Overview Research Activities 2002

Draft of 5th August 2003

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 Telematics Institute 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 Benelux.

General Director

G. van Oortmerssen
(till May 1, 2003)

Colophon

Issued by	Stichting Centrum voor Wiskunde en Informatica, July 2003 ©
Production	Communication and Publication Department CWI
Printing	Grafisch bedrijf Ponsen & Looijen bv, Wageningen

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

ISSN 1380-7846

CONTENTS

This Overview Research Activities is complementary to the Jaarverslag CWI (in Dutch) and CWI Annual Report (in English).

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

PREFACE

This Overview

This Overview is a comprehensive report of the CWI research activities in 2002 and is a supplement to *CWI Annual Report 2002*, which *highlights* CWI's scientific research.

The rationale of the new appearance of this Overview

Compared to previous years, this Overview has been restyled and redesigned to address the latest NWO requirements:

1. Missions of the research entities of CWI (i.e., the themes and clusters).
2. Additional data on the scientific staff (MSC or CR classification; period of appointment; projects in which she/he is involved).
3. More extensive progress reports on the research projects.
4. Identification of the funding sources of the projects.
5. Identification of affiliations of non-CWI co-authors.

Besides, CWI has added some new items to the Overview:

1. Societal aspects
2. Restructuring of some existing items
3. Spin-offs

Mission of CWI

CWI is the national research institute for Mathematics and Computer Science. It is a private, non-profit organization. Founded in 1946 (as Mathematisch Centrum), it aims at fostering mathematics and computer science research in the Netherlands. CWI receives a basic funding from the Netherlands Organization for Scientific Research (NWO), amounting to about 70% of the institute's total income. The remaining 30% is obtained through national research programmes, international programmes and contract research commissioned by industry.

CWI's mission is twofold: To perform frontier research in mathematics and computer science, and to transfer new knowledge in these fields to society in general and trade and industry in particular.

This mission is realized by several means. In addition to the standard ways of disseminating scientific knowledge, for example through publications, presentations at conferences, organization of workshops and exchange of researchers, CWI actively pursues joint projects with external partners, provides consulting services and actively stimulates the creation of spin-off companies. A technology transfer event is organized annually to promote these activities. Also special efforts are made to make research results known to non-specialist circles, ranging from researchers in other disciplines to the public at large. CWI has many contacts with national organizations for applied research with wide experience in turning research results directly into practical applications. Its researchers are supported by state-of-the-art computing facilities and a library of national importance.

CWI has always been very successful in securing considerable participation in European research programmes (ESPRIT, ACTS, TELEMATICS, BRITE, TMR, IST and others) and has extensive experience in managing these international collaborative research efforts. CWI is also strongly embedded in Dutch university research: about twenty of its senior researchers hold part-time positions as university professors and several projects are carried out in cooperation with university research groups. Annually CWI hosts some 200 visiting scientists from abroad.

CWI has a staff of 210 fte (full time equivalent), 160 of whom are scientific staff. It operates on an annual budget of M€ 13.

CWI's research entities

CWI's scientific research is organized in four *scientific clusters*, each consisting of 3–5 *scientific research themes*.

PNA – Probability, Networks and Algorithms

Research themes:

- PNA1 – Networks and Logic – Optimization

and Programming
- PNA2 – Advanced Communication Networks (pilot)
- PNA3 – Stochastics
- PNA4 – Signals and Images

SEN – Software Engineering

Research themes:

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

MAS – Modelling, Analysis and Simulation

Research themes:

- MAS1 – Applied Analysis and Scientific Computing
- MAS2 – Computing and Control
- MAS3 – Nonlinear Dynamics and Complex Systems (pilot)

INS – Information Systems

Research 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

Summary of contents

This Overview contains:

- Reports of the four clusters and their themes
- Five appendices:

  A CWI reports
  B Publications outside the research clusters
  C Survey of ERCIM Fellows and Indian Institute of Technology summer internships
  D Acronyms of universities in the Netherlands
  E PhD theses

Items per cluster

- General overview
  - Principal research area + mission
  - Cluster leader
  - Research themes; and their leaders
  - Other items of interest
- Staff survey

Items per theme

- Name of theme + acronym
- Mission of theme
- Theme leader
- Subthemes and their leaders
- Staff (+ affiliation of seconded staff)
- Scientific report: highlights, PhD research, and report per subtheme/project
- Societal aspects and knowledge transfer
- Organization of conferences, workshops, courses, etc.
- Lectures, conferences, courses, project meetings, working visits
- Memberships of committees and other professional activities
- Visitors
- Publications (books and book chapters, papers in refereed journals and proceedings, CWI reports, other publications)

PROBABILITY, NETWORKS AND ALGORITHMS

General overview

Principal research area and mission

PNA (Probability, Networks and Algorithms) focuses on discrete and probabilistic modelling and optimization (with discrete mathematics, logic, wavelets, operations research, and stochastics as prime tools), and on their applications in technology, management, image analysis, and life sciences, in particular (but not exclusively) in information and communication technology, logistics, 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 novel techniques for practical use and developing algorithms also belong to the objectives, as exemplified by participation in several externally funded application-oriented projects and by a 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. Consultancies and cooperation are performed with partners in transportation (Dutch Rail, State Highways), information technology (IBM, Hewlett Packard, Philips, Microsoft), communication (France Télécom, KPN Research, Surfnet, AT&T, Lucent Technologies, Ericsson, Bell Communications Research), public health (hospitals), environment (RIVM, North Sea Directorate), seismology (Shell, KNMI), and finance (Limperg Institute).

Much of PNA-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. Five members hold a university professorship, and three others have different 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.

Cluster leader

Prof.dr. A. Schrijver

Themes

Name	Leader
PNA1 – Networks and Logic – Optimization and Programming	A.M.H. Gerards
PNA2 – Advanced Communication Networks (pilot)	M.R.H. Mandjes
PNA3 – Stochastics	J. van den Berg
PNA4 – Signals and Images	H.J.A.M. Heijmans

Staff

- Networks and Logic – Optimization and Programming – PNA1
  - K.R. Apt
  - S. Brand
  - S. Etalle
  - S. Fiorini
  - R. Gennari
  - A.M.H. Gerards
  - D.C. Gijswijt
  - J.Y. Halpern
  - W.J. van Hoeve
  - M. Laurent
  - S.G.E. Maróti
  - M. Peeters
  - F. van Raamsdonk
  - A. Schrijver
  - A.G. Steenbeek
  - L. Stougie
  - C.F.M. Vermeulen
- Advanced Communication Networks – PNA2
  - R. Bekker
  - S.C. Borst
  - R.J. Boucherie
  - O.J. Boxma
  - S.K. Cheung
  - K.G. Dębicki
  - A.B. Dieker
  - R.L. Litjens
  - M.R.H. Mandjes
  - R. Núñez-Queija
  - D.T.M.B. van Ooteghem
  - W.R.W. Scheinhardt
  - M.J.G. van Uitert
  - A.P. Zwart
- Stochastics – PNA3
  - J. van den Berg
  - R.M. Brouwer
  - E. Capobianco
  - K.O. Dzhaparidze
  - J.A. Ferreira
  - R. Helmers
  - R. van der Horst
  - A. Jarai
  - M.S. Keane
  - S.W.W. Rolles
  - P.J.C. Spreij
  - B. Tarigan
- Signals and Images – PNA4
  - G.C.K. Abhayaratne
  - H.J.A.M. Heijmans
  - R. Huele
  - M.J. Huiskes
  - L. Kamstra
  - M.N.M. van Lieshout
  - P.J. Oonincx
  - E.J.E.M. Pauwels
  - G. Piella Fenoy
  - H. Rössler
  - B.A.M. Schouten
  - A.W.M. Smeulders
  - A.G. Steenbeek
  - R.S. Stoica
  - P.M. de Zeeuw
- Secretary:
  - S.J. van Dam

Networks and Logic – Optimization and Programming – PNA1

Mission

This theme 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 time-tabling, the design of VLSI-circuits, and computational biology. The techniques developed make use of models and methods from mathematics (mathematical logic, geometry, topology, graph theory), operations research (linear, integer, and semidefinite programming), and computer science (logic and constraint programming and complexity theory).

Theme leader

Prof.dr.ir. A.M.H. Gerards

Subthemes

Name	Leader
PNA1.1 – Networks and Optimization	A.M.H. Gerards, M. Laurent, A. Schrijver
PNA1.2 – Constraint and Integer Programming	K.R. Apt
PNA1.3 – Algorithmic and Combinatorial Methods for Molecular Biology	L. Stougie

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. K.R. Apt (0.2 UvA)	0.8	leader PNA1.2	indefinite	PNA1.2: CIP, FDP	D.3.2, D.3.3
S. Brand, Dipl.-Inform.	1.0	PhD student	2000-09-01 till 2004-09-01	PNA1.2: CIP	D.3.2, D.3.3
Dr. S. Etalle (0.9 UT)	0.1	senior researcher (NWO)	2000-07-15 till 2004-07-15	PNA1.2: FDP	C.2.0, C.2.2, D.1.6, D.3.3, K.6.5
Dr. S. Fiorini	0.04	post-doc (EU)	till 2002-01-15	PNA1.1: N&O	06A07, 05C20, 52B12, 90C57
Prof.dr.ir. A.M.H. Gerards (0.2 TUE)	0.8	leader PNA1.1	indefinite	PNA1.1: N&O, AMORE, PNA1.2: CIP	05B35, 05Cxx, 90C27
Ir. W.J. van Hoeve	0.8	PhD student	2000-10-01 till 2005-05-01	PNA1.2: CIP	D.3.2, D.3.3
Dr. M. Laurent	0.7	leader PNA1.1	indefinite	PNA1.1: N&O, SPCO	90Cxx, 90C27, 90C22
S.G.E. Maróti, MSc	1.0	PhD student (EU)	2001-02-01 till 2005-02-01	PNA1.1: N&O, AMORE	90C27, 90C90
Dr. M. Peeters	0.25	post-doc (EU)	2002-10-01 till 2003-10-01	PNA1.1: AMORE	90Bxx, 90B06 90Cxx, 90C90
Prof.dr. A. Schrijver (0.2 UvA)	0.8	leader PNA1.1	indefinite	PNA1.1: N&O	05Cxx, 68Qxx, 68Rxx, 90Cxx
A.G. Steenbeek (0.4 PNA4)	0.6	programmer	indefinite	PNA1.1: STAGE-SPOREN	
Dr. C.F.M. Vermeulen	1.0	post-doc (NWO)	2001-06-01 till 2003-08-01	PNA1.2: CIP	03B45, 03B47, 03B65, 03B70

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. R. Gennari (0.55 UvA)	0.45	PhD student, ERCIM Fellow	2002-07-16 till 2003-08-31	PNA1.2: CIP	D.3.2, D.3.3
Drs. D.C. Gijswijt (0.6 UvA)	0.4	PhD student	2002-01-01 till 2005-09-01	PNA1.1: N&O	05Cxx
Prof. J.Y. Halpern (0.5 NWO)	0.5	guest researcher	2001-08-01 till 2002-08-01	PNA1.2: FDP	C.2.4, D.4.6, F.4.1, I.2.4
Dr. F. van Raamsdonk (0.8 VU)	0.2	senior researcher	2001-08-01 till 2003-01-01	PNA1.2: FDP	3B15, 03B40, 03B70
Dr. L. Stougie (0.8 TUE)	0.2	leader PNA1.3	2000-01-01 till 2005-03-01	PNA1.3: ACMB PNA1.1: N&O	92B05, 90C27, 90C59, 68W25

Scientific report

Highlights

- M. Laurent has been awarded a 5-year VIDI research grant from NWO for her research project 'Semidefinite programming and combinatorial optimization'.
- A. Schrijver finished his book *Combinatorial Optimization – Polyhedra and Efficiency*, which will appear in 2003 with Springer-Verlag.
- June 25, A. Schrijver received an honorary doctorate degree in mathematics from the Univ. Waterloo, Ontario, Canada.

PhD research

Title	PhD research of S. Brand
Period	September 2000–September 2004
Leader	K.R. Apt
Funding	NWO

Progress report. *Brand* worked with *Apt* on the subject of efficient schedulers for a class of rules that naturally arise in the context of rule-based constraint programming. They systematically derived a scheduler for this rules from a generic iteration algorithm of *Apt* and applied it to so-called membership rules of *Apt* and E.B.G. Monfroy.

For these rules this led to an implementation that yields a considerably better performance than their execution as standard CHR rules. A paper on this subject will be presented during the ACM Symposium on Applied Computing (SAC 2003) conference.

Title	PhD research of R. Gennari
Period	July 2000–December 2002
Leader	K.R. Apt
Funding	UvA

Progress report. On December 2, *Gennari* defended her PhD thesis entitled *Mapping Inferences* at the UvA. It was written under the supervision of *Apt* and M. de Rijke (UvA). The topic of this thesis is constraint satisfaction problems and automated reasoning in modal logics.

Title	PhD research of D.C. Gijswijt
Period	January 2002–September 2005
Leader	A. Schrijver
Funding	UvA & NWO

Progress report. *Gijswijt* and *Schrijver* showed that the b-stable set polyhedron of graphs not containing a bad K_4-subdivision is determined by the edge and odd circuit inequalities.

Title	PhD research of W.J. van Hoeve
Period	January 2000–January 2004
Leader	K.R. Apt
Funding	NWO

Progress report. *Van Hoeve* worked with M. Milano (Univ. Bologna) on search heuristics for constraint and integer programming. In particular, they used 'reduced costs' obtained from a linear relaxation to guide the constraint programming tree search. This work resulted in a paper at the joint ERCIM/CologNet Workshop on Constraint Solving and Constraint Logic Programming in Cork (Ireland). A slighty different version was accepted for the Eighth International Conference on Principles and Practice of Constraint Programming in Ithaca (USA).
Van Hoeve and Milano started to extend this work to a general search strategy: Decomposition Based Search (DBS). A particular instance has been implemented, using semidefinite relaxation to solve the stable set problem.

Title	PhD research of S.G.E. Maróti
Period	February 2001–February 2005
Leader	A.M.H. Gerards
Funding	EU

Progress report. Within the framework of the European Research Training Network AMORE and in close cooperation with researchers and planners at the Dutch Railways, especially L.G. Kroon, *Maróti* works on the application of combinatorial and integer programming methods for railways optimization problems. In particular, he developed models and solution techniques for maintenance routing of rolling stock and for circulation of rolling stock of trains in the Netherlands.

With *Gerards* and *Schrijver*, he derived very short and easy proofs for recent results of Aguilera, Escalante, and Nasini, on the disjunctive index of relaxations of stable set polyhedra.

PNA1.1 – Networks and Optimization

Title	Network and Optimization Techniques (N&O)
Period	January 2002–January 2007
Leaders	A.M.H. Gerards, A. Schrijver
Staff	D.C. Gijswijt, S.G.E. Maróti, M. Laurent, L. Stougie
Funding	CWI
Partners	TUE, UvA, UU, Philips Research Laboratories, Karel Univ. Prague, Ecole Normale Supérieure Paris,

	IBM Research (Yorktown Heights, NY), Lucent Technologies (Murray Hill, NJ), Microsoft Research (Seattle, WA), Ohio State Univ. (Columbus, Ohio), Princeton Univ. (Princeton, NJ), Rice Univ. (Houston, TX), Univ. Waterloo (Ontario), Victoria Univ. (Wellington, New Zealand)

Progress report. Combinatorial optimization – polyhedra and efficiency. Schrijver finished his book *Combinatorial optimization - polyhedra and efficiency*, which will appear in 2003 with Springer-Verlag.

A grid theorem for binary matroids. J.F. Geelen (Canada), *Gerards*, and G. Whittle (New Zealand) continued their work towards a grid theorem for binary matroids. First they proved, in cooperation with N. Robertson (USA), a bound on the excluded minors for the matroids with branch-width k (to appear in *Journal on Combinatorial Theory, Series B*) and a structural characterization for high branch-width in matroids representable over fixed finite fields (a report is almost finished). At the end of the year, Geelen, *Gerards*, and Whittle proved that indeed matroids representable over a fixed finite field have large grid-minors if they have huge branch-width. This provides, among other things, evidence for Rota's conjecture.

Stable set polyhedra. See progress report on PhD research of *Gijswijt* and *Maróti*.

On-line routing. Stougie, S. Krumke (Konrad-Zuse-Zentrum Inform. Berlin), D. Poensgen (Konrad-Zuse-Zentrum Inform. Berlin), W.E. de Paepe (TUE), M. Lipmann (TUE), X. Lu (East China), R.A. Sitters (TUE), have obtained several results in the field of on-line routing. A first step to study on-line elevator systems has been made. *Stougie*, R.A. Sitters (TUE) and W.E. de Paepe (TUE) proved CNN-conjecture. This is considered one of the most important open problems in on-line optimization.

Randomized algorithms and counting. Stougie, M. Dyer (Univ. Leeds, UK) and R. Kannan (Carnegie Mellon Univ., Pittsburg, PA) completed work on fast randomized algorithms for convex optimization. *Stougie* and M. Dyer (Univ. Leeds, UK) studied the complexity of stochastic programming problems. *Stougie*, M. Dyer (Univ. Leeds, UK), M. Cryan (Univ. Leeds, UK) and H. Müller (Univ. Leeds, UK) counted the vertices of transportation polytopes approximately using Markov Chain techniques.

Transportation polytopes. Stougie derived a first strongly polynomial bound on the diameter of the transportation polytope. This, cubic, bound has been improved to a quadratic bound by *Stougie* and J. van den Heuvel (UK), and was later, improved to a linear bound by *Stougie* and G. Brightwell (UK).

Title	Semidefinite Programming and Combinatorial Optimization (SPCO)
Period	June 2001–January 2008
Leader	M. Laurent
Funding	CWI and NWO project (2003)
Partners	LAAS-CNRS (Toulouse), Univ. Klagenfurt (Austria), Univ. Rennes (France), TUD

Progress report. Laurent continued her research on semidefinite programming approaches to hard combinatorial optimization problems. In particular, she completed in collaboration with F. Rendl (Germany) an overview article about this topic (101 pages), which will appear as chapter of a Handbook on Discrete Optimization edited by K. Aardal, G. Nemhauser and R. Weismantel. She studied how an algebraic construction introduced by Lasserre applies to the max-cut problem. She proved that at least $n/2$ iterations are needed for finding the cut polytope as projection of a higher dimensional semidefinite relaxation. It is conjectured that $n/2$ is the exact value for the number of needed iterations. She also presented concise semidefinite representations for polytopes whose vertices form a real variety, in the case when the corresponding ideal is radical and the associated complex variety is finite. This extends known results for the grid case including 0/1 programming. Moreover, she proved results about flat extensions of combinatorial moment matrices, thus providing combinatorial analogues with simple proofs of known results from Curto and Fialkow for classic moment matrices.

Title	Algorithmic Methods for the Optimization of the Railways in Europe (AMORE)
Period	April 2000–March 2004
Leader	A.M.H. Gerards
Funding	EU (Research training network)
Partners	EUR, NS Reizigers,

	Univ. Konstanz, ETH (Zürich), Technical Univ. Denmark (Lyngby), Univ. Sapienza (Rome), Univ. degli Studi dell'Aquila (Italy), Computer Technology Institute (Patras, Greece)

Progress report. *Maróti* and *Peeters* work in close cooperation with researchers and planners of the Dutch Railways, especially L.G. Kroon, on the application of combinatorial and integer programming methods for railways optimization problems. *Maróti* developed models and solution techniques for maintenance routing of rolling stock and for circulation of rolling stock of intercity-lines in the Netherlands. *Peeters* and L.G. Kroon developed a branch-and-price approach to determine an efficient railway rolling stock circulation on a single line. The algorithm is tested on several real-life instances from NS Reizigers (a working paper is in preparation). See also Schrijver's consultancy project with NS Reizigers under 'Societal aspects and knowledge transfer'.

Externally financed networks

Title	Dutch-Hungarian cooperation project: Combinatorial and Algebraic Structures and Algorithms
Period	January 2001–December 2003
Leader	A.M.H. Gerards
Funding	NWO (networking)
Partners	TUE, Eötvös Loránd Univ. (Budapest)

Title	Discrete Optimization Network (DONET)
Period	March 1998–February 2003
Leaders	A.M.H. Gerards, A.Schrijver
Funding	EU (Research training network)
Partners	Cath Univ. Louvain (Belgium), RFW Univ. (Bonn), Univ. Pierre et Marie Curie (Paris), IASI (Rome), Univ. Lisbon, Ecole Polytechnique Fédérale de Lausanne, London School of Economics and Political Sciences, TUE, UM, UvA, Univ. Padova, Univ. Köln, Univ. Grenoble

PNA1.2 – Constraint and Integer Programming

Title	Constraint and Integer Programming Techniques (CIP)
Period	January 2002–January 2007
Staff	S. Brand, R. Gennari, J.Y. Halpern, W.J. van Hoeve, C.F.M. Vermeulen
Funding	CWI; NWO-project
Partners	ERCIM WG Constraints, Univ. Victoria (Canada), Univ. Singapore, Brooklyn College (USA)

Progress report. *Apt* worked on a number of aspects of logic and constraint programming. Jointly with *Vermeulen* he provided a denotational semantics for first-order logic that captures the two-level view of the computation process typical for constraint programming. At one level they have the usual program execution. At the other level an automatic maintenance of the constraint store takes place. They proved that the resulting semantics is sound with respect to the truth definition. By instantiating it by specific forms of constraint management policies one obtains several sound evaluation policies of first-order formulas. The paper on this subject was presented during the Logic for Programming, Artificial Intelligence and Reasoning (LPAR 2002) conference. (See PhD research *Brand*). Also, *Apt* contributed a chapter entitled *The Logic Programming Paradigm and Prolog* to the book *Concepts in Programming Languages* written by J. Mitchell (Stanford Univ.) and which appeared with Cambridge Univ. Press. *Apt* also published an obituary of Edsger Wybe Dijkstra, in which he discussed his scientific contributions and their impact, his opinions and legacy. The paper appeared in the *Formal Aspects of Computing* journal. Finally, he also worked on his book tentatively titled 'Principles of Contraint Programming'. The book will be ready in 2003.

Title	Foundations of Declarative Programming (FDP)
Period	January 2002–January 2007
Leader	K.R. Apt
Staff	S. Etalle, F. van Raamsdonk, J.Y. Halpern
Funding	CWI; NWO project
Partners	UT, VU

Progress report. The research of *Halpern* focused on security, causality, and representing uncertainty. With regard to security, together with his UvA-students R. Pucella and K. O'Neill, he worked on finding good models for notions such as anonymity and secrecy, as well as on mod-

elling resource-bounded intruders. With regard to causality, the focus was on getting good definitions of subtle notions like 'responsibility' and 'blame', using earlier definitions of 'cause' that J. Pearl (USA) and *Halpern* gave. Finally, with regard to representing uncertainty, *Grünwald* (INS4) and *Halpern* considered when we ignore the effect of the protocol used in doing probabilistic conditioning; this turns out to be critical in a number of statistical applications, and R. Pucella and *Halpern* axiomatized various notions of expectation.

Externally financed networks

Title	EU working group DEDUGIS
Period	April 1998–April 2002
Staff	K.R. Apt
Funding	EU (working group)
Partners	CNR/CNUCE, Univ. Pisa, GMD-First Berlin, Univ. Würzburg, Sistemi Territorialli Pisa, DEBIS Berlin, INTECS Pisa, SISTEMA Grosseto

Title	EU working group COTIC
Period	April 1997–April 2002
Staff	K.R. Apt
Funding	EU (working group)
Partners	UU, Univ. Pisa, Univ. Lisbon, Univ. Kent, SICS, CR&T

Title	Distributive imperative constraint programming (programme NWO-USSR co-operation)
Period	January 2002–January 2003
Staff	K.R. Apt
Funding	NWO (networking)
Partners	Russian Research Institute of Artificial Intelligence Moscow, Institute of Informatics Systems Novosibirsk

PNA1.3 – Algorithmic and Combinatorial Methods for Molecular Biology

Title	Algorithmic and Combinatorial Techniques in Molecular Biology (ACMB)
Period	January 2001–January 2006
Leader	L. Stougie
Funding	CWI; NWO life sciences (enhancement CWI)
Partners	TUE, UU, VU, WUR, Georgia Tech., Univ. Iceland, Carnegie Mellon. Univ., Celena Genomics

Progress report. K.M.J. de Bontridder (SIEMENS VDO Automative, Eindhoven), B. Halldersson (Celena Genomics, USA), M. Halldórsson (Univ. Iceland), C.A.J. Hurkens (TUE), J.K. Lenstra (TUE & Georgia Tech., USA), R. Ravi (Carnegie Mellon, USA), *Stougie* studied the minimum test set problem, important in medical diagnostics and biological identification. Approximation results have been obtained and exact algorithms have been designed.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- N&O; page 9.
- AMORE; page 10.
- ACMB; page 12.
- DONET; page 11.
- COTIC; page 12.
- DEDUGIS; page 12.

Other

- A. Schrijver started a consultancy project for NS Reizigers (Dutch Rail) on the optimum circulation of rolling stock on the Intercity-lines between the Randstad and the Northern and Eastern parts of the Netherlands.
- A. Schrijver supervised the MSc thesis of Cs. Berki at the VU on 'An algorithm for disjoint S-paths.
- A.G. Steenbeek develops and maintains software for the VU and for the UM to route medical students along trainee posts in hospitals.

Organization of conferences, workshops, courses, meetings

- Final meeting of the 'DEDUGIS' project, Amsterdam, April 25–26: K.R. Apt (organizer).
- Tagung 'Geometric Convex Combinatorics', Mathematisches Forschungsinstitut Oberwolfach, Oberwolfach, June 16–22: A.M.H. Gerards (co-organizer).
- 7th Annual Workshop of the ERCIM Working Group on Constraints, Cork, Ireland, June 19–21: K.R. Apt (co-organizer).

- HOR'02: The First International Workshop on Higher-Order Rewriting, Copenhagen, July 21: F. van Raamsdonk (co-organizer).

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Tagung 'Combinatorics', Mathematisches Forschungsinstitut Oberwolfach, January 6–12: M. Laurent, A. Schrijver (Lecture: *S-paths*).
- 6th International Workshop in Combinatorial Optimization Aussois, France, January 7–11: W.J. van Hoeve, S.G.E. Maróti.
- 27th Conference on the Mathematics of Operations Research, LNMB, Lunteren, January 15–16: A.M.H. Gerards, S.G.E. Maróti, W.J. van Hoeve, M. Laurent, L. Stougie.
- Theory Day, Nederlandse Vereniging voor Theoretische Informatica, Utrecht, March 1: J.Y. Halpern (Invited lecture: *Causes and explanations: a structural-model approach*), A. Schrijver (Invited lecture: *Matching, Colouring, Scheduling*).
- Winter School '3e cycle romand de Recherche Opérationnelle', Zinal, Switzerland, March 3–7: A. Schrijver (Lecture: *Course on combinatorial optimization*).
- Workshop on the Unusual Effectiveness of Logic in Computer Science, Saarbrücken, March 4–6: J.Y. Halpern (Invited lecture: *Causes and explanations: a structural-model approach*).
- Scientific part of AMORE Midterm meeting, Konstanz, March 9: A.M.H. Gerards, S.G.E. Maróti.
- CPAIOR'02, international workshop on the integration of Constraint Programming, Artificial Intelligence and Operations Research Techniques, Le Croisic, France, March 25–27: W.J. van Hoeve.
- Conference on Dimensions in Epistemic Logic, Roskilde, Denmark, May 2–4: J.Y. Halpern (Invited lecture: *Substantive rationality and backward induction*).
- Verenigde Vergadering, Koninklijke Nederlandse Akademie van Wetenschappen, May 13: A. Schrijver (Lecture: *Routeren*).
- Tagung 'Geometric Convex Combinatorics', Mathematisches Forschungsinstitut Oberwolfach, June 16–22: A.M.H. Gerards, D.C. Gijswijt, S.G.E. Maróti, M. Laurent, A. Schrijver (Lecture: *S-paths*).
- Joint Workshop of ERCIM Working Group on Constraints and the CologNet area on Constraint and Logic Programming on Constraint Solving and Constraint Logic Programming, Cork, Ireland, June 19–21: S. Brand (Lecture: *A note on redundant rules in rule-based constraint programming*), W.J. van Hoeve.
- Workshop on the Travelling Salesman Problem, Dagstuhl, Germany, June 23–28: L. Stougie (Lecture: *The on-line travelling salesman problem*).
- High Performance Optimization Techniques, Tilburg, June 27–28: M. Laurent.
- Workshop on On-Line Algorithms, Dagstuhl, Germany, June 30–July 5: L. Stougie.
- RTA'02: Conference on Rewriting Techniques and Applications, Copenhagen, July 22–24: F. van Raamsdonk.
- IFIP WG 1.6 Workshop, Copenhagen, July 25: F. van Raamsdonk.
- LFM'02: Logical Frameworks and Meta-Languages (workshop): Copenhagen, July 26: F. van Raamsdonk.
- ESSLLI 2002, Trento, Italy, August 5–16: R. Gennari.
- Workshop on Combinatorial Optimization, Como, Italy, September 3–4: L. Stougie (Lecture: *On-line routing problems*).
- International Conference on Principles and Practice of Constraint Programming (CP-2002) Ithaca, USA, September 7–13: S. Brand, W.J. van Hoeve.
- Workshop on Rule-Based Constraint Reasoning and Programming (RCoRP'02), Ithaca, USA, September 8: S. Brand (Lecture: *A note on redundant rules in rule-based constraint programming*).
- 5th European Symposium on Algorithms, Rome, September 16–21: L. Stougie (Lecture: *Branch-and-bound algorithms for the minimum test set problem*).
- Workshop on Semidefinite Programming and its Applications in Control Theory, Combinatorial and Global Optimization, Toulouse, September 27: M. Laurent.
- Third AMORE Research Seminar on Railway Optimization Problems, Oegstgeest, The Netherlands, October 1–4: A.M.H. Gerards, S.G.E. Maróti, M. Peeters, A. Schrijver (Lecture: *Railway optimization models*).
- Semidefinite Programming and Applications, MSRI, Berkeley, October 7–11: M. Laurent.

- LPAR2002 (Logic for Programming, Artificial intelligence and Reasoning), Tbilisi, Georgia, October 14–18: C.F.M. Vermeulen (Lecture: *First-order logic as a constraint programming language*).
- RAPID/AMSD Workshop, Zürich, October 17–18: S. Etalle.
- Workshop on On-Line Algorithms, Leuven, November 8–9: L. Stougie (Lecture: *The on-line travelling salesman problem*).
- Stieltjes Lustrumdag, The Hague, November 15: A. Schrijver (Lecture: *Het kleuren van grafen*).
- INFORMS Fall 2002, San Jose, November 17–20: M. Peeters (Lecture: *The co-printing problem, a branch-and-price procedure*).
- EIDMA Symposium, Mierlo, The Netherlands, November 21–22: A. Schrijver (Lecture: *Stable sets and Colouring*).
- Validation 2002, Genova, November 22–24: S. Etalle.
- Tagung 'Combinatorial Optimization', Mathematisches Forschungsinstitut Oberwolfach, November 24–30: A. Schrijver.
- Workshop on Dependability in the EU Sixth Framework Program, Pisa, November 25–27: S. Etalle.
- Workshop on DRM in FP6, Brussels, December 6: S. Etalle.

