the work in theme INS2 is centered around multimedia applications. The trust of the work shifts towards challenges posed by automatic generated multimedia documents. In this context constraint-based methods are the leading technology basis.

The activities in theme INS3 primarily deal with interactive scientific and information visualization. In 2001 this theme started as a pilot with a focus to improve our understanding and technology for desktop 3D virtual environments.

The core of theoretical investigations into new computing paradigms and machines – Quantum Computing – is undertaken in theme INS4.

The remaining activities within INS are projects geared at knowledge transfer towards research and industrial communities. An important output of the work in this cluster is the development of prototypes for demonstrating and experimenting with solutions. Many of these prototypes are used by affiliated research groups or find their way through partners in (inter)national consortia. The policy regarding their construction is to develop them up to the point that real applications can be built and exercised.

External Contacts

Exploitation of research prototypes, if warranted, is primarily done outside the institute. Therefore, the themes foster transfer of research to its business liaisons. The close affiliation with Data Distilleries secures knowledge transfer and feedback on problems in the area of databases and data mining. In Oratrix three former members of INS2 have brought results on multimedia authoring to the market. A new spin-off Epictiod has been established to bring research on facial animation to the market. It is supported by a project in theme INS2 to transfer results obtained in research. Another important outlet of the knowledge acquired is through active participation in International Standardization committees such as those organized in the context of the World Wide Web Consortium (W3C). INS participates in several large national projects (ICES/KIS, ToKeN2000), Telematics Top Institute (DMW, Uwish), international projects (QAIP, NeuroColt) and projects aimed at knowledge transfer (W3C, STW-FACES). Such participations are considered a valuable asset in driving frontier and innovative research. We expect to continue this line, balancing the challenges of today's ICT with long-term high-risk undertakings. The INS senior researchers participate in the National Research Schools (ASCI, SIKS, OzsL, IPA), broadly disseminate their research results in the international scene, and hold faculty positions at the universities.

Highlights

- H.L. Hardman was appointed part-time full professor at TUE
- R. van Liere was appointed part-time associate professor at TUE
- H.M. Buhrman was appointed part-time full professor at the Faculty of Sciences of the Universiteit van Amsterdam
- Furthermore, Dr. R.M. de Wolf received his PhD 'cum Laude' from the Universiteit van Amsterdam (PhD advisers Prof. H.M. Buhrman and Prof. P.M.P. Vitányi),

- Drs. M. de Graaf received the Nationale Scriptieprijs (f 25.000 or € 1150), CIVI-award.

Staff

- Standardization and Knowledge Transfer – INS0

  - M.L. Kersten
  - D.J.N. van Eijck
  - M. Hazewinkel
  - I. Herman
  - S. Hollaar
  - M. Pauly
  - S. Pemberton

- Data Mining and Knowledge Discovery – INS1

  - M.L. Kersten
  - C. Alkan
  - A.R. van Ballegooij
  - C. Blokker
  - P.A. Boncz
  - H.G.P. Bosch
  - P.M.E. De Bra
  - W.M. Lioen
  - J.A. List
  - N. Mamoulis
  - S. Manegold
  - N. Nes
  - A.R. Schmidt
  - A.P.J.M. Siebes
  - Z.R. Struzik
  - A.P. de Vries
  - M.A. Windhouwer
  - M. Zubowski

- Multimedia and Human-Computer Interaction – INS2

  - H.L. Hardman
  - D.C.A. Bulterman
  - M. Caceres
  - F.J. Cornelissen
  - K. Czajka
  - J. Geurts
  - J. Hendrix
  - M.W.J.H. Huijberts
  - A.P.C. Kiers
  - F.-M. Nack
  - S. Nagpal
  - H. Noot
  - J.R. van Ossenbruggen
  - O. Rosell
  - L.W. Rutledge
  - Zs.M. Ruttkay
  - P. Schmitz
  - S. Sire

- Visualization – INS3

  - R. van Liere
  - H. Huitema
  - W.C. de Leeuw
  - M.S. Marshall
  - J.D. Mulder
  - J.J. van Wijk

- Quantum Computing and Advanced Systems Research – INS4

  - P.M.B. Vitányi
  - A.E. Brouwer
  - H.M. Buhrman
  - W.K. van Dam
  - M. de Graaf
  - P.D. Grünwald
  - H. Klauck
  - T. Lee
  - R. Manniesing
  - H.P. Röhrig
  - R. Spalek
  - J.T. Tromp
  - R.M. de Wolf

- Secretary:

  - M.W.A. Hegt

CWI Reports

INS-R0101. C.A. Lindley, J.R. Davis, F.-M. Nack, L.W. Rutledge. *The application of rhetorical structure theory to interactive news program generation from digital archives.*

INS-R0102. Z.R. Struzik. *Oversampling the Haar wavelet transform.*

INS-R0103. A.R. Schmidt, F. Waas, M.L. Kersten, D. Florescu, I. Manolescu, M.J. Carey, R. Busse. *The XML benchmark project.*

INS-R0104. J.A. List, A.R. van Ballegooij, A.P. de Vries. *Known-item retrieval on broadcast TV.*

INS-R0105. J.R. van Ossenbruggen, H.L. Hardman, L.W. Rutledge. *Hypermedia and the semantic web: A research agenda.*

INS-R0106. F.J. Cornelissen. *Network quality of service for multimedia presentation generation systems.*

INS-R0107. J.P.T.M. Geurts, J.R. van Ossenbruggen, H.L. Hardman. *Application-specific constraints for multimedia presentation generation.*

INS-R0108. F.-M. Nack, M.A. Windhouwer, E.J. Pauwels, M.W.J.H. Huijberts, H.L. Hardman. *The role of high-level*

and low-level features in semi-automated retrieval and generation of multimedia presentations.

INS-R0109. A.P. de Vries, N. Mamoulis, N.J. Nes, M.L. Kersten. *Efficient image retrieval by exploiting vertical fragmentation.*

INS-R0110. Z.R. Struzik, W.J. van Wijngaarden. *Cumulative effective Hölder exponent based indicator for real time fetal heartbeat analysis during labour.*

INS-R0111. M.A. Windhouwer, A.R. Schmidt, R. van Zwol, M. Petkovic, H.E. Blok. *Flexible and scalable digital library search.*

Standardization and Knowledge Transfer – INS0

As of January 2000 part of the research activities of the former group INS3 has been turned into cluster projects, pending future developments in terms of reallocation of resources or thematic focus in the institute. Furthermore, as of January 2001, the institute's activities related to the World Wide Web Consortium (W3C) forms a project within this group.

Staff

- Prof. dr. M.L. Kersten, cluster leader (0.4 fte)
- Prof. dr. D.J.N. van Eijck, researcher
- Prof. dr. M. Hazewinkel, researcher
- Dr. I. Herman, researcher
- S. Hollaar, system administrator, as of December 1
- Dr. M. Pauly M.Sc., researcher, until October 1
- S. Pemberton, researcher

Scientific Report

W3C

Herman was responsible for running the W3C offices. In 2001 this required providing assistance to the Swedish and Greek offices to restart their activities; changing management in the UK office; visiting high-ranking officials in Morocco to support the local W3C office; participation in the creation of a partnership between the Dutch office and the ISOC-NL.

The W3C offices were extended to include the Korean Republic, Finland, Hungary, Spain, plus a regionalization of the current offices towards Austria, Ireland, the Benelux and China.

The W3C managerial tasks also called for a settling of the contractual arrangements between INRIA and MIT; management of the EU project Question-How, which includes all the offices and their hosts (including CWI); management of the presentation material on W3C activities.

Knowledge Transfer

Applied Logic

Van Eijck has continued his work, with colleagues from ILLC and from Uil-OTS (Utrecht), on a new format for Montague Grammar, IMG (Incremental Montague Grammar). He reported on this enterprise in an invited lecture at IWCS-IV (the International Workshop on Computational Semantics), in Tilburg, and at CLIN (Enschede), and he published a paper about it in the *Journal of Logic, Language and Information* (JoLLI). Van Eijck is also involved in interactive information engineering, in a pilot project with Elsevier Science BV (in collaboration with ILLC), together with Johan van Benthem and Maarten de Rijke (ILLC). With his co-workers Juan Heguiabehere and Breanndan Ó Nualláin at ILLC, Van Eijck published a paper on programming and automated (tableau) reasoning with Dynamic First Order Logic in the *Journal of the IGPL*. This provides a logical underpinning for Dynamo (see `http://www.cwi.nl/~jve/dynamo`). Van Eijck organized a workshop on tableau reasoning at the University of Amsterdam, and gave talks on constraint based tableau theorem proving at IJCAR (Sienna) and CSL, Paris. Finally, he taught several courses at the Universities of Amsterdam and Utrecht.

Pauly rounded off his research in the logic of games to the problem of coalition formation. This resulted in various journal papers and a dissertation. Pauly defended his PhD on 'Logic for Social Software' at the University of Amsterdam, on December 13, 2001. Thesis advisors were Johan van Benthem and Jan van Eijck. Pauly's coalition logic yields interesting new insights which go beyond the standard game-theoretic analysis of collective decision making; among other things, it sheds light on the complexity of reasoning about coalitional effectivity. Pauly has accepted a tenured position at the University of Liverpool.

Van Eijck and Pauly were involved in work done within the Spinoza project which aims to publish a Dutch high school level book on machine models and logic with Amsterdam University Press. The result of this has been tested out at some high schools in the Netherlands. A text-

book, written by Jan van Eijck, Jan Ketting, Jan Jaspars and Marc Pauly will appear with Amsterdam University Press in the course of 2002.

Automatic indexing and the TRIAL project
The contribution of CWI to the EU TRIAL project is concentrated on automatic indexing (besides some general managerial tasks. The software for the automatic indexing part was delivered in November 2001. As input this takes an IMS packaged XML file and a 'Identification cloud file' (structured according to the relevant DTD); as output it produces the same IMS packaged file but with key phrases added (according to the relevant DTD). In addition it produces an HTML file for human use which highlights the phrases selected (more precisely the evidence which made a certain phrase to be assigned because the actual phrase may very well be not present. Sample identification clouds thesauri have been produced (letters ABC and XYZ from the Bronstein small encyclopaedia). These suffice to make a good comparison between automatic key phrase assignment and human versions. From the experience gained in 2001 it is clear that the words occurring in identification clouds of a phrase need weights and that for optimal procedures a stochastic model for identification clouds needs to be developed.

Hopf algebras
In 1999 Hazewinkel gave a proof of the 1972 Dieters conjecture (paper published December 2001 in *Advances Math.*). In 2001 he managed to give a complete recursive description of the primitives of the Hopf algebra of noncommutative symmetric functions. (Preprint Nov. 2001). This also give a second completely different proof of the polynomial freeness of the algebra of quasisymmetric functions. Research further focuses on which of the many structures of the (Hopf) algebra of symmetric functions have natural analogues for the noncommutative symmetric functions and the quasisymmetric functions. A most important circumstance would appear to be that all three (*Symm, NSymm, QSymm*) can be interpreted as Hopf algebras of endomorphisms of Hopf algebras. (M. Hazewinkel, in preparation).

PhD Thesis

M. Pauly (2001). *Logic for Social Software*, December 13, University of Amsterdam. Thesis advisors: Prof. dr. J. van Benthem and Prof. dr. D.J.N. van Eijck.

Organization of Conferences, Workshops, Courses, etc.

D.J.N. van Eijck:
- Tableaux for Dynamic and Modal Logics workhop, ILLC, Amsterdam, April 5–6.
- ILLC Colloquium Afternoon With Hans Kamp, April 3, Amsterdam.
- (as organizer) Dutch Graduate School in Logic School Week, October 22–27, Nunspeet.

M. Hazewinkel:
- First Mathematical Knowledge Management consortium meeting, CWI, Amsterdam, December 13–14.
- TRIAL working meeting, CWI, Amsterdam, December 17–18.

M. Pauly:
- Workshop on Logic and Games at the European Summer School of Logic, Language and Information (ESSLLI), organized with Gabriel Sandu, University of Helsinki, August 20–24.

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

D.J.N. van Eijck:
- Context Semantics for NL, IWCS-IV, Tilburg, January 12.
- Constrained Hyper Tableaux, Zuidelijk Interuniversitair Colloquium, Eindhoven, March 20.
- Model Generation from Constrained Free Variable Tableaux, IJCAR, Sienna, June 22.
- Constrained Hyper Tableaux, CSL, Paris, September 11.
- Reasoning With Tableaux, OzsL Schoolweek, Nunspeet, October 22.
- Hyper Tableaux, OzsL Schoolweek, Nunspeet, October 23.
- Logic and Language Links, OzsL Schoolweek, Nunspeet, October 24.
- Quantification and Reference in Dynamic Semantics, Learning, Logic, and Grammar, Amsterdam, November 23.
- Update on Context Semantics for Natural Language, CLIN, University of Twente, Enschede, November 30.
- Equality Clause Reduction, Nancy, December 7.

- Expressivity of extensions of dynamic first-order logic (with Balder ten Cate and Juan Heguiabehere), Amsterdam Colloquium, Amsterdam, December 19.
- Dissemination of Logic in Action, Spinoza Farewell Meeting, Amsterdam, December 20.

M. Hazewinkel:

- INTAS Council of Scientists meeting, Brussels, February 23–25.
- TRIAL working meeting, Dublin (Ireland), February 8–11.
- Thesis opponent lecture C. Altafini, KTH, Stockholm, May 20.
- *Witt vectors, symmetric functions, noncommutative symmetric functions, and quasisymmetric functions. Their interrelations and similarities. A survey.* Colloquium lecture University of Stockholm, May 21.
- TRIAL evaulation meeting, Luxemburg, February 26–27.
- Meeting Council of Scientists, Brussels, May 31–June 1.
- TRIAL working meeting, Heidelberg (Germany), June 5–6.
- *Noncommutative and quasi-symmetric functions*, invited lecture Mondromy Conference, Steklov Institute of Mathematics, Moscow, June 26.
- *Witt vectors, symmetric functions, noncommutative symmetric functions, and quasisymmetric functions. Their interrelations and similarities. A survey.* Invited opening lecture, 4-th int. algebra conference, Sumy, Ukraina.
- Lectures on *Statistical, topological and metric aspects of thesauri and information retrieval*, 20 hours, August 9–23, Institute of Mathematics and Informatics, Lithuanian Academy of Sciences, Vilnius, Lithuania.
- TRIAL working meeting, Oxford (UK), September 16–18.
- Conference Mathematical Knowledge Management, Linz (Austria), September 22–27.
- Framework 6 planning meeting, Luxemburg, October 15–16.
- Meeting Council of Scientists, Brussels, December 12.

I. Herman:

- Eurographics'2002 Conference Tutorial on SVG, Manchester (UK), September 3–8.
- Euroweb 2001 Conference, keynote speech: Pisa (Italy), December 18–20.
- W3C Advisory Committee Meeting, Hong Kong (China), April 29.
- W3C Day, Sydney (Australia), May 8.
- XML Day, Amsterdam, September 22.
- W3C Day, Thessaloniki, October 13.
- SVG Presentation, CeIT, Hannover (Germany), March 26.

M. Pauly:

- *Von Logikspielen zur Logik des Spiels*, Mathematics and Computer Science Colloquium, University of Passau, Germany, January.
- *Coalitional Ability in Multi-Agent Systems: A Logical Aproach*, AAAI Symposium on Game Theoretic and Descision Theoretic Agents, Stanford University, USA, March.
- *On the Complexity of Coalitional Reasoning*, Second International Conference on Logic, Game Theory and Social Choice, St. Petersburg, Russia, June.
- *In Praise of Ignorance and Individualism*, Workshop on Logic and Games, University of Amsterdam, December.

S. Pemberton:

- Presentation: *Usability is not an ad-on*, SERC (Utrecht), February 20.
- Visit W3C Technical Plenary, Boston, February 28.
- Visit CHI 2001 Conference, Seattle, April 2–5.
- Visit W3C Advisory Committee, Hong Kong, April 29–30.
- Visit WWW10 Conference, Hong Kong, May 1–4.
- Presentation: *Support concepts for Web navigation: a cognitive engineering approach*, WWW10, the 10th International World Wide Web Conference, Hong Kong, May 2.
- Presentation: *XForms*, WWW10, May 2.
- Presentation: *XHTML*, WWW10, May 3.
- Presentation: *The Uwish Knowledge Centre*, SIGCHI.nl Summer conference, NL, June 12.
- Presentation: *XHTML*, *Usability and Accessibility*, SIGCHI.nl Summer conference, NL, June 12.
- Presentation: *XHTML*, XML Day, Helsinki, September 28.
- Presentation: *The XHTML Family: HTML in XML*, CWI in Bedrijf, October 5.
- Presentation: *Diversity*, Usability of Web-based Services Workshop, TNO, December 4.
- Visits W3C HTML Working Group: Boston March 1–2; Amsterdam June 21–22; New York September 10–11; Silicon Valley November 15–16.
- Visit W3C XForms Working Group: Boston February 26–27; Amsterdam June 18–20; New York September 5–7; Silicon Valley November 12–14.

- Visit W3C Advisory Committee, Nice November 5–7.
- Visit W3C Document Formats meeting, Tokyo, November 27–28.
- Visit SIGCHI.nl Summer conference June 12.
- Visit CCSC: Change and continuity in scientific communication, Amsterdam, June 25.
- Visit SIGCHI Executive Committee, Seattle, April 6–7.
- Visit SIGCHI Executive Committee, New Jersey, August 11–13.
- Visit SIGCHI Executive Committee, Amsterdam, December 9–11.

Visitors

Guests of Van Eijck:
- Peter Baumgartner (research visit, November 5 and 6).
- Valentin Goranko and Rohit Parikh, December 13 (PhD defence Pauly).

Guests of Hazewinkel:
- Dr. D. Malyshev and Dr. D. Malyshev (Univ. Kiev), March 18–26.
- Prof. U. Krasilshchik, June 12.
- Dr. D. Malyshev (Univ. Kiev), November 14–21, November 26 – December 12.

Memberships of Committees and Other Professional Activities

D.J.N. van Eijck:
- Professor of Logical Aspects of Computational Linguistics, University of Utrecht (since December 1990).
- 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 (since Spring 1997)
- Chairman of the VSNU Visitation Committee for Dutch University Curricula in Artificial Intelligence (Fall 2001).
- Member of the International User and Consultation Group for TRINDI.
- Member of the PhD Examination Board of Roberto Poli, UU (February 21, 2001).
- Member of the PhD Examination Board of Gwen Kerdiles, UvA (November 14, 2001).
- Supervisor of the Master Thesis of Derk Pietersen (together with A. Visser and H. Hendriks), CKI, UU (December 21, 2001).

M. Hazewinkel:
- Managing Editor book series *Mathematics and Its Applications*, Kluwer Academic Publishers, 1977.
- Managing Editor journal: *Acta Applicandae Mathematicae*, Kluwer Academic Publishers, 1983.
- Managing Editor *Encyclopaedia of Mathematics*; Vols 1–10, 1988–1994; first update volume, 1997; CDROM version, 1998; further update volumes 1999.
- Managing Editor *Handbook of Algebra* in 9 volumes; first volume 1996. Editorial board Trends in Scientific Research, Unesco/Reidel, 1984.
- Manager (coordinator) INTAS projects 96-0793 (1997–2000), 96–0741 (1997–2000), 97–0808 (1998–2001), 97–0804 (1999–2001).
- Member Steering committee ESF program on Noncommutative Geometry, 2000–2004.
- Member Scientific committee Monodromy in geometry and differential equations, Moscow, June 25–30.
- Member program committee First international conference on mathematical knowledge management, September 24–26, Schloss Hagenberg, Austria.
- Evaluator INTAS project proposals 2001.

S. Pemberton:
- Member advisory board Executive Committee of SIGCHI.
- Editor in Chief ACM/interactions.
- Chair W3C HTML Working Group.
- Chair W3C Forms Working Group.
- Member program committee NLUUG Autumn Conference, November 8.

Papers in Journals and Proceedings

U. Brandes, M. Eiglsperger, I. Herman, M. Himsolt, M.S. Marshall (2001). GraphML Progress Report, Structural Layer Proposal. *Proceedings Symposium on Graph Drawing GD'01*, Springer Verlag.

B. ten Cate, J. van Eijck, J. Heguiabehere (2001). Expressivity of Extensions of Dynamic Predicate Logic. R. van Rooy, M. Stokhof (eds.). *Proceedings of the Thirteenth Amsterdam Colloquium*, ILLC, Amsterdam, 61–66.

J. van Eijck (2001). Border Crossings. J. van Benthem, P. Dekker (eds.). *Logic in Action*, ILLC, Amsterdam, 51–74.

J. van Eijck (2001). Constrained Hyper Tableaux. L. Fribourg (ed.). *Computer Science Logic*, LNCS **2142**, 232–246.

J. van Eijck (2001). Model Generation from Constrained Free Variable Tableaux. R. Goré, A. Leitsch, T. Nipkov (eds.). *IJCAR 2001 – Short Papers*, Univ. of Siena, Siena, 160–169.

J. van Eijck (2001). Incremental Dynamics. *Journal of Logic, Language and Information* **10**, 319–351.

J. van Eijck, J. Heguiabehere, B. Ó Nualláin (2001). Tableau Reasoning and Programming with Dynamic First Order Logic. *Logic Journal of the IGPL* **9**, 411–445.

M. Hazewinkel (2001). Index *Discrete Mathematics* volumes 1–200. *Discrete Mathematics* **227/228**, 1–648.

M. Hazewinkel, R. Rudzkis (2001). Probabilistic model for the growth of thesauri. *Acta Appl. Math.* **67**, 237–252.

M. Hazewinkel (2001). Index *Information Processing Letters* volumes 1–75. *Information Processing Letters* **78**, 1–448.

M. Hazewinkel (2001). The algebra of quasisymmetric functions is free over the integers. *Advances Math.* **164**, 283–300.

I. Herman (2001). Minimal Graphics. *IEEE Computer Graphics & Applications* **21**(6).

M. Pauly (2001). A logical framework for coalitional effectivity in dynamic procedures. *Bulletin of Economic Research* **53**(4), 305–324.

S. Pemberton, M.A. Neerincx (2001). Support concepts for Web navigation: a cognitive engineering approach. *Conference proceedings of WWW10*, the 10th International World Wide Web Conference, May 1–10, Hongkong.

Other Publications

M. Hazewinkel (2001). Bookreview D. van Dalen, *Mystic, geometer, and intuitionist. The life of L.E.J. Brouwer. Volume 1: the dawning revolution*, Oxford Univ. Press, 1999. *Nieuw Archief voor Wiskunde*, 2001.

Bart Leurs (2001). *Quantum Filed Theory and the Jones Polynomial*. Master thesis, supervised by Hazewinkel.

S. Pemberton (2001). Modularization of XHTML. Altheim et al. *W3C Recommendation*, http://www.w3.org/TR/2001/REC-xhtml-modularization-20010410/

S. Pemberton (2001). XHTML 1.1 - Module-based XHTML. Altheim et al. *W3C Recommendation*, http://www.w3.org/TR/2001/REC-xhtml11-20010531/

S. Pemberton (2001). Photocopy this article! *ACM Interactions* **8**(1).

S. Pemberton (2001). The design of notations. *ACM Interactions* **8**(2).

S. Pemberton (2001). In search of the killer app. *ACM Interactions* **8**(4).

S. Pemberton (2001). The culture of uncertainty. *ACM Interactions* **8**(5).

S. Pemberton (2001). Did convergence kill the clock? *ACM Interactions* **8**(6).

Data Mining and Knowledge Discovery – INS1

Staff

- C. Alkan, MSc. student (TUD as of November 1)
- Drs. A.R. van Ballegooij, PhD student
- C. Blokker, MSc. student (UvA until February 1)
- Drs. P.A. Boncz, PhD student (as of July 1)
- Dr. ir. H.G.P. Bosch, postdoc (until April 1)
- Prof. dr. P.M.E. De Bra, senior researcher, seconded by TUE (0.2fte)
- Prof. dr. M.L. Kersten, senior researcher, theme leader, cluster leader
- Drs. W.M. Lioen, programmer (until December 1)
- Drs. J.A. List, PhD student
- Dr. N. Mamoulis, postdoc (until September 1)
- Dipl.-Inform. S. Manegold, PhD student
- Dr. N. Nes, postdoc
- Dipl.-Inform. A.R. Schmidt, PhD student
- Prof. dr. A.P.J.M. Siebes, advisor (UU)
- Dr. ir. Z.R. Struzik, postdoc
- Dr. ir. A.P. de Vries, postdoc
- Drs. M.A. Windhouwer, PhD student
- M. Zubowski, MSc. student (VU as of November 1)

Scientific Report

Data Mining – INS1.1

There were two main trajectories of work in 2001.

- Characterisation and analysis of heartbeat intervals, in particular fetal heartbeat.
- Setting up a methodology of data mining hybrid datasets, including knowledge discovery from characteristics derived from time series.

A novel approach to evaluating fetal status during labour has been proposed and tested. It utilizes wavelet style decomposition of the fetal heart rate and characterization of the variability component with the local roughness (Hölder) exponent. The cumulative local Hölder exponent based indicator has been demonstrated to coincide with fetochemical variables and with the decisions of obstreticians in a database of almost a thousand test cases. We have used Bayesian belief nets to establish relationships between variables of interest. This work has been done in collaboration with Utrecht University and Academic Hospital (UMC). These research activities with external partners are intensified, which lead to the preparation of three proposals for external funding.

Struzik and *Castelo* (Univ. Utrecht) worked together to clean the fetal heartbeat data which we got from AMC (collected by five different hospitals around the world). We also worked to set up the data mining experiment to approach the predictive model recovery from fetal heartbeat data. The main challenge in data cleaning was converting the data from an average (2 second based) format to highest accuracy, beat-to-beat interval format. The data mining experiment required deriving meaningful temporal features from fetal heartbeat and feeding them into the Bayesian Belief Net reasoning algorithm. The results have been submitted for publication.

Lioen was seconded to Data Distilleries for research and development on their data mining products. This secondment was turned into a permanent contract as of December 1, 2001.

Multimedia Databases – INS1.2

Research in multimedia databases investigates the role of data management techniques for the indexing and retrieval of multimedia data. The research takes place in context of two projects: Digital Media Warehouses (DMW) and Multimedia Information Analysis (MIA). Our participation in DMW focuses on indexing, while MIA concentrates on retrieval aspects. Additionally, the group participated in the Druid project and the DELOS Network of Excellence.

The activities in DMW, a cooperation with Telematics Institute and University of Twente, cover two aspects: XML handling in a database context and Feature grammars for multimedia indexing. The project is managed by De Vries.