Working visits

- Victoria Univ. Wellington, New Zealand, January 18–February 16: A.M.H. Gerards.
- Univ. Leeds, March 9–15: L. Stougie.
- Univ. Udine, April 14–20: K.R. Apt.
- Univ. Edinburgh, May 31: K.R. Apt.
- Univ. Bologna, to work with M. Milano, June 1–20: W.J. van Hoeve.
- Department of Combinatorics and Optimization, Univ. Waterloo, Ontario, June 11–15: A. Schrijver (Lectures: Seminar Faculty of Mathematics, June 12, *Permanents, Dimers, Edge-Colouring*; Seminar Department of Combinatorics and Optimization, June 13, *Embeddings and Eigenvalues*).
- Ecole Polytechnique, Paris, visiting I. Mackie and J.-P. Jouannaud, June 16–30: F. van Raamsdonk.
- National Univ. Singapore, July 15–December 31: K.R. Apt.
- Univ. Waterloo, Ontario, August 16–September 7: A.M.H. Gerards.
- IRIN, Univ. Nantes, October–December: S. Brand (Lectures: IRIN seminar, November 28 and LOGIN seminar, December 11, *Combination and derivation of rule-based constraint solvers for hyperarc-consistency*).
- Isaac Newton Institute, Cambridge, UK, October 2–31: L. Stougie (Lecture, October 29: *A strongly polynomial bound on the diameter of the transportation polytope*).
- Univ. Waterloo, Ontario, November 12–December 11: A.M.H. Gerards (Lecture, December 7: *Excluding a planar graph from binary matroids*).
- SINTEF and Technical Univ. Trondheim, Norway, December 7–12: L. Stougie.

Project meetings

- Kick-off meeting SAFE-NL the Dutch Security Platform (`http://wwwes.cs.utwente.nl/safe-nl`), UT, 18 January: S. Etalle.
- AMORE Midterm review meeting, Konstanz, March 8: A.M.H. Gerards, S.G.E. Maróti.
- AMORE business meeting, March 9, Konstanz: A.M.H. Gerards.
- Springer-Verlag, Heidelberg, June 19, November 4–5: A. Schrijver.
- AMORE business meeting, October 2, Leiden: A.M.H. Gerards.

Other lectures

- EIDMA Combinatorial Optimization Seminar, TUE, January 31: L. Stougie (Lecture: *Approximation algorithms for the minimum test set problem*).
- 5 lectures on constraint programming, Univ. Udine, April 14–20: K.R. Apt.
- Center for Rationality, Hebrew Univ., Jerusalem, April: J.Y. Halpern (Lecture: *Substantive rationality and backward induction*).
- Computer Science Department, Ben Gurion Univ., Beer Sheva, April: J.Y. Halpern (Lecture: *Causes and explanations: a structural-model approach*).
- Economics Department, Tel Aviv Univ., April: J.Y. Halpern (Lecture: *Causes and explanations: a structural-model approach*).
- Center for Rationality, Hebrew Univ., Jerusalem, April: J.Y. Halpern (Lecture: *Causes and explanations: a structural-model approach*).

- Philips Research Laboratories, Eindhoven, December 4: L. Stougie (Lecture: *A quadratic bound on the diameter of the transportation polytope*).
- LIFO seminar, Univ. Orléans, December 9: S. Brand (Lecture: *Schedulers and redundancy in rule-based constraint propagation*).

Courses

- LNMB and EIDMA course Combinatorial Optimization II, Utrecht, February–May: W.J. van Hoeve, S.G.E. Maróti.
- EIDMA Minicourse Graphs, Eigenvalues and Geometrical Representations by L. Lovász, TUE, April 22–26: A.M.H. Gerards, S.G.E. Maróti, M. Laurent, L. Stougie.

Memberships of committees and other professional activities

K.R. Apt

- Part-time professor at the UvA.
- Member Programming Committee 29th Annual ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages (POPL '02), Portland, USA.
- Member of the Executive Committee of the Association for Logic Programming, 1991–1994 and since 2001.
- Chairman and co-founder of the ERCIM Working Group on Constraints, since 1996.
- Member of the Board of the International Federation for Computational Logic (IFCoLoG), since 1999.
- Editor *Theory and Practice of Logic Programming* (TPLP), since 2001.
- Founder and editor-in-chief *ACM Transactions on Computational Logic* (TOCL), since 1999.
- Editor *Journal of Logic and Computation*, since 1989.

S. Etalle

- Editor of the Newsletter of the Association for Logic Programming, since 2001.
- Member Programming Committee ICLP 2002 (2002 International Conference on Logic Programming).
- Member Programming Committee LOPSTR 2002 (2002 International Workshop on Logic Program Synthesis and Transformation).
- Co-founder of SAFE-NL the Dutch Security Platform (http://wwwes.cs.utwente.nl/safe-nl), since 2002.

A.M.H. Gerards

- Part-time professor at the TUE.
- Supervisor MSc thesis *Toets op inplanbaarheid van rangeerbewegingen* of J.J.J. van de Broek.
- Associate editor *Mathematical Programming, Series A*, since 1999.
- Board member Landelijk Netwerk Mathematische Besliskunde, since 2001.
- Editor CWI Tracts, CWI Syllabi, since 1999.
- Editor *SIAM Journal on Discrete Mathematics*, since 1999.
- Member IPCO Steering Committee, Mathematical Programming Society, since 2002.
- Member PhD committee T. Vredeveld, April 23, TUE.

M. Laurent

- Editor *SIAM Journal on Optimization*, since 2001.
- Associate editor *Mathematics of Operations Research*, since 2001.
- Member-at-large of the Council of the Mathematical Programming Society, since 2000.

F. van Raamsdonk

- Member Program committee of RTA'02.

A. Schrijver

- Part-time professor at the UvA.
- Member Board EIDMA – Euler Institute for Discrete Mathematics and Its Applications, since 1993.
- Member Koninklijke Nederlandse Akademie van Wetenschappen (KNAW), since 1995.
- Member KNAW Akademie Raad voor de Wiskunde, since 1995.
- Member Programma Commissie Netwerken, Nederlandse Organisatie voor Wetenschappelijk Onderzoek, since 2000.
- Member Advies-Commissie Wiskunde (ACW), Nederlandse Organisatie voor Wetenschappelijk Onderzoek, since 2002.
- Member Science council Stieltjes Instituut voor Wiskunde, since 1992.
- Member Raad van Advies voor de Wiskunde, TUE, since 2000.
- Editor-in-chief *Combinatorica*, since 1993.

- Editor *Discrete Applied Mathematics*, since 1988.
- Advisory editor *Journal of Combinatorial Optimization*, since 1996.
- Editor *Journal of Combinatorial Theory, Series B*, since 1993.
- Editor *Journal of Combinatorics, Information and System Sciences*, since 1992.
- Associate editor *Mathematics of Operations Research*, since 1987.
- Advisory editor North-Holland Mathematical Library, since 1995.
- Editor *SIAM Journal on Discrete Mathematics*, since 1988.
- Member editorial board SIAM Monographs on Discrete Mathematics and Applications, since 2000.
- Member AB Landelijk Netwerk Mathematische Besliskunde, since 1989.
- Member Nevanlinna Prize Committee 2002.
- Supervisor MSc thesis of Cs. Berki (VU) on *An algorithm for disjoint S-paths.*

L. Stougie

- Member PhD committee T. Vredeveld, April 23, TUE.
- Member PhD committee M.E. van Bossum, June 5, UU.
- Member PhD committee W.E. de Paepe, September 30, TUE.

Visitors

- J.-B. Lasserre (CNRS, Toulouse), March 19–23. Host: M. Laurent.
- L. Lovász (Microsoft Research, Redmond, Washington), April 14–20. Host: A. Schrijver.
- M. Milano (Univ. Bologna), May 20–26. Lecture: *Operations research techniques in constraint programming.* Host: K.R. Apt.
- R.E. Bixby (CPLEX Inc. and Rice Univ., Houston, Texas), December 4–5. Host: A. Schrijver.

Publications

Books and book chapters

- K.R. Apt (2002). The Logic Programming Paradigm and Prolog, chapter 15 of *Concepts in Programming Languages*, J.C. Mitchell, Cambridge Univ. Press, 475–507, ISBN 0521780985.
- M. Laurent, M.M. Deza (ENS, Paris) (2001). *Geometrya razrezov i Metrik*, Russian translation of Geometry of cuts and metrics; Moscow, ISBN 5-9009126-84-7.

Papers in refereed journals and proceedings

K.R. Apt, C.F.M. Vermeulen (2002). First-order logic as a constraint programming language. A. Voronkov, M. Baaz (eds.). *Proceedings of the 9th International Conference LPAR2002*, LNAI **2514**, Springer-Verlag, 19–35.

K.M.J. de Bontridder (Siemens VDO Automotive, Eindhoven), J.K. Lenstra (Georgia Institute of Technology & TUE), J.B. Orlin (MIT), L. Stougie (2002). Branch and bound algorithms for the minimum test set problem. *Proceedings of the 10th European Symposium on Algorithms (ESA)*, LNCS **2461**, Springer-Verlag, Berlin, 223–233.

A. Bossi (Univ. Venice), N. Cocco (Univ. Venice), S. Etalle (2002). Transformation systems and nondeclarative properties. A.C. Kakas, F. Sadri (eds.). *Computational Logic: Logic Programming and Beyond, Essays in Honour of Robert A. Kowalski, Part I*, LNCS **2407**, Springer-Verlag, Berlin, 162–186.

F. Chu (Cornell Univ.), J. Gehrke (Cornell Univ.), J.Y. Halpern (2002). Least expected cost query optimization: What can we expect? *Proceedings of the 21st ACM Symposium on Principles of Database Systems*, 293–302.

R. Corin (UT), S. Etalle (2002). An Improved constraint-based system for the verification of security protocols.
M.V. Hermenegildo, G. Puebla (eds.). *Proceedings 9th Int. Static Analysis Symp. (SAS Madrid)*, LNCS **2477**, Springer-Verlag, Berlin, Madrid, 326–341.

G. Delzanno (Univ. Genova, Italy), S. Etalle (2001). Proof theory, transformations, and logic programming debugging security protocols. A. Pettorossi (ed.). *Proceedings 11th International Workshop on Logic Based Program Synthesis and Transformation (LOPSTR Paphos) – Selected papers*, LNCS **2372**, Springer-Verlag, Berlin, 76–90.

J.D. Doigon (Univ. Libre de Bruxelles), S. Fiorini (2002). Facets of the weak order polytope derived from the induced partition projection. *SIAM journal on Discrete Mathematics* **15**(1), 112–121.

J.F. Geelen (Univ. Waterloo, Ontario, Canada), A.M.H. Gerards, G. Whittle (Vic-

toria Univ., Wellington, New Zealand) (2002). Branch width and well-quasi-ordering in matroids and graphs. *Journal of Combinatorial Theory, Series B* **84**, 270–290.

Z. Haas (Cornell Univ.), J.Y. Halpern, L. Li (Lucent) (2002). Gossip-based ad hoc routing. *Proceedings of Infocom 2002*, 1707–1716.

J.Y. Halpern (2002). Characterizing the common prior assumption. *Journal of Economic Theory* **106**(2), 316–355.

J.Y. Halpern, P. Grünwald (2002). Updating probabilities. *Proceedings of the Eighteenth Conference on Uncertainty in AI*, 187–196.

J.Y. Halpern, K. O'Neill (Cornell Univ.) (2002). Secrecy in multi-agent systems. *Proceedings of the 15th IEEE Computer Security Foundations Workshop*, 32–46.

J.Y. Halpern, R. Pucella (Cornell Univ.) (2002). A logic for reasoning about upper probabilities. *Journal of AI Research* **17**, 57–81.

J.Y. Halpern, R. Pucella (Cornell Univ.) (2002). Reasoning about expectation. *Proceedings of the Eighteenth Conference on Uncertainty in AI*, 207–215.

S.O. Krumke (Konrad-Zuse-Zentrum Inform. Berlin), M. Lipmann (TUE), W.E. de Paepe (TUE), D. Poensgen (Konrad-Zuse-Zentrum Inform. Berlin), J. Rambau (Konrad-Zuse-Zentrum Inform. Berlin), L. Stougie, G. Woeginger (UT, TUE) (2002). How to cut a cake almost fairly. *Proceedings of the 13th ACM-SIAM Annual Symposium on Discrete Algorithms*, 263–264.

S.O. Krumke (Konrad-Zuse-Zentrum Inform. Berlin), L. Laura (Univ. Roma, La Sapienza), M. Lipmann (TUE), A. Marchetti Spaccamela (Univ. Roma, La Sapienza), W.E. de Paepe (TUE), D. Poensgen (Konrad-Zuse-Zentrum Inform. Berlin), L. Stougie (2002). Non-abusiveness helps: An O(1)-competitive algorithm for minimizing the maximum flow time in the online traveling salesman problem. *Proceedings of the 5th International Workshop on Approximation Algorithms for Combinatorial Optimization (APPROX)*, LNCS **2462**, Springer-Verlag, Berlin, 200–214.

M. Lipmann (TUE), X. Lu (East China Univ. Science and Technology, Shanghai), W.E. de Paepe (TUE), R.A. Sitters (TUE), L. Stougie (2002). On-line dial-a-ride problems under a restricted information model. *Proceedings of the 10th European Symposium on Algorithms (ESA)*, LNCS **2461**, Springer-Verlag, Berlin, 674–685.

M. Milano (Univ. Bologna, Italy), W.J. van Hoeve (2002). Reduced cost-based ranking for generating promising subproblems. *Proceedings of the Joint ERCIM/CologNet Workshop on Constraint Solving and Constraint Logic Programming*, 7–22.

M. Milano (Univ. Bologna, Italy), W.J. van Hoeve (2002). Reduced cost-based ranking for generating promising subproblems. *Proceedings of the Eighth International Conference on Principles and Practice of Constraint Programming (CP'02)* LNCS **2470**, Springer-Verlag, 1–16.

F. van Raamsdonk, P. Severi (Univ. Torino, Italy) (2002). Extracting proofs from programs. *Electronic Notes in Theoretical Computer Science* **70**(2).

A. Schrijver (2002). On the history of the transportation and the maximum flow problems. *Mathematical Programming* **91**, 437–445.

A. Schrijver (2002). A short proof of Guenin's characterization of weakly bipartite graphs. *Journal of Combinatorial Theory, Series B* **85**, 255–260.

A. Schrijver (2002). Strong t-perfection of bad-K_4-free graphs. *SIAM Journal on Discrete Mathematics* **15**, 403–415.

L. Stougie, A.P.A. Vestjens (CQM) (2002). Randomized algorithms for on-line scheduling problems: How low can't you go? *Operations Research Letters* **30**, 89–96.

CWI reports

PNA-R0210 INS-R0207

See page 170 or 173 for complete titles.

Other publications

Obituary

K.R. Apt (2002). Edsger Wybe Dijkstra (1930–2002): A portrait of a genius. *Formal Aspects of Computing* **14**(2), 92–98.

Book review

K.R. Apt (2002). Mathematical logic for computer science (Second revised edition). Mordechai Ben-Ari, Springer-Verlag, 2001, *Theory and Practice of Logic Programming* **2**(1), 123–124.

PhD thesis

R. Gennari (2002). *Mapping Inferences*, December 2, UvA. Thesis advisor: Prof.dr. K.R. Apt, co-advisor: M. de Rijke.

Technical reports published elsewhere

A. Alfieri (Politecnico di Torino), R. Groot (ORTEC), L. Kroon (EUR, NS Reizigers), A. Schrijver (2002). *Efficient Circulation of Railway Rolling Stock.* ERIM Research Report in Management ERS-2002-110-LIS, Erasmus Research Institute of Management, EUR.

K.M.J. de Bontridder (SIEMENS VDO Automative, Eindhoven), B. Haldersson (TUE), M. Haldersson (TUE), J.K. Lenstra (TUE), R. Ravi (Carnegie Mellon, USA), L. Stougie (2002). *Approximation Algorithms for the Test Cover Problem.* SPOR-Report 2002-10, TUE.

M. Cryan (TUE), M. Dyer (TUE), H. Müller (TUE), L. Stougie (2002). *Random Walks on the Vertices of Transportation Polytopes with Constant Number of Sources.* SPOR-Report 2002-14, TUE.

M. Dyer (Univ. Leeds, UK), R. Kannan (Carnegie Mellon Univ., Pittsburg, PA), L. Stougie (2002). *A Simple Randomised Algorithm for Convex Optimisation: Application to two-stage stochastic programming.* SPOR-Report 2002-05, TUE.

J. van den Heuvel (TUE), L. Stougie (2002). *A Quadratic Bound on the Diameter of the Transportation Polytope.* SPOR-Report 2002-17, TUE.

S.O. Krumke (Konrad-Zuse-Zentrum Inform. Berlin), W.E. de Paepe (TUE), D. Poensgen (Konrad-Zuse-Zentrum Inform. Berlin), L. Stougie (2002). *News from the Online Traveling Repairman.* SPOR-Report 2002-02, TUE.

M. Lipmann (TUE), X. Lu (East China Univ. Science and Technology, Shanghai), W. de Paepe (TUE), R. Sitters (TUE), L. Stougie (2002). *On-line Dial-a-ride Problems under a Restricted Information Model.* SPOR-Report 2002-07, TUE.

X. Lu (East China Univ. Science and Technology, Shanghai), R. Sitters (TUE), L. Stougie (2002). *A Class of On-line Scheduling Algorithms to Minimize Total Completion Time.* SPOR-Report 2002-11, TUE.

L. Stougie (2002). *A Polynomial Bound on the Diameter of the Transportation Polytope.* SPOR-Report 2002-15, TUE.

Articles in unrefereed journals and proceedings

S. Etalle (2002). ALP newsletter editorials of the following issues: February 2002, May 2002, August 2002, November 2002.

Advanced Communication Networks – PNA2

Mission

Communication networks are expanding at an unprecedented rate, in terms of traffic volume, the number of users, as well as the range of applications. The use of both the Internet and wireless services has undergone an explosive growth. Network operators anticipate further expansion, fuelled by the emergence of all-optical networking as well as the convergence of wireless and Internet access, along with a fundamental trend towards service integration. Future communication networks are expected to accommodate a variety of new services with a broad range of Quality of Service (QoS) requirements. This motivates the research effort in QoS-enabling mechanisms, and, more specifically, QoS-differentiation mechanisms. Some important subproblems are:

- Performance analysis of communication and computer networks, with emphasis on the integration of services in a single network, where differentiated QoS is offered. Analysis is mainly done by using methods from stochastics, in particular queueing theory. There is a focus on both wireline and wireless systems;
- Network traffic analysis (heavy tails, long-range dependence, and their impact on system performance);
- Network economics (pricing and cost allocation issues in communication networks).

Theme leader

Prof.dr. M.R.H. Mandjes

Subthemes

Name	Leader
PNA2.1 – Wireline Networks, TCP/IP	M.R.H. Mandjes
PNA2.2 – Wireless Networks, UMTS	S.C. Borst
PNA2.3 – Network Economics	M.R.H. Mandjes

PNA2.1: The research objective is to develop queueing-theoretic models, methods, and algorithms for studying congestion phenomena in communication networks. The research is motivated by the application of advanced technology in communication and computer networks. In 2002 there was a focus on issues related to service integration and quality differentiation in communication networks. Also emphasis was on feedback-based flow-control protocols, e.g., TCP (Transmission Control Protocol). The role of long-tailed phenomena, and the impact on network performance remained a prominent subject of research.

PNA2.2: The use of wireless communications continues to experience dramatic growth. While the proliferation of voice services has nearly reached ubiquity, the evolution of wireless data applications has only recently started to develop. To accommodate future expansion, next-generation mobile communication systems are being designed to provide Internet access and support high-speed wireless data applications, in addition to voice calls and short-messaging services. The research objective is to develop queueing-theoretic models and algorithms for dimensioning, engineering, and operating integrated-services wireless networks.

PNA2.3: On an abstract level, a communication network can be considered as a set of resources, for which an extensive set of users is competing. With economic models this competition can be described and analyzed. The key problem is the search for mechanisms that allocate the available resources (bandwidth, buffer space) to the population of heterogeneous users in an economically sound way. More specific problems are: (1) charging network users based on their contribution to congestion, by packet marking, (2) allocation of bandwidth through auctions, (3) models that allocate cost among network users, in conjunction with network measurements.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Drs. R. Bekker (0.6 fte at TUE)	0.4	PhD student	2001-10-01 till 2005-10-01	PNA2.1: FLOW	60K25, 68M20, 90B18, 90B22
Prof.dr.ir. S.C. Borst (0.2 at TUE, 0.5 at Lucent)	0.5	researcher, leader PNA2.2	indefinite	PNA2.1: FLOW, LT, QFN-IS/PS; PNA2.2: BANCA, PROMO	60K25, 68M20, 90B18, 90B22
Prof.dr. M.R.H. Mandjes (0.4 at UT)	0.6	theme leader, leader PNA2.1 and PNA2.3	indefinite	PNA2.1: FAST, FLOW, QFN-PS, LT; PNA2.3: COST, PRICE	60K25, 68M20, 90B18, 90B22
Dr. R. Núñez-Queija	0.5	researcher	1999-08-01 till 2005-04-01	PNA2.1: FLOW, LT, QFN-IS; PNA2.3: COST, PRICE	60K25, 68M20, 90B18, 90B22
Drs. M.J.G. van Uitert	1.0	PhD student	1999-05-01 till 2003-10-01	PNA2.1: QFN-IS/PS	60K25, 68M20, 90B18, 90B22

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr.ir. O.J. Boxma (TUE, swap with S.C. Borst)	0.1	researcher	1998-09-01 till 2002–12–31	Leading Bekker, Van Uitert; PNA2.1:FLOW, LT, QFN-PS	60K25, 68M20, 90B18, 90B22
Dr. R.J. Boucherie (UT)	0.2	researcher	1994-09-01 till 2002-10-31	PNA2.2: BANCA, PROMO	60K25, 68M20, 90B18, 90B22
Drs. S.K. Cheung (UT)	0.2	PhD student	2002-12-01 till 2006-11-30	PNA2	60K25, 68M20, 90B18, 90B22
Dr. K.G. Dębicki (NWO)	1.0	post-doc	2000-04-01 till 2002-03-31	PNA2.1: FAST, LT	60K25, 68M20, 90B18, 90B22
Drs. A.B. Dieker (NWO, UT)	1.0	PhD student	2002-04-01 till 2006-04-01	PNA2.1: FAST, LT, EQUIP	60K25, 68M20, 90B18, 90B22
Drs. R.L. Litjens (TNO Telecom)	0.2	PhD student	2002-12-01 till 2002-12-31	PNA2.2: BANCA, PROMO	60K25, 68M20, 90B18, 90B22
Dr.ir. W.R.W. Scheinhardt (UT, swap with M.R.H. Mandjes)	0.2	researcher	2000-09-01 till 2005-09-03	FLOW, LT	60K25, 68M20, 90B18, 90B22
Dr. A.P. Zwart (TUE)	0.2	researcher	2002-08-01 till 2003-07-31	PNA2.1: FAST, LT, QFN-IS, QFN-PS	60K25, 68M20, 90B18, 90B22

Scientific report

Highlights

- INFOCOM 2002 contribution by *Borst*, *Mandjes*, and *Van Uitert* was nominated for the best paper award.
- The project EQUANET (CWI, TUE, UT, TNO Telecom, Lucent Technologies) will receive SENTER-funding ('Doorbraak') in 2003 and 2004.
- The consultancy project FLORIN, funded by France Télécom, is planned for 2003.

PhD research

Title	PhD research of R. Bekker
Period	October 2001–October 2005
Leaders	O.J. Boxma, S.C. Borst
Funding	Philips
Partners	Philips, TUE

Progress report. The research of *Bekker* is focused on the performance analysis of current traffic control mechanisms in the Internet, in particular the Transmission Control Protocol (TCP). *Bekker* studied the workload process in several single-server queueing models, with state-dependent arrival rate and service speed. He derived equivalence relations for the workload distribution between two closely related models, and obtained some other fundamental relationships. Furthermore, *Bekker* did some teaching activites at TUE.

Title	PhD research of A.B. Dieker
Period	April 2002–April 2006
Leader	M.R.H. Mandjes
Funding	NWO
Partner	UT

Progress report. The research of *Dieker* is focused on the performance analysis network mechanisms that enable Quality of Service (QoS). For this, *Dieker* studies advanced simulation techniques based on Large Deviations theory. He applies these to communication systems in the presence of long-term correlated input processes like fractional Brownian motion.

Title	PhD research of M.J.G. van Uitert
Period	May 1999–October 2003
Leaders	S.C. Borst, O.J. Boxma
Funding	CWI
Partners	Lucent Technologies, TNO Telecom, TUE

Progress report. The research of *Van Uitert* is focused on the performance analysis of advanced scheduling mechanisms in future communication networks, in particular the Generalized Pro-

cessor Sharing (GPS) mechanism. *Van Uitert* studied several queueing models where the GPS mechanism is used to differentiate between traffic classes. She obtained both large-buffer and many-sources asymptotics for the probability that the workload of a particular class exceeds a certain threshold.
Furthermore, *Van Uitert* did some teaching activites at TUE.

PNA2.1 – Wireline Networks, TCP/IP

Title	FAST – Large-deviations asymptotics and fast simulation
Period	2001–2005
Leader	M.R.H. Mandjes
Staff	K.G. Dębicki, A.B. Dieker, M.R.H. Mandjes, A.P. Zwart
Funding	NWO
Partners	Lucent Technologies, UT, VUA, Univ. Wrocław

Progress report. *Dębicki* studied properties of *generalized Pickands constants* $\mathcal{H}_\eta$, that appear in the extreme value theory of Gaussian processes. He gave estimates of the rate of convergence and proved that $\Upsilon(\alpha) = \mathcal{H}_{B_{\alpha/2}}$ is continuous on $(0, 2]$, where $B_{\alpha/2}(t)$ is a fractional Brownian motion with Hurst parameter $\alpha/2$. It contradicts the well-known conjecture that $\Upsilon(\alpha)$ is discontinuous at $\alpha = 1$.

Dębicki and T. Rolski (Univ. Wrocław, Poland) studied the asymptotics of the distribution of supremum over a finite interval of a centered Gaussian process with stationary increments with a general negative drift function. This problem is related to the distribution of the buffer content in a transient Gaussian fluid queue, provided that at time 0 the buffer is empty. They illustrated the general theory by detailed analysis of the integrated Gaussian process and the fractional Brownian motion.

Dębicki, Z. Michna (Akademia Ekonomiczna, Wrocław) and T. Rolski (Univ. Wrocław) studied the stationary buffer content distribution in a fluid model, where the input rate is a stationary Gauss-Markov process. By the use of change of measure technique they provided the method of simulation of the *asymptotic constant* that appears in the formula for the exact asymptotics of stationary buffer overflow. They also proved the stability of the method. As a by-product they gave a formula for a lower bound for generalized Pickands constants.

Dębicki and *Mandjes* studied a queue fed by a large number n of independent continuous-time Gaussian processes with stationary increments. After scaling the buffer exceedance threshold B and the (constant) service capacity C by the number of sources (i.e., $B \equiv nb$ and $C \equiv nc$), they obtained asymptotically exact results for the probability that the buffer threshold is exceeded. They both considered the stationary overflow probability, and the (transient) probability of overflow at a finite time horizon T. They gave detailed results on the practically important cases in which the inputs are fractional Brownian motion processes or integrated Gaussian processes.

Borst, Dębicki and *Zwart* studied the supremum of a centered Gaussian process with stationary increments over a random interval. Their main result provides the exact asymptotics of the tail of the supremum distribution in the case that the length of the interval is regularly varying. In addition, they obtained explicit lower and upper bounds for the prefactor.

Dieker and *Mandjes* studied the simulation of fractional Brownian motion. They particularly focused on spectral techniques, and showed the asymptotic exactness for a wide class of spectral methods. Moreover, they showed the existence of a relation between these spectral methods and a method based on eigenvalues of circulant matrices.

Dieker and *Mandjes* started to work on the simulation of large deviation probabilities with importance sampling by an exponential change of measure. They derived necessary and sufficient conditions for efficiency of the simulation scheme, and showed that these conditions are 'tight' in the sense that they coincide under a weak condition. They apply these conditions to well-studied problems, for which they establish new results.

Title	EQUIP
Period	April 2002–April 2006
Leader	M.R.H. Mandjes
Staff	A.B. Dieker, V.F. Micola (UT), P.T. de Boer (UT), T. Igara (UT)
Funding	NWO
Partner	UT

Progress report. See the PhD research of *Dieker* (page 20).

Title	FLOW – End-to-end congestion-based flow control mechanisms
Period	2001–2005
Leader	S.C. Borst
Staff	R. Bekker, S.C. Borst, O.J. Boxma, M.R.H. Mandjes, R. Núñez-Queija, W.R.W. Scheinhardt
Funding	CWI (basic funding), Philips
Partners	Lucent Technologies, Philips, TUE, UT

Progress report. *Bekker*, *Boxma*, *Borst* and Kella (Hebrew Univ. Jerusalem) started work on queues with workload-dependent service and arrival rates. In the $M/G/1$ case, they obtained equivalence relations for the workload distribution between two closely related queues. Also, some fundamental relations between the workload just before arrival instants and the workload at arbitrary epochs in time are derived for the $G/G/1$ queue with general state-dependent release rate. Finally, for the $M/G/1$ case, they establish a proportionality relation between queues with finite and infinite buffer capacity.

Núñez-Queija and *Scheinhardt* initiated work on an integrated modelling of flow- and packet-level dynamics of the TCP/IP congestion control algorithm. Within a connection TCP operates at the packet-level, adjusting the rate at which packets are injected into the network to the available network resources. Connections are set up randomly in time and have a random duration that depends on the achievable throughput. It is therefore natural to part from the commonly adopted assumption of a static source population and examine the interaction between flow level dynamics (i.e., a stochastically varying number of active sources) and packet level dynamics.

N.D. van Foreest (UT), *Mandjes*, D. Mitra (Bell Labs, USA), and *Scheinhardt* continued working on (Markov-)fluid models with feedback. In the Markov-fluid input model the traffic rate at which the sources transmit depend on the state of a modulating Markov chain. In feedback models these traffic rates and generator matrix depend on the current buffer level. Earlier work concentrated on 'threshold-feedback', i.e., as a function of the buffer level, both the traffic rates and generator are step functions. The resulting models were applied for modelling TCP. Recent research focuses on model in which this function is continuous.

P.E. Lassila (UT, Helsinki Univ. of Technolgy), J.L. van den Berg (UT and KPN Research/TNO Telecom), *Mandjes,* and R.E. Kooij (KPN Research/TNO Telecom) examined integrated packet/flow-level models for TCP. Processor sharing (PS) models for TCP behaviour nicely capture the bandwidth sharing and statistical multiplexing effect of TCP flows on the flow level. However, these 'rough' models do not provide insight into the impact of the various parameters playing on the packet level, such as the round trip time and the buffer size. This motivates the examination of refinements of existing PS models, which do not only capture important flow level effects but take also into account the impact of packet-level parameters on the TCP-flow throughput.

Title	LT – Performance analysis of communication networks; focus on long-tailed traffic characteristics and fluid queues
Period	1996–2003
Leader	M.R.H. Mandjes
Staff	S.C. Borst, O.J. Boxma, K.G. Dębicki, A.B. Dieker, M.R.H. Mandjes, R. Núñez-Queija, W.R.W. Scheinhardt, A.P. Zwart
Funding	CWI (basic funding), NWO
Partners	Columbia Univ., EURANDOM, Lucent Technologies, TUE, Univ. Wrocław, UT

Progress report. *Borst*, *Boxma*, *Núñez-Queija*, and *Zwart* continued their investigation of the $M/G/1$ queue with regularly varying service requirement distribution. In particular, they studied the effect of the service discipline on the tail behaviour of the waiting- and/or sojourn time distribution, demonstrating that different disciplines lead to quite different tail behaviour. The orientation of the work is methodological, examining four different methods for determining tail behaviour, and illustrating them for service disciplines like First-Come First-Served, Processor Sharing and Last-Come First Served.

Boxma, S. Foss (Herriot-Watt, UK), J.M. Lasgouttes (EURANDOM), and *Núñez-Queija* studied the tail asymptotics 'for heavy-tailed service requirement distributions' and heavy-traffic limit of the waiting time in the $GI/G/1$ queue with *Random Order of Service*. Each time the service of a customer is completed, the next customer to be served is selected at random from all waiting customers, irrespective of their order of arrival and service requirements. The randomness in

the service process adds an additional complication to the analysis, compared with that of other service disciplines mentioned above. In the case of regular variation, the tail of the waiting time was shown to be of the same order as with the First-Come First-Served discipline, the pre-factor being smaller.