Windhouwer worked on the Acoi system architecture, a part of the DMW project. A major part of this year was spent on the integration of the results of the various DMW and AMIS partners in one demonstrator. The demonstrator provides integrated concept- and content-based search for structured, semi-structered and multimedia data on the Australian Open tennis tournament. The demo was given at the TI PSC meeting, ICT Kenniscongres 2001 and VLDB 2001, and will be shown at ICDE 2002. The architecture of the demonstrator is described in a book chapter, a CWI technical report and short papers related to the demonstrations.

Apart from the DMW demonstrator, feature grammars have been applied in the collaboration between INS1, INS2 and PNA4. In this collaboration, feature extractors from PNA4 are plugged into the Acoi system. The Acoi system functions as a style repository and is used to predict the style of paintings from the Rijksmuseum that are not annotated by an expert. The same features are also to be used by the Cuypers system of INS2 to combine multiple paintings in such a way that information about the style is visualized for the user. This work resulted in a paper and a CWI technical report.

To support these case studies of the Acoi system architecture, the implementation has been extended and made more mature. A first developers manual has been written, and knowledge transfer has started by distributing stable versions of the system to both internal (INS1) and external (TI) projects.

Schmidt's work centered around performance evaluation of XML processing systems and querying. A first version of the XMark Benchmark has been released along with the tools that are necessary to run the benchmark. The benchmark was well received in the community as the download numbers show. Furthermore, he continued his work on querying XML data and presented some results at the IEEE International Conference on Data Engineering in Heidelberg. During his three-month visits to Microsoft in Seattle, he applied his research in the optimizer group of SQL Server. Towards the end of the year he started writing up his thesis.

Another significant part of the activities on Multimedia databases takes place in the context of the Multimedia Information Analysis (MIA) project, a multi-year multidisciplinary project funded under ICES/KIS. The notion of *query articulation*, the key idea developed last year, has

been further refined in the Image Spotter prototype, and evaluated on its merits in the video domain. The day-to-day management of these activities are taken care of by *De Vries*, while policy and preparatory actions for its successor project, called MultimediaN, are undertaken largely by *Kersten.*

Bosch finalized his work on the Image Spotter, which uses local-spatial based image regions, i.e. sub-images, as input for a query-by-example search system. The results obtained have been published and the prototype implementation has been demonstrated at various occassions.

Ballegooij, List and *De Vries* focused their research activities in 2001 on the implementation of a video retrieval system on top of Monet. Ballegooij concentrated on the visual channel, while List focused on the audio channel. The resulting prototype covers data management (indexing and retrieval) of MPEG I encoded video data with Monet. Initial experiments with video content analysis and retrieval are described in a CWI report. Subsequently, the system has been applied – with considerable success – in the video track at TREC 2001, an international benchmarking activity for the evaluation of information retrieval systems. Our TREC experiments were designed to evaluate the idea of query articulation in a practical setting. Although the results were promising, we need to investigate means to reduce the large amount of user effort required to achieve the desired retrieval performance. To improve the retrieval system from its current state, we started to develop a query language oriented more toward the multimedia domain, and investigate the application of probabilistic techniques in the retrieval model.

De Vries and *Mamoulis* have applied the database technique of vertical fragmentation in a novel application domain, to improve the efficiency of nearest neighbour search in high-dimensional spaces. The results are published as a technical report, and a paper on this technique has been accepted for publication at SIGMOD.

De Vries and *Van Ossenbruggen* (INS2) acquired the Waterland project, together with NOB, NOS, University of Twente and TNO. The project focuses on semi-automatic techniques for metadata extraction in the digital production of media. Unfortunately, the resulting vacancy has not yet been filled in.

De Bra focused his research on adaptive hypermedia and web-based information systems. The new AHA project was started with subsidy from the NLnet Foundation, described at length at http://aha.win.tue.nl/. A new NWO project, NASH, was funded, and complements projects Dynamo and RTIPA in which mainly INS2 and TUE are active.

Database architectures – INS1.3

Manegold, Boncz and *Kersten* extended their work on the impact of modern hardware features – especially hierarchical cache-memory systems and super-scalar CPUs – on the performance of databases. Exhaustive experiments on various hardware platforms confirmed that – unless special care is taken — main-memory access forms a severe performance bottleneck on virtually any contemporary computer architecture. Our memory-conscious algorithms proved to minimize the main-memory access costs on all systems.

The thurst of work in 2001, aside from writing chapters for their PhD theses, focused on exhaustive experimentation with several 'real-life' applications (e.g., TPC-H benchmark, XML benchmark, multirelational data mining). These experiments brought to light that, with memory access being optimized, pure CPU costs become crucial. Apparently, the code of query processing algorithms, is too data-dependent, thus compilers cannot detect all potential for optimization at compile time. Hence, we re-implemented the key algorithms, making extensive use of our macro expansion technique to get more 'compiler-friendly', i.e., less data dependent code. The improvement turned out to be up to a factor 10 on pure CPU costs and about factor 5 on overall costs.

For cost modelling, we developed a novel generic technique to build physical database cost models for hierarchical memory systems. Our approach accurately considers the impact of memory caches and gathers main-memory and I/O cost models within a common framework. Constructing cost functions for query processing algorithms now boils down to simply describing the algorithms' data access using a few key pattern. The complex functions are then derived automatically. Furthermore, we extended our query optimizer with heuristic optimization rules, mainly geared towards reduction of intermediate result sizes.

Boncz joined the group formally as of July 1st, but was seconded back to Data Distilleries for wrapping up the design and implementation of their data mining tools. Deployment of

the Monet database kernel in their product-line proved valuable to assess the design decisions made in a real-life setting. The Monet improvements developed at Data Distilleries are included in our experimentation platform without legal limitations.

The activities of Kersten in this area are mainly focused on preparing the experimental platform for the years to come, i.e Monet version 5. This version involves a major rewrite of around 20% of the code base (ca 25 K lines). The targets set are to change the architecture more towards a virtual machine for database processing, and to secure a situation were multi-level and multi-query optimization techniques can be experimented with. Concurrently, *Nes* developed a state-of-the-art SQL to MIL (Monet Interface Language) compiler as a necessary step towards supporting a broader application field. In addition, Nes spent substantial time and effort on securing the computer infrastructure of INS.

Cooperation with Delft University on extensions of Monet into the direction of supporting geographical information system have been initiated. This activity is managed at their side by W. Quak, who aims to compare the functional/performance of the Monet system against the commercial systems supporting the *Kadaster* database. The master student *C. Alkan* was hired to work on this project. At our side this project was supported by N. Nes.

As of early November we contracted the master student *M. Zubowski*, who is working on his thesis on parallel database on SMP architectures under the guidance of P. Boncz.

Organization of Conferences, Workshops, Courses, etc.

De Bra:
- Organizer and PC co-chair of the Third Workshop on Adaptive Hypermedia, held at the ACM Hypertext Conference, Aarhus, Denmark, August 2001. (Proceedings are published as Springer LNCS **2266**.)

De Vries:
- Co-organizer (with D. Hiemstra) of the 2nd Dutch Information Retrieval Workshop, January 2001, University of Twente, Enschede, The Netherlands

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

Ballegooij:
- ASCI 2001 Conference, May 30 – June 1, Heijen, The Netherlands.
- Int. Conf. on Very Large Database, VLDB 27, September 11–14, Roma (Italy)
- Tenth Text Retrieval Conference, November 13–16, NIST, Gaithersburg, (USA)

Boncz:
- *Monet: a high performance database kernel for query-intensive applications*, NGI Databaseclub, January 21, Gilze-Rijen
- PKKD'01 invited speaker aCRM workshop, *aCRM with Data Distilleries: experiences, lessons learned and open challenges*, September 11–15, Freiburg (Germany)
- *(multimedia) database system research at CWI/INS1*, working visit Philips Natlab, November 17, Eindhoven

Bosch:
- SPIE Workshop on Storage and Retrieval for Media Databases, *A case for Image Quering through Image Spots*, January 23–27, San Jose (USA)

Kersten:
- Stanford University, working visit Wiederhold, May 16–19, Palo Alto (USA)
- ACM Sigmod conference, May 19–25, Santa Barbara (USA)
- British National Conference on Databases (BNCOD), *Memory-Aware Query Routing in Interactive Web-based Information Systems*, July 2–5, Oxford(UK)
- EUROPAR, invited keynote speech, *Macro- and Micro- Parallelism in a DBMS*, August 28–30, Manchester(UK)
- GMD Darmstadt advisory board meeting, March 27–28, Darmstadt (Germany)
- Int. Conf. on Very Large Database, VLDB 27, September 11–14, Roma (Italy)

List:
- Tenth Text Retrieval Conference, November 13–16, NIST, Gaithersburg, (USA)

Nes:
- Int. Conf. on Very Large Database, VLDB 27, September 11–14, Roma (Italy)

Schmidt:
- Nearest Concept Queries Int. Conf. on Data Enginering, April 2–6, Heidelberg (Germany)

- The XMark project Microsoft Research, Seattle (USA), June 29
- The XMark project Microsoft SQL Server Development, July 27, Seattle (USA)

Struzik:
- *Reasoning from non-stationarity*, Conference Horizons in Complex Systems, Messina (Italy), December 5–8
- *Wavelet Transform Based Multifractal Formalism in Outlier Detection and Localisation for Financial Time Series*, Conference on Quantitative methods in Economics Research II, Warsaw (Poland), September 21
- *Determining local singularity strengths and their spectra with the wavelet transform*, workshop Information Theory Days, Warsaw, (Poland), April 23–29

De Vries:
- IEEE International Conference on Multimedia and Expo (ICME 2001), *Exact Matching in Image Databases*, August 22–25, Tokyo, Japan
- Delos management meeting, Pisa, Italy, February 22
- Tenth Text Retrieval Conference (TREC-10), *Lazy Users and Automatic Video Retrieval Tools in (the) Lowlands*, Washington, USA, November 10
- ECIR PC meeting, Glasgow, Scotland, December 17

Windhouwer:
- ICT Kenniscongres 2001, *The Acoi search engine*, September 6–7, The Hague, The Netherlands
- Int. Conf. on Very Large Database, VLDB 27, Sepember 11–14, Roma (Italy)

Visitors

- Prof. A. Orlowski (IF-PAN)
- Prof. G. Dewey (Keck Graduate Institute)

Memberships of Committees and Other Professional Activities

Boncz:
- Member program committee VLDB 2001, September, Italy
- Member program committee EDBT 2002, March 2002, Czech Republic

De Vries:
- Member program committee VLDB 2001, September, Italy
- Supporting European Program Chair (Apers (UT)) with Organization VLDB 2001 (with Flokstra and Van Keulen (UT)
- Member program committee WebNet 2001 Conference, October, Orlando, Florida, USA
- Member program committee ECIR 2002, March 2002, Scotland
- ICT Kenniscongres 2001, *Minds and Mirrors: Multimedia Retrieval*, September 7, The Hague, The Netherlands
- Teaching: SIKS course 'Information Retrieval', in cooperation with Hiemstra (UT), March 5–6, Nijmegen, as well as PhD committee member for Arampatzis (Nijmegen), and three lectures for MSc. courses in Twente, one for an MSc. course in Eindhoven
- Reviewing for *ICDE, EDBT, ACM Multimedia, Int. Journal for Cooperative Information Systems*

Kersten:
- Editor: The *VLDB Journal and Distributed* and *Parallel Databases*
- Invited Speaker: Micro and Macro-parallelism in a DBMS, Europar, August 28, Manchester (UK)
- Member program committee ACM Sigmod 2001, May, Santa Barbara (USA)
- Member program committee International Data Engineering Conference, April, Heidelberg (Germany)
- Member program committee RIDE workshop, April, Heidelberg (Germany)
- Member steering committee Token2000 (NWO)
- Member of the VLDB Endowment Executive Board
- Member of the IFIP WG-2 Databases workinggroup
- Member scientific advisory board GMD Darmstadt
- Member board of the Amsterdam New Media Association (as of December)
- Non-executive board member of Data Distilleries

Mamoulis:
- Served as a reviewer for IEEE TKDE Journal and Int. Conference on Data Engineering '01

Struzik:
- Member program committee DEXA September 2–6 Aix-en-Provence (France)
- Member technical committee IASTED September 3–7 Munich (Germany)
- Working visit to Boston (USA), March 16–April 1, Center for Polymer Studies (CPS), Boston University. Talk: *Can Fractals Walk? A Real Time Fetal Heartbeat Analysis*

- Working visit Institute of Physics, Polish Academy of Sciences, April 19–20, Warsaw

Software Developed

The Monet database system forms the core of the research experimentation platform of INS1 (www.cwi.nl/∼monet). The code base is maintained and enhanced in close cooperation with Data Distilleries as part of their involvement with the MIA project. Nes continued the development of the SQL-92 to MIL compiler. Manegold maintained the quality control system for the Monet code base. Kersten started the development of version 5.0, which is geared at a simplified architecture using a virtual machine approach.

Windhouwer developed and maintained the ACOI search engine; an extensive code base to collect, analyze, and index multimedia information on the web (www.cwi.nl/∼acoi).

Schmidt developed the XML-benchmark suite and evaluated various systems during hist internship at Microsoft. Kersten prepared the XMark website to increase visibility and provide access to the source and documentation. Around 3000 downloads have been counted since.

Papers in Journals and Proceedings

I. Bartolini, P. Ciaccia, F. Waas (2001). FeedbackBypass: A new Approach to Interactive Similarity Query Processing. *Proceedings of the International Conference on Very Large Data Bases (VLDB)*, Rome, Italy, 201–210.

H.G.P. Bosch, A.P. de Vries, N. Nes, M.L. Kersten (2001). A case for Image Quering through Image Spots. *Storage and Retrieval for Media Databases 2001,* **4315** *of Proceedings of SPIE*, San Jose, CA, USA, 20–30.

H.G.P. Bosch, A. van Ballegooij, A.P. de Vries, M.L. Kersten (2001). Exact matching in image databases. *Proceedings of the 2001 IEEE International Conference on Multimedia and Expo (ICME2001)*, Tokyo, Japan, 513-516.

P. De Bra, J.P. Ruiter (2001). AHA! Adaptive Hypermedia for All. *Proceedings of the WebNet Conference*, 262–268.

P.Ch. Ivanov, L.A. Nunes Amaral, A.L. Goldberger, S. Havlin, M.G. Rosenblum, H.E. Stanley, Z.R. Struzik (2001). From 1/f Noise to Multifractal Cascades in Heartbeat Dynamics. *CHAOS. An Interdisciplinary Journal of Nonlinear Science* **11** (special issue on Unsolved Problems of Noise).

M.L. Kersten, S. Manegold, P.A. Boncz, N. Nes (2001). Macro- and Micro- Parallelism in a DBMS. *Proceedings of the European Conference on Parallel Processing (EuroPar)*, LNCS, Springer-Verlag, Manchester, UK, 6–15.

F. Waas, M.L. Kersten (2001). Memory-Aware Query Routing in Interactive Web-based Information Systems. *Proceedings of the British National Conference on Databases (BNCOD)*, Oxford, UK, LNCS, Springer-Verlag, 68–184.

N. Mamoulis, K. Stergiou (2001). Non-Binary CSPs Using the Hidden Variable Encoding. *International Conference on Principles and Practice of Constraint Programming (CP)*, Paphos, Cyprus, LNCS, Springer-Verlag, 68–182.

N. Mamoulis, D. Papadias (2001). Selectivity Estimation of Complex Spatial Queries. *Proceedings of the International Symposium on Spatial and Temporal Databases (SSTD)*, Los Angeles, CA, USA, 155–174.

A.R. Schmidt, M.L. Kersten, M.A. Windhouwer (2001). Querying XML Documents Made Easy: Nearest Concept Queries. *Proceedings of the IEEE International Conference on Data Engineering (ICDE)*, Heidelberg, Germany, 321–329.

A.R. Schmidt, F. Waas, M.L. Kersten, D. Florescu, M.J. Carey, I. Manolescu, R. Busse (2001). Why and How to Benchmark XML Databases. *ACM SIGMOD Record* **3**(30).

Z.R. Struzik (2001). Wavelet Methods in (Financial) Time-series Processing. *Physica A: Statistical Mechanics and its Applications* **296**(1–2), 307–319.

Z.R. Struzik (2001). Revealing Local Variability Properties of Human Heartbeat Intervals with the Local Effective Hölder Exponent. *Fractals* **9(1)** 77–93.

A.P. de Vries (2001). Content independence in multimedia databases. *Journal of the American Society for Information Science and Technology* **52**(11), 954–960.

H. Wu, P. De Bra (2001). Sufficient Conditions for Well-Behaved Adaptive Hypermedia Systems. *Proceedings of the First Asia-Pacific Conference on Web Intelligence: Research and Development*, Lecture Notes in Artificial Intelligence **2198**, Springer, 148–152.

H. Wu, E. De Kort, P. De Bra (2001). Design Issues for General-Purpose Adaptive Hypermedia Systems. *Proceedings of the ACM Conference on Hypertext and Hypermedia*, Aarhus, Denmark, 141–150.

CWI Reports

The following CWI reports were published by members of theme INS1. See page 91 for the complete titles.

INS-R0102	INS-R0103	INS-R0104
INS-R0109	INS-R0110	INS-R0111

Other Publications

P. De Bra, P. Brusilovsky, T. Murray, M. Specht (2001). Adaptive Web-based Textbooks. (Panel introduction) *Proceedings of the WebNet Conference*, 269–271.

H.E. Blok, M.A. Windhouwer, R. van Zwol, M. Petkovic, P.M.G. Apers, M.L. Kersten, W. Jonker (2001). Flexible and scalable digital library search. *Proceedings of the International Conference on Very Large Data Bases (VLDB)*, Rome, Italy, Poster.

D. Hiemstra (ed.) (2001). Fascinating relations between media and text. *International congress of the Academia Europaea*, Erasmus Universiteit Rotterdam.

M.L. Kersten (2001). *The Acoi search engine.* ICT Kenniscongres, September 6–7, The Hague, The Netherlands.

Multimedia and Human-Computer Interaction – INS2

Staff

- Prof. dr. H.L. Hardman, theme leader
- Dr. D.C.A. Bulterman, external advisor
- M. Caceres, visiting student (from December)
- Drs. F.J. Cornelissen, PhD student (until April 1)
- K. Czajka, visiting student (from November)
- Ir. J. Geurts, PhD student (until October 15)
- Drs. J. Hendrix, researcher (until May)
- Ir. M.W.J.H. Huijberts, PhD student (until October 31)
- Ms. Ir. A.P.C. Kiers, project member (until February 15)
- Dr. F.-M. Nack, researcher
- S. Nagpal, visiting student (May-July)
- Drs. H. Noot, programmer
- Dr. J.R. van Ossenbruggen, researcher
- O. Rosell Martinez, visiting student (from September)
- Dr. L.W. Rutledge, researcher
- Ms. dr. Zs.M. Ruttkay
- P. Schmitz, guest (July)
- Dr. S. Sire, ERCIM fellow (February – October)

Scientific Report

Hypermedia Presentation Generation – INS2.1

The main motivation for the group's research in recent years has been the automated generation of hypermedia presentations to account for widely differing user and device contexts. Automatic hypermedia generation is based on the availability of data with machine-processable semantics and richly annotated multimedia content. These requirements have recently received a large amount of attention in the context of the Semantic Web activity of W3C. The developments around the Semantic Web have made the group's research questions even more relevant. Our involvement in an application area and our understanding of the underlying issues has given us a strategic position in obtaining European and national projects. In particular, we are partners in the European thematic network OntoWeb and national projects NWO NASH (Networked Adaptive Structured Hypermedia) and ToKeN2000 I2RP (Intelligent Information Retrieval and Presentation in Public Historical Multimedia Databases).

In addition to obtaining funding for the group's research, group resources were devoted to the organization of two international conferences: the first international conference on Computational Semiotics for Games and New Media (COSIGN 2001) and the 8th International Conference on Multimedia Modeling (MMM 2001).

2001 saw the completion of the ITEA RTIPA and original ToKeN2000 projects. In both cases, in addition to a number of publications, demonstrators were created. We have now progressed to the stage that our software environment provides a workbench that allows us to explore and test alternative strategies for hypermedia presentation generation. In particular, the Cuypers system is able to extract multimedia items from the Rijksmuseum database and generate user-tailored presentations for a variety of display devices. This was demonstrated at the ICT Kenniscongres in September. A demonstrator for varying network conditions was created for the final RTIPA review. Our official involvement in the

NWO Dynamo project has also come to a close, but we will continue to have ties with the project until the PhD students at the TUE have finished. A pilot project E-linCC was carried out within the Telematica Instituut. The deliverables of this pilot were the giving of a Semantic Web tutorial to members of the institute and a description of the state of the art of the Semantic Web and its implications for E-learning. In addition to these projects, Van Ossenbruggen and Rutledge contributed actively to the development of W3C's SMIL 2.0 (Synchronized Multimedia Integration Language).

Lynda Hardman was appointed as part-time professor in Multimedia and Internet Technology at the University of Eindhoven in September. This has involved her working more closely with the group of Paul De Bra and Geert-Jan Houben, strengthening the ties already created through the Dynamo and RTIPA projects. The NWO NASH project, already approved, was co-written with Paul De Bra and we await the result of a second ToKeN2000 proposal, CHIME, also submitted jointly with the TUE group. In addition, the ToKeN2000 I2RP (Intelligent Information Retrieval and Presentation in Public Historical Multimedia Databases) was approved. This gives the group a solid base for continuing the work on automated hypermedia presentation generation. Hardman's own research interests are in the capturing of graphic design information and in incorporating multimedia in the Semantic Web.

Dick Bulterman continues to have ties with the group in the role of external advisor. In particular, collaborating on work within the W3C SYMM working group and supporting the use of the GRiNS software within the group's research, in particular within the context of the RTIPA project.

Joost Geurts continued work on constraint-programming as part of the presentation generation process, and contributed significantly to the design and development of the Cuypers system. He also completed writing his Master's Thesis (hosted at the University of Amsterdam, co-supervised by Krzysztof Apt).

Michèle Huijberts' interests were in the area of integrating heterogeneous (multimedia) data types in a distributed database environment.

Frank Nack continued work on the role of semiotics in multimedia. He also participated in writing two European project proposals, with CWI as the project coordinator in one of them. He was joint program chair and organiser of COSIGN 2001. He collaborated with Menzo Windhower (INS1) on extracting features from images in order to combine them into a higher level grammar which is better able to describe the semantics of the image.

Jacco van Ossenbruggen published and successfully defended his PhD thesis *Processing Hypermedia: A Matter of Style*. In addition to continuing his own research on generating hypermedia presentations he also initiated work on integrating existing technologies for bringing multimedia towards the Semantic Web. He coordinated the software development efforts for the Cuypers hypermedia presentation generation demonstrator and continued to supervise Joost Geurts. He continued to play a key role in the running of the RTIPA, DYNAMO and ToKeN2000 projects. He contributed significantly to the writing of the NWO NASH, ToKeN2000 I2RP and ToKeN2000 CHIME proposals.

Lloyd Rutledge contributed significantly to the research carried out within the group, in particular for the MIA project, producing papers and giving a number of high-profile SMIL tutorials. He co-chaired the MMM 01 conference. He performed joint work with Patrick Schmitz. He continues to play a significant role in the W3C SYMM working group and as CWI's W3C AC representative.

Patrick Schmitz visited during the summer to collaborate on publications on the timing model underlying the W3C recommendation SMIL 2.0 and on the combination of fragments within XML documents.

Stéphane Sire visited the group as an ERCIM fellow. His work investigated the creation of tools for supporting collaboration among authors.

The aim of the ToKeN2000 initiative is to enrich the experience users have with accessing information. In particular, for the I2RP project, where we are interested in capturing graphic and communication design into a presentation generation system, we invited visitors with expertise in this area (Karolina Czajka and Marcos Caceres) who started towards the end of the year.

Social User Interfaces – INS2.2

Expression sculpting with constraints

An environment has been fully implemented for different platforms to use constraints for defining facial expressions and animations. The type

of constraints can be extended by the user. Demos have been made to show the benefits of the technology.

Talking heads
We have refined and improved the MPEG-4 compatible mouth repertoire and a vizeme set for Dutch language, in co-operation with IPO. We have carried out empirical experiments to find out about facial signals accompanying speech, in co-operation with E. Krahmer, IPO/KUB.

Exploration of the expression space
Emotion Squares, a navigation and control tool to generate instances of expressions controlled by 15 parameters, have been developed.

Blending of expressions
Animation Editor has been extended with facilities to blend and concatenate animations.

Evaluation of talking heads
We have started work on evaluating talking heads, and embodied conversational agents, in general. For this purpose, we adapted a 3D realistic head. We organized a panel discussion on the topic, and submitted a workshop proposal for 2002. These activities are preparatory activities for being able to do our own evaluation and provide methodological frameworks.

High-level control of talking heads
In co-operation with C. Pelachaud at University Roma 'La Sapienza', a framework of a high-level, XML-like language has been proposed, allowing high-level control of facial animation, using constraint-based building blocks.

Model-based recognition of expressive faces
In co-operation with SZTAKI, it has been investigated whether Cellular Neural Network technology can be used for facial recognition and synthesis. Two items have been identified as possible further joint projects: model-based recognition of facial expressions using markers, and fast synthesis of realistic, biological models.

PhD Thesis

J.R. van Ossenbruggen (2001). *Processing Structured Hypermedia – A Matter of Style.* Vrije Universiteit, April 10.

Knowledge Transfer

Joost Geurts:
- *Demo of Cuypers System*, ICT Kenniscongres, The Hague, September 6–7.

Lynda Hardman:
- *SMIL and multimedia authoring*, Moderne Informatiesystemen seminar TU/e, February 6 and 13.
- *Semantic Web Tutorial*, Invited lecture, Telematica Instituut, December 17.
- *SMIL: The Synchronized Multimedia Integration Language*, Tutorial, given at:
  Half-day: TUE, February 26.
  Half-day: The Tenth International World Wide Web Conference (WWW 10), Hong Kong, May 1.

Frank Nack:
- *The Semantic Web – Developing a Library of Alexandria for the 21st Century?* First Annual Diffuse Conference, From Convergence to Consolidation What's Next in the Information Market? A conference organized by the IST Diffuse Project, Brussels, Belgium, March 7.
- *Do Virtual Beings Need Psychotherapy?*. International Symposium on Computer Graphics – Enabling Technology for the Information Society, Fraunhofer Institute for Computer Graphics, Darmstadt, Germany, May 28.