Dębicki and *Mandjes* studied on-off fluid queues under a heavy-traffic environment parameterization. Highly-aggregated traffic in communication networks is often modelled as *fractional Brownian motion* (fBm). This is justified by the theoretical result that the sum of a large number of on-off inputs, with either on-times or off-times having a heavy-tailed distribution with infinite variance, converges to fBm, after rescaling time appropriately. For performance analysis purposes, the key question is whether this convergence carries over to the stationary buffer content process. They proved that, in a heavy-traffic queueing environment, this property indeed holds.

Mandjes studied the decay rate of overflow in a queue fed by many Gaussian sources, and in particular how this decay rate behaves as a function of the buffer size. The main result of this study describes the relation between the shape of this function, and the correlation structure. More specifically, it is shown that the curve is *convex* at some buffer size b if and only if there are *negative* correlations on the time scale at which the overflow takes place. Notice that Gaussian traffic models are capable of modelling a broad variety of correlation structures, ranging from short-range dependent (e.g., Ornstein-Uhlenbeck type) to long-range dependent models (e.g., fractional Brownian motion, with Hurst parameter H exceeding $\frac{1}{2}$).

Title	QFN-IS – Quality-of-service in future networks; emphasis on integrated services
Period	2000–2005
Leader	S.C. Borst
Staff	S.C. Borst, R. Núñez-Queija, M.J.G. van uitert, A.P. Zwart
Funding	CWI (basic funding)
Partners	INRIA, Lucent Technologies, TUE

Progress report. Borst, *Núñez-Queija* and *Van Uitert* started work on a system with two service classes, one of which supports elastic traffic. The traffic characteristics of the other class can be completely general, allowing streaming applications as an important special case. The link capacity is shared between the two traffic classes in accordance with the Generalized Processor Sharing (GPS) discipline. They examined the user-level performance of the elastic traffic. The elastic traffic users randomly initiate file transfers with a heavy-tailed distribution. Within the elastic traffic class, the active flows share the available bandwidth in an ordinary Processor-Sharing (PS) fashion. For a certain parameter range, they established that the transfer delay incurred by the elastic traffic flows is asymptotically equivalent to that in an isolated PS system with constant service rate. This service rate is only affected by the streaming traffic through its average rate.

Borst, Núñez Queija and *Zwart* studied a system with two heterogeneous traffic classes. The users from both classes randomly generate service requests, one class having light-tailed properties, the other one exhibiting heavy-tailed characteristics. The active traffic flows share the available bandwidth in a Processor-Sharing (PS) fashion. The number of simultaneously active traffic flows is limited by a threshold on the maximum system occupancy. The exact asymptotics of the transfer delays incurred by the users from the light-tailed class were determined, showing that the *order* of the tail is determined by that of the service requests of the light-tailed class. It was also shown that absence of the threshold mechanism causes a dramatic change in the qualitative delay performance of the light-tailed flows, manifesting itself in a markedly heavier tail of the delay distribution.

E. Altman (INRIA and CESIMO Venezuela), K. Avrachenkov (INRIA) and *Núñez-Queija* studied regular and singular perturbation of Markov chains with a denumerable state space. In the case of singular perturbation, the transition probabilities of a Markov chain with several ergodic classes is perturbed such that *rare* transitions between the different ergodic classes are allowed. Previous work on the subject relied on strong ergodicity assumptions that are typically not met in queueing applications. By relaxing the conditions, a number of useful results become available for the analysis of a large class of queueing models with multiple customer classes. Building on the theory of μ-geometric ergodic Markov Chains, the steady state distribution of the perturbed process can be expressed as a Taylor series in the perturbation parameter.

The coefficients in this series can be recursively computed.

Title	QFN-PS – Quality-of-service in future networks; emphasis on packet scheduling algorithms
Period	1999–2004
Leader	S.C. Borst
Staff	S.C. Borst, O.J. Boxma, M.R.H. Mandjes, D.T.M.B. van Ooteghem (TUE), M.J.G. van Uitert, A.P. Zwart
Funding	CWI (basic funding)
Partners	Lucent Technologies, TNO Telecom, TUE

Progress report. *Mandjes* and *Van Uitert* finished work on queueing models with Gaussian input flows. They first focused on a (two-node) tandem queue, fed by a large number of Gaussian inputs. With service rates and buffer sizes at both nodes scaled appropriately, Schilder's sample-path large deviations theorem can be applied to calculate the asymptotics of the overflow probability of the second queue. More specifically, they derived a lower bound on the exponential decay rate of this overflow probability and presented an explicit condition for the lower bound to match the exact decay rate. Examples show that this condition holds for a broad range of frequently-used Gaussian inputs. Next, they considered a model for a single node, equipped with a priority scheduling policy. They showed that the analysis of the tandem queue directly carries over to this priority queueing system.

Mandjes and *Van Uitert* started work on the Generalized Processor Sharing (GPS) mechanism serving two traffic classes, consisting of a large number of independent identically distributed Gaussian flows with stationary increments. Their goal is to obtain the logarithmic asymptotics or exponential decay rate of the overflow probability in one of the queues. First they derive both an upper and a lower bound on the overflow probability. Scaling the buffer sizes of both queues and the service rate with the number of sources, they can then apply Schilder's sample-path large deviations theorem to calculate the logarithmic asymptotics of the upper and lower bound. They prove that the upper and lower bound match for the scenario where the GPS weight of the other class is smaller than the average rate. In case the GPS weight of both classes is larger than the average rate at which the flows send, they can show under certain conditions that the bounds match.

Mandjes, Mannersalo (VTT, Finland), Norros (VTT, Finland), and *Van Uitert* started work on performance measures in queues fed by a large number of fractional Brownian motion (fBm) input processes. They focus on calculating the logarithmic many-sources asymptotics. First results have yielded the decay rate of the probability of the busy period in a single queue exceeding some predefined threshold. Also, earlier results on the tandem system were refined.

Dębicki and *Van Uitert* started work on a (two-node) tandem queue fed by a single Gaussian flow with stationary increments. They are interested in the exact and logarithmic large-buffer asymptotics of the overflow probability in the second queue. They also started work on a GPS queue serving two Gaussian flows. The goal is again to obtain the exact or logarithmic large-buffer asymptotics of the overflow probability in one of the queues.

PNA2.2 – Wireless Networks

Title	BANCA – Effective-bandwidth calculations for integrated-services networks
Period	2002–2005
Leader	S.C. Borst
Staff	S.C. Borst, R.J. Boucherie, R.L. Litjens
Funding	CWI (basic funding)
Partners	Ericsson, Lucent Technologies, TNO Telecom, TUE, UT

Progress report. *Borst*, K. Ramanan (Bell Labs, USA), K. Kumaran (Bell Labs, USA) and Ph.A. Whiting (Bell Labs, USA) provided methods to compute capacity regions for wireless and wireline communication systems comprising heterogeneous users with different Quality-of-Service (QoS) requirements such as packet delay constraints. They consider a set of heterogeneous users with relative priorities who are served by the Largest-Weighted-Delay-First (LWDF) discipline. Under certain assumptions on the traffic characteristics of the users, they describe a simple method for computing the asymptotic QoS measures. The computation involves solving M one-dimensional optimization problems where M is the number of distinct priority classes. As a by-product, given a certain QoS requirement for each class, this also yields a method for determining the capacity region, defined to be the set of combinations of users for which the QoS requirement

can be fulfilled for every class. The capacity region not only sheds insight into the behaviour of the system under the LWDF discipline, but also describes the largest capacity region that can be achieved within a large class of scheduling disciplines.

Boucherie and *Litjens* have investigated several aspects of performance evaluation of nest-generation wireless networks. They already completed 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. They also studied sensitivity properties 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. They continued a throughput analysis in processor-sharing models, concentrating on both video and data services. Various throughput measures are derived and compared.

Title	PROMO – Processor-sharing models for best-effort wireless services
Period	2002–2005
Leader	S.C. Borst
Staff	S.C. Borst, R.J. Boucherie, R.L. Litjens
Funding	CWI (basic funding)
Partners	Ericsson, Lucent Technologies, TNO Telecom, TUE, UT

Progress report. Channel-aware scheduling strategies, such as the Proportional Fair algorithm for the CDMA 1xEV-DO system, provide an effective mechanism for improving throughput performance in wireless data networks by exploiting channel fluctuations. The performance of channel-aware scheduling algorithms has mostly been explored at the packet level for a static user population, often assuming infinite backlogs.

Borst studied the performance at the flow level in a dynamic setting with random finite-size service demands. He showed that in certain cases the user-level performance may be evaluated by means of a multi-class Processor-Sharing model where the total service rate varies with the total number of users. The latter model provides explicit formulas for the distribution of the number of active users of the various classes, the mean response times, the blocking probabilities, and the mean throughput. In addition he showed that, in the presence of channel variations, greedy, myopic strategies which maximize throughput in a static scenario, may result in sub-optimal throughput performance for a dynamic user configuration and cause potential instability effects.

PNA2.3 – Network Economics

Title	COST – Cost allocation in communication networks; focus on statistical analysis of measurements
Period	2002–2006
Leader	M.R.H. Mandjes
Staff	M.R.H. Mandjes, R. Núñez-Queija
Funding	CWI (basic funding)
Partners	KPN/TNO Valley, UT, Telematics Institute, Microsoft Research

Progress report. Mandjes has analyzed a communication network, used by customers with heterogeneous service requirements, in which service differentiation is achieved through priority queueing. The network is used by two types of users: One type is delay-sensitive ('voice'), whereas the other is delay-tolerant ('data'); These preferences are reflected in their utility curves. Two models are considered: In the first the *network* determines the priority class of the users, whereas the second model leaves this choice to the *users*. For both models the prices that maximize the provider's profit are determined. Importantly, these situations do *not* coincide. The analysis uses elements from queueing theory, but also from micro-economics and game theory (e.g., the concept of a Nash equilibrium).

Title	PRICE – Quality-of-service differentiation: microeconomic analysis
Period	2002–2006
Leader	M.R.H. Mandjes
Staff	M.R.H. Mandjes, R. Núñez-Queija
Funding	CWI (basic funding)
Partners	KPN/TNO Valley, UT, Telematics Institute, Microsoft Research

Progress report. Mandjes, Núñez-Queija

started work with J.L. van den Berg (KPN Research/TNO Valley) on price setting in a system with two best-effort classes. Users willing to transmit a file of a given size choose the service class depending on the prices and the expected *stretch* (transfer time, relative to the file size) in each service class, or do not join the system. Thus, the loads on each of the service classes depends on the prices. The operator of the system is supposed to be a revenue-maximizing agent. The system was modelled as an $M/G/1$ Processor-Sharing (PS) queue with strict service priority classes. Given a static allocation of traffic to both service classes, the high priority class experiences an ordinary $M/G/1$ PS system and the low priority class sees an $M/G/1$ PS queue that is subject to random service interruptions. Under certain assumptions, there exist price functions and a corresponding *Nash equilibrium* for the allocation of the traffic, under which the operator's revenue is maximized. In the revenue-maximizing allocation, small files are transmitted using the high priority class and large files in the low priority class. Surprisingly, it may be that a set of medium-sized files are blocked from the system.

Mandjes and J. Timmer (UT) started studying Paris Metro Pricing (PMP) as a mechanism for offering differentiated QoS. In PMP providers divide their networks into logically separated subnetworks, all of them 'best-effort' but having different prices. The cheapest network being the most attractive, it will have the highest congestion level, and hence the worst performance. It is unclear what happens if there are multiple competing providers offering PMP. Earlier results showed that under specific assumptions the providers do not have any incentive to split their network. Mandjes and Timmer develop a game-theoretic framework to systematically examine this issue. Importantly, it is shown that the providers' willingness to split their resources into subnetworks critically relies on the specific assumptions made.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- EQUANET; SENTER-funded. Other partners: TUE, UT, TNO Telecom, Lucent Technologies. Period: 2002-12-01 till 2004-12-01.
- All other projects except EQUIP had partners in public and private sector.

Contract research

- WorldCom EMEA, Amsterdam, January–February 2002: M.R.H. Mandjes.
- France Télécom, Paris, December 2002–December 2003: S.C. Borst, M.R.H. Mandjes, R. Núñez-Queija.

Teaching activities

- Course Netwerken van Wachtrijen, TUE, January–February: R. Bekker, S.C. Borst.
- LNMB course Stochastic Operations Research II: Stochastic Dynamic Programming and the Control of Queues, February–March: S.C. Borst.
- Course Wiskunde 1 voor ST, TUE, September–October: R. Bekker.
- Exercises Stochastische Processen 2, TUE, September–November: R. Bekker.
- Exercises Wachttijd- en Stagnatieproblemen, TUE, March–June: M.J.G. van Uitert.
- Course Stochastische Beslissingsproblemen, TUE, January–February & December: R. Núñez-Queija.
- Course Stochastische Modellen voor Telecommunicatie, UT, May–June: M.R.H. Mandjes.
- Course Stochastic Models for Telecommunication, COST Summer School, Darmstadt, Germany, August: M.R.H. Mandjes.
- Projects Wiskundige Modellering, TUE, March–June & September–November: R. Núñez-Queija.
- Exercises Stochastische Processen 1, TUE, September–November: R. Núñez-Queija.
- Exercises Lineaire Algebra & Lineaire Analyse 1, TUE, September–November: R. Núñez-Queija.

Organization of conferences, workshops, courses, meetings

- Organization of four-weekly reading seminar: R. Núñez-Queija and M.J.G. van Uitert.
- Organization of biannual (May 15 & November 20) Queueing Seminar: M.R.H. Mandjes and R. Núñez-Queija.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- LNMB conference, Lunteren, January 15–17: R. Bekker, S.C. Borst, K.G. Dębicki,

R. Núñez-Queija.

- CWI Scientific Meeting, February 22: M.R.H. Mandjes (Invited lecture: *Advanced Communication Networks*).
- Seminar INRIA Rocquencourt, April 5: M.R.H. Mandjes (Invited lecture: *Feedback fluid queues*).
- Nederlands Mathematisch Congres, April 5: S.C. Borst (Invited lecture: *Generalized Processor Sharing queues with heterogeneous traffic classes*), R. Núñez-Queija.
- PNA Colloquium, CWI Amsterdam, April 8: M.J.G. van Uitert (Invited lecture: *Improving the Internet with Generalized Processor Sharing*).
- Self-similarity and applications, Clermont-Ferrand, France, May 27–30: K.G. Dębicki (Invited talk: *Continuity Conjecture for Pickands Constants*).
- INFOCOM 2002, New York, USA, June 25–27: S.C. Borst, M.R.H. Mandjes, M.J.G. van Uitert (Submitted talk, accepted for proceedings: *Generalized Processor Sharing queues with heterogeneous traffic classes*), M.R.H. Mandjes and W.R.W. Scheinhardt (Submitted talk, accepted for proceedings: *A simple model of network access: feedback adaptation of rates and admission control*).
- MCQT '02, Madrid, Spain, July 2–5: R. Bekker (Submitted talk: *Queues with workload-dependent service and arrival rates*), O.J. Boxma (Invited talk: *Multi-class queueing systems: exact and asymptotic analysis*), R. Núñez-Queija (Submitted talk: *Queues with equally heavy sojourn time and service requirement distributions*).
- Seminar Microsoft Research Cambridge, UK, July 15: M.R.H. Mandjes (Invited lecture: *Models for TCP performance analysis*).
- European Meeting of Statisticians, Prague, Czech Republic, August 18–23: K.G. Dębicki (Submitted talk: *Properties of Generalized Pickands constants*).
- COST Summer School, Darmstadt, Germany, August 26–30: A.B. Dieker, M.R.H. Mandjes (teacher).
- Conference on Modern Problems in Applied Probability, Edinburgh, UK, September 21–29: O.J. Boxma (Invited talk: *On M/G/1 ROS waiting time*), Mandjes (Invited talk: *Traffic with an fBm limit: convergence of the workload process*), R. Núñez-Queija (Invited talk: *The M/G/1 Processor Sharing queue with service interruptions*).
- Applications of Mathematics, XXXI Conference, Zakopane, Poland, September 17–24: K.G. Dębicki (Submitted talk: *Supremum of a Gaussian process over a random interval*).
- Performance Evaluation 2002, Rome, Italy, September 22–27: O.J. Boxma (invited talk: *Tales of tails*), R. Núñez-Queija (2 submitted talks: *Analysis of two competing TCP/IP connections, User-level performance of elastic traffic in a differentiated-services environment*).
- IFIP WG7.3 Workshop, Rome, Italy, September 28: R. Núñez-Queija (Invited talk: *The M/G/1 Processor Sharing queue with preemptive priority differentiation*).
- CWI in Bedrijf, October 18: R. Núñez-Queija (*Quality of Service in modern telecommunications*).
- SN-SOR seminar, EURANDOM & TUE, October 22: R. Núñez-Queija (Invited talk: *Processor sharing with service differentiation*).
- SN-SOR seminar, EURANDOM & TUE October 29: M.J.G. van Uitert (Invited talk: *Sample-path large deviations for tandem queues with Gaussian inputs*).
- Seminar Univ. Helsinki, Helsinki, Finland, November 7: M.J.G. van Uitert (Invited talk: *Sample-path large deviations for tandem and priority queues with Gaussian inputs*).
- Stochastics and statistics conference, Lunteren, November 11–13: A.B. Dieker.
- Kaleidoscoopdag 'Wachtrijen', Wiskundig Genootschap, November 27: O.J. Boxma (Invited talk: *Erlang's erfenis*), R. Núñez-Queija (Invited talk: *Wachten of niet wachten – dat is de vraag*).

Working visits

- P. Robert, INRIA, Rocquencourt, France, April: M.R.H. Mandjes.
- P. Key, L. Massoulié and A. Ganesh, Microsoft Research, Cambridge, UK, July: M.R.H. Mandjes.
- I. Norros and P. Mannersalo, VTT, Helsinki, Finland, November: M.R.H. Mandjes and M.J.G. van Uitert.

Other lectures

- Levy seminar, TUE, May 21: M.J.G. van Uitert (*Weak convergence in D topology*).

- Philips Research Laboratory, Eindhoven, October 4: R. Bekker (*Queues with workload-dependent service and arrival rates*).

Memberships of committees and other professional activities

S.C. Borst

- Professor of Stochastic Operations Research (part-time), TUE.
- Member of Technical Staff (part-time), Lucent (Bell Labs), Murray Hill, NJ, USA.
- Area editor of the journal *Operations Research Letters*.
- Associate editor of the journal *Operations Research*.
- Associate editor of the journal *Performance Evaluation*.
- Member of the program committee of the Performance 2002 conference, Rome, Italy.
- Member of IFIP Working Group 7.3 (also of its advisory board).
- Member of the user committee of the STW project 'Modelling and Performance Analysis of Telecommunication Systems'.
- Member of the user committee of the STW project 'Stochastic Network Analysis for the Design of Self-Optimising Cellular Mobile Communications Systems'.
- Member of the PhD committee of N. Boots (thesis advisors M.R.H. Mandjes, H.C. Tijms).

K.G. Dębicki

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

M.R.H. Mandjes

- Professor of Stochastic Operations Research (part-time), UT.
- Thesis advisor of N. Boots (with H.C. Tijms), VU, February 2002.
- Program Committee member ITC 18.
- Project Management Committee member EQUANET (SENTER-funded).

R. Núñez-Queija

- Assistant professor of Stochastic Operations Research (part-time), TUE.
- Member of the TWAIO examination committee of Vitali Romanov, Stan Akkermans Instituut.

Visitors

- M.I. Reiman (Bell Labs, Murray Hill, NJ, USA), January. Host: S.C. Borst.
- Z. Michna (Akademia Ekonomiczna, Wrocław, Poland), August. Host: K.G. Dębicki.
- T. Rolski (Univ. Wrocław), December. Host: K.G. Dębicki.

Publications

Papers in refereed journals and proceedings

E. Altman (INRIA, France and CESIMO Facultad de Ing., ULA, Mérida, Venezuela), T. Jimenez (CESIMO Facultad de Ing., ULA, Mérida, Venezuela), R. Núñez Queija (2002). Analysis of two competing TCP/IP connections. *Performance Evaluation* **49**, 43–55.

S.C. Borst, O.J. Boxma, R. Núñez-Queija (2002). Heavy tails: the effect of the service discipline. T. Field, P.G. Harrison, J. Bradley, U. Harder (eds.). *Computer Performance Evaluation – Modelling Techniques and Tools, Proceedings TOOLS 2002*, London, UK, (Springer Verlag, Berlin), 1–30.

S.C. Borst, M.R.H. Mandjes, M.J.G. van Uitert (2002). Generalized Processor Sharing Queues with heterogeneous traffic classes. *Proceedings Infocom 2002 Conference*, New York, USA, 74–83.

S.C. Borst, R. Núñez-Queija, M.J.G. van Uitert (2002). User-level performance of elastic traffic in integrated-services networks. *Performance Evaluation* **49**, 507–519.

R.J. Boucherie, R.L. Litjens (2002). Performance analysis of fair channel sharing policies in an integrated cellular voice/data network. *Telecommunication Systems* **19**, 147–186.

K. Dębicki (2002). Ruin probability for integrated Gaussian processes. *Stoch. Proc. Appl.* **98**, 151–174.

K. Dębicki, T. Rolski (Univ. Wrocław, Poland)(2002). A note on transient Gaussian fluid models. *Queueing Syst. Theory Appl.* **42**, 321–342.

K. Kumaran (Bell Labs, Murray Hill, NJ, USA), S.C. Borst, S.E. Golowich (Bell Labs,

Murray Hill, NJ, US) (2002). Correlated shadow fading in wireless networks and its effect on call dropping. *Wireless Networks* **8**, 61–71.

M.R.H. Mandjes, D. Mitra, (Bell Labs, Murray Hill, NJ, USA), W. Scheinhardt (2002). A simple model of network access: feedback adaptation of rates and admission control. *Proceedings Infocom 2002 Conference*, New York, USA, 3–12.

M.R.H. Mandjes, A. Ridder (VU) (2002). A large deviations analysis of the transient of a queue with many Markov fluid inputs: approximations and fast simulation. *ACM Transactions on Modeling and Computer Simulation* **12**, 1–26.
R. Núñez Queija

(2002). Queues with equally heavy sojourn time and service requirement distributions. *Ann. Oper. Res.* **113**, 101–117.

E. Altman (INRIA, France), K. Avrachenkov (INRIA, France), C. Barakat (INRIA, France), R. Núñez Queija (2002). State-dependent M/G/1 type queueing analysis for congestion control in data networks. *Comp. Networks* **39**, 789–808.

M.J.G. van Uitert, S.C. Borst (2002). A reduced-load equivalence for Generalised Processor Sharing networks with long-tailed input flows. *Queueing Systems* **41**, 123–164.

CWI reports

PNA-R0201	PNA-R0202	PNA-R0204
PNA-R0205	PNA-R0206	PNA-R0207
PNA-R0209	PNA-R0215	PNA-R0218
PNA-R0220	PNA-R0221	PNA-R0223

See page 170 for complete titles.

Other publications

S.C. Borst, O.J. Boxma, R. Núñez-Queija, J.A. Morrison (TUE) (2002). *The Equivalence between Processor Sharing and Random Order of Service.* SPOR-Report 2002-01, TUE.

M.R.H. Mandjes, D. Mitra (Bell Labs, NJ, USA), W. Scheinhardt (2003). A simple model of network access: feedback adaptation of rates and admission control. *Computer Networks* **41**, 489–504.

K. Ramanan (Bell Labs, NJ, USA), S.C. Borst, K. Kumaran (Bell Labs, NJ, USA), Ph.A. Whiting (Bell Labs, NJ, USA) (2002). *Optimal Capacity Regions for Communications Systems with QoS Constraints.* Technical Memorandum, Bell Laboratories, Lucent Technologies.

Stochastics – PNA3

Mission

Rigorous theoretical and applied research in probability and statistics. One of our goals is to play a substantial role in the development of several promising subfields.

Besides doing research on a high level, we consider it as an important duty to detect and study new important international developments and make these known to the Dutch community through courses, informal discussions and working groups. A good example is our study group on Stochastic Loewner Evolution which has attracted much interest from mathematicians at other Dutch institutes.

The following subjects have our particular attention:

- Percolation phenomena and, more generally, stochastic systems with very many interacting components; these are motivated by the study of a variety of biological and physical processes and, more recently, certain communication systems.
- Modelling and spectral analysis of stochastic processes driven by fractional Brownian motion, important in modern queueing theory and finance.
- Statistical estimation of Poisson intensity functions and Edgeworth/saddlepoint/bootstrap based approximations. Also statistical methods for applications in insurance (ruin probabilities) and accountancy (bootstrap calibration).

Theme leader

Dr. J. van den Berg

Subthemes

Name	Leader
PNA3.1 – Probability	J. van den Berg
PNA3.2 – Statistics	R. Helmers
PNA3.3 – Stochastic Analysis	K.O. Dzhaparidze
PNA3.4 – Ergodic Theory and Dynamical Systems	M.S. Keane

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. J. van den Berg	0.9	theme leader, leader PNA3.1	indefinite	PNA3.1	60K35, 60C05, 60G60
Drs. R.M. Brouwer	1.0	PhD student	2001-02-01 till 2005-02-01	PNA3.1: NWO-SOC	60K35, 60C05, 60G60
Dr. K.O. Dzhaparidze	1.0	leader PNA3.3	indefinite	PNA3.3	60GXX, 60HXX, 62MXX
Dr. J.A. Ferreira	1.0	post-doc	2001-03-01 till 2002-11-01	PNA3.3: project EU-DYNSTOCH	60GXX, 60G51, 60G25
Dr. R. Helmers	1.0	leader PNA3.2	indefinite	PNA3.2	62E20, 62G09, 62G20
R. van der Horst	0.75	programmer	indefinite	PNA3.2	Not applicable
Dr. A. Jarai	1.0	post-doc	2002-09-01 till 2004-09-01	PNA3.1: NWO-DPP	60K35, 60GXX
Prof.dr. M.S. Keane	0.8	leader PNA3.4	1994-01-01 till 2002-04-01	PNA3.4	60-XX 37-XX

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. E. Capobianco (ERCIM Fellow)	1.0	post-doc	2001-04-01 till 2002-10-01	PNA3.3	91B84, 65T60, 42C40
S.W.W. Rolles (UvA)	0.2	PhD student	1998-10-01 till 2002-03-01	PNA3.1: EU-RANDOM RRW	60K35 60K37
Dr. P.J.C. Spreij (UvA)	0.2	senior researcher	till 2002-12-31	PNA3.3	60GXX, 60HXX, 91B84, 62GXX
B. Tarigan, MSc (KNAW)	1.0	PhD student	2000-09-01 till 2004-09-01	PNA3.2: KNAW-SMCS	62P05, 62F12, 62M99

Scientific report

Highlights

- On March 19 a Farewell Symposium was held in honour of Mike Keane, who left CWI in April. Lectures by H. Furstenberg (Jerusalem), A. Gandolfi (Milano), G. Keller (Erlangen) and C. Newman (New York) attracted a large audience.
- S.W.W. Rolles defended her thesis on March 20, after which she started an assistant-professorship at UCLA.
- The theme has organized a study group on Stochastic Loewner Evolution, one of the most interesting subjects in modern probability. Participants come from several institutes including the universities of Leiden, Amsterdam (both UvA and VU), Utrecht, Delft and Eindhoven.

PhD research

Title	PhD research of R.M. Brouwer
Period	February 2001–February 2005
Leader	J. van den Berg
Funding	NWO

Progress report. See report on NWO-SOC.

Title	PhD research of B. Tarigan
Period	September 2000–August 2004
Leader	R. Helmers
Funding	KNAW

Progress report. See page 32.

Title	PhD research of S.W.W. Rolles
Period	October 1998–March 2002
Leader	M.S. Keane
Funding	EURANDOM

Progress report. See highlights above.

PNA3.1 – Probability

Title	NWO-SOC: Mathematical models of biological and physical processes with self-organized critical behaviour
Period	2001–2005
Leader	J. van den Berg
Staff	R.M. Brouwer, M.S. Keane
Funding	NWO: salary R.M. Brouwer
Partners	Several

Progress report. Motivated by certain models of so-called excitable media (forest fires, neurons, epidemics) *Van den Berg* and *Brouwer* have studied the following problem: consider a super- (but near-) critical percolation model on the square lattice; if we remove the infinite cluster, how close to (or far from) percolation is the resulting system? Computer simulations and rigorous arguments have led to some unexpected conjectures and conditional theorems. A paper is in preparation. Recently, *Brouwer* started to work on a signal-recovery system on the tree. This model is motivated by nerve systems. Some preliminary results have been obtained.

Title	NWO-DPP: Dynamic percolation phenomena near criticality
Period	2002–2004
Leader	J. van den Berg
Staff	A. Jarai
Funding	NWO (open competition): salary A. Jarai
Partners	Several

Progress report. *Van den Berg* and *Jarai* have revised their paper 'On the lowest crossing in 2D critical percolation'. The final version has been accepted for publication in the *Annals of Probability.*

Another topic studied by *Jarai* is Invasion percolation. His paper *Invasion percolation and the incipient infinite cluster in 2D* has recently been accepted for publication. With R.W. van der Hofstad (UU) *Jarai* gave a construction of the 'incipient infinite cluster' for unoriented percolation in dimensions $d > 6$. With S. Athreya (Indian Statistical Institute, New Delhi) he showed that the stationary distribution of the 'Abelian sandpile model' has an infinite volume limit in dimensions $d > 1$.

Title	NWO-HONG: Dutch-Hungarian cooperation
Period	2002
Leader	J. van den Berg
Staff	R.M. Brouwer, A. Jarai, M.S. Keane
Funding	NWO, OTKA (Hungary): reciprocal visits, workshops
Partners	Univ. Budapest (B. Tóth and D. Szász), EURANDOM (W.Th.F. Den Hollander)

Progress report. *Van den Berg* visited the Technical Univ. Budapest for one week in May, and had interesting discussions with B. Tóth and D. Szász. B. Tóth participated in the EURANDOM workshop on Discrete Probability, of which Van den Berg was co-organizer.

Title	EURANDOM-RRW: Reinforced random walks on finite graphs
Period	1998–2002
Leader	M.S. Keane
Staff	S.W.W. Rolles
Funding	EURANDOM
Partner	EURANDOM

Progress report. S.W.W. Rolles finalized her PhD thesis and received her degree in March. See page 30.

Title	General research in probability theory
Period	indefinite
Leader	J. van den Berg
Staff	M.S. Keane
Funding	CWI
Partners	Cornell Univ., USA (H. Kesten), Chalmers Univ. (J. Steif), Milan, Italy (A. Gandolfi), VU (R. Meester), IMPA, Rio de Janeiro, Brazil (V. Sidoravicius)

Progress report. *Van den Berg* and Kahn (Rutgers Univ.) have obtained several extensions and

generalizations of a correlation-like inequality they published in the *Annals of Probability* in 2001. A new paper is in preparation.

Van den Berg has invested much time on studying recent results by Lawler, Schramm, Werner and others on Stochastic Loewner Evolution. This is one of the most exciting topics in modern probability. This self-study, and communication with other researchers interested in this field, has led to the organization of a study group which started at CWI in December and which has attracted participants from several other institutes.

Van den Berg spent six weeks at the Isaac Newton Institute in Cambridge (UK), where he participated in the programme on Computation, Combinatorics and Probability. At the Newton Institute he had many discussions with other participants, in particular J. Steif (Georgia Tech. Univ. and Chalmers Univ.). One of the problems they considered concerns the 'one-dimensional critical forest-fire model'. This has been quite extensively studied in the physics literature but the level of understanding of this model is still far from satisfactory. Challenging and important mathematical problems, like uniqueness of the stationary distribution, are left. *Jarai* was also involved in this research. Partial results were obtained, we soon hope to make more progress.

PNA3.2 – Statistics

Title	General research in statistics
Period	indefinite
Leader	R. Helmers
Funding	CWI
Partners	Karel Univ., Czech Republic (M. Huškova), Hong Kong (B-Y. Jing), Univ. Western Ontario, Canada (R. Zitikis) St. Petersburg, Russia (N. Gribkova)

Progress report. The research of *Helmers* on saddlepoint approximations, Poisson intensity functions and Edgeworth/bootstrap based methods was continued. With N. Gribkova a paper on Edgeworth expansions for studentized trimmed mean was completed (Report PNA-R0214); the paper was submitted for publication. With B-Y. Jing, G. Qin (Atlanta, USA) and W. Zhou a paper on saddlepoint approximations to studentized trimmed means was completed (Report PNA-R0219) and submitted for publication.

Van der Horst contributed to the numerical work to assess the quality of the saddlepoint approximations in various cases of interest. Earlier work by *Helmers* with W. I Mangku (Bogor, Indonesia) and R. Zitikis (Univ. Western Ontario) was continued: Two papers were revised and accepted for publication by the *Journal of Multivariate Analysis* (JMA) a Festschrift in honour of Constance van Eeden (IMS Lecture Notes Series). A third joint paper is respectively of being revised for *JMA*.

Title	Bootstrap calibration and the stringer bound
Period	2000–today
Leader	R. Helmers
Staff	R. van der Horst
Funding	Limperg Institute

Progress report. Contacts were maintained with G.B. Broeze (Court of Audit, The Hague) concerning a project with the Limperg Institute on risk assessment by auditors.

Title	KNAW-SMCS – Statistical Methods for Compound Sums, with applications in finance
Period	2000–2004
Leader	R. Helmers
Staff	B. Tarigan
Funding	KNAW: salary B. Tarigan
Partners	ITB, Bandung (Subanar)

Progress report. Tarigan mainly worked on the problem of statistically estimating the probability of ruin in the classical Poisson risk model, under the additional assumption that the claim sizes are exponentially distributed. For this important special case a simple 'plug-in' estimator for the ruin probability (with infinite time horizon) can easily be written. It is assumed throughout that only a single realization (past data) of the compound Poisson process is observed in a bounded window, which expands in time. Previous work on a CLT and on corrections for skewness and bias of the proposed estimator was continued. The focus was on the case that the initial capital u gets large and it was found that the requirement $u/\sqrt{n} \to 0$, where n denotes the expected size of the past data set, is essential to obtain the desired asymptotic results. The latter condition also seems to explain the empirical fact (confirmed by QQ-plots) that typically very large datasets are needed before 'asymptotic normality' really starts to work.

Asymptotic expansions for negative moments of zero-truncated Poisson random variables were

derived and subsequently applied to obtain asymptotic approximations for the central moments of the empirical mean claim interarrival time, a parameter of the Poisson risk model. A survey paper by *Helmers* and *Tarigan* on compound sums and their applications in finance was completed and will appear in the *Indonesian Journal of Mathematics*. Moreover, work on the problem to estimate the probability of ruin in the Poisson risk model, with a general claimsize distribution was initiated. Our estimator is more general in scope, but in the spirit of earlier proposals by Croux & Veraverbeke and others.

Also research was started to obtain the (empirical) Edgeworth expansion (*Helmers* and *Tarigan*) and the saddlepoint approximation for a Studentized compound sum (work by *Helmers* with B-Y. Jing and W. Zhou), with potential applications in accountancy and insurance.

Title	Consultancy North Sea Directorate
Period	2000–2002
Leader	R. Helmers
Staff	R. van der Horst
Funding	North Sea Directorate (Ministry of Transport and Public Works)

Progress report. A long-term statistical consultation project on estimating the intensity of oil pollution has been completed with in March a final report.

PNA3.3 – Stochastic Analysis

Title	EU-DYNSTOCH (European project on statistical methods for dynamical stochastic models)
Period	2000–2004
Leader	K.O. Dzhaparidze
Staff	J.A. Ferreira, P.J.C. Spreij
Funding	EU: salary J.A. Ferreira
Partners	See next project

Progress report. Within the framework of the TMR project DYNSTOCH, the members of the Amsterdam and Helsinki teams developed a general theory of information processes for filtered experiments. The first paper 'Information concepts in filtered experiments' by *Dzhaparidze, Spreij* and E. Valkeila (Helsinki) appeared in *Probability Theory and Mathematical Statistics*. The publication of the second one, in *Annals of Probability*, is postponed till January 2003.

Title	General research in stochastic analysis
Period	indefinite
Leader	K.O. Dzhaparidze
Staff	M.S. Keane, P.J.C. Spreij, E. Capobianco
Partners	Several, including INRIA and Univ. of Aarhus, Berlin, Freiburg, Helsinki, Padua and Paris

Progress report. The main topic of research in 2002 was spectral analysis of fBm (fractional Brownian motion). A basic paper 'A frequency domain approach to some results on fractional Brownian motion' by *Dzhaparidze* and *Ferreira* appeared in *Statist. Probab. Lett.* J.H. van Zanten (VU) joined *Dzhaparidze* in his research on this subject. This collaboration resulted in a number of reports on series expansion of fBm, as well as of stochastic integrals with respect to fBm. The results have been extended to the fractional Brownian sheet and the proof is provided for the optimal property of the expansions. See e.g., the reports 2002-5, 2002-14 and 2002-15 of Department of Stochastics, VU and the technical reports published elsewhere. These results are submitted for publication to certain mathematical journals.

PNA3.4 – Ergodic Theory and Dynamical Systems

Title	General research in ergodic theory and dynamical systems
Period	has ended April 2002
Leader	M.S. Keane
Funding	CWI
Partners	Several including UL (S. Verduyn Lunel), Kyushu, Japan (T. Hamachi), Nikei Univ., Japan (M. Mori Nikei), Oregan Univ., Corvallis, USA (R. Burton), Wrocław (J. Serafin), Univ. Cambridge, UK (C. Sparrow)

Progress report. Two articles in refereed journals were published.

Societal aspects and knowledge transfer

Contract research

- Bootstrap calibration see page 32.
- Consultancy North Sea Direcorate, see page 33.

Teaching activities

Van den Berg gave courses on Markov Chains at the UvA, and (with R. Meester) Percolation in the joint Master programme of UvA and VU.

Organization of conferences, workshops, courses, meetings

Helmers

R. Helmers organized a KNAW research workshop 'Computer-intensive Statistics', June 10–29, at the Institute of Technology Bandung (ITB, Indonesia), as part of the scientific cooperation programme SPIN on Applied Mathematics between The Netherlands and Indonesia.

J. van den Berg

- Organizer of 'Farewell Symposium for Mike Keane', March 19.
- Co-organizer (with O. Häggström (Gothenburg) of the workshop 'Discrete Probability', June 17–20, at EURANDOM (Eindhoven, The Netherlands).
- Organizer of the Study group Stochastic Loewner Evolution, started December 2002.
- Co-organizer with M.N.M. van Lieshout (PNA4) of the bi-weekly Spatial Stochastics seminar at CWI.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Conference on Lévy Processes – Theory and Applications, Univ. of Aarhus, January 21–25: J.A. Ferreira.
- Miniworkshop on Percolation, Disorder and Random Walks, IMPA 'Rio de Janeiro, Brazil', February 18–19: J. van den Berg (Invited talk: *The lowest crossing in 2D critical percolation*).
- Workshop Wiskunde in de Industrie, UvA, February 18–22: R.M. Brouwer.
- Smoothing 2002 Workshop on Nonparametric Smoothing in Complex Statistical Models, Ascona, Switzerland, April 28–May 3: E. Capobianco (Talk: *Hammerstein system and independent components for representing and decomposing volatility processes*).
- Aio meeting stochastics network, Hilversum, The Netherlands, May 13-15: R.M. Brouwer (Talk: *A percolation model related to forest fires*).
- DYNSTOCH workshop on Statistical Inference for Stochastic Processes, La Manga, Cartagena, Spain, May 18–22: K.O. Dzhaparidze, P.J.C. Spreij.
- Conference 'Mathematical Statistics and Applications' in honour of Constance van Eeden. Centre de recherches mathématiques, Univ. Montréal, Canada, May 24–25: R. Helmers (Invited talk: *Statistical estimation of Poisson intensity functions*).
- Nordstat 2002 19th Conference on Mathematical Statistics, Stockholm, Sweden, June 9–16: E. Capobianco (Talk: *On Support Vector Machines and Sparse Approximation for Random Processes*).
- KNAW conference on Applied Mathematics, Bandung, Indonesia, June: R. Helmers and B. Tarigan (Invited joint lecture: *Compound sums and their applications in finance*).
- Workshop Discrete Probability, EURANDOM, Eindhoven, The Netherlands, June 17–20: J. van den Berg, co-organizer: R.M. Brouwer.
- CEF 2002 8th International conference of the Society for Computational Economics, Aix-en-Provence, France, June 27–29: E. Capobianco (Talk: *Risk and Multi-resolution Regimes in Volatility Processes*).
- Conference dedicated to the 90th Anniversary of B.V. Gnedenko, Kiev, June 3–7: P.J.C. Spreij.
- 24th European Meeting of Statisticians, Prague, August 19–23: J. van den Berg (Invited talk: *Crossings in 2D percolation*), R. Helmers (Talk: *The Empirical Edgeworth expansion for a Studentized Trimmed mean*).
- School and Colloquium: Stochastic Analysis and Applications in Control, Statistics and Financial Modelling, Tbilisi, Georgia, September 1–7: K.O. Dzhaparidze (Lecture: *Spectral analysis and series expansion).*
- PHYSICS-SIGNALS-PHYSICS School of nonlinear physics and information sciences, Les Houches Center of Physics, September 8–13: E. Capobianco (Talk: *Cascade Dynamics Processes for Inverse Problems*).
- The second Conference on Actuarial Sciences and Finance, Samos, Greece; the conference also included two short courses (Extreme values with applications in insurance and finance / Modelling dependence in actuarial science and finance) September 16–22: B. Tarigan.

- Workshop 'Stochastic Models from Statistical Physics III', EURANDOM, Eindhoven, The Netherlands, October 7–11: R.M. Brouwer, A. Jarai.
- 'Stochastics Meeting Lunteren', November 11–13: J. van den Berg, R.M. Brouwer, K.O. Dzhaparidze, A. Jarai, B. Tarigan.

Working visits

- Technical Univ. Budapest, June 1–6: J. van den Berg (Seminar talk: *FKG type inequalities and problems*).
- Isaac Newton Institute, Cambridge, UK, September 15–October 31: J. van den Berg (Seminar talk : *Self-destructive Percolation*).
- Newton Institute, Cambridge, UK, October 14–19: R.M. Brouwer.
- One day visit to Department of Mathematics, Bogor Agricultural Univ., Bogor, Indonesia, June 7: R. Helmers (Invited lecture: *Compound sums and their applications in finance*).
- 'Computation, Combinatorics and Probability' at the Isaac Newton Institute, Cambridge, UK, September 14–October 5: A. Jarai (Talk : *Incipient infinite clusters in two and high dimensions* on October 2).
- CNR Padova, Italy several visits: P.J.C. Spreij.

Other lectures

- Mark Kac seminar, Utrecht, June 7: J. van den Berg (Talk: *Box-crossings in two-dimensional percolation*).
- Warwick, UK, October 9: J. van den Berg (Seminar talk: *On the existence and non-existence of some peculiar infinite-volume particle systems*).
- Statistical Laboratory, Cambridge, UK, October 22: J. van den Berg (Seminar talk: *The lowest crossing in 2D critical percolation*).

Courses

- PhD study group on Large Deviations, March–May: R.M. Brouwer, B. Tarigan.
- PhD study group on Branching Processes, October–December: R.M. Brouwer, B. Tarigan.
- Course on Measure Theoretic Probability, September–December: R.M. Brouwer, B. Tarigan.
- Study group on Stochastic Loewner Evolution (started December 2002): J. van den Berg (organizer), R.M. Brouwer, A. Jarai, B. Tarigan.

Memberships of committees and other professional activities

J. van den Berg

Member of the PhD thesis committees for S.W.W. Rolles (UvA, March 20), and L. Booth (June 13).

R. Helmers

- Project leader 'Mathematical Statistics and Probability' of the KNAW project on Applied Mathematics (EPAM).
- Member of the Steering committee 'Statistical Auditing' of the Limperg Institute.

P.J.C. Spreij

- Board of Section Mathematical Statistics of the VVS.
- Leader of the Amsterdam team of the European Research Network DYNSTOCH.
- Leader of the theme group Financial Mathematics of the Stieltjes Institute.

Visitors

- N. Gribkova (St. Petersburg State Transport Univ., Russia) visited CWI for a month in January/February gave lecture in Spatial Stochastics Seminar. Host: R. Helmers.
- A. Gandolfi (Milano, Italy), March 15–19: (Talk at Farewell Symposium for Mike Keane: *On the percolation cluster*). Host: J. van den Berg.
- C.M. Newman (New York Univ.), March 18–20: (Talk at Farewell Symposium for Mike Keane: *Aging in one dimension and scaling limits*). Host: J. van den Berg.
- H. Furstenberg (Jerusalem, Israel), March 18–21: (Talk at Farewell Symposium for Mike Keane: *Stationary processes and recurrent fractal measures*). Host: J. van den Berg.
- G. Keller (Erlangen, Germany), March 18–21: (Talk at Farewell Symposium for Mike Keane: *Spectral perturbation theory for hyperbolic dynamical systems*). Host: J. van den Berg.
- M. Aizenman (Princeton, USA), April 9–11: (Talk: *Spectral and dynamical properties of Schroedinger operators with random potential*). Host: J. van den Berg.

- V. Sidoravicius (IMPA, Rio de Janeiro, Brazil), April 14–18: (Talk: *Glauber dynamics at zero temperature: from fixation to chaotic time dependence*). Host: J. van den Berg.
- W. Zhou (Hong Kong Univ. of Science and Technology) visited CWI for a week in September, gave lecture in Spatial Stochastics Seminar. Host: R. Helmers.
- F. Merkl (Bielefeld, Germany), September 11–13. (Talk: *Random Schroedinger operators with scaled Gibbsian potentials*). Host: J. van den Berg.
- N. O' Connell (Warwick, UK), December 12–14. (Talk at Spatial Stochastics Seminar). Host: J. van den Berg.

Publications

Papers in refereed journals and proceedings

J. van den Berg, H. Kesten (Cornell Univ.) (2002). Randomly coalescing random walks in dimension $d \geq 3$. V. Sidoravicius (ed.). *In and Out of Equilibrium*, Birkhäuser, 1–45.

E. Capobianco (2002). Hammerstein system representation of financial volatility processes. *The European Physical Journal* **B 27**(2), 201–212.

E. Capobianco (2002). Multiresolution approximations for volatility processes. *Quantitative Finance* **2**, 91–110.

K. Dzhaparidze, J.A. Ferreira (2002). A frequency domain approach to some results on fractional Brownian motion. *Statist. Probab. Lett.* **60**, 229–235.

K. Dzhaparidze, P.J.C. Spreij, E. Valkeila (Univ. Helsinki), (2002). Information concepts in filtered experiments. *Probability Theory and Mathematical Statistics*, **67**, 38–56.

M. Keane, J. Serafin (Univ. Wrocław) (2002). Generators *Periodica Mathematica Hungarica* **44**, 187–194.

M. Keane, S.W.W. Rolles (2002). Tubular recurrence. *Acta Mathematica Hungarica* **97**, 207–221.

S. Rolles, M. Löwe (KUN), F. Merkl (Univ. Bielefeld) (2002). Moderate deviations for longest increasing subsequences: the lower tail. *J. Theor. Probability* **15**, 1031–1047.

CWI reports

PNA-R0213	PNA-R0214	PNA-R0216
PNA-R0217	PNA-R0219	PNA-R0222

See page 170 for complete titles.

Other publications

Technical reports published elsewhere

Kacha Dzhaparidze, Harry van Zanten (VU) (2002). *A Series Expansion of Fractional Brownian Motion.* Report 2002-5 of the Department of Stochastics, VU.

Kacha Dzhaparidze, Harry van Zanten (VU) (2002), *Series Expansions of Stochastic Integrals with Respect to Fractional Brownian Motion.* Report 2002-14 of the Department of Stochastics, VU.

Kacha Dzhaparidze, Harry van Zanten (VU) (2002). *Optimality of an Explicit Series Expansion of the Fractional Brownian Sheet.* Report 2002-15 of the Department of Stochastics, VU.

Articles in unrefereed journals and proceedings

A.J. van Es (UvA), P.J.C. Spreij, J.H. van Zanten (VU) (2002). *Nonparametric Volatility Density Estimation for Discrete Time Models.* Mathematics ArXiv PR/0206142.

Peter Spreij (2002). De Ito-formule zonder stochastische integralen. *Nieuw Archief voor Wiskunde* **3**(1), 21–22.

PhD thesis

S.W.W. Rolles (2002). *Random Walks in Stochastic Surroundings*, UvA. Thesis advisor: Prof.dr. M.S. Keane.

Signals and Images – PNA4

Mission

Digital image processing is a multidisciplinary science that borrows principles from diverse fields such as communications theory, optics, surface physics, visual psychophysics, computer science and mathematics. The many applications of image processing include: astronomy, ultrasonic imaging, remote sensing, video communications, industrial inspection, machine vision, medical imaging, and microscopy. Rapid advances in communications theory and sensor technology and the ever continuing increase of computational

power have led to an explosion of visual data. The usefulness of such visual resources is largely determined by their accessibility and portability and as such, these data sets present great challenges in terms of coding, transmission, storage, querying, indexing, display and protection. To face such challenges it is not sufficient to develop faster hardware or to design more efficient algorithms. Rather, a deeper understanding of the intrinsic difficulties in visual data representation and analysis is required. This has resulted in a growing demand for sophisticated geometrical and statistical image and signal models, and one of the major goals of the 'Signals and Images' research theme PNA4 is to fall in with these demands. The NWO strategic report *Nieuwe Dimensies, Ruimer Bereik*, published in 2002, explicitly mentions mathematical imaging as one of the challenging research areas in mathematics in the years to come.

Theme leader

Dr.ir. H.J.A.M. Heijmans

Subthemes

Name	Leader
PNA4.1 – Image Understanding, Retrieval, and Indexing	E.J.E.M. Pauwels
PNA4.2 – Image Representation and Analysis	H.J.A.M. Heijmans
PNA4.3 – Stochastic Geometry	M.N.M. van Lieshout

PNA4.1 investigates mathematical methodologies to generate content-specific descriptions of images and video, for the purpose of robust indexing, understanding and retrieval from large databases.

PNA4.2 deals with multiresolution signal and image representations in general, and methods in wavelet analysis and mathematical morphology in particular. Furthermore, it seeks to use such representations for problems in image analysis and coding.

PNA4.3 is concerned with the modelling and analysis of random geometric structures using techniques from spatial statistics and stochastic geometry.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr.ir. H.J.A.M. Heijmans	1.0	theme leader, leader PNA4.2	indefinite	PNA4.1: EUROPHLUKES; PNA4.2: MASCOT, MRIAS, Wavelets, Watermarking for Multimedia, AMM[1]	42C40, 68U10, 94A08
Dr.ir. M.J. Huiskes	1.0	researcher	2001-08-01 till 2003-08-01	PNA4.1: FOUNDIT, CBIR	68T45, 68T37, 62H30
Drs. L. Kamstra	1.0	PhD student	1999-10-01 till 2003-10-01	PNA4.2: Wavelets and their applications	42C40, 94A08
Dr. M.N.M. van Lieshout	0.8	researcher, leader PNA4.3	indefinite	PNA4.3: See page 42	62M30
Dr. ir. P.J. Oonincx	1.0	researcher	1996-02-01 till 2002-05-01	PNA4.2: STW project MRIAS	42C40, 42A38, 68U10
Dr. E.J.E.M. Pauwels	0.85	researcher, leader PNA4.1	indefinite	PNA4.1: CBIR, FOUNDIT, EUROPHLUKES	68T45, 68T37, 62H30

[1] Multiresolution image analysis and synthesis

G. Piella Fenoy	1.0	PhD student	1999-08-01 till 2003-08-01	PNA4.2: MRIAS	42C40, 68U100, 94A08
Dr. B.A.M. Schouten	0.4	project leader	2002-05-01 till 2003-05-01	PNA4.1: BIOVISION	68T45
A.G. Steenbeek	0.4	programmer	indefinite	PNA4.1, PNA4.2, PNA4.3	Not applicable
Dr.ir. R.S. Stoica	1.0	researcher	2001-01-01 till 2002-12-31	PNA4.3: Inference for random sets	62M30
Dr. P.M. de Zeeuw	1.0	programmer	indefinite	PNA4.1, PNA4.2	Not applicable
Y.-W. Zhan MSc.	1.0	researcher	2001-11-01 till 2003-11-01	PNA4.2: MASCOT, AMM	42C40, 94A08

Seconded

Name	**Fte**	**Function(s)**	**Period**	**Subthemes + projects**	**Classification (MSC or CR)**
Dr. G.C.K. Abhayaratne	1.0	ERCIM Fellow	2002-06-01 till 2003-03-01	PNA4.2: MASCOT	94A08, 68U10
Drs. R. Huele (CML)	1.0	researcher	2001-12-01 till 2004-09-30	PNA4.1: EUROPHLUKES	68T45
H. Rössler (UvA)		student	2001-09-01 till 2002-08-31	PNA4.2	
Prof. dr. A.W.M. Smeulders (UvA)	0.1	advisor	till 2003-06-30	PNA4.1, PNA4.2, PNA4.3	

Scientific report

Highlights

- Establishing the ERCIM Working Group on Image and Video Understanding.
- Initiation of EU project BIOVISION.
- Completion of PhD thesis by M.J. Huiskes.
- Student's best paper award at 'The Fifth International Conference on Information Fusion' by *G. Piella Fenoy*.
- Organization of national seminar 'Wavelets and their Applications'.

PhD research

Title	PhD research of L. Kamstra
Period	October 1999–September 2003
Leader	H.J.A.M. Heijmans
Funding	NWO

See page 40 for progress report.

Title	PhD research of G. Piella Fenoy
Period	August 1999–July 2003
Leader	H.J.A.M. Heijmans
Staff	P.M. de Zeeuw
Funding	STW

Progress report. *Piella Fenoy* has entered her last year and is expected to defend her PhD thesis in October 2003. For an account of the research, see page 41.

PNA4.1 – Image Understanding, Retrieval, and Indexing

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. In fact, an efficient strategy will often be task-dependent and therefore necessitates its own specific focus, as expounded below.

Title	CBIR – Content-Based Image Retrieval
Period	April 1999–March 2003
Leader	E.J.E.M. Pauwels
Staff	M.J. Huiskes
Funding	CWI (basic funding)
Partner	ESAT (Univ. Leuven, Belgium)

Progress report. This project focuses on a number of generic methodologies for content-based image retrieval (CBIR) and covers topics such

as segmentation, feature extraction and selection, relevance and saliency measures and models for user feedback. The project addresses fundamental aspects in both algorithm and interface design. Most of this work has a strong statistical flavour. For instance, on the topic of image segmentation, *Pauwels*, in collaboration with G. Frederix (ESAT, Univ. Leuven, and Provinciale Hogeschool Limburg, Hasselt, Belgium) is looking at statistically principled cluster detection in feature space. Clusters in these spaces are indicative of perceptually salient regions in the original image. The research reformulates the problem as a hypothesis test in which it is determined whether the proposed cluster-structure is compatible with the actual data. A similar approach is used to judge saliency, but this time the emphasis is on expectation failure: Discrepancies between model and data are used to guide visual attention. Finally, *Pauwels* and *Huiskes* are also looking at classification and dimension reduction techniques to address problems of visual learning, i.e., finding correlations between semantic image annotations and machine-computable features.

Title	FOUNDIT – Feedback-Operated User Interface for Design and Image Retrieval
Period	September 2001–August 2003
Leader	E.J.E.M. Pauwels
Staff	M.J. Huiskes, E.J.E.M. Pauwels
Funding	EU (project funding)
Partners	Univ. Gent, Sophis Systems N.V., Pianezza Paolo SNC, Clama Mattress Ticking NV, Chantemur

Progress report. A second CBIR-related research theme is the development of a specialized search engine for decoration designs 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 is being carried out within the framework of the EC project FOUNDIT and the main effort was focused on image segmentation, feature extraction and standardization. To address the difficult problem of figure-ground segregation, a segmentation algorithm was developed based on local colour coalitions. The figure-ground segregation was used as a crucial step in the development of more sophisticated localized features that encode spatial organization of different image-motifs. As part of this work, *Huiskes* has started the development of a software toolbox for image understanding. Furthermore, we have started work on an MPEG-7 compatible XML-schema for the semantic annotation of digital designs.

Title	EUROPHLUKES
Period	December 2001–October 2004
Leader	E.J.E.M. Pauwels
Staff	H.J.A.M. Heijmans, A.G. Steenbeek, R. Huele, E.J.E.M. Pauwels
Funding	EU (project funding)
Partners	CML (UL), MARIS B.V., Sea Watch Foundation, Alnitak, CIRCé, ESPARTE, CEMMA, Museu de Baleia, IMAR, Tethys, Univ. College Cork, Wild Idea, Ecologic, Greenland Inst. of Natural Resources, Oceanopolis, GREC, Projecto Delfim, Whale Watch Azores

Progress report. 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. We developed a user-friendly interface and extraction software that supports the semi-automatic contour-extraction of the trailing edge of sperm whale tails. These contours are then encoded as a mathematical signature function that can be compared to the signature of other whales in the database. This way, a shortlist of images of whales with similar signatures can be compiled and submitted for definitive photo-id by an expert.

In collaboration with *Huele* (CML and CWI) the extraction and matching was tested on an extensive photo-collection supplied by various EUROPHLUKES partners, as well as on actual field tests in the Gulf of Mexico. Another task that was carried out by PNA4 is the inclusion of a secure watermark in the images of the database.

PNA4.2 – Image Representation and Analysis

Title	MASCOT – Metadata for Advanced Scalable Video Coding Tools
Period	May 2001–April 2003
Leader	H.J.A.M. Heijmans
Staff	G.C.K. Abhayaratne, Y.-W. Zhan
Funding	EU (project funding)
Partners	ENSMP-CMM, ARMINES-CMM, HHI, PUT, LEP, GET-ENST, UPC, VUB

Progress report. MASCOT is a European project in the FET-Open Programme coordinated by *Heijmans* in which eight European partners collaborate. 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 optimization of advanced and dedicated prediction schemes. The collaboration with B. Pesquet-Popescu from ENST in Paris, which was initiated a year ago, has been continued. 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 has finished C++ software for motion-compensated 3D-subband coding. This software contains several novel aspects. In contrast to other approaches in the literature on temporal wavelet transforms, the Haar wavelet is replaced by one with a longer filter, a 5/3 wavelet. Secondly, the memory-constraint technique with lifting schemes is realized, which is able to remove boundary effects that usually occur between two successive groups of frames. Finally, an optimization criterion is suggested for matching pixels in the current and the reference frames, which, in combination with the former features, yields better energy distribution of the decomposed bands. Results have been reported at one of the MPEG meetings.

Temporal lifting schemes result in detail frames containing the high frequency components in temporal domain. Compression of such frames, that are different from usual still images, can benefit from nonlinear spatial decomposition techniques such as morphological and adaptive wavelet transforms. *Abhayaratne* and *Heijmans* have focussed on developing and exploiting novel morphological and adaptive wavelet transforms for improving the compression performance of detail frames in the context of MASCOT wavelet video codec.

Title	BIOVISION
Period	May 2002–April 2003
Leader	B.A.M. Schouten
Funding	EU (project funding)
Partners	Daon (Ireland), BTexact Technologies (UK), TeleTrusT (Germany), National Physical Laboratory (UK), Consiglio Nazionale delle Ricerche (Italy), CESG (UK) , Nationwide Building Society (UK), University of Applied Sciences Giessen-Friedberg (Germany), Saflink (USA), Authenti-Corp (USA), IBM, William Frys law firm Dublin, and others

Progress report. The BIOVISION project aims to contribute to a secure, user-friendly, socially acceptable and ethical use of biometrics in Europe. It prepares the ground for future RTD activities by investigating the likely commercial application of biometrics over the forthcoming 10 years and identifying research challenges. Amongst them are technological challenges like improvements in performance and reliability, robustness and scalability are addressed. Focus is placed on how technology can assist on eliminating hindering factors within regulatory, medical and user perception framework. In November the participants joined in a two-day workshop in Amsterdam, working on a roadmap to the successful deployment of Biometrics. A final version will be issued in May 2003.

Title	NWO project Wavelet analysis and applications
Period	October 1999–September 2003
Leader	H.J.A.M. Heijmans
Staff	L. Kamstra
Funding	NWO
Partners	J.B.T.M. Roerdink (RUG), C.R. Traas (UT), H.G. ter Morsche (TUE)

Progress report. The research of *Kamstra* focused on multiresolution decompositions of signals with function values in a finite set that is not neces-

sarily a ring. He has defined a discrete wavelet transform on such finite valued signals and investigated properties of these transforms. His results make it possible to give explicit examples of linear and nonlinear discrete wavelet transforms of binary signals without using the so-called lifting scheme.

In addition, *Kamstra* developed the composition scheme, a method to construct wavelet transforms with a large support from wavelet transforms with smaller supports. This scheme can also be used to build nonlinear wavelet transforms. He investigated the capabilities of a large number of linear and nonlinear binary wavelet transforms with respect to binary image compression. It turned out that, in most cases, nonlinear transforms perform significantly better.

Kamstra is currently working on a substantial contribution to the theory of linear binary wavelet transforms. Since linear transforms are more structured and less complicated than nonlinear transforms they are a good starting point to translate useful concepts, like vanishing moments, from the continuous domain to the discrete domain. He plans to incorporate results obtained in the linear case into the nonlinear binary wavelets setting.

Title	STW project Multiresolution image analysis and synthesis
Period	October 1999–September 2003
Leader	H.J.A.M. Heijmans
Staff	G. Piella Fenoy, P.J. Oonincx, P.M. de Zeeuw
Funding	STW
Partners	TNO-TM, NLR, Thales, RUG

Progress report. The work in this project comprises two major ingredients: (*i*) the design of adaptive lifting schemes for the construction of nonlinear wavelets, and (*ii*) the investigation of multiresolution tools for image fusion. The work on adaptive wavelets has appeared in various journal and conference publications. *Piella Fenoy* and *Heijmans*, in collaboration with *Abhayaratne* and B. Pesquet-Popescu (ENST, Paris) are currently working on issues of quantization and integer-to-integer adaptive lifting schemes and their application in lossy and lossless image and video compression. The work on image fusion concerns the design of new region-based multiresolution fusion algorithms. To compare different algorithms or to optimize the choice of the parameters, one is in need of an objective image quality measure. *Piella Fenoy* and *Heijmans* have introduced a new quality measure for image fusion. Preliminary experiments show that this measure is consistent with subjective tests and support our belief that it can be a starting point for a unified fusion assessment method.

Oonincx and *De Zeeuw* concluded their research on image retrieval based on an adaptive wavelet scheme. The scheme has been extended with a suitable metric for measuring the distance between feature vectors.

Title	Watermarking for Multimedia
Period	January 2002–indefinite
Leader	H.J.A.M. Heijmans
Staff	H.J.A.M. Heijmans
Funding	CWI (basic funding)
Partner	Philips

Progress report. The increasing importance of digital media creates an urgent need for methods that can guarantee protection of copyright ownership. Existing cryptographic systems are only of limited use here; once the data is decrypted it can easily be reproduced without any quality loss. Digital watermarking technology is complementary to cryptography and one of its most important applications is copyright protection. The basic underlying idea is to embed an invisible but robust identification code into the data (e.g., an image). The purpose of this new project is to develop new mathematical algorithms in the field of information hiding, watermarking and steganography.