Jacco van Ossenbruggen:
- *Multimedia on the Semantic Web*, MIA project meeting, UvA, March 2.
- *Application-Level and Server-Side Content Adaptation*, RTIPA project meeting, LIP6 Paris, March 13.
- *The Cuypers Architecture*, RTIPA Workshop, Rennes, March 26–27.
- *Demo of Cuypers System*, ICT Kenniscongres, The Hague, September 6–7.
- *Virtueel Platform*, invited expert on streaming media, Amsterdam, October 9.
- *Structured Documents on the Web*, Invited lecture, VUA, December 11.
- *Multimedia on the Semantic Web*, CWI in Bedrijf, Amsterdam, October 5.
- *Semantic Web Tutorial*, Invited lecture, Telematica Instituut, December 17.

Lloyd Rutledge:
- *Generation of hypermedia presentations from databases*, Invited talk, 2nd Dutch Information Retrieval Workshop, TU Enschede, January 18.
- *Semantic Web*, Panel member, ACM Hypertext 2001, Aarhus, August 17.
- *SMIL 2.0 – Authoring for the Next Wave of Web Multimedia*, Invited talk, ICT Kenniscongres, The Hague, September 6.
- *Is Streaming Media Becoming Mainstream?*, Panel member, ACM Multimedia 2001, Ottawa, October 4.
- *SMIL: The Synchronized Multimedia Integration Language*, Tutorial, given at:
  Half-day: ACM Multimedia 2001, Ottawa, October 1.
  Full-day: ACM Hypertext 2001, Aarhus, August 15.
  Half-day: Multimedia Modeling 2001, ISOC.nl and W3C.nl, CWI, November 5.

Zsòfia Ruttkay:
- *Animated Chartoon Faces*, University Cape Town, May 15.
- *FESINC: Facial Expression Sculpturing with Interval Constraints*, Workshop paper presentation, Workshop on Representing, Annotating and Evaluating Non-Verbal and Verbal Communicative Acts to Achieve Contextual Embodied Agents, May 29, Montréal, Canada.
- *Computer Facial Animation*, MTA, SZTAKI, Hungary, October 8.
- *Facial Animation with CharToon*, ELTE, Budapest, Hungary, October 15.
- *Facial Animation with CharToon*, University Roma La Sapienza, Rome, Italy, November 12.
- *Computer Facial Animation*, University Roma Tre, Rome, Italy, November 20.

Organization of Conferences, Workshops, Courses, etc.

Lynda Hardman:
- Semantic Web Panel, The Tenth International World Wide Web Conference (WWW 10), May 1–5, 2001, Hong Kong.

Frank Nack:
- Local Chair and Organizing Committee member for 1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001), CWI, September 10–12.

Lloyd Rutledge:
- General Co-Chair for Eighth International Conference on Multimedia Modeling 2001 (MMM01), November 5–7.

Zsòfia Ruttkay:
- Co-organizer for Symposium on Embodied Conversational Agents, CWI, December 7.

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

Dick C.A. Bulterman:
- *RTIPA/ITEA project meeting*, Oratrix, Amsterdam, February 21.
- *RTIPA/ITEA project meeting*, LIP6 Paris, March 13–14.
- *RTIPA/ITEA project meeting*, Milan, September 5.
- *RTIPA/ITEA project meeting*, Amsterdam, October 29.
- *RTIPA/ITEA final review*, Paris, November 18.

Joost Geurts:
- Maja Kuzmanovic and Craig Lindley, Starlab, Brussels, Belgium, March 16.
- *First DELOS International Summer School on Digital Library Technologies (ISDL 2001)*, Pisa, Italy, July 9–13.
- *ICT Kenniscongres*, The Hague, September 6–7.
- *1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001)*, CWI, September 10–12.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.

Lynda Hardman:
- *AMC: project proposal meeting*, Amsterdam, January 10.
- *RTIPA/ITEA project meeting*, LIP6 Paris, March 13–14.
- *Bridge Project Proposal Meeting*, Vienna University, Vienna, April 4.
- *Bijzondere Programmaraad*, Telematica Instituut, Enschede, April 11.
- Maja Kuzmanovic and Craig Lindley, Starlab, Brussels, Belgium, March 16.
- *The Tenth International World Wide Web Conference (WWW 10)*, Hong Kong, May 1–5.
- *EnCKompass workshop on e-Content Management and Personalisation*, TUE, Eindhoven, June 29.
- *Adaptive Hypertext workshop*, TUE, Eindhoven, July 2.
- *ACM Conference on Multimedia 2001 (MM01)*, Ottawa, October 1–4.
- *European Conference on Digital Libraries 2001*, Darmstadt, Germany, September 4–8.

- *1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001)*, CWI, September 10–12.
- *RTIPA/ITEA project meeting*, Amsterdam, October 29.
- *Collaborative Filtering Recommender Systems*, by Joe Konstan, SIGCHI.nl talk, VU, November 1.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.
- *OntoWeb workshop*, Amsterdam, December 6–8.

Michèle Huijberts:
- Maja Kuzmanovic and Craig Lindley, Starlab, Brussels, Belgium, March 16.
- *1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001)*, CWI, September 10–12.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.

Frank Nack:
- Dynamo Project Meeting, Eindhoven, January 9 and September 18.
- *First Annual Diffuse Conference, From Convergence to Consolidation, What's Next in the Information Market?* A conference organized by the IST Diffuse Project, Brussels, March 7.
- Maja Kuzmanovic and Craig Lindley, Starlab, Brussels, Belgium, March 16.
- *Bridge Project Proposal Meeting*, Vienna University, Vienna, April 4.
- *COSIGN 2001 Program Committee Meeting*, London, UK, May 15.
- *ACM Multimedia 2001 Program Committee Meeting*, Buffalo, New York, USA, June 6.
- *Ontoweb Kick-off Workshop*, Heraklion Greece, June 13–15.
- *Konzeption für ein Konfigurationsmanagement zur Unterstützung eines objekt-orientierten Vorgehensmodells*, Bachelor thesis presentation for Eleke Nauman, Fachhochschule Darmstadt, July 6.
- *Lehrstuhl für Multimedia-Konzepte und Anwendungen*, Prof. Dr. Elisabeth André, Universität Augsburg, July 11.
- Forschungszentrum Informatik, Forschungsbereich WIM, Karlsruhe, Germany, July 23.
- Institut fuer Informatik und Wirtschaftsinformatik – Multimediale Informationssysteme, Vienna University, Vienna, August 21–28.
- *1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001)*, CWI, September 10–12.
- *Dynamo Project Meeting*, Eindhoven, September 18.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.
- *Independent Artist Network, Bedarfsanalyse, Marktanalyse, Demonstrator*, Bachelor thesis presentation for Matthisa Petry, Fachhochschule Darmstadt, December 6.

Jacco van Ossenbruggen:
- *Dynamo project meeting*, TUE Eindhoven, January 9.
- *AMC: project proposal meeting*, Amsterdam, January 10.
- *Global Grid*: WTCW project meeting, January 15.
- *RTIPA/ITEA project meeting*, LIP6 Paris, March 13–14.
- Maja Kuzmanovic and Craig Lindley, Starlab, Brussels, Belgium, March 16.
- *RTIPA Workshop*, Rennes March 26–27.
- *Waterland: Kick-off project meeting*, NOB Hilversum, April 5.
- *The Tenth International World Wide Web Conference (WWW 10)*, Hong Kong, May 1–5.
- *'Ondernemingsraad' cursus*, Noordwijk, May 31.
- *ICT Kenniscongres*, The Hague, September 6–7.
- *Dynamo project meeting*, TUE Eindhoven, September 18.
- *1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001)*, CWI, September 10–12.
- *RTIPA/ITEA project meeting*, Amsterdam, October 29.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.
- *OntoWeb workshop*, Amsterdam, December 6–8.
- *Ambient Intelligence meeting*, Philips Research Eindhoven, December 14.

Han Noot:
- Working visit to University Roma La Sapienza and University Roma Tre, November 11–26.

Oscar Rosell:
- *1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001)*, CWI, September 10–12.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.

- RTIPA, Corinne Horellou, Thales Group, Paris, France, November 19.

Lloyd Rutledge:
- *2nd Dutch Information Retrieval Workshop*, TU Enschede, January 18.
- *W3C SYMM Working Group face-to-face meeting*, Boston, USA, March 1–2.
- *Hypertext 2001 Program Committee Meeting*, Aarhus, April 6.
- *Structural Computing Workshop*, Aarhus, August 14.
- *ACM Conference on Hypertext 2001 (HT01)*, Aarhus, August 15–17.
- *ACM Conference on Multimedia 2001 (MM01)*, Ottawa, October 1–4.
- *Kabinet Online Slotbijeenkomst*, Amsterdam, October 8.
- *Collaborative Filtering Recommender Systems*, by Joe Konstan, SIGCHI.nl talk, VU, November 1.
- *Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, CWI, November 5–7.

Zsòfia Ruttkay:
- *Workshop on Representing, Annotating and Evaluating Non-Verbal and Verbal Communicative Acts to Achieve Contextual Embodied Agents*, May 29, Montréal, Canada.
- *The 5th International Conference on Autonomous Agents (Agents 2001)*, Montréal, Canada, May 30 – June 1.
- Working visit to University Cape Town, May 12–19.
- Working visit to University Roma La Sapienza and University Roma Tre, November 11–26.
- Working visit to MTA SzTAKI, October 1–31.

Stéphane Sire:
- Maja Kuzmanovic and Craig Lindley, Starlab, Brussels, Belgium, March 16.
- *The Seventh European Conference on Computer Supported Cooperative Work*, Bonn, Germany, September 18–20.
- *The 4th International Conference on the Electronic Document*, Toulouse, France, October 24–26.

Memberships of Committees and Other Professional Activities

Dick Bulterman:
- General Co-chair of Eighth International Conference on Multimedia Modeling 2001 (MMM01).
- W3C SYMM Working Group.

Lynda Hardman:
- Part-time professor Multimedia and Internet Technologies at the TUE (from September).
- Member of PhD committee for Jacco van Ossenbruggen.
- Member of editorial board for the New Review of Hypermedia and Multimedia (NRHM).
- Reviewing for conference papers: Adaptive Hypertext 01, ACM Hypertext 01, ACM Multimedia 01, World Wide Web 10.
- Reviewing for journal papers: IEEE Multimedia (2).
- Committee Vereniging Werkgemeenschap Informatiewetenschap (Information Science).

Michèle Huijberts:
- Documentation Chair for Eighth International Conference on Multimedia Modeling 2001 (MMM01), November 5–7.

Frank Nack:
- Supervision of Bachelor Theses at GMD Darmstadt:
  Eleke Nauman. *Konzeption für ein Konfigurationsmanagement zur Unterstützung eines objekt-orientierten Vorgehensmodells*, July 6.
  Matthisa Petry. *Independent Artist Network, Bedarfsanalyse, Marktanalyse, Demonstrator*, December 6.
  Karolina Czajka. *Design of interative and adaptive interfaces to exploit large media-based knowledge spaces in the domain of museums for the fine arts*, anticipated July 2002.
- Local Chair and Organizaing Committee member for 1st International Conference on Computational Semiotics in Games and New Media (COSIGN 2001), CWI, September 10–12.
- Editor of the Media Impact Column of *IEEE MM journal*.
- Program committees: ACM Multimedia 2001, COSIGN 2001, 24th European Colloquium on Information Retrieval Research (ECIR02).
- Reviewing activities: IEEE Intelligent Systems magazine, International Workshop on Content-Based Multimedia Indexing (CBMI 01).
- Member of ACM-SIGMM.
- Member of the MPEG-7 DDL group.

Jacco van Ossenbruggen:
- Program committees: WWW 2002, Multimedia Modeling 2001.
- Reviewing activities: ACM Hypertext 2001, ACM Multimedia 2001.
- W3C SYMM Working Group.

Zsòfia Ruttkay:
- ERCIM Constraints working group.
- ERCIM e-Learning working group.

- EUROGRAPHICS.

Lloyd Rutledge:

- General Co-chair of Eighth International Conference on Multimedia Modeling 2001 (MMM01).
- W3C Advisory Committee (AC) Representative from CWI.
- Program committees: ACM Hypertext 2001, WWW 2002, Document Engineering 2001.
- Reviewing activities: ACM Multimedia 2001, Multimedia Modeling 2001, ACM Journal on Multimedia Systems, IEEE Transactions on Knowledge and Data Engineering.
- W3C SYMM Working Group.
- Memberships in ACM SIGs: SIGWeb, SIGMM.

Visitors

- Catherine Pelachaud, University Roma La Sapienza, January 26.
- Clara Mancini, Knowledge Media Institute, January 30.
- Stéphane Sire, ERCIM Fellowship, February – October.
- Peter Werkhoven, TNO, April 12.
- Sarabh Nagpal, May – July.
- Christian Floerkemeier, June 6.
- Patrick Schmitz, June – July.
- Mark van Doorn, Philips, July 6.
- Pieter Toussaint, Leiden Universiteit Medisch Centrum, July 11.
- Oscar Rosell, September – December.
- Joe Konstan, University of Minnesota, November 2.
- Stefano Boccini, November 21.
- Karolina Czajka, November – December.
- Marcos Caceres, Queensland University, November – December.
- Jan Baeke, Film Museum, December 19.

Software Developed

Joost Geurts/Jacco van Ossenbruggen/Oscar Rosell:

- Cuypers ToKeN2000 demonstrator.

Han Noot:

- EPICTOID CharToon: Modules of the CharToon software were adapted to be used at University Roma La Sapienza, and University Roma Tre, to control a 3D head, to design and test vizemes, and to study the display of conflicting facial expressions.

Papers in Journals and Proceedings

J. Geurts, Jacco van Ossenbruggen, Lynda Hardman (2001). Application-Specific Constraints for Multimedia Presentation Generation. *Proceedings of the Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, Amsterdam, The Netherlands, 247–266.