Title	Internships from IIT
Period	Indefinite
Leader	H.J.A.M. Heijmans
Staff	G. Piella Fenoy, P.M. de Zeeuw, N. Gupta
Funding	CWI (basic funding)
Partner	Indian Institute of Technology, New Delhi

Progress report. A prototype of the Matlab fusion toolbox (MATIFUS) is up and running. The toolbox has been furnished with six multiresolution schemes. *Gupta* (internship from IIT) extended the Matlab image fusion toolbox MATIFUS with a user-friendly and versatile graphical user interface.

Title	Axiomatics of mathematical morphology
Period	indefinite
Leader	H.J.A.M. Heijmans
Staff	P.M. de Zeeuw, Y.-W. Zhan
Funding	CWI (basic funding)
Partners	The Johns Hopkins Univ., UvA, Univ. Louis Pasteur Strassbourg, Ecole Nationale des Mines de Paris, Hewlett Packard Laboratories (Haifa)

Progress report. This research is concerned with various theoretical and applied aspects of mathematical morphology. Because of time limitations, only limited efforts were devoted to this project in 2002.

PNA4.3 – Stochastic Geometry

Title	Inference for random sets
Period	January 2001–December 2002
Leader	M.N.M. van Lieshout
Staff	R.S. Stoica
Funding	NWO

Progress report. During the year 2002, *Van Lieshout* and *Stoica* worked on three subprojects. They extended some recent exact simulation methods for point processes to marked patterns and carried out a simulation study to compare the efficiency (speed of convergence) of these methods when applied to a range of models. A C++ library is under construction.

The second subproject consisted of proposing a new method for simulating marked point processes using Metropolis-Hastings dynamics. This work extends the previous work of Kendall and Møller (2000) to marked point processes and introduces for the first time the possibility of performing change moves.

Finally, they studied the effect on the interaction structure of merging and splitting labels in finite random field models.

Title	Non-parametric estimation in generalised area-interaction processes
Period	April–July 2002
Leader	M.N.M. van Lieshout
Staff	P. Gregori Huerta
Funding	Univ. Jaume I, Spain
Partner	J. Mateu

Progress report. *Gregori Huerta* visited CWI on a Universitat Jaume I travel grant. During his visit, in collaboration with *Van Lieshout* and J. Mateu (Jaume I), he generalized shot noise point processes by replacing the L_1 norm by the supremum norm. The relation to multitype pairwise interaction processes was investigated, and Markov properties and Ruelle stability established. Exact samplers for the new models were proposed, and non-parametric estimation for the influence function carried out. Other model parameters were estimated by the Monte Carlo maximum likelihood method.

Title	Statistical inference for line segment models
Period	September–December 2002
Leader	M.N.M. van Lieshout
Staff	K.K. Berthelsen
Funding	Univ. Aalborg

Progress report. As part of the duties required to gain a Danish PhD degree, Berthelsen paid an extended visit to CWI. In collaboration with *Van Lieshout*, he started his investigations in modelling of and inference for line segment processes, considered both as random sets or as marked point processes. Particular attention was paid to asymptotics.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- MASCOT; see page 40.
- EUROPHLUKES; see page 39.
- FOUNDIT; see page 39.
- BIOVISION; see page 40.
- STW project; see page 41.
- Watermarking for Multimedia, see page 41.

Teaching activities

- Lecturer 'Economische Sectoren en Technology', Cath. Univ. Brussels, E.J.E.M. Pauwels.
- Lecturer in ASCI course on 'Mathematical Morphology', February 4–8: H.J.A.M. Heijmans.
- Course Fourier Analysis UvA, January–February: P.J. Oonincx.
- Advisor of trainees from UvA: P.J. Oonincx.
- Advisor of trainee from Hogeschool Holland, Diemen: M.J. Huiskes.
- Supervision of trainees from IIT New Delhi: H.J.A.M. Heijmans; see page 41

- Lecturer Interface and Design; School of Art and Technology Utrecht; course on Visulalization and Content Based Image Retrieval; January-February: B.A.M. Schouten.

Other external contacts

- Coordination of EU project FOUNDIT (Feedback-Operated User Interface for Design and Image Retrieval): E.J.E.M. Pauwels.
- Chair of ERCIM WG on Image and Video Understanding: E.J.E.M. Pauwels.
- Coordination of EU project MASCOT (Metadata for Advanced Scalable Video Coding Tools): H.J.A.M. Heijmans.
- Coordination of EU project to establish European Biometric Forum: B.A.M. Schouten.

Spin-off

Founding of KnownObjects, a spin-off in the field of Content-Based Image and Video Processing, Biometrical Recognition and Authentication, January 2002: B.A.M. Schouten.

Organization of conferences, workshops, courses, meetings

- Signals and Images Seminar (bi-weekly): R.S. Stoica.
- Spatial Stochastics Seminar (bi-weekly): M.N.M. van Lieshout.
- PNA Colloquium (bi-monthly): M.N.M. van Lieshout.
- Organization and chair of three ERCIM WG *Image Understanding* meetings, E.J.E.M. Pauwels: Amsterdam, February 22, Vienna, June 6 and Amsterdam, December 12–13.
- Dutch Wavelet Seminar, December 6, CWI. Main speaker: A. Cohen (Paris): L. Kamstra, H.J.A.M. Heijmans.
- MASCOT workshop on Upcoming Video Standards, Brussels: H.J.A.M. Heijmans (with other MASCOT partners).
- Organization and chair of First FOUNDIT User committee meeting, Gent Univ., Dept. Textiles, February 26: E.J.E.M. Pauwels, M.J. Huiskes.
- CWI in Bedrijf, FOUNDIT-demo: October 18: E.J.E.M. Pauwels.
- Co-organization meeting Section Mathematical Statistics of the VVS (Vereniging voor Statistiek en Operationele Research), Statistische Dag, Utrecht, March 25: M.N.M. van Lieshout.
- 2nd Fraunhofer-CWI Workshop, Amsterdam, April 19: M.N.M. van Lieshout.
- Mini-symposium Stochastic Geometry, Amsterdam, May 22: M.N.M. van Lieshout.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Annual meeting section Mathematical Statistics VVS (Vereniging voor Statistiek en Operationele Research), VU, January 31: M.N.M. van Lieshout.
- Stochastic geometry, spatial statistics and statistical physics, Oberwolfach, Germany, February 10–16: M.N.M. van Lieshout. (Invited talk: *Markov sequential spatial processes*).
- First SIAM conference on Imaging Science, Boston, March 4–6: H.J.A.M. Heijmans (Invited lecture: *Semi-lattices and Self-Dual Morphology*, submitted lecture: *Adaptive Lifting Schemes with Perfect Reconstruction*), E.J.E.M. Pauwels (Talk 1: *Regression Models for Relevance Feedback and Feature Selection in CBIR*; Talk 2: *Image Segmentation based on Statistically Principled Clustering*).
- Magdeburger Stochastik Tage, Magdeburg, Germany, March 20–22: M.N.M. van Lieshout. (Talk: *Markov sequential point processes*).
- IEEE Benelux Signal Processing Symposium Leuven, Belgium, March 21–22: G. Piella Fenoy (poster, joint work with H.J.A.M. Heijmans and B. Pesquet-Popescu, ENST, Paris).
- Statistische Dag, Utrecht, The Netherlands, March 25: M.N.M. van Lieshout.
- European Workshop on 3D City Modelling, Cath. Univ. Brussels, Belgium, March 26: E.J.E.M. Pauwels.
- Sixth International Symposium on Mathematical Morphology, Sydney, Australia, April 3–5: H.J.A.M. Heijmans (Lecture: *Morphological Scale-Spaces, Scale-Invariance, and Lie Groups*).
- Symposium on the occasion of the presentation of 'Nieuwe dimensies, ruimer bereik. Een nationale strategie voor wiskundeonderzoek en gerelateerde masteropleidingen', The Hague, April 18: M.N.M. van Lieshout.
- ERCIM-ESF Workshop, Amsterdam, May 30–31: M.N.M. van Lieshout.

- Vision Solutions, Nijmegen, The Netherlands, June 4: M.J. Huiskes.
- EURANDOM Workshop on Discrete Probability, Eindhoven, June 17–18: P. Gregori Huerta, M.N.M. van Lieshout (17th only).
- Portuguese Conference on Pattern Recognition RECPAD, Aveiro, Portugal, June 27–28: L. Kamstra (Lecture: *A Method for Constructing Nonlinear Discrete Wavelet Transforms*).
- Mini Conference on Archives, V2 Media Lab, Rotterdam, The Netherlands, July 5: Concept V2 and B.A.M. Schouten (Lecture: *The Semantic Gap in Visual Information Retrieval*).
- International Conference on Information Fusion (ICIF 2002) Annapolis, USA, July 8–11: G. Piella Fenoy (poster, award as the best student paper).
- International Conference on Image Processing ICIP, Rochester, USA, September 22–25: L. Kamstra (Lecture: *Nonlinear Binary Wavelet Transforms and Their Application to Binary Image Compression*).
- International Conference on Image Processing ICIP, Rochester, USA, September 22–25: H.J.A.M. Heijmans (Lecture: *Building Adaptive 2D Wavelet Decompositions by Update Lifting*).
- Information Hiding workshop, Noordwijkerhout, The Netherlands, October 7–9: H.J.A.M. Heijmans.
- Conference 'Perspectives on Networked Knowledge Spaces'. MARS Exploratory Media Lab, Fraunhofer Institute for Media and Communication, October 25–26: B.A.M. Schouten (Lecture: *Perception and Image Understanding*).
- Bijeenkomst Stochastici, Lunteren, November 11–13: K.K. Berthelsen (Univ. Aalborg, Denmark), M.N.M. van Lieshout, R.S. Stoica.
- Workshop 'Mathematical Aspects of Visual Cognition', Hamburg, November 14–15: H.J.A.M. Heijmans (Invited lecture: *Morphological Scale-Spaces*).
- Scientific Meeting ERCIM WG on Image Understanding: December 13: A.G. Steenbeek (Talk: *Photo-identification of Sperm Whales*).
- COMPASS Workshop, December 17: M.J. Huiskes.

Working visits

- Philips Research Lab Eindhoven, The Netherlands, January 7: B.A.M. Schouten.
- CSIRO Sydney, Australia, April 8: H.J.A.M. Heijmans.
- Forbo Novilon, April 16: E.J.E.M. Pauwels, M.J. Huiskes.
- Univ. of Applied Sciences, Giessen-Friedberg, Germany, August 22–23: B.A.M. Schouten.
- J. Zerubia, INRIA, Sophia-Antipolis, France, August 26–28: M.N.M. van Lieshout.
- Collaboration with TNO-TM, Soesterberg, The Netherlands (From September 2002 onwards, every two weeks): G. Piella Fenoy.
- B. Pesquet-Popescu, ENST Paris, France, September 10–11: H.J.A.M. Heijmans.
- INRIA, Sophia-Antipolis, Ariane group, September 16: E.J.E.M. Pauwels (Invited lecture: *A Statistically Principled Approach to Clustering and Segmentation*).
- Johns Hopkins Univ., Baltimore, USA, September 25–29: H.J.A.M. Heijmans (Invited lecture: *Building Adaptive Wavelets by Update lifting*).
- INRIA, Sophia-Antipolis, France, October 21–25: R.S. Stoica.
- ENSEA, Cergy, Paris, France, October 30–31: E.J.E.M. Pauwels: (Invited lecture: *Distribution-free stats for segmentation and clustering*).
- UT, November 27: B.A.M. Schouten.
- Univ. Pierre et Marie Curie, Paris, France, December 16–17: H.J.A.M. Heijmans (Invited lecture: *Adaptive Wavelets based on Seminorm Criteria*).
- Philips Research Lab Eindhoven, The Netherlands, December 18: H.J.A.M. Heijmans, E.J.E.M. Pauwels.

Project meetings

- FOUNDIT Consortium Meeting: Frankfurt Heimtex, Germany, January 12: M.J. Huiskes, E.J.E.M. Pauwels.
- MASCOT 3rd Progress Meeting, HHI Berlin, January 17–18: H.J.A.M. Heijmans, Y.-W. Zhan.
- ERCIM meetings: 1. Amsterdam, February 22: H.J.A.M Heijmans, M.J. Huiskes, E.J.E.M. Pauwels; 2. Vienna, Austria, June 6: H.J.A.M. Heijmans, E.J.E.M. Pauwels; 3. Amsterdam, December 12–13: H.J.A.M Heijmans, M.J. Huiskes, M.N.M. van Lieshout, E.J.E.M. Pauwels, B.A.M. Schouten.
- NWO project 'Wavelet Analysis and Applications' Progress Meeting, CWI, March: H.J.A.M. Heijmans, L. Kamstra.

- Department of Mathematics of the Univ. of Castellon, Spain (prof. J. Mateu), March 11–15 to prepare a grant proposal: R.S. Stoica (Talk: *Analysis of marked point processes with applications*).
- Fifth meeting user's committee (STW) project CWI.4616 (Multiresolution image analysis and synthesis: from axiomatics to applications), NLR, April 18: G. Piella Fenoy, H.J.A.M. Heijmans, M.J. Huiskes, E.J.E.M. Pauwels.
- MASCOT Midterm Review and 4th Progress Meeting, Barcelona, Spain, May 21–24: H.J.A.M. Heijmans, Y.-W. Zhan.
- FOUNDIT Midterm review meeting, Luxemburg, June 26: E.J.E.M. Pauwels, M.J. Huiskes.
- FOUNDIT Technical Meetings at Sophis, Wevelgem, Belgium: January 9, April 5, May 2, June 13, August 14, October 8: E.J.E.M. Pauwels, M.J. Huiskes.
- BIOVISION 1st Progress Meeting, Fraunhofer Institute, Darmstadt, Germany, July 16–19: B.A.M. Schouten.
- BIOVISION 2th Progress Meeting, London, UK, September 5–6: B.A.M. Schouten.
- MASCOT 5th Progress Meeting, CMM Paris, France, September 12–13: H.J.A.M. Heijmans, G.C.K. Abhayaratne, Y.-W. Zhan.
- Pianezza, Italy, Integration and testing for FOUNDIT project, September 22–26: E.J.E.M. Pauwels, M.J. Huiskes.
- MASCOT Software Integration Meeting, VUB Brussels, Belgium, November 7: H.J.A.M. Heijmans, G.C.K. Abhayaratne, Y.-W. Zhan.
- BIOVISION 1st Workshop, Amsterdam, October 9–11: B.A.M. Schouten.
- EUROPHLUKES Progress Meeting, Madeira, Portugal, November 21–25: H.J.A.M. Heijmans, E.J.E.M. Pauwels, A.G. Steenbeek.

Other lectures

- Oberseminarium Stochastik, Ruhr-Univ. Bochum, Germany, January 17–18 (with visit to Prof. H. Dehling): M.N.M. van Lieshout (Lecture: *Extrapolating and interpolating spatial patterns*).
- Signals and Images Seminar, CWI, March: L. Kamstra (Lecture: *Using Nonlinear Binary Wavelet Transforms to Compress Binary Images*).
- Signals and Images Seminar, CWI, March: P. J. Oonincx (Lecture: *The Empirical Mode Decomposition and a seismic application*)
- Ecole Normale Supérieure, Paris, France, April 26 (with visit to Prof. F. Baccelli): R.S. Stoica (Lecture: *Simulating line networks using the Candy model*).
- Mini-symposium Stochastic Geometry, CWI, May 22: P. Gregori Huerta (Lecture: *Some remarks on area-interaction and shot-noise weighted point processes*), M.N.M. van Lieshout (Lecture: *Locally scaled Markov point processes*).
- Utrecht Stochastics Seminar, June 12: M.N.M. van Lieshout (Lecture: *Locally scaled Markov point processes*).
- Signals and Images Seminar, CWI, July 3: G.C.K. Abhayaratne (Lecture: *Spatially Adaptive Lifting for Lossless Video Coding*).
- Signals and Images Seminar, CWI, September 4: H.J.A.M. Heijmans (Lecture: *Mathematical Challenges in Image Watermarking*).
- Spatial Stochastics Seminar, CWI, October 1: K.K. Berthelsen (Lecture: *Inference for point processes using path sampling and perfect simulation*).
- CWI Scientific Meeting, November 22: M.N.M. van Lieshout (Lecture: *Marked point processes and their applications*).
- Dutch Wavelet Seminar, CWI, December 6: L. Kamstra (Lecture:*Binary Wavelet Transforms*)
- COMPASS Workshop, December 17: M.J. Huiskes (Lecture: *Model Analysis for Stock Assessment Procedures*).
- Polytechnical Univ. of Barcelona, Spain, December 19: G. Piella Fenoy (Lecture: *Wavelets no Lineares Mediante Filtros Adaptativos*)

Courses

- Course on Colour, UvA, March 25: M.J. Huiskes, G. Piella Fenoy, Y.-W. Zhan.
- Summer school on Stereology and geometric tomography, Sandbjerg, Denmark, June 17–21: R.S. Stoica.
- Summer course on Wavelets and Applications, Barcelona, Spain, July 1–7: G. Piella Fenoy.

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 project Wavelets and their Applications; partners: CWI, RUG, TUE, UT.
- Member of Technical Committee of IEEE Conference on Image Processing (ICIP 2002), Rochester, USA, September 22–25.
- Member of Technical Committee of Sixth International Symposium on Mathematical Morphology (ISMM2002), Sydney, Australia, April 3–5.
- Member of PhD committee of E. Engberts, UvA, September 3.
- Member of PhD committee of A. Jonk, UvA, September 3.
- Member of Technical Committee of ICCVG 2002 International Conference on Computer Vision and Graphics, Zakopane, Poland, September 25–29.
- Senior Member of IEEE.

M.N.M. van Lieshout

- Secretary/treasurer of the VVS (Vereniging Voor Statistiek en Operationele Research).
- Member steering committee Complex stochastic models, EURANDOM.
- Member ERCIM Vital Statistics Taskforce.
- Member PhD committee Maria João Paulo; PhD thesis *Statistical sampling and modelling for forest production*, WUR, The Netherlands, November 4.
- Member Klankbordgroep IResearch, NWO.

E.J.E.M. Pauwels

- Coordinator of FOUNDIT project (EU, 5th FP, September 2001–August 2003).
- Course Technologie en Economische Sectoren at Cath. Univ. Brussels, Belgium.
- Member of PhD committee Jerome Fournier, (ENSEA) *Indexation d'images par le contenu et recherche interactive dans les bases généralistes*.
- Chairman of ERCIM Working Group on Image and Video Understanding.
- Coordinator of 6FP EoI and subsequent NoE-proposal 'Image and Video Understanding: Extracting Semantics from Visual Data'.
- Member Programme Committee CIVR2002, The Challenge of Image and Video Retrieval.

B.A.M. Schouten

- Chairman Working Group Research and Development, Dutch Biometric Forum.
- Member of the Board, Dutch Biometric Forum.
- Member Curriculum Committee Scientific Visualization, School of Art and Technology, Utrecht, The Netherlands.
- Master class on Data clouds; Itau Cultural, Medialab, São Paulo, Brazil, August.

P.M. de Zeeuw

- Reviewer of a project of the USA National Science Foundation.
- Reviewer of a project of the Israel Science Foundation.

Visitors

- P. Soille (JRC Ispra, Italy), February 8–13. Host: H.J.A.M. Heijmans.
- J. Zerubia (INRIA Sophia-Antipolis, France), February 25. Hosts: M.N.M. van Lieshout, R.S. Stoica.
- P. Gregori Huerta (Univ. Jaume I, Castellon, Spain), April 9–July 8. Host: M.N.M. van Lieshout.
- C. Lacoste (INRIA Sophia-Antipolis, France), May 21–24. Hosts: M.N.M. van Lieshout, R.S. Stoica.
- K.K. Berthelsen (Univ. Aalborg, Denmark), September 9–December 14. Host: M.N.M. van Lieshout.
- M. van Droogenbroeck (Louvain-la-Neuve, Belgium), November 6. Host: H.J.A.M. Heijmans.
- B. Pesquet-Popescu (ENST Paris, France), December 4–6. Host: H.J.A.M. Heijmans.
- A. Cohen (Univ. Pierre et Marie Curie, Paris, France), December 5–6. Host: H.J.A.M. Heijmans.

External Speakers Signals and Images seminar
Host: R.S. Stoica

- A. Nigten (V2-laboratory, Rotterdam, The Netherlands), February 20.
- S. Oomes (Eccentric Vision), March 20.
- P. Bakker (Shell Rijswijk, The Netherlands), September 11.
- A. Bagdanov (UvA - Intelligent Sensory Information Systems Group), October 10.

- A. Kuijper (Institute of Information and Computing Science), Utrecht University, October 23.
- J-M. Geusebroek (UvA - Intelligent Sensory Information Systems Group), November 20.
- M. Loog (Image Sciences Institute, UMC Utrecht, The Netherlands), December 4.

Publications

Books and book chapters

M.N.M. van Lieshout, A.J. Baddeley (2002). Extrapolating and interpolating spatial patterns. A.B. Lawson, D.G.T. Denison (eds.). *Spatial Cluster Modelling* **4**, Chapman and Hall/CRC Press, Boca Raton, 61–86, ISBN 1-58488-266-2.

R.S. Stoica, M.N.M. van Lieshout, X. Descombes (INRIA Sophia-Antipolis, France), J. Zerubia (INRIA Sophia-Antipolis, France) (2002). An application of marked point processes to the extraction of linear networks from images. J. Mateu, F. Montes (eds.), Chapter 12 in *Spatial statistics: case studies*, Southampton, WIT Press, 287–312, ISBN 1-85312-649-7.

Papers in refereed journals and proceedings

G. Caenen, E.J. Pauwels (2002). Logistic regression models for relevance feedback in content-based Image Retrieval. *Proceedings of SPIE, Storage and Retrieval for Media Databases 2002*, **4676**, 49–58.

T.-Q. Deng (Harbin Inst. of Techn, China), H.J.A.M. Heijmans (2002). Grey-scale morphology based on fuzzy logic. *J. Mathematical Imaging and Vision* **116**, 155–171.

H.J.A.M. Heijmans, R. van den Boomgaard (UvA) (2002). Algebraic framework for linear and morphological scale-spaces. *J. Visual Communication and Image Representation* **13**, 269–301.

H.J.A.M. Heijmans, R. Kresch (HP Labs, Haifa) (2002). Inf-semilattice approach to self-dual morphology. *J. Mathematical Imaging and Vision* **17**, 55–80.

H.J.A.M. Heijmans, G. Piella, B. Pesquet-Popescu (ENST Paris) (2002). Building adaptive 2D wavelet decompositions by update lifting. *Proceedings of the IEEE International Conference on Image Processing*, Rochester, USA.

H.J.A.M. Heijmans (2002). H. Talbot (CSIRO, Sydney) (ed.). *Proceedings 6th ISMM, Mathematical Morphology and its Applications to Image and Signal Processing*, Sydney, Australia, 253–263.

L. Kamstra (2002). Nonlinear binary wavelet transforms and their application to binary image compression. *Proceedings of the International Conference on Image Processing*, volume III, Rochester, New York, USA, 593–596.

L. Kamstra (2002). A method for constructing nonlinear discrete wavelet transforms. *Proceedings of the 12th Portuguese Conference on Pattern Recognition*, Aveiro, Portugal.

P.J. Oonincx, P.M. de Zeeuw (2002). An application of space-adaptive lifting: image retrieval. *Proceedings of a G24 conference held in Paris and Louvain-la-Neuve on Coherent States, Wavelets and Applications,* Paris, France, 10–12.

E.J. Pauwels, V. Kreinovicht (Univ. Texas El Paso), S.A. Ferson, L. Ginzburg (2002). A Feasible Algorithm for Locating Concave and convex zones of interval data and its Use in statistics-based clustering. *Proceedings of SCAN 2002*, Paris, France, 23–27.

B. Pesquet-Popescu (ENST Paris), G. Piella, H.J.A.M. Heijmans (2002). Adaptive update lifting with gradient criteria modeling high-order differences. *Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing*, Orlando, Florida.

B. Pesquet-Popescu (ENST Paris), G. Piella, H.J.A.M. Heijmans (2002). Construction of adaptive wavelets using update lifting and quadratic decision criteria. *Proceedings of EUSIPCO 2002*, 151–154.

G. Piella, H.J.A.M. Heijmans, B. Pesquet-Popescu (ENST Paris) (2002). Adaptive update lifting with a decision rule based on derivative filters. *IEEE Signal Processing Letters* **9**, 329–332.

G. Piella, H.J.A.M. Heijmans (2002). Adaptive lifting schemes with perfect reconstruction. *IEEE Trans. Signal Processing* **50**, 1620–1630.

G. Piella (2002). A region-based multiresolution image fusion algorithm. *Proceedings of ICIF*, Annapolis, USA.

G. Piella, H.J.A.M. Heijmans (2002) Multiresolution image fusion guided by a multimodal segmentation. *Proceedings of Advanced Concepts for Intelligent Vision Systems*, Ghent, Belgium, 175–182.

G. Piella, H.J.A.M. Heijmans, B. Pesquet-Popescu (ENST Paris) (2002). Adaptive wavelet decompositions driven by the gradient norm. *Proceedings of the 3rd IEEE Benelux Signal Processing Symposium*, Leuven, Belgium, 109–112.

CWI reports

PNA-R0208 PNA-R0211
PNA-R0212 PNA-R0224

See page 170 for complete titles.

Other publications

PhD theses

G.C.K. Abhayaratne (2002). *Lossless and Nearly Lossless Digital Video Coding*, Univ. of Bath, UK, June. Thesis advisor: Prof. D.M. Monro.

M.J. Huiskes (2002). *Automatic Differentiation Algorithms in Model Analysis*, WUR, March 19. Thesis advisors: Prof.dr.ir. J. Grasman and Prof. Stein.

Technical reports published elsewhere

U. Hahn (Univ. Aarhus), E.B.V. Jensen (Univ. Aarhus), M.N.M. van Lieshout, L.S. Nielsen (Univ. Aarhus) (2002). *Inhomogeneous Spatial Point Processes by Location Dependent Scaling.* Research Report **16**, Laboratory for Computational Stochastics, Univ. Aarhus.

Y.-W. Zhan, M. Picard (ENST Paris), B. Pesquet-Popescu (ENST Paris), H.J.A.M. Heijmans (2002). Long temporal filters in lifting schemes for scalable video coding. *Document m8680*, Klagenfurt MPEG meeting.

Articles in unrefereed journals and proceedings

H.J.A.M. Heijmans (2002). MASCOT-Adaptive and Morphological Wavelets for Scalable Video Coding. *ERCIM News,* **48**, January.

M.N.M. van Lieshout (2002). Review of 'Geometric aspects of probability theory and mathematical statistics' by V.V. Buldygin and A.B. Kharazishvili. *Nieuw Archief voor Wiskunde* **3** (1), 88.

Newsletters

M.N.M. van Lieshout (2002). Zelfportretten: wat wiskundigen beweegt. *Nieuwe dimensies, ruimer bereik. Een nationale strategie voor wiskundeonderzoek en gerelateerde masteropleidingen*, 27.

Software developed

- *MATIFUS* Matlab Fusion Toolbox: G. Piella Fenoy, P.M. de Zeeuw, H.J.A.M. Heijmans.
- *LISQ:* the wavelet lifting scheme on quincunx grids in Matlab: P.M. de Zeeuw.
- *FOUNDIT Image Understanding Toolbox* (progress): M.J. Huiskes, E.J.E.M. Pauwels.
- *EUROPHLUKES*: Software developed by A.G. Steenbeek:

  1. *Phlex:* Interactive JAVA-tool for the extraction of fluke contours in images of whales.
  2. *Matcher:* JAVA-program to find matching contours in a data base that match the signature of image supplied by user. The program presents a list of all images, sorted by their match value.
  3. *Marker:* Embeds watermark into image using spread spectrum techniques.

Deliverables for projects

H.J.A.M. Heijmans, Y.-W. Zhan et al (2002). Various Deliverables.

H.J.A.M. Heijmans (2002). EUROPHLUKES MASCOT Deliverable D7.1: Specifications of Watermarking Algorithm.

H.J.A.M. Heijmans (2002). EUROPHLUKES Deliverable D7.2: Report on Evaluations of Existing Watermarking Techniques.

M.J. Huiskes (2002). The FOUNDIT Feature Factory: Progress in the development of a feature factory for design image retrieval

M.J. Huiskes, E.J. Pauwels (2002). FOUNDIT Deliverable D2.1: The FOUNDIT Search Engine: A Parametric Model for Relevance Feedback and Feature Selection in Image Database Navigation.

E.J. Pauwels, M.J. Huiskes, P. Bernard (2002). Report on Specifications and Requirements for Content-Based Image Retrieval Search Engine and Interface. FOUNDIT Deliverable D1.1.

E.J. Pauwels (2002). FOUNDIT Deliverable D6.2: Dissemination and Use Plan.

SOFTWARE ENGINEERING

General overview

Principal research area and mission

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 with Dutch universities and international partners continued and further extended. Applications and technology transfer were 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 our spin-off companies (Software Improvement Group and Adaptive Planet) assure this knowledge transfer.

Cluster leader

Prof.dr. P. Klint

Themes

Name	Leader
SEN0 – Biography of Aad van Wijngaarden	P. Klint
SEN1 – Interactive Software Development and Renovation	P. Klint
SEN2 – Specification and Analysis of Embedded Systems	W.J. Fokkink
SEN3 – Coordination Languages	J.J.M.M. Rutten
SEN4 – Evolutionary Systems and Applied Algorithmics	J.A. La Poutré

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 was focused on four areas: μCRL language and toolset, 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 a career of 38 years with CWI (and formerly MC), J.W. de Bakker left CWI on July 1. On August 30, on the occasion of his retirement, a farewell symposium was organized consisting of a

scientific part and a festive dinner party in the evening. On this occasion he received a high royal decoration. He also received a *Liber Amicorum* edited by F. de Boer, M. van der Heijden , P. Klint and J. Rutten.

- J.W. Klop received an honorary doctorate from the University of East Anglia.
- M.G.J. van den Brand was appointed as assistant professor at the VU.
- A. van Deursen was appointed as assistant professor at the TUD.
- Six PhD theses were successfully defended by (former) SEN members:
  T. Kuipers, S.P. Luttik, L.M.F. Moonen, R. van Stee, Y.S. Usenko, M.B. van der Zwaag.
- A new spin-off company *Adaptive Planet* was created that uses the results of the concluded Manifold project in SEN3.
- SEN members have acted as editors in the editorial boards of 12 journals.
- SEN members have participated in the PCs of 36 international workshops and conferences.
- SEN has cooperations with the following companies: ABN AMRO, Adaptive Planet, Almende, Cap Gemini, Ericsson (Sweden), First Result, France Télécom, Groeneveld Group, ING, KPN, KPN Research, NLR, Lucent, Ordina, Philips Research, Post Kogeko Transport Group, Software Improvement Group, Thales, TNO-TPD, Verimag (France), Vos Logistics.

Staff

- Biography of Aad van Wijngaarden – SEN0
  - G. Alberts
  - J.W. de Bakker
- Interactive Software Development and Renovation – SEN1
  - J.A. Bergstra
  - M.G.J. van den Brand
  - A. van Deursen
  - E.G. van Emden
  - R. de Haan
  - J. Heering
  - H.A. de Jong
  - M. de Jonge
  - P. Klint
  - R. Lämmel
  - L.M.F. Moonen
  - P.A. Olivier
  - J.J. Vinju
  - J.M.W. Visser
- Specification and Analysis of Embedded Systems – SEN2
  - B. Badban
  - J.A. Bergstra
  - S.C.C. Blom
  - C.F. Daws Poulastrou
  - W.J. Fokkink
  - R.J. van Glabbeek
  - J.F. Groote
  - J. Hooman
  - N.Y. Ioustinova
  - J.W. Klop
  - I.A. van Langevelde
  - B. Lisser
  - S. Mauw
  - S.M. Orzan
  - J. Pang
  - J.C. van de Pol
  - Y.S. Usenko
  - J.A. Valero Espada
  - M.B. van der Zwaag
- Coordination Languages – SEN3
  - F. Arbab
  - J.W. de Bakker
  - F. Bartels
  - C.L. Blom
  - F.S. de Boer
  - M.M. Bonsangue
  - F.J. Burger
  - C.T.H. Everaars
  - J.V. Guillen Scholten
  - J.F. Jacob
  - J.N. Kok
  - C. Kupke
  - A. Kurz
  - A. Palmigiano
  - C. Pierik
  - B. Romero Matia
  - J.J.M.M. Rutten
  - P. Singh
  - L.W.N. van der Torre
  - P. Zoeteweij
- Evolutionary Systems and Applied Algorithmics – SEN4
  - F. Alkemade
  - S.M.Bohte
  - D.D.B. van Bragt
  - E.H. Gerding
  - J.I. van Hemert
  - P.J. 't Hoen
  - J.N. Kok

- E. Kutschinski
- C.D.D. Neumann
- J.A. La Poutré
- D.J.A. Somefun

- Secretary:
  - J.J. Bruné-Streefkerk

Biography of Aad van Wijngaarden – SEN0

Mission

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 this 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 led him to 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.