L. Hardman, P. Schmitz, J. van Ossenbruggen, W. ten Kate, Lloyd Rutledge (2000). The Link vs. the Event: Activating and Deactivating Elements in Time-Based Hypermedia. *New Review of Hypermedia and Multimedia* **6**, 89–109.

C. Lindley, F. Nack (2001). Categorical, Narrative and Hybrid Behavior Generation in the GENIE Environment for Interactive Narratives in Virtual Worlds. *International Conference on Media Futures*, Florence, Italy, 65–68.

F. Nack (2001). Play the game, *IEEE MultiMedia* **8**(1), 8–10.

F. Nack, Wolfgang Putz (2001). Designing Annotation Before It's Needed. *Proceedings ACM Conference on Multimedia 2001 (MM01)*, Ottawa, Canada, 251–260.

J. van Ossenbruggen, J. Geurts, F. Cornelissen, L. Rutledge, L. Hardman (2001). Towards Second and Third Generation Web-Based Multimedia. *Proceedings The Tenth International World Wide Web Conference (WWW 10)*, Hong Kong, 479–480.

Zs. Ruttkay (2001). Constraint-based facial animation. *International Journal of Constraints* **6**, 85–113.

Zs. Ruttkay, H. Noot (2001). FESINC: Facial Expression Sculpturing with Interval Constraints. *Workshop on Representing, Annotating and Evaluating Non-Verbal and Verbal Communicative Acts to Achieve Contextual Embodied Agents*, Montréal, Canada, 71–76.

L. Rutledge (2001). Multimedia Standards: Building Blocks of the Web. *IEEE Multimedia*, 13–15.

L. Rutledge (2001). SMIL 2.0: XML For Web Multimedia. *IEEE Internet Computing*, 78–84.

L. Rutledge, Lynda Hardman (2001). The Rise and Fall of Multimedia Authoring. *International Conference on Media Futures*, Florence, Italy, 17–20.

L. Rutledge, P. Schmitz (2001). Improving Media Fragment Integration in Emerging

Web Formats. *Proceedings of the Eighth International Conference on Multimedia Modeling 2001 (MMM01)*, Amsterdam, The Netherlands, 147–166.

S. Sire (2001). Collaborative authoring with document fragments and contracts (Poster). *Proceedings Supplement of the Seventh European Conference on Computer Supported Cooperative Work (ECSCW 2001)*, Bonn, Germany.

S. Sire, Y. Rekik, C. Vanoirbeek (2001). A flexible authoring process for collaborative authoring based on document fragments and contracts. *Proceedings 4th International Conference on the Electronic Document (CIDE 2001)*, Toulouse, France.

CWI Reports

The following CWI reports were published by members of theme INS2. See page 91 for the complete titles.

INS-R0101 INS-R0105 INS-R0106
INS-R0107 INS-R0108

Other Publications

L. Rutledge, A. Cohen (eds.) (2001). *W3C, Synchronized Multimedia Integration Language (SMIL) 2.0 – Linking Modules.* W3C Recommendation. `http://www.w3.org/TR/smil20/extended-linking.html`

D.C.A. Bulterman, J. van Ossenbruggen, L. Rutledge et al. (contributing eds.) (2001). A. Cohen (ed.). *W3C. Synchronized Multimedia Integration Language (SMIL) 2.0.* W3C Recommendation, `http://www.w3.org/TR/smil20/`

Visualization – INS3

Staff

- Dr. ir. R. van Liere, senior researcher, pilot leader
- Drs. H. Huitema, PhD student (until May 1)
- Dr. W.C. de Leeuw, postdoc
- Drs. M.S. Marshall, PhD student (until Nov 1)
- Dr. J.D. Mulder, postdoc
- Prof. dr. J.J. van Wijk, advisor

Scientific Report

The new INS3 pilot on Visualization and 3D User Interfaces started in 2001. Two research areas were identified; Visualization and 3D Interfaces. 2001 was mainly used to develop a research agenda in these areas.

Visualization – INS3.1

The main focus of the research in INS3.1 is on the analysis, manipulation and visualization of time-dependent volume data sets. The developed methods will be applied to biological data sets acquired from confocal microscopes.

A novel approach to tracking features in time-dependent 3D data was developed by De Leeuw and Van Liere. The novelty stems from the description of features as points in a multidimensional attribute space and using distances between points are used as a measure for feature correspondence in order to track features among time steps. Interaction is used to experiment with the correspondence measure. The method extends previous in that tracking problems related to noisy confocal data can be circumvented. This work has been done in collaboration with the Swammerdam Institute for Life Sciences, University of Amsterdam.

Marshall completed the work on graph drawing. This work resulted in a PhD thesis at the University of Bordeaux.

3D User Interfaces – INS3.2

The term 3D user interfaces comprises all aspects involved in allowing humans to interact with computer generated 3D worlds. These aspects include the hardware (display devices, input devices, computing components, etc.) as well as the software (image generation, input processing, etc.) necessary to enable such interaction. Research in 3D user interfaces overlaps with many research topics in virtual reality.

The focus in 2001 was to determine a future vision for the research activities. An initial track will be to study those environments and techniques which allow users to preform interactive 3D tasks in a direct and natural way. To study these issues a near-field virtual environment, the Personal Space Station (PSS) has been built. The primary motivations for building the system are to provide an ergonomical virtual environment that can be used under normal office working conditions and that allows for direct natural

interaction.

Four Dutch research institutes have purchased a PSS prototype to use it as a research tool in their own particular research field. The intent is to collaborate very closely with these institutes in order to test and validate the methods developed in the project.

The work in this project has been done by Mulder and Van Liere.

PhD Theses

R. van Liere (2001). *Studies in Interactive Visualization*, University of Amsterdam, March 14. Thesis advisor: Prof. dr. P. Klint.

M.S. Marshall (2001). *Methods and Tools for the Visualization and Navigation of Graphs*, University of Bordeaux, June 7. Thesis advisor: Ms. Prof. dr. M. Delest.

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

- IEEE Visualization 2001, October, San Diego: De Leeuw.
- Symposium 'Echt of Namaak', December, Groningen: Van Liere, invited speaker.

Visitors

- Dr. G Thomas, November 1–6
- Dr. O. Baudon, December 1–2

Memberships of Committees and Other Professional Activities

Van Liere:
- Member program committee IEEE Visualization 2001, October, San Diego
- Member program committee EG/IEEE Symposium on Data Visualization, May, Switzerland
- Member program committee EG Workshop on Virtual Environments, May, Stuttgart, Germany
- Part time associate professor (UHD) at Technische Universiteit Eindhoven, 0.2 fte
- Reviewer for the journals: *IEEE Transactions on Visualization and Computer Graphics, Journal of Parallel and Distributed Computing, IEEE Transactions on Parallel and Distributed Systems*
- Member of PhD committees: M.S. Marshall, (University of Bordeaux), June. G. Gernot, (University of Pretoria), November

De Leeuw:
- Reviewer for IEEE Visualization 2001
- Reviewer for EG/IEEE Symposium on Data Visualization 2001

Mulder:
- Reviewer for EG Workshop on Virtual Environments

Software Developed

The Portable Virtual Reality (PVR) system forms the core of the research experimentation platform for the 3D user interface activities of INS3. Mulder and Van Liere have maintained and enhanced the code to include support for the PSS environment.

The Proteus system has been developed for the visualization of time dependent confocal data sets. De Leeuw has developed the code in close collaboration with the Swammerdam Institute for Life Sciences, University of Amsterdam.

Papers in Journals and Proceedings

W.C. de Leeuw, R. van Liere (2001). Chromatin Decondensation: a Case Study of Tracking Features in Confocal Data. *Proceedings IEEE Visualization 2001* (Kenneth Joy, Amitabh Varshney, Thomas Ertl), 441–444.

M.S. Marshall, I. Herman, G. Melançon (2001). An object-oriented design for graph visualization. *Software: Practice & Experience* **31**, 739–756.

U. Brandes, M. Eiglsperger, I. Herman, M. Himsolt, M.S. Marshall (2001). GraphML Progress Report, Structural Layer Proposal. *Proceedings of the Symposium on Graph Drawing GD'01*, Springer-Verlag.

Quantum Computing and Advanced Systems Research – INS4

Staff

- Prof. dr. ir. P.M.B. Vitányi, group leader, 80% CWI 20% UvA
- Prof. dr. A.E. Brouwer (seconded Univ. Eindhoven) 20% CWI, 80% TUE

- Prof. dr. H.M. Buhrman, leader of quantum computing project, 80% CWI 20% UvA
- Drs. W.K. van Dam, PhD student UvA
- Drs. M. de Graaf, PhD student CWI (NWO-SION)
- Dr. P.D. Grünwald, postdoc CWI (NWO-SION)
- Dr. H. Klauck, postdoc CWI (NWO-SION)
- Drs. T. Lee, PhD student CWI (EU project QAIP)
- Drs. R. Manniesing, PhD student CWI (NWO)
- Drs. H.P. Röhrig PhD student CWI (NWO-SION)
- R. Spalek, trainee VU
- Dr. J.T. Tromp, postdoc CWI
- Dr. R.M. de Wolf, PhD student UvA

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, computational complexity theory, descriptive complexity, Kolmogorov complexity, and applied complexity theory. Considerations are with respect to both sequential and parallel computation and quantum computing.

In the quantum computing project results in quantum communication complexity are: *Interaction in quantum communication and the complexity of set disjointness*, *Klauck*, STOC 2001. *Lower bounds for quantum communication complexity*, by Klauck, FOCS 2001, studies the problem of showing that a large amount of quantum communication is necessary to compute certain Boolean functions. The obtained results are exponentially larger than results achievable with previous techniques and allow to separate the quantum versions of nondeterministic and bounded error communication complexity.

The quantum computing paradigm was successfully applied in the area of property testing by *Buhrman, Fortnow, Newman* and *Röhrig*. The paper *quantum fingerprinting* by Buhrman, Cleve, Watrous, and De Wolf that appeared in *Physical Review Letters* (PRL) and was joint work with the quantum computing group in Calgary, got coverage in the press, for example Physics Update Now, Süd Deutsche Zeitung. The paper constructs a quantum analogue of the classical finger printing technique. The quantum scheme has already, by other researchers, been applied in the several areas for example quantum digital signatures.

Van Dam, together with *S. Hallgren* investigated a simplified version of the important hidden subgroup problem. *Van Dam*, together with *P. Hayden*, solved the problem that in the presence of arbitrary catalysts, any pure bipartite entangled state can be converted into any other to unlimited accuracy without the use of any communication, quantum or classical. They coined the phrase 'embezzling entangled quantum states' for this process. *Van Dam* together with M. Mosca and U. Vazirani showed that a proposal by MIT's physicist Fahri to solve NP hard problems by adiabatic quantum computation was (in the intended research direction) doomed to failure. This work was reported at the 2001 IEEE Symp Found. Comp. Sci.

Quantum information theory was investigated by *Vitányi* who extended the work on quantum Kolmogorov complexity. This was published in *IEEE Trans. Inform. Th.* Moreover, *Vitányi* was plenary speaker at the *Dagstuhl 10 Years Celebration* on quantum computing, which was published in the festive volume 2000 of Springer Lecture Notes in Computer Science.

The masters thesis of *De Graaf* on the 'Quantum Yao Principle' written under supervision of *Buhrman, De Wolf* and *Torenvliet* received the industrial CIVI price (dfl 25000) and was accepted for STACS 2002.

Ronald de Wolf received his PhD Cum Laude on his thesis *Quantum Computing and Communication Complexity*.

Vitányi and N. Chater (Warwick Univ., UK) worked in cognitive psychology based on algorithmic information theory. One item is the so-called Universal Law of Generalization formulated by Shepard as a robust psychological law that relates the distance between a pair of items in psychological space and the probability that they will be confused with each other, of comparable scope and generality as Newton's general law of gravitation in physics. We generalized Shepard's approach and provided this initially ad-hoc law with a mathematical derivation from first principles. The results are to appear in the *J. Math. Psychology*. Other work in cognitive sciences together with N. Steward (Warwick Univ.) appeared in *Behavior and Brain Sciences*.

Vitányi and H. Diederik (RIVM), P.P.H. Le Brun (Central Hospital Pharmacy The Hague),

H.W. Frijlink (Department of Pharmaceutical Technology and Biopharmacy, University of Groningen), D.M. Barends (RIVM), investigated time-dependent nonlinearity of nebulizer drug output. They analyze a simple compartment model to obtain an analytic expression of this function. This enables calculation of the nebulizing time required to deliver a given dose based on the efficiency of the nebulizing process. They also present an analytic expression for the remainder volume of solvent at the end of the nebulizing time. As an example, they verified the theoretical results with experimental efficiency of particular nebulizing events from data in the literature, related to nebulizing 1.0 % m/v salbutamol aqueous solution.

Buhrman, Vitányi, Tromp found improved time and space bounds for universal reversible simulation of irreversible computations (like quantum computation). They gave the first simultaneous subquadratic space and subexponential time simulation. This work was presented at ICALP 2001 and also published in *Journal of Physics A*.

Grünwald worked on the Maximum Entropy (ME) Principle together with *Dawid* (University College London). He also worked on a generalization of a characterization of Maximum Entropy distributions. His results appeared in COLT 2001.

Grünwald started to work with *Rissanen* on extending entropification to arbitrary, nonsymmetric loss functions. He applied entropification together with *Tirri* to Bayesian posteriors based on conditional likelihood.

Grünwald and *Vitányi* were the Conference Co-chairs of the international *ACM Conference on Computational Learning Theory*, 2001, that was held in Amsterdam,and organized by CWI.

Vitányi together with M. Li (UCSB and BioInformatics Solutions Inc.), X. Li (Univ. Western Ontario), and B. Ma (Univ. Western Ontario and BioInformatics Solutions Inc.) proposed a new class of similarity measures aimed at measuring the evolutionary relation of sequences. A prime example is the 'normalized information distance', based on the noncomputable notion of Kolmogorov complexity. We demonstrate that it is a metric, takes values in $[0, 1]$, and is universal. To apply it (and some related metrics) we use a simple approximation scheme to computationally compare whole mitochondrial genomes and infer their evolutionary history. This results in a first completely automatic computed whole mitochondrial phylogeny tree. In another paper, to appear in *Scientific American*, it is shown that the same method works to automatically compute a phylogeny tree of a set of chain letters collected over the last 30 years.

Vitányi served in the Organizing/Program Committee 'Workshop on Complexity and Inference' for the 'Computational Information Theory and Coding Year' (2001–2002) at DIMACS at Rutgers University. He also served as member of IFIP WG 1.2 on data-compression and 1.4 (co-chair) on computational learning.)

Vitányi, Tromp together with P. Gács (Boston Univ.) investigated notions of 'algorithmic' sufficient statistic. In probabilistic statistics one analyzes the average-case performance of the selection process. For traditional problems, dealing with frequencies over small sample spaces, this approach is appropriate. But for current novel applications, average relations are often irrelevant, since the part of the support of the probability density function that will ever be observed has about zero measure. This is the case in, for example, complex video and sound analysis. There arises the problem that for individual cases the selection performance may be bad although the performance is good on average. We embark on a systematic study of model selection where the performance is related to the individual data sample and the individual model selected. While Kolmogorov complexity is the accepted absolute measure of information content of an individual finite object, a similarly absolute notion is needed for the relation between an individual data sample and an individual model summarizing the information in the data, for example, a finite set (or probability distribution) where the data sample typically came from. The statistical theory based on such relations between individual objects can be called algorithmic statistics, in contrast to classical statistical theory that deals with relations between probabilistic ensembles. This work appeared in *IEEE Trans. Inform. Th.*

Vitányi extended the work on sufficient statistic from finite set models and computable probability models to the ultimate total recursive function models. This expresses the old quest, essential to many fields from AI to Statistics (and a main item in popular science like M. Gell-Mann's 'The Jaguar and the Quark') of separating the meaningful information in the data from the accidental, random, and meaningless information. In

applied statistics this is the ultimate goal of MDL approaches who try to do this in a probabilistic (average) sense.

Vitányi and *N. Vereshchagin* continued related work on 'Kolmogorov structure function' and precisely analyzed the possible behaviour of this familiar but essentially little understood object. This function gives us detailed information about the individual data-to-model relation in (algorithmic) statistics.

Vitányi and *S. Haldar* (Lucent and TenTimes Software) worked at shared variable constructions in distributed systems. Shared registers are basic objects used as communication mediums in asynchronous concurrent computation. A concurrent timestamp system is a higher typed communication object, and has been shown to be a powerful tool to solve many concurrency control problems. It has turned out to be possible to construct such higher typed objects from primitive lower typed ones. The next step is to find efficient constructions. They propose a very efficient wait-free construction of bounded concurrent timestamp systems from 1-writer multireader registers. This work is to appear in *J. Assoc. Comp. Mach. Tromp, Vitányi* improved earlier work on randomized two-process test-and-set implementions from multireader shared registers. *Vitányi* found a general construction scheme for multi-reader shared registers from single-reader shared registers (essentially physical flip-flops) which leads to different constructions that are optimal according to both local and global criteria.

Vitányi, Tromp together with K. Amano (Tohoku Univ, Japan) and O. Watanabe (Tokyo Inst. of Technology) investigated a generalized ruin problem in games of chance. They resolved the expected length of a fair game up until one player (the final winner) remains. The basis of this problem came from a question in neurobiology: the orientation selectivity of the visual system. The results were presented in RANDOM-APPROX 2001 Conference in Berkely, California.

PhD Thesis

R.M. de Wolf (2001). *Quantum Computing and Communication Complexity*, University of Amsterdam, Cum Laude. Thesis advisors: H.M. Buhrman and P.M.B. Vitányi.

Awards

H. Buhrman:
- Part-time ordinary professor in theory of computation (quantum computing) at the University of Amsterdam.

M. de Graaf:
- CiVi prize (Centraal Instituut Voor Industrieontwikkeling) (Industrie) van 25,000 guilders for best masters thesis computer science in the Netherlands.

H. Klauck:
- Preis für den Naturwissenschaftlichen Nachwuchs, received from Johann Wolfgang Goethe Universität Frankfurt for the dissertation: *Über beschränkte Interaktion in der Kommunikationskomplexität.*

R. de Wolf:
- NWO Talent stipendium.

Organization of Conferences, Workshops, Courses, etc.

- Buhrman together with Röhrig and De Wolf organized the main international conference on Quantum Computing *Quantum Information Processing 2001 (QIP'2001)* held in Amsterdam. This event got coverage in the national and international press: NRC handelsblad, Automatisering Gids, Financieel-Economische Tijd, Wired, Deutschland Funk. (See: http://www.cwi.nl/~qip). Buhrman is invited speaker at QIP'2002 to be held at IBM TJ Watson in New York, 2002.
- Buhrman organized a working group meeting for the fifth framework program project QAIP in Amsterdam. Most of the participating sites participated.
- Buhrman co-organized with U. Vazirani from UC Berkeley a quantum computing workshop held just before FST&TCS in Bangalore, India.
- Buhrman co-organized a colloquium on quantum computing at NEC research institute, Princeton, USA.
- Grünwald and Vitányi were conference co-chairs of COLT 2001, the *Fourteenth Annual Conference on Computational Learning Theory* in Amsterdam. This conference was held July 16–19 at the premises of the Royal Dutch Academy of Sciences in Amsterdam.
- Grünwald was co-organizer and chair of the one-day workshop *Minimum Description Length: developments in Theory and New Applications.* The workshop was held December 8

in Whistler, British Columbia, Canada, as part of the NIPS 2001 conference.
- Vitányi was/is program committee member of International Conference on Algorithms, Languages, and Programming, Paderborn (ICALP), Malaga (Spain), 2002; European Conference on Machine Learning (ECML), 2001 and again in 2002 and the Organizing/Program Committee 'Workshop on Complexity and Inference' for the 'Computational Information Theory and Coding Year' (2001-2002) at DIMACS at Rutgers University;
- Vitányi is site coordinator of the EU fourth framework BRA IV NeuroCOLT II Working Group EP 27150 on fundamental understanding of learning and of when and how it can be implemented algorithmically. Vitányi is work area manager of two out of three work areas. There are 11 European institutes in the working group. (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.)
- 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.

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

A.E. Brouwer:
- July 8–13, Second Workshop on Algebraic Graph Theory, International Centre for Mathematical Sciences, Edinburgh, Scotland.
- December 2–8, Oberwolfach Seminar on Finite Geometries, Oberwolfach, Germany.

H. Buhrman:
- January 11–15, Fourth Workshop on Quantum Information Processing (QIP 2001), Amsterdam.
- January 19, ACCS Seminar University of Amsterdam. Talk: *Quantum Communication Complexity.*
- February 1 – September 1, Visit Princeton University/NEC research institute/Institute for Advanced studies , Princeton, USA.
- February 27, DIMACS/Rutgers theory seminar, New Brunswick, USA. Talk: *Simultaneous Message Passing with Quantum Bits.*
- March 8, NEC theory seminar, Princeton, USA. Talk: *Quantum Computing.*
- March 14–16 QAIP review meeting, Seefeld, Austria.
- March 12, IBM Zurich. Talk: *Quantum Computing.*
- April 13, Boston University theory seminar, Boston, USA. Talk: *Simultaneous Message Passing with Quantum Bits.*
- May 4–6, Hartmanis celebration Cornell University, USA.
- June 17–21, Conference on Computational Complexity, Chicago, USA.
- July 3–10, visit Cleve, Watrous, Hoyer, Calgary University, Canada.
- July 16, Princeton University, Quantum Computing seminar. Princeton, USA. Talk: *Shor's Factoring Algorithm.*
- October 28–31, QIPC yearly meeting, Torino, Italy.
- November 9, Symposium New Approaches toward computing, Brussels. Talk: *Quantum Computing.*
- November 16–18, STACS PC meeting, Antibes, France.
- November 22, Physics seminar, University of Amsterdam. Talk: *Quantum Fingerprinting.*

M. de Graaf:
- January 11–15, Fourth Workshop on Quantum Information Processing (QIP 2001), Amsterdam.
- July 16–19, The Fourteenth Annual Conference on Computational Learning Theory.

P. Grünwald:
- April 22–28, *CoSCo (Complex Systems Computation) group*, Helsinki, Finland. Hosted by Professor H. Tirri.
- April 5, EURANDOM, Eindhoven, the Netherlands . Talk: *Maximum Generalised Entropy, Game Theory and Pythagoras.*
- May 16, Universiteit Utrecht, The Netherlands. Hosted by Professor Richard Gill. Talk: *Maximum Generalised Entropy, Game Theory and Pythagoras.*
- June 5, Vrije Universiteit Amsterdam, The Netherlands. Hosted by Professor Aad van der Vaart. Talk: *Maximum Generalised Entropy, Game Theory and Pythagoras.*
- July 16–19, COLT-2001, (the annual conference on Computational Learning Theory), Amsterdam, The Netherlands. Talk: *Maximum Entropy and the Glasses You are Looking Through.*
- September 18, University of California at Berkeley, Berkeley, California, USA. Hosted by Professor B. Yu. Talk: *Maximum Generalised Entropy, Game Theory and Pythagoras.*

- October 7–14, Ohio State University, Columbus, Ohio, USA. Hosted by Professor I.J. Myung.
- October 15–17, University of Illinois at Urbana-Champaign, Urbana-Champaign, Illinois, USA. Hosted by Professor D. Roth. Talks: (1) *Universal Modeling: introduction to modern MDL*; (2) *Generalized entropy concentration, Game Theory and Algorithmic Randomness.*
- November 6, Stanford University, Stanford, CA, USA. Hosted by Professor D. Koller. Talk: *Universal Modeling: introduction to modern MDL.*
- December 1–6, University of California at Santa Cruz, Santa Cruz, California, USA. September . Hosted by Professor M. Warmuth and Professor D. Draper. Frequent visits by Professor J. Rissanen. Talks: (1) *Universal Modeling: introduction to modern MDL* (October 26th); (2) *Maximum Generalised Entropy, Game Theory and Pythagoras* (November 5th). Within this visit a number of smaller visits took place.
- December 7–8, NIPS 2001, (the annual conference on *Neural Information Processing Systems*), Whistler, British Columbia, Canada. Talks: (1) *Occam, Bayes, MDL and the Real World* (in the NIPS workshop on Occam's Razor, December 7); (2) *Universal Modeling: introduction to modern MDL* (in the NIPS workshop on Minimum Description Length, December 8).

H. Klauck:

- January 12, QIP 2001, Amsterdam. Open Session. Talk: *Rounds in quantum communication.*
- February 19–23, Dagstuhl Seminar Automata, Logic, Infinite Games, Dagstuhl, Germany. Talk: *Algorithms for parity games.*
- June 12, Dortmund, Germany. Host Ingo Wegener. Talk: *Quantum communication complexity.*
- July 6–8, STOC 2001, Hersonissos, Crete, Greece. Talk: *Interaction in Quantum Communication and the Complexity of Set Disjointness.*
- July 8–12, ICALP 2001, Hersonissos, Crete, Greece.
- October 14–17, FOCS 2001, Las Vegas, USA. Talk: *Lower bounds for quantum communication complexity.*

T. Lee:

- September 23–28, The Fourth International Tbilisi Symposium on Language, Logic and Computation, Borjomi, Georgia.

R. Manniesing:

- January 11–15, Fourth Workshop on Quantum Information Processing (QIP 2001), Amsterdam.
- July 16–19, The Fourteenth Annual Conference on Computational Learning Theory.

H. Röhrig:

- January 11–15, Fourth Workshop on Quantum Information Processing (QIP 2001), Amsterdam.
- April 4 – May 5, NEC Research Institute, host Lance Fortnow.
- April 9, Lov Grover at Bell Labs.
- June 1 – August 30, summer student at NEC Research Institute, two lectures on introduction Quantum Computing.
- August 23, visit to Yevgeniy Dodis at NYU.
- September 29–31, QIPC workshop Torino.

J.T. Tromp:

- On leave developing bioinformatics software at Bioinformatics Solutions Inc.