Theme leader

Prof.dr. P. Klint

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. G. Alberts (seconded NWO)	0.8	researcher	2000-05-01 till 2003-12-31	Biography Van Wijngaarden, history of computing	01-XX , 65-03 , 68-03
Prof.dr. J.W. de Bakker	p.m.	advisor	2000-05-01 till 2003-12-31	Advising Alberts	

Scientific report

In 2002 research was continued by archival searches and interviews in the Netherlands, France (Grenoble) and the UK (Oxford and Manchester).

Societal aspects and knowledge transfer

Teaching activities

UvA, Computer Science, Spring 2002; Course Computerhistorie, G. Alberts, E.H. Dooijes (UvA).

History of computing in the press

Alberts issued a press release on half a century of stored program computers in the Netherlands, 50 years after the official installation of ARRA, Amsterdam automatic relay computer, at the Mathematical Centre in Amsterdam, June 21, 1952. The release was published with picture in *Computable* and several newspapers and magazines.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

G. Alberts

- Instituut Collectie Nederland/Werkgroep Verzamelbeleid Computerhistorie, Amsterdam, February 27: (Lecture: *Oude computers: nieuw erfgoed, inleiding*).
- Bits and Bytes congres *Chemistry in bits and bytes*, Symposium Sigma, KUN, March 19: (Lecture: *Chemische processen en automatisering, een gekatalyseerde geschiedenis*).
- NMC38. GMFW symposium Archieven van wiskundigen: snippers met formules at the 38-th Nederlands Mathematisch Congres, Eindhoven, April 4–5: (Lecture: *Van Wijn-*

gaarden en Van Dantzig uit oud papier).
- BSHS. Do collections matter to instrument studies (conference British Society for the History of Science, Oxford, UK) June 29–30: (Lecture: *Ephemeral objects, computers in the museum*).
- GEWINA. Symposium Wetenschap en Oorlog, Vereniging voor de Geschiedenis van Geneeskunde, Wiskunde, Natuurwetenschappen en Techniek, Delft, October 12: (Lecture: *Continuïteit in de Tweede Wereldoorlog: vernieuwing van onderzoek in de luwte van de bezetting*).
- CWI in Bedrijf, Amsterdam, October 18, Wetenschapsdag, October 20: (Poster: *Rekengeluiden*).
- ACONIT Conference on the History of Computing and Networks, Grenoble, France, November 25–27: (Lecture: *Numerical analysis, the shortest lived of disciplines*).

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, Commissie Persoonlijke Archieven van Wiskundigen.
- Member PhD committee D. Beckers, KUN, *Propaedeutic mathematics and the rise of pure mathemtics in the Netherlands around 1800.*
- Head of the Science and Society research programme, KUN.

Publications

Papers in unrefereed journals and bookchapters

G. Alberts (2002). Geschiedenis van het wiskundig modelleren: opkomst en toepasbaarheidspretenties in Nederland. P. Hulshof et al (red.). *Advanced Decision Making; de rol van kwantitatieve modellen in de praktijk*, WBS, Tilburg, 11–21.

G. Alberts, L. Peeperkorn (KUN), A. Kok (KUN) (2002). Oude computers als piepjong erfgoed. *Museumvisie* **3**, 33–37.

G. Alberts (2002). Een halve eeuw computers in Nederland. 1. Een willekeurig getal. *Nieuwe Wiskrant* **22**(1), 6–8.

G. Alberts (2002). Hoe deskundigen wiskundigen werden. F. van Lunteren, B. Theunissen, R. Vermij (red.). *De opmars van deskundigen. Souffleurs van de samenleving.* AUP, Amsterdam, 131–146.

Interactive Software Development and Renovation – SEN1

Mission

The mission of this theme is to advance the state of the art in development and renovation of large software systems.

The general approach is to bring together established fundamental notions such as modularization, term rewriting, and program generation with pragmatic needs such as component-based development and understanding or transforming legacy systems. *Formal language definitions* play an important role in this approach: They describe the syntax and semantics of a domain-specific or programming language and form the basis for the analysis and transformation of software in existing languages, for the generation of specific tools, and for the development of domain-specific languages.

The *development* of large software systems is addressed by explicitly describing the cooperation protocols of components, by explicitly packaging subsystems, and by using methods for unit testing and daily builds. Key questions are related to controlling the configuration, building and distributing processes and optimizing the description of component interfaces.

The *renovation* of software systems is addressed by developing new techniques for the analysis and transformation of software systems. Key questions cover traversing programs, describing analysis or transformation, visualizing the results of an analysis, collecting the results of an analysis in a language-

independent fashion, using the results of an analysis for program transformations, and showing the correctness of these transformations.

Theme leader

Prof.dr. P. Klint

Subthemes

Name	Leader
SEN1.1 – Software Renovation	A. van Deursen
SEN1.2 – Domain-Specific Languages	J. Heering
SEN1.3 – Generic Language Technology	M.G.J. van den Brand

SEN1.1 aims at developing methods, tools, and techniques that help to make software systems sufficiently flexible.

SEN1.2 studies the 'when and how' of DSL design and development. More specifically, it studies advanced tools and methods for domain analysis and DSL development in general as well as in particular cases.

SEN1.3 is concerned with the redesign, re-implementation, and improvement of the ASF+SDF Meta-Environment. The primary goal is to develop a flexible and extensible generic environment to be used as infrastructure in domain-specific language prototyping (SEN1.2) and software renovation (SEN1.1).

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. M.G.J. van den Brand	0.15	researcher, leader SEN1.3	indefinite	SEN1.3: ASF+SDF, AirCube, leading PhD students	D.2
Dr. A. van Deursen	1.0	researcher, leader SEN1.1	indefinite	SEN1.1: DocGen, NAME, SEN1.2: DSL/TI, leading PhD students	D.2
J. Heering	1.0	researcher, leader SEN1.2	indefinite	SEN1.2: DSL/TI	D.2
Drs. H.A. de Jong	1.0	project member, PhD student	2000-01-01 till 2003-12-31	SEN1.3: PhD research, ASF+SDF	D.2
Drs. M. de Jonge	1.0	project member, PhD student	1999-04-01 till 2003-03-31	SEN1.1: PhD student, SEN1.2: PhD research, DSL/TI	D.2
Prof.dr. P. Klint	0.6	theme leader	indefinite	SEN1.1, SEN1.2: DSL/TI, SEN1.3: ASF+SDF, leading PhD students	D.2
Drs. L.M.F. Moonen	1.0	project member, PhD student	1999-04-01 till 2003-03-31	SEN1.1: PhD research, DocGen, NAME, leading E.G. van Emden	D.2

Dr. P.A. Olivier	0.6	PhD student, post-doc	1999-11-01 till 2003-02-28	SEN1.3: ASF+SDF	D.2
Drs. J.J. Vinju	1.0	project member, PhD student	2002-02-01 till 2004-01-31	SEN1.3: PhD research, ASF+SDF, AirCube	D.2
Drs. J.M.W. Visser	1.0	project member, PhD student	1999-04-01 till 2003-03-31	SEN1.1: PhD research, SEN1.2: PhD research, DSL/TI	D.2

Seconded

Name	**Fte**	**Function(s)**	**Period**	**Subthemes + projects**	**Classification (MSC or CR)**
Prof.dr. J.A. Bergstra (UvA)	0.1	advisor	indefinite	SEN1.1; SEN1.2; SEN1.3	D.2
E.G. van Emden (Univ. Victoria, Canada)	0.5	trainee	2001-10-01 till 2002-07-01	SEN1.1: Master thesis research	D.2
R. de Haan (UvA)	0.33	trainee	2000-01-01 till 2003-12-31	SEN1.3: Master thesis research	D.2
Dr.ing. R. Lämmel (VU)	0.2	post-doc	2000-01-01 till 2002-02-28	SEN1.2: DSL/TI, leading J.M.W. Visser	D.2

Scientific report

Highlights

- Appointment of M.G.J. van den Brand as assistant professor (VU).
- Appointment of A. van Deursen as assistant professor (TUD).
- PhD defence T. Kuipers and L.M.F. Moonen.
- Successful completion of DSL/Telematics Instituteproject.
- Publication of ASF+SDF compiler article in *ACM Transactions on Programming Languages and Systems*.
- First real-life software audit in cooperation with the Software Improvement Group BV.
- Program chair WCRE 2002.

PhD research

Title	PhD research of H.A. de Jong
Period	January 2000–January 2004
Leaders	P. Klint, M.G.J. van den Brand
Funding	CWI

Progress report. De Jong worked with *Olivier* on the design, development, and deployment in the ASF+SDF Meta-Environment of APIGen: The generation of an abstract programming interface for the creation, inspection, and manipulation of parse trees for a target language, derived from an (annotated) syntax specification for that language.

He also worked with *Olivier* and *Klint* on the prototype for a 'next generation ToolBus', which is a re-implementation in Java of a thorough redesign of the current ToolBus driven by and based on experience with the ToolBus in the ASF+SDF Meta-Environment.

Another activity has been the day-to-day maintenance of the ASF+SDF Meta-environment software, and support of the growing community of users of our software as well as aiding and supporting initiatives to improve its quality and maintainability.

Title	PhD research of M. de Jonge
Period	April 1999–January 2003
Leaders	P. Klint, A. van Deursen
Funding	Telematics Institute

Progress report. De Jonge developed a technique for 'conservative' prettyprinting. It preserves layout during prettyprinting whenever possible. The results were presented at ICSM 2002. He also worked on automated software assembly. This resulted in techniques for building software product lines. This was presented at SPLC2. His results on implementation-level component composition, i.e., source tree composition, were presented at ICSR7. Finally, he finished his PhD

thesis entitled *To Reuse or to be Reused, Techniques for Component Composition and Construction*.

Title	PhD research of L.M.F. Moonen
Period	April 1999–March 2003
Leader	P. Klint, A. van Deursen
Funding	CWI

Progress report. With *Van Emden*, *Moonen* developed the Cosmo code smell browser. It detects code smells in Java source code and visualizes them so that they can be used to review the quality of the analyzed code, and explore it to find regions that could benefit from refactoring. He finished his PhD thesis entitled *Exploring Software Systems*.

Title	PhD research of J.J. Vinju
Period	February 2000–February 2004
Leader	P. Klint, M.G.J. van den Brand
Funding	CWI

Progress report. *Vinju* added traversal functions to the ASF+SDF compiler, developed an ASF+SDF library, and added various experimental primitives to ASF+SDF such as the manipulation of term annotations during rewriting. Also, syntactic disambiguation by means of rewriting and the possibility to use abstract (rather than only concrete) syntax in specifications were added.

Title	PhD research of J.M.W. Visser
Period	April 1999–March 2003
Leader	P. Klint, R. Lämmel
Funding	Telematics Institute

Progress report. *Visser* continued his work on generic traversal, resulting in several publications on visitor combinators and functional strategies. He released new versions of the software packages Strafunski, JJForester, and JJTraveler. Together with *Van Deursen*, he created the software package ControlCruiser for Cobol control flow analysis and visualization. Finally, he finished his PhD thesis entitled *Generic Traversal over Typed Source Code Representations*.

SEN1.1 – Software Renovation

The objective of SEN1.1 is to develop methods, tools, and techniques that help to make software systems stay sufficiently flexible. In 2002, specific attention was paid to three areas:

1. tool support for quality assurance;
2. program analysis methods; and
3. agile software evolution.

In addition to the auditing work done in the DocGen project (see page 56), work was done on visualizing areas of poor quality in object-oriented programs. This has resulted in jCosmo, a tool capable of detecting bad smells in code, presenting them in various graphical ways. This work was done in collaboration with the Univ. Victoria, Canada (*Van Emden*). See also *Moonen*'s PhD work report on this page.

In order to support sophisticated forms of program analysis, the notions of generic traversals was further elaborated. Object-oriented traversals are studied by means of the JJTraveler framework, which also includes a library of key visitor combinators. Traversals in functional programs are studied by means of Strafunski, a framework for strategic programming in Haskell. JJTraveler has been applied to the analysis and visualization of control dependencies in Cobol programs, resulting in a tool called ControlCruiser. See also *Visser*'s PhD work report on this page.

Software renovation technology can be applied in more than just post-project maintenance activities. Of particular interest are refactoring and program understanding support during the software development process. We are analyzing how our technology can be successfully accommodated in the category agile development methodologies. This is done by participating in the European NAME project, a network for the evaluation of agile methodologies (see below).

Klint and C. Verhoef (VU) investigated the connection between knowledge management and software renovation. Starting point was an existing model for knowledge creation and the question was whether and how this might be instantiated for software renovation. The result is a specific model for creating and managing knowledge about software assets.

Title	DocGen – Documentation Generation
Period	1999– indefinite
Leader	A. van Deursen
Staff	L.M.F. Moonen
Funding	(consultancy)
Partners	Software Improvement Group BV

Progress report. As part of the quality assurance activities of SEN1.1, a significant commercial audit was conducted. In collaboration with the

SEN1 spin-off company Software Improvement Group BV, the reliability, maintainability, and data integrity of a Cobol system consisting of two million lines of code was analyzed. This has resulted in a number of research challenges that are currently being addressed in the subtheme.

Title	NAME – Network of Agile Methodologies Experience
Period	July 2002–July 2003
Leader	L.M.F. Moonen
Staff	A. van Deursen
Funding	EU (SFT, network)
Partners	Free Univ.Bolzano, Datasiel SpA, Polytechnic Valencia, Technical Univ. Munich, Univ. Cagliari, Univ. Sheffield

Progress report. This network started on July 1. On October 22, SEN1.1 organized a workshop with various industrial partners, in which experience in the use of extreme programming practices were shared, resulting in a research agenda on the topic of agile methodologies. The first review of NAME took place in December.

SEN1.2 – Domain-Specific Languages

SEN1.2 studies the 'when and how' of DSL design and development. More specifically, it studies advanced tools and methods for domain analysis and DSL development in general as well as in particular cases.

Title	DSL/Telematics Institute–Domain-Specific Languages
Period	1999–July 2002
Leaders	A. van Deursen, J. Heering
Staff	M. de Jonge, P. Klint, R. Lämmel, J.M.W. Visser
Funding	Telematics Institute
Partners	Telematics Institute, ING, CAP Gemini, Lucent, Ordina

Progress report. The DSL/Telematics Instituteproject was successfully completed on July 1. The work was continued as a CWI-funded activity.

Van Deursen, *Klint*: The application of feature diagrams in the context of domain-specific languages was studied, resulting in a Feature Description Language (FDL) that has been formally defined using ASF+SDF and that can be used to give a feature description of either a complete application domain or a large software system. Feature diagrams offer a concise description for the combinatorial explosion of possible feature combinations. This presents problems for the automatic processing of feature descriptions, in particular if constraints are imposed on the use of (combinations of) features. *Klint* carried out initial experiments with the use of binary decision diagrams (BDDs) to perform the resolution of these constraints.

De Jonge: See PhD work report (page 54).

Heering: DSL design and development is hard, requiring both domain and language development expertise. Few people have both. Furthermore, DSL implementation techniques are more varied than those for general purpose programming languages, requiring careful consideration of the factors involved. Joint with M. Mernik (Univ. Maribor, Slovenia) and A.M. Sloane (Macquarie Univ., Sydney, Australia), a comprehensive survey of the 'when and how' of domain-specific languages is being prepared. The work on Language Design Assistants (LDAs) incorporating significantly more knowledge about programming and domain-specific languages than current language development systems was continued. Special attention was paid to DSL design pattern support. (Report in preparation).

Lämmel: Work on generic programming, in the context of term rewriting and functional programming, was continued, partly in cooperation with *Visser* and S. Peyton Jones (Microsoft Research, Cambridge). This has resulted in several publications. Further work was done on the foundations and applications of aspect-oriented programming. Furthermore, previous work on Grammar Engineering was continued, in cooperation with J. Kort (UvA), S.A. Klusener (SIG/VU), and C. Verhoef (VU).

SEN1.3 – Generic Language Technology

SEN1.3 is concerned with the redesign, reimplementation, and improvement of the ASF+SDF Meta-Environment. The primary goal is to develop a flexible and extensible generic environment to be used as infrastructure in domain-specific language prototyping (SEN1.2) and software renovation (SEN1.1).

Title	ASF+SDF
Period	1998– indefinite
Leader	M.G.J. van den Brand
Staff	H.A. de Jong, P. Klint, P.A. Olivier. J.J. Vinju
Funding	CWI
Partners	UvA, VU, First Result, Software Improvement Group BV

Progress report. *Van den Brand* was employed as 'spécialiste étranger académique' in the Protheo group at LORIA Nancy during 2002. His main activities there concerned the development of a new environment for the rewrite logic language ELAN developed at LORIA. He continued to lead SEN1.3 during this period, and made many small improvements to the ASF+SDF Meta-Environment:

- Buttons to invoke ASF-functionality, compiled specifications, and foreign tools;
- SDF-checker, a well-formedness checker for grammars written in SDF; and
- ASF-checker, a typechecker for ASF rewrite rules, which detects uninstantiated variables, etc.

Furthermore, the Meta-Environment was completely restructured on the architecture level. The tight coupling with ASF was removed to facilitate the integration of other rewriting-based formalisms such as ELAN.

De Jong: See PhD work report (page 54).

Klint: With *De Jong* and *Olivier* work was started on a 'next generation ToolBus'. The major issues to be addressed are transaction-oriented messaging, error recovery, and value-based vs. reference-based transmission of large values. A small first prototype was implemented in Java to experiment with potential solutions and to explore new implementation techniques. A first progress report was given at FMCO 2002. Furthermore, he started on a framework for experimentation with various origin tracking methods. The framework is based on rewriting with annotations and is described in ASF+SDF.

Olivier: Worked on APIGen with *De Jong*, on the further development of TIDE, a distributed debugger for heterogeneous distributed systems, and on the 'next generation ToolBus' mentioned above. Furthermore, he developed a new GUI for the ASF+SDF Meta-Environment and cooperated with LORIA on Java and C versions of the ATerm library.

Vinju: See PhD work progress report (page 55).

Title	AirCube: Rewrite rules
Period	2001–2003
Leader	M.G.J. van den Brand
Staff	J.J. Vinju
Funding	LORIA (Nancy)
Partners	INRIA/LORIA Nancy

Progress report. *Vinju* worked at LORIA in the Protheo group in the period September–November under the leadership of *Van den Brand* and in cooperation with P.-E. Moreau on the problem of typed trees with maximal sharing in Java (solved) and a generic Meta-Environment suitable for ASF, ELAN, and other rewriting-based formalisms. These results will be published in 2003. While at LORIA, he gave two presentations on 'Realities of (Scientific Software) Engineering' and on 'Programming with ATerms using APIGen'.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- AirCube; see page 57.
- ASF+SDF; see page 57.
- DSL/Telematics Institute; see page 56.
- NAME; see page 56.

Contract research

- DocGen; see page 55.

Teaching activities

- Course on Software Engineering, UvA, September–December: A. van Deursen.
- Four lectures on module algebra, MoSIS Seminar, Univ. Bergen, Norway, November 12–13: J. Heering.

Organization of conferences, workshops, courses, meetings

- First Dutch NAME workshop, Amsterdam, October 22: L.M.F. Moonen.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Hawaii International Conference on Systems Sciences (HICCS-35), Hawaii, January 7–10: J. Heering (co-organizer DSL minitrack).
- CSMR 2002 Budapest, Hungary, March 11–13: A. van Deursen.
- ETAPS 2002 and LDTA, Grenoble, France, April 9–14: P. Klint, J.J. Vinju (Lecture: *Disambiguation filters for scannerless generalized LR parsers*).
- Workshop on Generative Programming/ICSR7, Austin, USA, April 12–23: M. de Jonge (Lecture: *Grammars as feature diagrams, Source tree composition*), J.M.W. Visser (Lecture: *Grammars as feature diagrams*).
- Third Stratego Users Day, Utrecht, May 3: J. Heering.
- XP 2002/WTiXP 2002, Alghero, Italy, May 25–30: L.M.F. Moonen (WTiXP organization, *The video store revisited: Thoughts on refactoring and testing*).
- European Science Foundation (ESF), Amsterdam, May 30–31: P. Klint.
- GP 2002/ECOOP 2002, Malaga, Spain, June 9–12: J.M.W. Visser.
- IWPC 2002/VISSOFT 2002, Paris, France, June 25–July 2: A. van Deursen (Lecture: *Conditional call graphs, Building programming composition tools using visitor combinators*), L.M.F. Moonen (Lecture: *Lightweight impact analysis using island grammars*).
- Second Product Line Conference, San Diego, USA: August 19–22: M. de Jonge (Lecture: *Feature-based product line instantiation*).
- ICT Kenniscongres, September 5: P. Klint (Lecture: *Productsoftware: Van requirements naar realisatie*).
- ICSM 2002, Montréal, Canada, October 2–6: A. van Deursen (Lecture: *Software architecture reconstruction tutorial, Member panel on teaching software evolution*), M. de Jonge (Lecture: *Prettyprinting for software reengineering*).
- WCRE 2002, Richmond, USA, October 26–November 2: A. van Deursen (Program co-chair), L.M.F. Moonen (Lecture: *Java quality assurance by dectecting code smells*).
- Formal Methods for Components and Objects (FMCO 2002), Leiden, November 7: P. Klint (Lecture: *ToolBus: The next generation*).

Working visits

- Visiting Committee INRIA, INRIA Rocquencourt, January 13–15: P. Klint.
- INRIA Conseil Scientifique, INRIA Rocquencourt, June 10–12: P. Klint.
- S. Peyton Jones, Microsoft Research, Cambridge, June 18–22: R. Lämmel (Lecture: *Functional strategic programming*).
- IBM T.J. Watson Research Center, Yorktown Heights, August 23: M. de Jonge (Lecture: *Variability management*).
- IBM T.J. Watson Research Center, Yorktown Heights, October 21–22: P. Klint (Lecture: *Generic language technology*).

Project meetings

- AirCube meeting, Gulpen, The Netherlands, January 31: M.G.J. van den Brand (Lecture: *The new ELAN+SDF Meta-Environment*), E.G. van Emden (Lecture: *Java visualization using ASF+SDF and Rigi*), H.A. de Jong, P. Klint (Lecture: *Feature descriptions and binary decision diagrams)*, P.A. Olivier, J.J. Vinju (Lecture: *Disambiguation filters for SGLR*), J.M.W. Visser (Lecture: *Functional strategy combinators*).
- NAME kick-off meeting, Bolzano, Italy, July 25: L.M.F. Moonen (Lecture: *Reverse engineering and extreme programming research at CWI*).
- NAME local workshop, CWI, October 22: L.M.F. Moonen (Lecture: *Introduction to NAME and goals of this workshop*).
- SAGA project meeting, Univ. Bergen, Norway, November 13: J. Heering.
- NAME project meeting, Technical Univ. Munich, Germany, November 25–26: L.M.F. Moonen (Lecture: *Results from the first NAME workshop at CWI*).
- NAME review, Brussels, December 9: L.M.F. Moonen.

Memberships of committees and other professional activities

M.G.J. van den Brand

- Editor (with R. Lämmel) of the proceedings of the Second Workshop on Language Descriptions, Tools and Applications (LDTA 2002).
- PC chair Second Workshop on Language Descriptions, Tools and Applications (LDTA 2002).

- Member Programme Committee Sixth European Conference on Software Maintenance and Reengineering (CSMR 2002).
- Member Programme Committee Workshop On Rule Based Programming (RULE 2002).

A. van Deursen

- Co-advisor T. Kuipers and L.M.F. Moonen.
- Program co-chair of the Ninth Working Conference on Reverse Engineering (WCRE 2002).
- Editor (with E. Burd) of the proceedings of the Ninth Working Conference on Reverse Engineering (WCRE 2002).
- Member Programme Committee International Conference on Software Maintenance (ICSM 2002).
- Member Programme Committee Second IEEE International Workshop on Source Code Analysis and Manipulation.
- Member Programme Committee Third International Conference on Extreme Programming and Flexible Processes in Software Engineering (XP 2002).
- Member Programme Committee Workshop on Testing in eXtreme Programming (WTiXP 2002).
- Member Programme Committee First International Workshop on Software Visualization (VISSOFT 2002).

J. Heering

- Co-organizer (with M. Mernik and A.M. Sloane) of DSL Minitrack at Hawaii International Conference on Systems Sciences (HICCS-36).
- Member Programme Committee Second International Workshop on Language Descriptions, Tools, and Applications (LDTA 2002).

P. Klint

- Member PhD committee S.P. Luttik.
- Member PhD committee M.B. van der Zwaag.
- Editor IEE Proceedings-Software.
- Editor Science of Computer Programming.
- President European Association for Programming Languages and Systems (EAPLS).
- Member Adviescommissie Informatica (ACI).
- Member Informatica Platform Nederland (IPN).
- Member Programme Committee Ninth International Conference on Algebraic Methodology and Software Technology (AMAST 2002).
- Member Programme Committee Second International Workshop on Reduction Strategies in Rewriting and Programming (WRS 2002).
- Member Programme Committee International Conference on Principles and Practice of Declarative Programming (PPDP 2002).
- Member Programme Committee International Conference on Aspect-Oriented Software Development (AOSD 2003).

R. Lämmel

- Member Programme Committee 26th IEEE Conference COMPSAC 2002.
- Co-chair PC Second International Workshop on Language Descriptions, Tools, and Applications (LDTA 2002).

L.M.F. Moonen

- Editor of the proceedings of the Workshop on Testing in eXtreme Programming (WTiXP 2002).
- Member Programme Committee Seventh European Conference on Software Maintenance and Reengineering (CSMR 2003).
- Member Programme Committee Ninth Working Conference on Reverse Engineering (WCRE 2002).
- Member Programme Committee Third International Conference on eXtreme Programming and Agile Processes in Software Engineering (XP 2002).

Visitors

- M. Haveraaen (Univ. Bergen, Norway), April 24. Host: J. Heering.
- Y. Srikant (Indian Institute of Science, Bangalore, India), June 17. Host: P. Klint.
- R. Hirschfeld (DoCoMo Research Labs, Munich, Germany), June 24–26. Host: R. Lämmel.
- J. Saraiva (Univ. Minho, Portugal), July 4. Host: J.M.W. Visser.
- V. Sarkar (IBM T.J. Watson Research Center, USA), August 12. Host: J. Heering.
- H. Mueller (Univ. Victoria, Canada), December 3. Host: P. Klint.

Publications

Books and book chapters

A. van Deursen, T. Kuipers (2002). Effectief beheer middels documentatiegeneratie. J. van Bon (ed.). *IT Beheer Jaarboek*, Ten Hagen Stam, Chapter 2.9, ISBN 90-440-0394-1.

A. van Deursen, P. Klint, J.M.W. Visser (2002). Domain-Specific Languages. *The Encyclopedia of Library and Information Science*, Marcel Dekker, 113–127, ISBN 0 8247 2074 1.

A. van Deursen, P. Klint, J.M.W. Visser (2002). Domain-Specific Languages. *The Encyclopedia of Microcomputers*, Marcel Dekker, 53–68, ISBN 0 824727274.

A. van Deursen, L.M.F. Moonen, A. van den Bergh (SIG), G. Kok (SIG) (2002). Refactoring test code. G. Succi, M. Marchesi, D. Wells, L. Williams (eds.). *Extreme Programming Perspectives*, Addison-Wesley, 141–152, ISBN 0-201-77005-9.

Papers in refereed journals and proceedings

M.G.J. van den Brand, J.J. Vinju (2002). How ASF+SDF technology can be used to develop an Action Semantics environment. *Proceedings Action Semantics 2002* (AS 2002), Brics Notes Series NS-02-8, 43–44.

M.G.J. van den Brand, P. Klint, J.J. Vinju (2002). Term rewriting with type-safe traversal functions. *Proceedings Second International Workshop on Reduction Strategies in Rewriting and Programming* (WRS 2002), ENTCS **70**(6).

M.G.J. van den Brand, P.-E. Moreau (INRIA), C. Ringeissen (INRIA) (2002). The ELAN environment: A rewriting logic environment based on ASF+SDF technology. ENTCS **65**(3).

M.G.J. van den Brand, J. Scheerder (UU) J.J. Vinju, E. Visser (UU) (2002). Disambiguation filters for scannerless generalized LR parsers. R. Horspool (ed.). *Proceedings 11th International Conference on Compiler Construction* (CC 2002). LNCS **2304**, Springer-Verlag, 143–158.

M.G.J. van den Brand, J. Heering, P. Klint, P.A. Olivier (2002). Compiling language definitions: The ASF+SDF compiler. *ACM Transactions on Programming Languages and Systems* **24**(4), 334–368.

A. van Deursen (2002). Software architecture recovery and modelling. *ACM Applied Computing Review* **10**(1), 4–7.

A. van Deursen, P. Klint (2002). Domain-specific language design requires feature descriptions. *Journal of Computing and Information Technology* **10**(1), 1–17.

A. van Deursen, L.M.F. Moonen (2002). The video store revisited: Thoughts on refactoring and testing. *Proceedings 3rd International Conference on Extreme Programming and Agile Processes in Software Engineering* (XP 2002), Univ. Cagliary, 71–76.

A. van Deursen, J.M.W. Visser (2002). Building program understanding tools using visitor combinators. *Proceedings 10th International Workshop on Program Comprehension* (IWPC 2002), IEEE Computer Society, 137–146.

A. van Deursen, E. Visser (UU) (2002). The Reengineering Wiki. *Proceedings 6th European Conference on Software Maintenance and Reengineering* (CSMR 2002), IEEE Computer Society, 217–220.

A. van Deursen, M. de Jonge, T. Kuipers (2002). Feature-based product line instantiation using source-level packages. *Proceedings Second Software Product Line Conference* (SPLC2), LNCS **2379**, Springer-Verlag, 217–234.

A. van Deursen, T. Lethbridge (Univ. Ottawa), P. Stevens (Univ. Edinburgh) (2002). How should software maintenance and evolution be taught? *Proceedings International Conference on Software Maintenance (ICSM 2002)*, IEEE Computer Society, 248–250.

E.G. van Emden, L.M.F. Moonen (2002). Java quality assurance by detecting code smells. *Proceedings Ninth Working Conference on Reverse Engineering*, IEEE Computer Society Press, 97–106.

M. de Jonge (2002). Pretty-printing for software reengineering. *Proceedings IEEE International Conference on Software Maintenance (ICSM 2002)*, IEEE Computer Society, 550–559.

M. de Jonge (2002). Source tree composition. *Proceedings Seventh International Conference on Software Reuse*, LNCS **2319**, Springer-Verlag, 17–32.

P. Klint, C. Verhoef (VU) (2002). Enabling the creation of knowledge about software assets. *Data and Knowledge Engineering* **41**, 141–158.

R. Lämmel, J.M.W. Visser (2002). Design patterns for functional strategic programming. *Proceedings 2002 ACM SIGPLAN workshop on Rule-based Programming*, ACM Press, 1–14.

R. Lämmel, J.M.W. Visser (2002). Typed combinators for generic traversal. *Proceedings Practical Aspects of Declarative Programming* (PADL 2002), LNCS **2257**, Springer-Verlag, 137–154.

L.M.F. Moonen (2002). Lightweight impact analysis using island grammars. *Proceedings Tenth International Workshop on Program Comprehension* (IWPC 2002), IEEE Computer Society Press, 219–228.

CWI reports

SEN-R0204 SEN-R0205 SEN-R0210
SEN-R0212 SEN-R0214 SEN-R0215
See page 170 for complete titles.

Other publications

PhD theses

T. Kuipers (2002). *Techniques for Understanding Legacy Software Systems*, UvA, February 26. Thesis advisors: Prof.dr. P. Klint, dr. A. van Deursen.

L.M.F. Moonen (2002). *Exploring Software Systems*, UvA, December 5. Thesis advisors: Prof.dr. P. Klint, dr. A. van Deursen.

Articles in unrefereed journals and proceedings

A. Maccari (Nokia, Helsinki), A.A. Terekhov (Moscow State Univ.), G.H. Galal (Univ. London), D. Rayside (Univ. Waterloo), C. Riva (Nokia, Helsinki), A. van Deursen (2002). PREA – Panel on reverse engineering and architectural evolution. *ACM SIGSOFT Software Engineering Notes* **27**(5), 91–93.

Software developed

- ASF+SDF Meta-Environment: releases 1.1, 1.2, and 1.3: M.G.J. van den Brand, H.A. de Jonge, P.A. Olivier, J.J. Vinju.
- *Autobundle:* program configuration tool (new release): M. de Jonge.
- *ControlCruiser:* Cobol control flow analysis and visualization: A. van Deursen, J.M.W. Visser.
- *jCosmo:* Java code smell browser: E.G. van Emden, L.M.F. Moonen.
- *JJForrester:* Java parser and abstract syntax tree generator (new release): T. Kuipers, J.M.W. Visser.
- *JJTraveller:* Java visitor combinator framework and library (new release): A. van Deursen, J.M.W. Visser.
- *Strafunski:* Haskell strategic programming framework (new release): R. Lämmel, J.M.W. Visser.
- *XT:* program transformation toolkit (new release): M. de Jonge, J.M.W. Visser, E. Visser.

Deliverables for projects

J.H. Canós (Univ. Politecnica de Valencia), M. Holcombe (Univ. Sheffield), A. Janes (Free Univ. Bolzano), M. Marchesi (Univ. Cagliari), L.M.F. Moonen, M. Reisoli (Datasiel SpA), B. Rumpe (Technical Univ. Munich), B. Russo (Free Univ. Bolzano), N. Serra (Univ. Cagliari), A. Sillitti (Univ. Genova), G. Succi (Free Univ. Bolzano) (2002). *Research Roadmap on Agile Methodologies, NAME deliverable.*

Specification and Analysis of Embedded Systems – SEN2

Mission

The main research of this theme concentrates techniques to improve the quality of software components typically found in embedded systems such as communication protocols and systems in telecommunication. For this purpose we study and develop formal techniques for the unambiguous description, design and documentation of full software systems. An important vehicle is the language μCRL: micro Common Representation Language; others are timed automata and modal logics. We work with a wide range of analysis techniques and resources to prove that programmed systems exhibit their expected functionality. We employ methods from algebra and logics, as well as term rewriting. For the analysis of data and processes, dedicated tools for proof checking, state-space analysis and reduction, simulation, and testing are used. In order to assess the viability of various techniques and tools, we carry out experiments in the realm of fundamental distributed algorithms and embedded and hybrid control systems. Industrial application of our techniques, in the form of case studies, is an important activity.

Theme leader

Prof.dr. W.J. Fokkink

Subthemes

Name	Leader
SEN2.1 – Distributed Systems	J.C. van de Pol
SEN2.2 – Process Theory and Verification	W.J. Fokkink

SEN2.1 studies specification, analysis and testing techniques for computer controlled systems, allowing to design and build these more efficiently, and with fewer embedded faults. This is achieved by developing and implementing algorithms for the analysis and verification of distributed systems for the μCRL toolset. Furthermore, the techniques and algorithms are assessed and improved via case studies in various application domains (communication protocols, embedded systems, hybrid systems, etc.).

SEN2.2 deals with the development of methods for proof checking as a means to improve the quality of mathematical proofs. Furthermore, it is concerned with the fundamental study of verification techniques. Central issues are process theory, binary decision diagrams, automated deduction, and term rewriting. SEN2.2 develops technology that is applied in SEN2.1.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Drs. B. Badban	1.0	PhD student	2002-01-01 till 2005-12-31	SEN2.2: IT-VDS	D.2.4, F.3.1
Dr. S.C.C. Blom	1.0	project member	2000-03-01 till 2006-02-28	SEN2.1: SVC, ESI	D.2.4, F.3.1
Dr. C.F. Daws Poulastrou	1.0	researcher	2002-09-01 till 2002-11-30	SEN2.1	D.2.4, F.3.1
Prof.dr. W.J. Fokkink	0.8	theme leader, leader SEN 2.2	indefinite	SEN2.1: SVC, PROGRESS, KTVFM, ESI	D.2.4, F.3.1
Dipl.ing. N.Y. Ioustinova	1.0	project member	2001-10-01 till 2004-09-30	SEN2.1: SVC, KTVFM	D.2.4, F.3.1
Prof.dr. J.W. Klop	0.4	CWI Fellow	indefinite	SEN2.2	F.3.1
Drs. I.A. van Langevelde	1.0	project member	1998-08-01 till 2003-07-31	SEN2.1: SVC	D.2.4, F.3.1
Drs. B. Lisser	1.0	programmer	indefinite	SEN2.1: SVC	Not applicable
Drs. S.M. Orzan	1.0	PhD student	2000-06-01 till 2004-05-31	SEN2.1: PROGRESS	D.2.4, F.3.1
Drs. J. Pang	1.0	PhD student	2000-08-01 till 2004-07-31	SEN2.1: PROGRESS	D.2.4, F.3.1
Dr. J.C. van de Pol	1.0	leader SEN2.1	indefinite	SEN2.1: PROGRESS, SVC, KTVFM SEN2.2: IT-VDS	D.2.4, F.3.1
Drs. Y.S. Usenko	1.0	project member	1998-09-01 till 2002-08-31	SEN2.1: SVC, KTVFM	D.2.4, F.3.1
Drs. J.A. Valero Espada	1.0	PhD student	2001-03-01 till 2005-02-28	SEN2.1: PROGRESS	D.2.4, F.3.1
Drs. M.B. van der Zwaag	1.0	PhD student	1998-04-01 till 2002-03-31	SEN2.1: PRIMETIME	D.2.4, F.3.1

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. J.A. Bergstra (UvA)	0.1	advisor	indefinite	SEN2	D.2.4, F.3.1
Drs. H. Goeman (UL)	0.8	researcher	2001-01-01 till 2002-03-09	SEN2.2	F.3.1
Dr. R.J. van Glabbeek (Stanford Univ.)	1.0	researcher	2002-11-01 till 2002-12-31	SEN2.2	F.3.1
Prof.dr.ir. J.F. Groote (TUE)	0.2	researcher	2000-09-01 till 2002-08-31	SEN2.1	D.2.4, F.3.1
Dr. J. Hooman (KUN)	0.2	researcher	2001-01-31 till 2003-02-01	SEN2.1: PROGRESS	D.2.4, F.3.1
Dr. S. Mauw (TUE)	0.2	researcher	indefinite	SEN2.1	D.2.4, F.3.1

Scientific report

Highlights

- J.W. Klop received an honorary doctorate from the Univ. East Anglia on July 11.
- Acquisition of the project *Formal Methods for the Royal Netherlands Navy*, funded by the Dutch Ministry of Defense (joint with NLR).
- Acquisition of the project *Tools and Techniques for Integrating Performance Analysis and System Verification* in the NWO Open Competition (joint with TUE).
- PhD theses: S.P. Luttik (UvA), Y.S. Usenko (TUE), M.B. van der Zwaag (UvA).

PhD research

Title	PhD research of B. Badban
Period	January 2002–December 2005
Leader	J.C. van de Pol
Funding	NWO

Progress report. With *Van de Pol*, *Badban* developed a more expressive fragment of equational binary decision diagrams, augmented with the natural numbers. Equational binary decision diagrams play an important role in the theorem prover that was designed for μCRL.

Title	PhD research of S.M. Orzan
Period	January 2000–May 2004
Leader	J.C. van de Pol
Funding	STW (PROGRESS)

Progress report. With *Blom*, *Orzan* designed and implemented distributed algorithms for strong bisimulation reduction of state spaces. They also analyzed the theoretical complexities and tested the performance. With *Van de Pol* she defined a *space calculus*, where heterogeneous distributed dataspace systems can be described. They gave an operational semantics to this language and implemented tools to assist the functional and performance analysis of concrete distributed systems. Functional behaviour can be checked by an automatic translation to μCRL and the use of a model checker. Performance analysis can be done using an automatically generated distributed C-prototype.

Title	PhD research of J. Pang
Period	August 2000–July 2004
Leader	W.J. Fokkink
Funding	STW (PROGRESS)

Progress report. With *Fokkink*, *Pang* devised an improved cones and foci method for protocol verification. With *Fokkink* and *Groote* he composed a manual correctness proof of a sliding window protocol in μCRL, using this cones and foci method. He performed a number of case studies. With *Fokkink*, R. Hofman (VU) and R. Veldema (VU) he specified and analyzed the cache coherence protocol for a Java distributed share memory implementation. He supported with *Fokkink* and B. Karstens (UU) the redesign of the lift system using μCRL and timed automata. He analyzed the Needham-Schroeder public-key protocol in μCRL. He built a model of a lift system for staircases using hybrid automata.

Title	PhD research of J.A. Valero Espada
Period	March 2001–February 2005
Leader	J.C. van de Pol
Funding	STW (PROGRESS)

Progress report. With *Van de Pol*, *Valero Espada* investigated the distributed shared dataspace architecture JavaSpaces. A complete formal model of the middleware was specified in μCRL. This model was used to verify by model checking nontrivial JavaSpaces applications. With *Van de Pol*

he explored the theory of abstract interpretation, which is a framework for program analysis that consists of the extraction of approximations of programs by eliminating uninteresting information. The necessary theory and definitions for performing abstractions to μCRL specifications have been formalized and proved in PVS. Furthermore, small examples have been abstracted by hand and justified in PVS as well.

Title	PhD research of Y.S. Usenko
Period	February 1998–August 2002
Leader	W.J. Fokkink
Funding	Dr. Tesy (September 1998–August 2008)

Progress report. *Usenko* devised linearization algorithms for μCRL and timed μCRL specifications, and completed his PhD thesis. Furthermore, he collaborated in a project with NLR on modelling and verifying an in-flight data acquisition unit for Lynx helicopters.

Title	PhD research of M.B. van der Zwaag
Period	April 1998–March 2002
Leader	W.J. Fokkink
Funding	NWO

Progress report. *Van der Zwaag* completed his PhD thesis.

SEN2.1 – Distributed Systems

Title	IT-VDS – Integrating Techniques for the Verification of Distributed Systems
Period	January 2002–December 2005
Leader	J.C. van de Pol
Staff	B. Badban
Funding	NWO
Partner	TUE

Progress report. See the PhD research of *Badban* (page 63).

Title	SVC – Systems Validation Centre
Period	September 1998–December 2002
Leader	W.J. Fokkink
Staff	S.C.C. Blom, N.Y. Ioustinova, I.A. van Langevelde, B. Lisser, J.C. van de Pol, Y.S. Usenko
Funding	Telematics Institute
Partners	UT, TICO

Progress report. *Van de Pol* conducted research in verification of embedded software systems, by means of theorem proving and model checking. Several interesting combinations were found, such as detecting confluence information by a theorem prover, by which a symbolic reduction of the state space is reached. This research, which was performed in collaboration with *Blom*, makes model checking applicable to larger problems. Also prototype software-links to the theorem prover PVS and the explicit state model checker CAESAR/ALDEBARAN were constructed, and experimented with.

Van Langevelde worked with J.M.T. Romijn (TUE) on a Promela model of the IEEE P1394.1 Draft Standard for High Performance Serial Bus Bridges. *Van Langevelde* completed his research on symmetry in labelled transition systems; possible continuations of this work include a symbolical symmetry checker and a bisimulation reduction tool based on symmetry.

Lisser implemented and documented a new application programmers interface for the μCRL toolset, a new compiling rewriter, a recoverable distributed state space generator for extremely large state spaces, and a graphical user interface for viewing linearized process equations.

Ioustinova worked with N. Sidorova (TUE) and M. Steffen (Christian-Albrechts-Univ. Kiel) on an approach for automatic closing open asynchronous systems. The approach was implemented for systems specified in DTPromela.

Title	KTVFM – Case study on the relevance of formal methods for the Royal Netherlands Navy
Period	January 2002–June 2002
Leaders	W.J. Fokkink, J.C. van de Pol
Staff	N.Y. Ioustinova, Y.S. Usenko
Funding	Dutch Ministry of Defense
Partners	E. Kesseler (NLR), Y. Yushtein (NLR)

Progress report. A prototype of Automatic In-flight Data Acquisition Unit for Lynx helicopters was developed by means of refinement, using the B method.

Title	CES.5008 – Improving the quality of embedded systems by formal design and systematic testing
Period	August 2000–July 2004
Leader	W.J. Fokkink
Staff	J. Pang
Funding	STW (PROGRESS)
Partner	B. Wanschers (Add-Controls)

Progress report. See the PhD research of *Pang* (page 63).

Title	CES.5009 – Formal design, tooling, and prototype implementation of a real-time distributed shared data space
Period	June 2000–February 2005
Leader	J.C. van de Pol
Staff	S.M. Orzan, J.A. Valero Espada
Funding	STW (PROGRESS)
Partner	J. Hooman (KUN)

Progress report. J. Hooman and *Van de Pol* investigated formal reasoning about processes on top of the distributed dataspace architecture Splice of Thales Nederland. To study the basic properties of Splice and to support compositional verification, they defined a denotational semantics for a basic Splice-like language. To increase the confidence in this semantics, also an operational semantics was defined which was shown to be equivalent to the denotational one using PVS. Moreover, they proved that the denotational semantics distinguishes exactly those programs that have a different operational behaviour in a particular context. The resulting denotational semantics was applied to prove correctness of transparent replication of components on top of Splice.

For more information, see the PhD research of *Orzan* and *Valero Espada*.

Title	PRIMETIME – Protocols, Reference models and Interaction schemes for Multimedia Environments
Period	April 1998–March 2002
Leader	W.J. Fokkink
Staff	M.B. van der Zwaag
Funding	NWO

Progress report. See PhD research of *Van der Zwaag* for a progress report.

Title	ESI – Embedded Systems Institute
Period	May 2000–April 2002
Leader	W.J. Fokkink
Staff	S.C.C. Blom
Funding	CWI-TUE exchange programme
Partner	EESI, TUE

Progress report. Blom worked on a Java package for Lego and Fischer Technik with support for distributed programming.

SEN2.2 – Process Theory and Verification

Fokkink and *Van Glabbeek* proved inaxiomatizability results for n-nested trace and n-nested simulation semantics. Together with P. de Wind (VU) they worked on modal decomposition in structural operational semantics. *Fokkink* collaborated with T.D. Vu (VU) on bounded nondeterminism in structural operational semantics.

Klop completed a book on term rewriting systems that will be published by Cambridge University Press.

Daws Poulastrou worked with M. Kwiatkowska (Univ. Birmingham) and G. Norman (Univ. Birmingham) on the automatic verification of the IEEE-1394 root contention protocol with KRONOS.

Groote worked on a modal formula checker and the definition of concrete data types for μCRL. *Mauw* developed together with V. Bos (TUE) version 1.13 of a LaTeX macro package for drawing Message Sequence Charts. *Mauw* worked on the formalization of an operational semantics for black box security protocols and supporting tools.

Societal aspects and knowledge transfer

Projects with partners in public and private section

- SVC; see page 64.
- KTVFM; see page 64.
- CES.5008; see page 64.

Other items

- W.J. Fokkink, N.Y. Ioustinova, J.C. van de Pol and Y.S. Usenko collaborated with E. Kesseler and Y.A. Yushtein from NLR on a project aimed to transfer existing knowledge on formal methods to the Royal Netherlands Navy.
- 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 participated in the 'IEEE P1394.1 Reflector Discussion List', advocating the need for formal methods in standardization and pointing out weak points in the Draft Standard.
- J.C. van de Pol, S.M. Orzan and J.A. 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, meetings

- 2nd Workshop on Security: Applications, Formal aspects and Environments in the Netherlands, CWI, June 14: W.J. Fokkink, I.A. van Langevelde, J.C. van de Pol (organizer).
- Courses on μCRL and formal language theory at the VU: W.J. Fokkink.
- Course on μCRL, TUE: J.F. Groote.
- Course on process algebra, KUN: J.W. Klop.
- Weekly seminar (PAM) on process theory, protocol verification, term rewriting and theorem proving, CWI: I.A. van Langevelde (organizer).

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- 1st Workshop on Security: Applications, Formal aspects and Environments in the NetherLands, Enschede, January 18: W.J. Fokkink, J. Pang.
- 42nd European Study Group Mathematics with Industry, Amsterdam, February 18–22: S.M. Orzan, J. Pang.
- 6th Dutch Proof Tools Day, Utrecht, February 22: J.C. van de Pol (Lecture: *Verification of Distributed Systems with the μCRL toolset*), J. Pang, J.A. Valero Espada.
- 17th ACM Symposium on Applied Computing, Madrid, March 11–14: J.C. van de Pol (Lecture: *Formal Verification of Replication on a Distributed Data Space Architecture*).
- UNU/IIST 10th Anniversary Colloquium, Lisbon, March 16–22: J. Pang.
- Geburtstagskolloquium Prof. H. Schwichtenberg, Munich, April 5–7: J.C. van de Pol (Lecture: *Zero, Successor and Equality in Binary Decision Diagrams*).
- 5th International Conference on Coordination Models and Languages, York, April 7–12: J.A. Valero Espada (Lecture: *Formal Specification of JavaSpaces Architecture using μCRL*).
- 10th Jornadas de Concurrencia, Jaca, Spain, June 12–14: J.A. Valero Espada (Lecture: *μCRL Specification of Event Notification in JavaSpaces*).
- 11th Symposium on Formal Methods Europe, Copenhagen, July 20–24: N.Y. Ioustinova (Lecture: *Closing Open SDL-Systems for Model Checking with DTSpin*).
- Honorary Doctorate Professor J.W. Klop at the Univ. East Anglia, Norwich, July 10–11: J.J. Bruné, J.W. Klop (Lecture: *Proving Termination by Iterative Path Orders*).
- 7th International Workshop on Formal Methods for Industrial Critical Systems, Málaga, July 12–13: C.F. Daws Poulastrou (Lecture: *Automatic Verification of the IEEE-1394 Root Contention Protocol with KRONOS*), W.J. Fokkink.
- 13th International Conference on Rewriting Techniques and Applications, Copenhagen, July 22–24: J.C. van de Pol (Lecture: *JITty: A Rewriter with Strategy Annotations*).
- 14th Conference on Computer Aided Verification, Copenhagen, July 27–31: B. Badban, J.C. van de Pol (Lecture: *State Space Reduction by Proving Confluence*).
- 1st International Workshop on Parallel and Distributed Model Checking, Brno, Czech Republic, August 19: S.M. Orzan (Lecture: *A Distributed Algorithm for Strong Bisimulation Reduction of State Spaces*).
- 13th Conference on Concurrency Theory, Brno, August 20–23: W.J. Fokkink (Invited talk: *Refinement and Verification Applied to an In-Flight Data Acquisition Unit*), S.M. Orzan.
- 1st International Workshop on Foundations of Coordination Languages and Software Architectures, Brno, August 24: S.M. Orzan (Lecture: *Distribution of a Simple Shared Dataspace Architecture*).
- 3rd Workshop on Verification and Computational Logic, Pittsburgh, October 5: J.F. Groote (Lecture: *Computer Assisted Manipulation of Algebraic Process Specifications*), Y.S. Usenko (Lecture: *Linearization of μCRL Specifications*).
- TERMGRAPH 2002 and ICGT 2002, Barcelona, October 7–11: S.C.C. Blom (Lecture: *Lifting Infinite Normal Form Definitions from Term Rewriting to Term Graph Rewriting*).
- 4th International Conference on Formal Engineering Methods, Shanghai, October 21–25: J. Pang (Lecture: *Analysis of a Security Protocol in μCRL*).

- 3rd PROGRESS Workshop on Networked Embedded Systems, Utrecht, October 24: W.J. Fokkink, N.Y. Ioustinova, S.M. Orzan, J. Pang, J.C. van de Pol, J.A. Valero Espada.
- 1st International Symposium on Formal Methods for Components and Objects, Leiden, November 5–8: J. Hooman (Lecture: *Formal Reasoning about Components of a Distributed Dataspace Architecture*), J. Pang, J.A. Valero Espada.
- IPA Fall Days on Networked Embedded Systems, Hellevoetsluis, The Netherlands, November 18–22: B. Badban, S.C.C. Blom (Lecture: *A Java Package for Lego and Fischer Technik with Support for Distributed Programming*), I.A. van Langevelde (Lecture: *Bluff Your Way in Verification (with Buzzwords from IEEE 1394.1)*), J. Pang (Lecture: *Analysis of a Distributed System for Lifting Trucks*).
- 9th Asia Pacific Software Engineering Conference, Brisbane, December 4–6: N.Y. Ioustinova (Lecture: *Abstraction and Flow Analysis for Model Checking Open Asynchronous Systems*).

Project meetings

- EIFFRA meetings, Zürich, January 9, March 27, August 28: W.J. Fokkink.
- TT-Medal meeting, Helsinki, June 29, September 5: W.J. Fokkink.
- DeFINE/DeSIRE Workshop, Pisa, November 25–27: J.C. van de Pol (Lecture: *Formal Methods and Software Architecture for Dependability*).

Other lectures

- Philips Research Colloquium, Eindhoven, October 16: W.J. Fokkink (Lecture: *Verification of High Performance Serial Bus Bridges*).

Courses

- 2nd International Summer School on Computational Logic, Basilicate, Italy, August 24–30: B. Badban, N.Y. Ioustinova.
- Summerschool MDA for Embedded System Development, Brest, France, September 16–20: J. Pang.
- Calculemus Autumn School on Computer Algebra and Deduction Systems, Pisa, September 23–October 4: J.A. Valero Espada.

Memberships of committees and other professional activities

W.J. Fokkink

- Professor of Computer Science, VU.
- Coordinator CWI Security Platform.
- Member science committee IPA.
- Member steering committee SAFE-NL.
- Reviewer ITEA project VIVIAN.
- Member programme committee FMICS'02, Málaga, Spain, July 12–13.
- Member programme committee IPA Fall Days on Networked Embedded Systems, Hellevoetsluis, November 18–22.
- Member programme committee 8th Dutch Testing Day, CMG, Rotterdam, November 20.
- Member PhD committee V. Bos, TUE, March 7.
- Member PhD committee J. Kleijn, TUE, March 7.
- Member PhD committee S.P. Luttik, UvA, April 3.
- Member PhD committee M. Stoelinga, KUN, April 22.
- Member PhD committee M.B. van der Zwaag, UvA, October 11.
- Member PhD committee J. den Hartog, VU, October 17.
- Member PhD committee M. Bognar, VU, November 26.

J.C. van de Pol

- Vice-chair ERCIM working group FMICS.
- Reviewer ITEA project SOPHOCLES.

J.W. Klop

- Professor of Computer Science, VU.
- Head of Theoretical Computer Science, VU.
- Member editorial board CWI Tracts and Syllabi.
- Member IFIP WG 1.6 on Term Rewriting.
- Chairman Dutch Association for Theoretical Computer Science (NVTI).
- Editor NVTI Nieuwsbrief.

J.F. Groote

- Professor of Computer Science, TUE.
- Director of Education, Computer Science curriculum, TUE.
- Board member of the Eindhoven Embedded Systems Institute.

- Reviewer for the Ministry of Defense regarding the project 'Study on Relevance of Formal Methods for the Royal Netherlands Navy'.
- Member PhD committee S.P. Luttik, UvA, April 3.
- Member PhD committee M. Geilen, TUE, October 8.
- Member PhD committee M.B. van der Zwaag, UvA, October 11.

S. Mauw

- Managing director postgraduate study program for design engineers in software technology, TUE.
- Board member on education of post-graduate programem Information and Communication Technology, TUE.
- Member programme committee SAM'02, Las Vegas, USA, June 24–27.
- Member programme committee FORTE'02, Houston, USA, November 11–14.
- Co-advisor V. Bos, TUE, March 7.

Visitors

- J. Aghav (Tata Institute of Fundamental Research), Bombay, March 8–23 (Lecture: *Validation of Real-Time Constraints in Embedded Systems*).
- Th. Arts (Ericsson, Stockholm), April 12–21 (Lecture: *Formal Verification of Software*).
- S. Nain (IIT Delhi, New Delhi), May 14–July 19 (Lecture: *Complete and Omega Complete Axiomatizations of Process Equivalences*).

Publications

Papers in refereed journals and proceedings

Z.M. Ariola (Univ. Oregon), S.C.C. Blom (2002). Skew confluence and the lambda calculus with letrec. *Annals of Pure and Applied Logic* **117**(1–3), 95–168.

F. Bittner (UU), D. Denteener (Philips Research), S. Kronemeijer (Philips Research), M. Nuyens (UvA), S.M. Orzan, J. Rougemont (Heriot-Watt Univ.), E. Verbitskiy (EURANDOM), D. Znamenski (VUA) (2002). On lossless compression of 1-bit audio signals. *Proceedings 42nd European Study Group with Industry*, CWI Syllabus **51**, 2002.

S.C.C. Blom (2002). Lifting infinite normal form definitions from term rewriting to term graph rewriting. *Proceedings 1st Conference on Graph Transformation (TERMGRAPH'02)*, ENTCS.

S.C.C. Blom, S.M. Orzan (2002). A distributed algorithm for strong bisimulation reduction of state spaces. *Proceedings 1st Workshop on Parallel and Distributed Model Checking (PDMS'02)* **68**(4), ENTCS.

S.C.C. Blom, J.C. van de Pol (2002). State space reduction by proving confluence. *Proceedings 14th Conference on Computer Aided Verification (CAV'02)*, LNCS **2404**, Springer-Verlag, 596–609.

D. Chkliaev (TUE), J. Hooman, E. de Vink (TUE) (2002). Formal verification of an improved sliding window protocol. *Proceedings 3rd PROGRESS Workshop on Networked Embedded Systems*, Utrecht.

C.F. Daws Poulastrou, M. Kwiatkowska (Univ. Birmingham) G. Norman (Univ. Birmingham) (2002). Automatic verification of the IEEE-1394 root contention protocol with KRONOS. *Proceedings 7th Workshop on Formal Methods for Industrial Critical Systems (FMICS'02)*, ENTCS **66**(2).

A.G. Engels (TUE), S. Mauw, M.A. Reniers (TUE) (2002). A hierarchy of communication models for Message Sequence Charts. *Science of Computer Programming* **44**(3), 253–292.

L.M.G. Feijs (TUE), N. Goga (TUE), S. Mauw, J. Tretmans (TUE) (2002). Test selection, trace distance and heuristics. *Proceedings 14th Conference on Testing of Communicating Systems (TestCom'02)*, Berlin, Kluwer, 267–282.

W.J. Fokkink, N.Y. Ioustinova, E. Kesseler (NLR), J.C. van de Pol, Y.S. Usenko, Y.A. Yushtein (NLR) (2002). Refinement and verification applied to an in-flight data acquisition unit. *Proceedings 13th Conference on Concurrency Theory (CONCUR'02)*, LNCS **2421**, Springer-Verlag, 1–23.

J.F. Groote, B. Lisser (2002). Computer assisted manipulation of algebraic process specifications. *Proceedings 3rd Workshop on Verification and Computational Logic (VCL'02)*, Pittsburgh.

J. Hooman, J.C. van de Pol (2002). Formal verification of replication on a distributed data space architecture. *Proceedingsedings 17th ACM Symposium on Applied Computing (SAC'02)*, ACM Press, 351–358.

N.Y. Ioustinova, N. Sidorova (TUE), M. Steffen (Christian-Albrechts-Univ. Kiel) (2002). Closing open SDL-systems for model checking with DTSpin. *Proceedings 11th Symposium of Formal Methods Europe (FME'02)*, LNCS **2391**, Springer-Verlag, 531–548.

N.Y. Ioustinova, N. Sidorova (TUE), M. Steffen (Christian-Albrechts-Univ. Kiel) (2002). Abstraction and flow analysis for model checking open asynchronous systems. *Proceedings 9th Asia Pacific Software Engineering Conference*, IEEE Computer Society Press, 227–235.

S. Mauw, V. Bos (TUE) (2002). Drawing Message Sequence Charts with LaTeX. *TUGBOAT* **22**(1–2), 87–92.

S. Mauw, W.T. Wiersma (TUE), T.A.C. Willemse (TUE) (2002). Language-driven system design. *Proceedings 35th Annual Hawaii International Conference on System Sciences (HICSS-35)*, minitrack on Domain-Specific Languages for Software Engineering, Hawaii. IEEE Computer Society.

S.M. Orzan, J.C. van de Pol (2002). Verification of distributed dataspace architectures. *Proceedings 3rd PROGRESS Workshop on Networked Embedded Systems*, Utrecht.

S.M. Orzan, J.C. van de Pol (2002). Distribution of a simple shared dataspace architecture. *Proceedings 1st Workshop on Foundations of Coordination Languages and Software Architectures (FOCLASA'02)*, ENTCS **68**(3).

J. Pang, W.J. Fokkink, R.F.H. Hofman (VU), R.S. Veldema (VU) (2002). Model checking a Java distributed shared memory protocol implementation. *Proceedings 3rd PROGRESS Workshop on Networked Embedded Systems*, Utrecht.

J.C. van de Pol (2002). JITty: a rewriter with strategy annotations. *Proceedings 13th Conference on Rewriting Techniques and Applications (RTA'02)*, LNCS **2378**, Springer-Verlag, 367–370.

J.C. van de Pol, J.A. Valero Espada (2002). Formal specification of JavaSpaces architecture using μCRL. *Proceedings 5th Conference on Coordination Models and Languages (COORDINATION'02)*, LNCS **2315**, Springer-Verlag, 274–290.

J.C. van de Pol, J.A. Valero Espada (2002). μCRL specification of event notification in JavaSpaces. *Proceedings 10th Jornadas de Concurrencia*, Jaca, 191–204.

M.A. Reniers (TUE), J.F. Groote, M.B. van der Zwaag, J.J. van Wamel (2002). Completeness of timed μCRL. *Fundamenta Informaticae* **50**(3–4), 361–402.

Y.S. Usenko (2002). State space generation for the HAVi leader election protocol. *Science of Computer Programming* **43**(1), 1–33.

Y.S. Usenko (2002). Linearization of μCRL specifications. *Proceedings 3rd Workshop on Verification and Computational Logic (VCL'02)*, Pittsburgh.

CWI reports

SEN-R0201 SEN-R0207 SEN-R0209
SEN-R0225 SEN-R0227 SEN-R0228
SEN-R0229 SEN-R0231

See page 170 for complete titles.

Other publications

PhD theses

S.P. Luttik (2002). *Choice Quantification in Process Algebra*. Thesis advisor: Prof.dr. J.A. Bergstra, April 3, UvA.

Y.S. Usenko (2002). *Linearization in μCRL*. Thesis advisor: Prof.dr.ir. J.F. Groote, December 2, TUE.

M.B. van der Zwaag (2002). *Models and Logics for Process Algebra*. Thesis advisor Prof. dr. J.A. Bergstra, October 11, UvA.