P.M.B. Vitányi:

- January 11–15, Fourth Workshop on Quantum Information Processing (QIP 2001), Amsterdam.
- March 23 – April 2, EU NeuroColt II Workshop on Computational Complexity Aspects of Learning, Sestriere, Italy. Talk: *Algorithmic Statistics.*
- May 13 – June 10, visit Comp. Sci. Department, Univ Califormia, Santa Barbara. Talk May 30 at UC Riverside: *The Quantum Computing Challenge*; Talk June 1 at UC Santa Barbara: *The Quantum Computing Challenge.*
- June 29 – July 15, visit Computer Science Dept, Crete University; ACM Symp. Parallel Algorithms and Architectures 2001, Hersonissos, Crete, Greece; ACM Symp. Theory of Comput. 2001. Hersonissos, Crete, Greece; Intern. Coll. Automata, Languages, and Programming, Hersonissos, Crete, Greece; Talk: *Time and space bounds for reversible simulation.*
- September 7–24, visit Comput. Sci. Dept Univ. Salerno, Workshop on Combinatorics of Searching Sorting and Coding, Ischia. Talk on September 8: *A Lower Bound on the Average-Case Complexity of Shellsort.*

- September 25–October 8, visit Comp. Sci. Dept. Univ. Marseille, Workshop on Algorithmic Information Theory, and Workshop on Cellular Automata. Talk on September 26: *Algorithmic Statistics*. Visit Comp. Sci. Dept. Univ. Lisbon, Portugal. Talk on October 2: *The Quantum Computing Challenge*. Workshop on Distributed Algorithms (DISC 2001) Impromptu Talk: *Optimal Multireader Registers*.
- July 16–19, The 14th Annual Conference on Computational Learning Theory, Amsterdam, Netherlands. Impromptu Talk: *Algorithmic Statistics*.
- December 3–13, *NIPS 2001* (the annual conference on 'Neural Information Processing Systems'), Whistler, British Columbia, Canada. Invited Talks: (1) *Data compression in model selection and prediction: Occam's razor vindicated by rigorous proof.* (in the NIPS workshop on Occam's Razor, December 7). (2) *Algorithmic Statistics* (in the NIPS workshop on Minimum Description Length, December 8).

R. de Wolf:

- January 11, talk: *Quantum fingerprinting, simultaneous message passing, and data structures*, Fourth Workshop on Quantum Information Processing (QIP 2001), Amsterdam.
- March 14, talk: *Quantum computing*, NSA colloquium (Natuur- en Sterrenkunde Studenten Amsterdam), Amsterdam.
- May 8, talk: *Quantum lower bounds*, University of Waterloo, Canada.
- May 17, talk: *Quantum lower bounds*, Summer School in Quantum Computing, Fields Institute, University of Toronto, Canada.
- June 1, talk: *Quantum computing*, Mathematical Logic Colloquium Utrecht.
- June 19, talk: *Communication complexity lower bounds by polynomials*, IEEE Computational Complexity 2001, Chicago.
- November, talk: *Quantum communication complexity: Some recent results*, Caltech IQI seminar, Pasadena (CA).
- December, talk: *Quantum communication complexity: Some recent results*, MIT quantum computing seminar, Boston (MA).

Memberships of Committees and Other Professional Activities

H. Buhrman:

- Coordinator of fifth framework project QAIP.
- Coordinator of the NWO project 'Extending Feasible Computation: Quantum Computing'.
- Promotor (PhD advisor) of Ronald de Wolf (PhD cum laude), Mart de Graaf, Hein Röhrig, and Troy Lee.
- Member PhD committee Wim van Dam.
- Member of Steering Committee for Anual Conference on Quantum Information Processing (QIP).
- Member of the Steering Committee for the Annual Conference on Computational Complexity (CCC), since 1998.
- Member of the program committee of Mathematical Foundations of Computer Science (MFCS 2001) that was held in Marianske Lazne, Czech Republic.
- Member of the program committee of the International Symposium on Theoretical Aspects of Computer Science (STACS 2002) that will be held in Antibes-Juan les Pins, France. The number of submissions was unusually high this year: 210 versus 150 in other years.
- Member of the program committee of Foundations of Software Technology and Theoretical Computer Science (FST&TCS 2001) that was held in Bangalore, India.
- Member of the program committee of the Conference on Computational Complexity (CCC 2002) to be held in Montréal, Canada.

P.D. Grünwald:

- Member of the program committee of UAI-2001, the Seventeenth Conference on Uncertainty in Artificial Intelligence. This conference was held August 2–5 in Seattle, USA.
- Until July 1, Grünwald worked parttime (0.5 fte) at EURANDOM in the Complex Statistical Models Group. EURANDOM is a European research institute for the study of stochastic phenomena, located at the campus of Eindhoven Technical University. After July 1st, Grünwald worked full-time at CWI.
- ESPRIT BRA VI NeuroCOLT II Working Group EP 27150: on Fundamental Understanding of Learning and Algorithmic Implementations.
- FoLLI (The European Association for Logic, Language and Information) (member).

P.M.B. Vitányi:

- Professor of Computer Science, Universiteit van Amsterdam.
- Guest Editor *J. Computer and System Sciences*, special issue on Computational Learning Theory, 1994–1998.
- Editor *International Journal of Foundations of Computer Science*, World Scientific, since 2001.

- Editor *Distributed Computing*, Springer-Verlag, since 1987.
- Editor *Theory of Computing Systems* (Formerly: *Mathematical Systems Theory*), Springer Verlags, since 1991.
- Editor *Information Processing Letters* North-Holland/Elsevier, since 1993/94.
- Editor *Parallel Processing Letters*, World Scientific Publishers, Singapore, since 1991.
- Editor *Journal of New Generation Computer Systems*, Akademie-Verlag, Berlin, since 1989.
- Editor *Frontiers in Computing Systems Research*, Plenum Annual Review Book Series, Plenum Press, since 1988.
- Member of the Scientific Board, *Encyclopaedia of Mathematics*, Reidel (updated and annotated translation of the Soviet *Mathematical Encyclopaedia.*) since 1987.
- Program Committee, 13th European Conference on Machine Learning (ECML'02), which will be co-located in Helsinki with the 6th European Conference on Principles and Practice of Knowledge Discovery in Databases (PKDD'02).
- Program Committee, Eighth Annual International Computing and Combinatorics Conference (COCOON'02), Singapore, August 2002.
- Program Committee, International Conference on Algorithms, Languages, and Programming, (ICALP), Malaga (Spain), 2002.
- Program Committee, 12th European Conference on Machine Learning (ECML '01), 2001 which will be co-located in Freiburg with the 5th European Conference on Principles and Practice of Knowledge Discovery in Databases (PKDD'01).
- Organizing/Program Committee *Workshop on Complexity and Inference* for the *Computational Information Theory and Coding Year* (2001–2002) at DIMACS at Rutgers University.
- Member of EU fifth frameworkproject QAIP, IST–1999–11234.
- Member of the NoE QUIPROCONE IST–1999–29064.
- Member of the ESF QiT Programmme.
- Amsterdam Site Manager of ESPRIT BRA VI NeuroCOLT II Working Group EP 27150: on Fundamental Understanding of Learning and Algorithmic Implementations.
- Member IFIP WG 1.2 on Descriptive Complexity and Applications, since 1991; co-chair of IFIP WG 1.4 on Computational Machine Learning, since 1992.
- Publiciteits commissie van het Wiskundig Genootschap (Publicity Committee Dutch Mathematical Society), since 1989.
- Advisor *Monash Key Centre for Computational Data Analysis*, Monash University, Clayton Campus, Melbourne, Australia.
- Advisor and evaluator for/of the Japanese Discovery Science Project. The *Discovery Science* is a three year project from 1998 through 2000 that targets to (1) develop new methods for knowledge discovery, (2) install network environments for knowledge discovery, and (3) establish the Discovery Science as a new area of Computer Science. A systematic research is planned that ranges over philosophy, logic, reasoning, computational learning and system developments.
- Member of the Dutch Robosoccer committee *Autonomous Interacting Multiagent Soccer.*
- 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.
- PhD Supervisor in 2001 of W. van Dam, R. de Wolf, H. Röhrig, R. Manniesing, University of Amsterdam.

Visitors

- March 5–6: C. Smith, Univ. Maryland, USA.
- March 5 – April 5: L. Antunes, Univ. Porto, Comp. Sci.
- April 11–12: M. Hutter, IDSIA, Lugano, Switzerland.
- June 20–21: C. Smith, Univ. Maryland, USA.
- July 1–3: A.P. Dawid, University College London, funded by EURANDOM, Eindhoven.
- September 6–8: M. Santha, C. Dürr, and P. Senn, Univ. of Paris Sud.
- October 19: Troy Lee, Caltech.
- October 17–18: S. Massar, ULB Brussels.
- October 19: J. Hoepman, University of Twente.
- October 26: G. Brassard, University of Montréal.
- October 27: J. Hoepman, University of Twente.
- October 20 – November 21: N.K. Vereshchagin, Comp. Sci, Moscow State Univ., Russia.

- November 16–17: N. Chater, Warwick Univ., Psych. Dept., UK.
- November 22 – December 6: Eldar Fischer, Technion, Israel.
- December 18–20: S. Massar and S. Pironio, ULB Brussels.

Papers in Journals and Proceedings

K. Amano, J. Tromp, P. Vitányi, O. Watanabe (2001). On a generalized ruin problem. *Proceedings RANDOM 2001*, LNCS, Springer-Verlag.

G.T. Bogdanova, A.E. Brouwer, S.N. Kapralov, P.R.J. Östergård (2001). Error-Correcting Codes over an Alphabet of Four Elements. *Designs, Codes and Cryptography* **23**, 333–342.

H. Buhrman, R. Cleve, W. van Dam (2001). Quantum entanglement and communication complexity. *SIAM Journal on Computing* **30**(8), 1829–1841.

H. Buhrman, R. Cleve, J. Watrous, R. de Wolf (2001). Quantum Fingerprinting. *Physical Review Letters* **87**(16).

H. Buhrman, S. Fenner, L. Fortnow, L. Torenvliet (2001). Two oracles that force a big crunch. *Computational Complexity* **10**, 93–116.

H. Buhrman, J. Tromp, P. Vitányi (2001). Time and space bounds for reversible simulation. *Proceedings ICALP 2001*, LNCS, Springer-Verlag, Berlin.

H. Buhrman, J. Tromp, P. Vitányi (2001). Time and space bounds for reversible simulation. *Proceedings ICALP 2001*, LNCS, Springer-Verlag, Berlin.

H. Buhrman, Ch. Dürr, M. Heiligman, P. Høyer, F. Magniez, M. Santha, R. de Wolf (2001). Quantum algorithms for element distinctness. *Proceedings of 16th IEEE Conference on Computational Complexity*, 131–137.

H. Buhrman, J. Tromp, P. Vitányi (2001). Time and space bounds for reversible simulation. *Journal of Physics A: Mathematical and General* **34**, 6821–6830.

H. Buhrman, S. Fenner, L. Fortnow, L. Torenvliet (2001). Two oracles that force a big crunch. *Computational Complexity* **10**, 93–116.

A. Ambainis, R. de Wolf (2001). Average-Case Quantum Query Complexity. *Journal of Physics A: Mathematical and General* **34**(35), 6741–6754.

H. Buhrman, R. de Wolf (2001). Complexity Measures and Decision Tree Complexity: A Survey. *Theoretical Computer Science*.

H. Buhrman, R. de Wolf (2001). Communication Complexity Lower Bounds by Polynomials. *Proceedings of 16th IEEE Conference on Computational Complexity*, 120–130.

N. Chater, P.M.B. Vitányi, N. Steward (2001). Universal generalization and universal inter-item confusability. *Behavior and Brain Sciences*.

W. van Dam, M. Mosca, U. Vazirani (2001). How Powerful is Adiabatic Quantum Computation? *Proceedings 42nd IEEE Symp. Foundations of Computer Science*.

P. Gács, J. Tromp, P. Vitányi (2001). Algorithmic Statistics, *IEEE Trans. Inform. Th.* **47**(6), 2443–2463.

M. de Graaf, R. de Wolf (2001). On Quantum Versions of the Yao Principle. *Proceedings of 19th Annual Symposium on Theoretical Aspects of Computer Science (STACS'2002)*.

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APPENDIX
SURVEY OF FTP DOWNLOADS OF CWI REPORTS

Downloads 1996–2001

Year	# of reports downloaded	Total # of hits
2001	967	279008
2000	853	149416
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1997	536	28332
1996	441	19857

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1881	AA	CS-R9406. *Data Mining: the search for knowledge in databases.* Marcel Holsheimer and Arno P.J.M. Siebes
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1234	PNA	PNA-R0103. *Dynamic rate control algorithms for HDR throughput optimization.* Simon C. Borst and Philip A. Whiting
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1074	MAS	MAS-R9925. *Factorization of RSA-140 using the number field sieve.* Stefania Cavallar, Bruce Dodson, Arjen K. Lenstra, Paul C. Leyland, Walter M. Lioen, Peter L. Montgomery, Brian Murphy, Herman J.J. te Riele and Paul Zimmermann
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939	MAS	MAS-R0007. *Factorization of a 512–bit RSA modulus.* Stefania Cavallar, Walter M. Lioen, Herman J.J. te Riele, Bruce Dodson, Arjen K. Lenstra, Peter L. Montgomery and Brian Murphy

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910	INS	INS-R0023. *Wavelet methods in (financial) time-series processing.* Zbigniew R. Struzik
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812	INS	INS-R9905. *An organic database system.* Martin L. Kersten and Arno P.J.M. Siebes
801	MAS	MAS-R9832. *Test set for initial value problem solvers.* Walter M. Lioen and Jacques J.B. de Swart
796	INS	INS-R0008. *Outlier detection and localisation with wavelet based multifractal formalism.* Zbigniew R. Struzik and Arno P.J.M. Siebes
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787	AP	CS-R9567. *A survey of automated timetabling.* Andrea Schaerf
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2706	AA	CS-R9430. *Homogeneous discoveries contain no surprises: Inferring risk-profiles from large databases.* Arno P.J.M. Siebes
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