Coordination Languages – SEN3

Mission

Large systems of distributed, heterogeneous software components play an increasingly important role within our society. The paradigm shift from objects to components in software engineering is necessitated by such societal demands, and is fuelled by Internet-driven software development. Using components means understanding how they individually interact with their environment, and specifying how they should engage in mutual, cooperative interactions in order for their composition to behave as a *coordinated* whole. Coordination models and languages address such key issues in Component Based Software

Engineering as specification, interaction, and dynamic composition of components.
The activity in this theme is focused on:

1. Development and application of compositional specification and verification methods for dynamically reconfigurable systems of components, and their utilization for semi-automatic verification tools.
2. Development of formal models for coordination, components, and component-based software that

   a capture the relevant semantics of a component, as well as its syntax, in its interface;
   b allow compositional derivation of the properties of a system from those of its constituent components; and
   c support notions of distribution and mobility. Development of and experiments with the coordination models and languages, and using them to work on real applications.

3. Study of the foundations of computation, notably operational semantics and coalgebraic methods, and the use of coalgebra and coinduction in the formal models for coordination and composition of components.

There is a close interaction between the three subthemes of SEN3 on our focal topics of coordination, components, and coalgebras. The importance of the symbiosis of experimental and theoretical computer science research is illustrated by the work on Reo (see page 75) and its underlying model of Abstract Behaviour Types. This work involves compositional construction of component connectors which uses coalgebra for its formal model, as well as specification and verification methods for component reconfiguration, involving programming logics. The practical relevance of the empirical systems work previously carried out within the now-complete Manifold project in this theme is underlined by the launching of the new spin-off company *Adaptive Planet* in 2002.

Theme leader

Prof.dr. J.J.M.M. Rutten

Subthemes

Name	Leader
SEN3.1 – Formal Methods for Coordination Languages	F.S. de Boer
SEN3.2 – Coordination and Component-Based Architectures	F. Arbab
SEN3.3 – Coalgebraic Models of Computation	J.J.M.M. Rutten

SEN3.1 is concerned with the development and application of formal methods for coordination languages. SEN3.2 deals with models, languages, and tools for coordination and compositional construction of component-based software systems for parallel, distributed, and mobile platforms. SEN3.3 is concerned with the study of coalgebra and coinduction as a general theory of various kinds of dynamical systems and as the basis for semantical models of various programming languages.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. F. Arbab	1.0	Leader SEN3.2	indefinite	SEN3.1: Mobi-J; SEN3.2: Tel. Inst. Archi-Mate, Adaptive Planet, B.V., NWO CBCS	D.1, D.2, D.3, F.1

Drs. F. Bartels	1.0	PhD student	1999-09-01 till 2003-08-01	SEN3.3: NWO PROMACS	F.1, F.3, F.4
Drs. C.L. Blom	1.0	programmer	indefinite	SEN3.2: NWO CBCS, Tel. Inst. ArchiMate	D.2
Dr. F.S. de Boer	0.7	leader SEN3.1	indefinite	SEN3.1: NWO Mobi-J; EU Omega; SEN3.2: Tel. Inst. ArchiMate; SEN3.3	D.2, F.3, F.4
F.J. Burger	0.6	programmer	indefinite	SEN3.2: Tel. Inst.; ArchiMate	D.2
Drs. C.T.H. Everaars	1.0	programmer	indefinite	SEN3.2	D.2
Drs. J.V. Guillen Scholten	1.0	PhD student	2001-07-01 till 2005-06-30	SEN3.2: Mobi-J, SEN3.2: Tel. Inst.; ArchiMate	D.1, D.2
Drs. J.F. Jacob	1.0	project member	2002-03-01 till 2006-02-28	SEN3.1: EU Omega	D.2, F.3, F.4
Dr. A.B. Kurz	1.0	post-doc	2001-09-16 till 2002-11-30	SEN3.3: NWO COCON	F.1, F.3, F.4
Prof.dr. J.J.M.M. Rutten	1.0	theme leader, leader SEN3.3	indefinite	SEN3.1, SEN3.2: Tel. Inst.; ArchiMate, SEN3.3: NWO PROMACS, NWO COCON, NWO COMOLO	D.2, F.1, F.3, F.4
Dr. L.W.N. van der Torre	1.0	post-doc	2002-12-01 till 2005-12-01	SEN3.2: Tel. Inst.; ArchiMate	D.1, D.2, F.1, F.3, F.4
Ir. P. Zoeteweij	1.0	PhD student	2001-04-01 till 2005-03-31	SEN3.2: NWO CBCS	D.1, D.2

Seconded

Name	**Fte**	**Function(s)**	**Period**	**Subthemes + projects**	**Classification (MSC or CR)**
E. Abraham-Mumm (CAU[2])	1.0	PhD student	2000-01-01 till 2004-01-01	SEN3.1	D.1, D.2
Prof.dr. J.W. de Bakker (retired)	0.8	senior researcher (until July 1st), advisor (from July 1st)	indefinite	SEN3.1, SEN3.2, SEN3.3	D.2, F.3, F.4
Dr. M.M. Bonsangue (UL)	0.2	senior researcher	indefinite	SEN3.1: NWO Mobi-J	D.2, F.3, F.4
Prof.dr. J.N. Kok (UL)	p.m.	advisor	indefinite	SEN3.1, SEN3.2, SEN3.3	D.2, F.3, F.4
Drs. C. Kupke (UvA)	0.4	PhD student	2002-02-01 till 2006-02-01	SEN3.3: NWO COMOLO	F.1, F.3, F.4
B. Romero Matia (Univ. Catalunga)	1.0	trainee	2002-10-01 till 2003-07-01	SEN3.2	D.1, D.2
A. Palmigiano (Univ. Barcelona)	1.0	trainee	2002-10-01 till 2002-12-31	SEN3.3	F.3, F.4
Drs. C. Pierik (UU)	0.1	PhD student	2002-01-01 till 2006-01-01	SEN3.1: NWO Mobi-J	D.2, F.3, F.4
P. Singh (IIT)	1.0	Master student	2002-05-14 till 2002-07-31	SEN3.2	D.1, D.2

[2]CAU, Christian-Albrechts-Universität zu Kiel, Germany

Scientific report

Highlights

- Organization of the First International Symposium on Formal Methods for Objects and Components (FMCO), November 5–8, 2002, Leiden, The Netherlands.
- Adaptive Planet, B.V. (in the Netherlands), is a spin-off of CWI with the partnership of the software company Adaptive Planet, Belgium. The main technology offered by Adaptive Planet, Belgium, is a component hot-swapping software that was developed to allow transparent, dynamic remote linking and loading of new or modified component code into a running system. Because this system has a very small foot-print, it is especially suitable for the mobile device market. The complementarity of this system with the work in SEN3 on Manifold and Reo led to the formation of the spin-off to merge the hot-swapping system with Manifold and exploit the resulting technology. Adaptive Planet sees Manifold as a first step toward incorporating the powerful exogenous coordination model of Reo into their future software products.
- After a career of 38 years with CWI (and formerly MC), J.W. de Bakker left CWI on July 1. See also SEN general on page 49.

PhD research

Title	PhD research of F. Bartels
Period	September 1999–August 2003
Leader	J.J.M.M. Rutten
Funding	NWO (PROMACS project)
Partners	TUE (Baeten, Andova)

Progress report. The study of categorical formulations of well-behaved operator specification formats was continued. The main part of the work was spent on establishing a tight correspondence between natural transformations of a given type and sets of transition rules in a certain format. One result of this effort was the introduction of PGSOS, an adaptation of the GSOS specification format to probabilistic transition systems.

Title	PhD research of J.V. Guillen Scholten
Period	July 2001–June 2005
Leader	F. Arbab
Funding	CWI, Telematics Institute (ArchiMate)
Partner	CAU, De Roever: Mobi-J

Progress report. Work on building a component-based coordination framework where components communicate through and are coordinated by mobile channels continued in 2002. The focus was on the implementation of mobile channels in distributed environments and on schemes to enable components to use these channels. The framework is now defined and its Java implementation is under way. Additionally, a state-of-the-art study of enterprise architecture modelling tools was conducted for the ArchiMate project, aiming to develop visualization of architectures in an integrated semantic framework.

Title	PhD research of C. Kupke
Period	February 2002–January 2006
Leader	J.J.M.M. Rutten
Funding	NWO (COMOLO project)
Partners	UvA (Venema), KUN (Jacobs, Hughes)

Progress report. Kupke started his PhD project about Coalgebras and Modal Logic early 2002. He has acquainted himself with modal logic, universal algebra, and the theory of coalgebras and category theory. Some first results have been obtained on categories of coalgebras over the category of Stone spaces. There is a close relation to modal logic as one can obtain mathematically adequate semantics for modal logic by considering coalgebras for the so-called Vietoris functor.

Title	PhD research of P. Zoeteweij
Period	April 2001–March 2005
Leader	F. Arbab
Funding	NWO (CBCS project)
Partner	PNA1 (Apt)

Progress report. As part of the project 'Coordination-Based Parallel Constraint Solving' the use of the DICE framework as a platform for cooperation of constraint solvers was investigated. Solver cooperation is an important motivation for parallel or distributed constraint solving. A number of extensions to the existing framework have been proposed, to make it more applicable in this area. These extensions are currently being implemented.

Title	PhD research of C. Pierik
Period	January 2002 – January 2006
Leader	F.S. de Boer
Funding	UU
Partner	UU (Meyer)

Progress report. Pierik has developed a tool which supports the specification and verifica-

tion of annotated object-oriented flow-charts. This tool will be extended to (sequential) Java programs with sub-typing (inheritance) and exception handling.

Title	PhD research of E. Abraham-Mumm
Period	January 2000–January 2004
Leader	F.S. de Boer
Funding	NWO/DFG
Partner	CAU (De Roever)

Progress report. *Abraham-Mumm* is a PhD student of CAU (Kiel, Germany) funded by the Mobi-J project. Under supervision of *De Boer* and W.P. de Roever (CAU, Kiel) she has developed a proof theory for the multi-threaded flow of control in Java. Currently, she is developing a front-end tool for PVS which generates the verification conditions of an annotated (multi-threaded) Java program.

SEN3.1 – Formal Methods for Coordination Languages

The research in this subtheme concerns the development and application of formal methods for dynamically reconfigurable systems with special emphasis on coordination languages and object-oriented programming languages like Java. The application of formal methods involves the development of tool-support for the computer-aided specification and verification.

Title	OMEGA- Correct Development of Real-Time Embedded Systems in UML (Unified Modelling Language)
Period	January 2002 – January 2005
Leader	F.S. de Boer
Staff	F.S. de Boer, M.M. Bonsangue, J.F. Jacob
Funding	EU project IST-2001-33522
Partners	Verimag (Sifakis), CAU (De Roever), KUN (Hooman), Weizmann Institute (Pnueli, Harel), Oldenburg (Damm), PSA Peugeot Citroën, Daimler Chrysler, Telelogic, I-Logix

Progress report. This project aims at the definition of a development methodology in UML for embedded and real-time systems based on formal techniques. Until now CWI has developed in this context (1) a formal model of components in UML: *De Boer, Bonsangue*, and *Jacob*, (2) an extension of the Object Constraint Language OCL: *De Boer, Bonsangue*, and the PhD student M. Kyas (CAU, under supervision of *De Boer*), and (3) a formal semantics of the kernel model language which consists of a subset of UML specifically tailored towards the application of formal specification and verification techniques (by *De Boer*).

Title	Mobi-J: Assertional methods for mobile asynchronous channels in Java
Period	November 2001–November 2004
Leader	F.S. de Boer
Staff	F. Arbab, F.S. de Boer, M.M. Bonsangue, J.V. Guillen Scholten, J.F. Jacob
Funding	NWO
Partners	CWI, Leiden Institute for Advanced Computer Science (LIACS) (Bonsangue), CAU (De Roever)

Progress report. The project aims at the development of a programming environment which supports component-based design and verification of Java programs. *Guillen Scholten* under supervision of *Arbab, De Boer*, and *Bonsangue*, has defined an extension of the Java language called Mobi-J with a notion of component which allows for the encapsulation of its internal data-processing and composition by means of mobile asynchronous channels. Under supervision of *De Boer*, De Roever and the PhD student Abraham-Mumm (CAU) have developed together with M. Steffen (CAU) an assertional proof method for the specification and verification of the multi-threaded flow of control in Java. This assertional method extends and generalizes the Object Constraint Language (OCL) used in the Unified Modelling Language (UML). Furthermore PhD student *Pierik* (UU, under supervision of *De Boer*) has developed tool-support for the specification and verification of Java programs. The master student R. de Haan (UvA, supervised by *Klint* and *De Boer*) additionally has developed a tool which makes use of the ASF+SDF Meta-Environment for the generation of verification conditions.

We organized the FMCO 2002, the first international symposium on formal methods for objects and components, November 5–8, 2002, Leiden, The Netherlands. This symposium was organized in the context of the bilateral NWO/DFG project Mobi-J by *De Boer, Bonsangue* and W.P. de Roever (CAU). FMCO 2002 was sponsored by CWI, IPA, EATCS, KNAW,

LIACS, Lorentz Center, Microsoft, and the EU project OMEGA.

FMCO 2002 has been a very successful event which provided an inspiring environment for top researchers in the areas of software engineering and formal methods to discuss the concepts of reusability and modifiability in component-based and object-oriented software systems. There were about 100 participants in total from all over the world (The Netherlands, Germany, UK, and other European countries, USA, Japan, Hong Kong, Korea). The results will be published in *Lecture Notes in Computer Science* by Springer-Verlag and in the sister journals *Theoretical Computer Science and Science of Computer Programming* by Elsevier.

Currently we are organizing FMCO 2003, November, 2003, in Leiden, The Netherlands.

SEN3.2 – Coordination and Component-Based Architectures

The research in this subtheme is focused on the development of formal models for components and component-based software that enable construction of systems by composition of exogenously coordinated software components, allow compositional derivation of the properties of a system from those of its constituent components, and support notions of distribution and mobility. The objective of this work is to use the models and formalisms we develop as the foundation for our implementation of practical component-based software engineering tools and support environments.

Title	ArchiMate – Enterprise Architecture Animation
Period	July 2002–December 2004
Leader	F. Arbab
Staff	F. Arbab, C.L. Blom, F.S. de Boer, F.J. Burger, J.J.M.M. Rutten, J.V. Guillen Scholten, L.W.N. van der Torre
Funding	Telematics Institute
Partners	Telematics Institute, Ordina Institute, KUN, UL, ABP, ABN-AMRO, Belastingdienst

Progress report. The goal of this project is to provide an integration of architectures – principles, methods and models – used in the design and realization of organizational structures, business processes, information systems, and infrastructures. An intensive study of the state of the art in enterprise architecture modelling tools was conducted in 2002, in which our group at CWI took a leading role. The work on the visualization engine of the ArchiMate project, in which CWI is the leading partner, and the semantic model for representation of architectural concepts, in which CWI is a major player, started in 2002 and is proceeding as planned. Our project staff was completed in December 2002, when *Van der Torre* joined SEN3 as a post-doc to work on ArchiMate. The first draft for the conceptual model of ArchiMate was produced.

Title	CBCS – Coordination Based Constraint Solvers
Period	2000–2003
Leader	F. Arbab
Staff	F. Arbab, C.L. Blom, P. Zoeteweij
Funding	NWO
Partners	PNA1 (Apt), Univ. Nantes (Monfroy)

Progress report. With planned improvements to the DICE framework, its applicability as a platform for cooperation of constraint solvers has been investigated. This identified a number of necessary extensions that are currently being implemented. The partial results of this work were presented in international workshops and conferences in 2002. *Arbab* worked on adding fault tolerance to the BTTF distributed termination detection algorithm and *Blom* implemented the new version of this algorithm, incorporating proper instrumentation to yield actual performance measurements.

Title	SEEDIS – Software Engineering Environments for Distributed Information Systems
Period	November 1999–April 2002
Leader	F. Arbab
Staff	F. Arbab, F.J. Burger, C.T.H. Everaars
Funding	EU
Partners	Univ. Cyprus (Papadopoulos), Univ. East Anglia (Glauert), Univ. Manchester (Banach), Space Applications Services, Belgium

Progress report. The SEEDIS project was concluded in 2002 with a workshop organized in Cyprus. In addition to project partners, this workshop was also attended by researchers from LIACS. The final report of this project was submitted to and accepted by the European Commission.

Title	NA – Implementation of a sparse grid method for time-dependent advection-diffusion-reaction-reaction-problems
Period	November 2001–November 2002
Leader	C.T.H. Everaars
Staff	F. Arbab, C.T.H. Everaars
Funding	NCF
Partner	MAS2 (Koren)

Progress report. This research focused on the parallelization of a sparse-grid method for time-dependent advection-diffusion problems. The starting point was a sequential ANSI C program that through a coarse-grain restructuring (a cut-and-paste method) was reorganized into a new parallel/distributed structure. The glue code necessary in the cut-and-paste work is written in the coordination language Manifold. The resulting renovated software runs more efficiently in modern parallel/distributed environments. The final report of the project is in preparation.

Title	Reo – Compositional Connectors for Coordination of Components
Period	2002–2005
Leader	F. Arbab
Staff	F. Arbab, F.S. de Boer, M.M. Bonsangue, C.T.H. Everaars, J.J.M.M. Rutten, J.V. Guillen Scholten, P. Singh, B. Romero Matia
Funding	CWI
Partner	LIACS

Progress report. Generalization of the concepts in Reo has led to the notion of Abstract Behaviour Types as a model for describing components, their interfaces, and their coordinating connectors. *Rutten* has produced a coalgebraic formal semantics for a kernel of Reo. *Guillen Scholten's* work on a distributed Java implementation of mobile channels continued in 2002, to produce an underlying platform for Reo. A summer student intern, *Singh*, developed a proof-of-concept simulator for Reo. *Romero Matia* started to work on a GUI for the visual programming environment of Reo as her Masters thesis project.

Title	Adaptive Planet – Spin-off Technology Transfer
Period	January 2002–December 2004
Leader	F. Arbab
Staff	F. Arbab, C.L. Blom, F.J. Burger, C.T.H. Everaars
Funding	CWI
Partner	Adaptive Planet, B.V.

Progress report. *Designer* is a software product offering of Adaptive Planet, B.V. The design and implementation of *Designer* is intricately based on Manifold. In addition to the involvement of our staff for the purpose of technology transfer (of the Manifold system to Adaptive Planet), our collaboration in the design and implementation of the preliminary version of the *Designer* software addressed a few necessary enhancements to the Manifold system. More substantially, we worked together with Adaptive Planet to successfully merge the Manifold system with their hot-swapping software, producing a commercially viable unified distributed component coordination technology upon which *Designer* is built and operates. Arbab organized an Adaptive Planet desk at two events: ICT Kennis Congres, The Hague, September 5–6 and CWI in Bedrijf, Amsterdam, October 5.

SEN3.3 – Coalgebraic Models of Computation

The activity in this subtheme is centered on the development of coalgebra as a unifying mathematical framework for (transition, dynamical, probabilistic) systems, various (object-oriented and component-based) programming paradigms, as well as different branches within computer science (semantics, formal methods) and mathematics (parts of system theory, discrete mathematics, analysis, combinatorics). In collaboration with *Arbab*, a formal semantics for the calculus of component connectors, Reo, has been developed, based on the final coalgebra of streams. In particular, proofs by coinduction of a number of connector network equivalences have been given.

Title	COCON – Coalgebra and control
Period	September 2001–September 2003
Leader	J.J.M.M. Rutten
Staff	A.B. Kurz, J.J.M.M. Rutten
Funding	NWO
Partners	MAS2 (Van Schuppen, Komenda), Ludwig-Max. Univ., Munich, Masaryk Univ. Brno

Progress report. Together with Komenda, *Kurz* has continued his work on coalgebraic methods for control theory. In addition, work on algebraic development techniques was continued together with Bidoit and Hennicker (LMU Munich). Together with Dirk Pattinson (LMU Munich) and Rosicky (Masaryk Univ.), connections between coalgebras and modal logic were studied. *Kurz* has left the project (and CWI) prematurely, because he accepted a lectureship at the Univ. of

Leicester. His position will be filled by Ms. M. Sirjani, early 2003.

Title	PROMACS - Probabilistic methods for the analysis of continuous systems
Period	September 1999–Augustus 2003
Leader	J.J.M.M. Rutten
Staff	F. Bartels, J.J.M.M. Rutten
Funding	NWO
Partners	TUE (Baeten, Andova)

Progress report. See page 72 (PhD research *Bartels*).

Title	COMOLO - Coalgebra and modal logic
Period	February 2002–January 2006
Leader	J.J.M.M. Rutten
Staff	C. Kupke, J.J.M.M. Rutten
Funding	NWO
Partners	UvA (Venema), KUN (Jacobs, Hughes)

Progress report. See page 72 (PhD research *Kupke*).

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- OMEGA; see page 73.
- ArchiMate; see page 74.
- Adaptive Planet; see page 75.
- SEEDIS; see page 74.

Teaching activities

- Tutorial 'A semantic thread from object to components', ECOOP 2002, June 10–14: F. Arbab, M.M. Bonsangue, F.S. de Boer.
- Course on programming logics for object-oriented languages, 14th European Summer School in Logic, Language and Information (ESSLLI), August 5–16: F.S. de Boer.
- Course on Algebraic Specification, VU, April–May: J.J.M.M. Rutten.
- Course on Streams and Coinduction, Univ. Montréal, September 30–October 4: J.J.M.M. Rutten.

Other external contacts

- Coordination of the EU project SEEDIS: F. Arbab (see page 74).
- Supervision of P. Singh, a trainee from IIT, New Delhi, 2002-05-14 till 2002-07-31: F. Arbab.
- Supervision of B. Romero Matia, a trainee from Technical Univ. of Catalunya (UPC), 2002-10-01 till 2003-07-01: F. Arbab.

Spin-offs

Adaptive Planet

- **Name**: Adaptive Planet, B.V.
- **Year of foundation**: 2002.
- **Mission**: Develop and market products and services based on an enabling technology that supports dynamically reconfigurable component-based software for applications running on distributed and mobile platforms.
- **Number of staff**: 3.
- **Theme related to spin-off**: SEN3.

Organization of conferences, workshops, courses, meetings

- ACG-colloquium (Amsterdam Coordination Group), bi-weekly.
- First International Symposium on Formal Methods for Objects and Components (FMCO), November 5–8, Leiden, The Netherlands. Co-organizer: F.S. de Boer.
- Adaptive Planet desk, CWI in Bedrijf, Amsterdam, October 5: F. Arbab.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- ETAPS 2002, Grenoble, France, February 8–14: F.S. de Boer.
- OMG-days, Amsterdam, February 5: J.V. Guillen Scholten.
- NVTI (Dutch Association for Theoretical Computer Science) Theory day, March 1, Amsterdam: J.W. de Bakker, F.S. de Boer, F. Arbab, M.M. Bonsangue, F. Bartels, A.B. Kurz, C. Kupke, J.J.M.M. Rutten.
- Estonian Winterschool in Computer Science (EWSCS), Estonia, March 3–8: F. Bartels (*Categorical Modelling of GSOS rules*).
- WATA 2002, Dresden, Germany, March 4–6: J.J.M.M. Rutten (*Coinductive Counting with Weighted Automata*).

- IPA Spring Days on Middleware, April 3–5: J.V. Guillen Scholten.
- CMCS 2002, Grenoble, France, April 6–7: F. Bartels (*GSOS for Probabilistic Systems, accepted for proceedings*), C. Kupke, J.J.M.M. Rutten (*Bisimulation in Enumerative Combinatorics, accepted for proceedings*).
- Coordination 2002, York, UK, April 8–14: F. Arbab (Lecture: *Coordination Through Channel Composition*, accepted refereed paper).
- FoSSaCS 2002, Grenoble, France, April: A.B. Kurz (*Definability, Canonical Models, Compactness for Finitary Coalgebraic Modal Logic*, accepted for proceedings).
- ECOOP 2002, Malaga, Spain, June 10–12: F. Arbab, M.M. Bonsangue, F.S. de Boer (*A Semantic Thread From Objects to Components*, one-day tutorial).
- ERCIM CologNet workshop on Contraint Solving (CLP), Cork, Ireland, June 19–21: P. Zoeteweij (*A Coordination-based Framework for Parallel Constraint Solving*).
- PDPTA 2002, Las Vegas, USA, June 24–27: F. Arbab (track chair).
- ICALP 2002, Malaga, Spain, July 12–13: F. Arbab (*Mobile Channels, Implementation Within and Outside Components*, accepted refereed paper).
- FOCIASA 2002, Brno, Czech Republic, August 23–25: J.V. Guillen Scholten (*A Channel-based Coordination Model for Components*).
- COMPSAC 2002, Oxford, UK, August 26–29: J.V. Guillen Scholten (*MoCha, A Middleware Based on Mobile Channels*).
- CP 2002, 8th International Conference on Principles and Practice of Constraint Programming, Cornell Univ., Ithaca, USA, September 8–13: P. Zoeteweij.
- COSOLV 2002, Second Workshop on Cooperative Solvers in Constraint Programming, Ithaca, USA, September 8: P. Zoeteweij (*Coordination-based Solver Cooperation in DICE*).
- FTRTFT 2002, Oldenburg, Germany, September 9–13: F.S. de Boer, J.F. Jacob.
- IFIP WG 2.2 meeting, Oldenburg, Germany, September 13–14: F.S. de Boer. J.J.M.M. Rutten.
- WADT 2002, Frauenchiemsee, Germany, September 23–27: A.B. Kurz (*Institutions for Notions of Behaviour and Reachable-Part*), J.J.M.M. Rutten (Invited lecture: *A Coinductive Calculus of Component Connectors*).
- CONCUR'02, Brno, Czech Republic, September: A.B. Kurz.
- Workshop on mathematical models and techniques for analysing systems, Montréal, Canada, September 30–October 4: J.J.M.M. Rutten (invited course on streams and coinduction).
- OZSL Schoolweek Amsterdam, October 14–18: C. Kupke.
- FMCO 2002, Leiden, November 5–8: F. Arbab (*Abstract Behavior Types*: Invited presentation: *A foundation model for components and their composition*), F.S. de Boer, M.M. Bonsangue, J.V. Guillen Scholten, J. Jacob, J.J.M.M. Rutten.

Working visits

- Institute of Cybernetics, Tallinn, Estonia, March 11–12: F. Bartels (Lecture: *Generalized Coinduction*).
- PC meeting MFCS 2002, Warsaw, Poland, April 26–28: J.J.M.M. Rutten.
- TUE, May 8: J.V. Guillen Scholten- Hosts: G. Russello, M. Chaudron.
- Coalgebra meeting, Nijmegen, May 17: F. Bartels (*Natural Transformations for Non-Category-Theorists*), A.B. Kurz, J.J.M.M. Rutten.
- LMU and GKLI, Munich, Germany, September 9–23: A.B. Kurz. Host: D. Pattinson.
- Oxford Univ., England, November 19–20: J.J.M.M. Rutten (*A Calculus of Component Connectors*). Host: A. Baltag.
- Univ. Paul Sabatier, Toulouse, France, December 12–15: L.W.N. van der Torre.

Project meetings

- Mobi-J workshop, Kiel, Germany, January 14–18: F. Arbab (*Coordination of Mobile Components*), F.S. de Boer, M.M. Bonsangue, J.V. Guillen Scholten.
- Omega project meeting, Grenoble, France, January 30–February 2: F.S. de Boer.
- Omega Project meeting, March 14–15: F.S. de Boer.
- INCO-KIT meeting, Larnaca, Cyprus, April 20–24: F. Arbab (Lecture: *Coordination through Channel Composition*), F.S. de Boer, M.M. Bonsangue (Lecture: *Proto-typing components*), J.V. Guillen Scholten (Lecture: *Mobile Channels, Implementation Within and Outside Components*), J.N. Kok, J.J.M.M. Rutten, P. Zoeteweij (Lecture: *A coordination-Based Framework for Parallel Constraint Solving*).

- *Omega Project meeting*, Paris, France, May 16–17: M.M. Bonsangue, J.F. Jacob (Lecture: *The Omega Component Model*).
- Mobi-J meeting, Freiburg, Germany, May 25–June 2: F. Arbab (Lecture: *Component Coordination Through Channel Composition*), F.S. de Boer, M.M. Bonsangue, J.V. Guillen Scholten (Lecture: *A Channel-based Coordination Model for Components*), J.F. Jacob, C. Pierik, J.J.M.M. Rutten.
- Omega Review Meeting, Brussels, Belgium, June 27–28: F.S. de Boer, J.F. Jacob.
- Omega meeting, Oldenburg, Germany, September 8: F.S. de Boer, J.F. Jacob.

Other lectures

- CWI Scientific Meeting, CWI, November 22: F. Arbab (Lecture: *Component Composition and Coordination in Reo*).

Courses

- Summerschool Models, Algebras and Logic of Engineering Software, Marktoberdorf, Germany, July 30–August 10: J.V. Guillen Scholten, C. Pierik.

Memberships of committees and other professional activities

F. Arbab

- Member IPA, Dutch Graduate School Institute for Programming and Algorithmics.
- Reviewer for the IST programme, the EC, March 18–25.
- Programme committee chair and Steering Committee Member, Coordination 2002, York, UK, April 8–11.
- Programme Committee member, IRMA 2002: International Conference on Information Resources Management Association, Seattle, WA, USA, May 19–22.
- Track Chair, Coordination and Component-Oriented Computing (Languages, Models, Systems), PDPTA 2002: International Conference on Parallel and Distributed Processing Techniques and Applications, Las Vegas, Nevada, USA, June 24–27.
- Associate Editor, Proceedings of the International Conference on Parallel and Distributed Processing Techniques and Applications Las Vegas, Nevada, USA, June 24–27.
- Programme committee Member, ICALP'02 Workshop on Formal Methods and Component Interaction, Malaga, Spain, July 12–13.
- Steering Committee Member and Vice chair, Euro-Par 2002, Paderborn, Germany, August 27–30.
- Vice chair, Euro-Par 2002 Workshop on Parallel Programming: Models, Methods, and Programming Languages, Paderborn, Germany, August 27–30.
- Coordinator, ESPRIT INCO-DC EC project 962144.
- Evaluator for the IST project ArchWare, the EC, November 28.

J.W. de Bakker

- Member Koninklijke Nederlandse Akademie van Wetenschappen, since 1989.
- Member Academia Europaea (AE), since 1990.
- Member AE committee on Mathematics and Informatics.
- Editor Cambridge University Press Tracts in Theoretical Computer Science.
- Editor *Theoretical Computer Science*.
- Editor *Fundamenta Informaticae*.
- Member emeritus IFIP Working Group 2.2 on Formal Description of Programming Concepts.
- Member Steering Committee European Educational Forum (IPA, BRICS, TUCS and four further consortia).
- Member Board of Curators Special Chair on Foundations of Computer Science, esp. Coalgebra, VU.
- Member VSNU National Visiting Commmittee on Education in Computer Science.
- (Co)project leader NWO/EW project Biography of Aad van Wijngaarden.
- Thesis advisor of J. den Hartog: Probabilistic extensions of semantical models, October 17, VU. Co-advisors: J.J.M.M. Rutten, E.P. de Vink.

F. Bartels

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

F.S. de Boer

- Member of the programme commitee of the Third workshop on Models for Time-Critical Systems (MTCS 2002), co-located with CONCUR 2002, Brno, Czech Republic, August 24.
- Member of the programme commitee of the IFIP Conference on Theoretical Computer Science (TCS 2002), Montréal, Canada, 2002.
- Member of the programme commitee of the Seventh International Symposium on Formal Techniques in Real Time and Fault Tolerant Systems) Conference, Oldenburg, Germany, September 9–12.
- Member of the organizing committee of the first International Symposium on Formal Methods for Components and Objects, November 5–8, Lorentz Center, UL.
- Co-advisor of W. de Vries: Agent Interaction: Abstract Approaches to Modelling, Programming and Verifying Multi-Agent Systems, November 11. Thesis advisors: J.-J. Ch. Meyer, J. Treur.
- Member IPA, Dutch Graduate School Institute for Programming and Algorithmics.
- Member of the IFIP Working Group 2.2 Formal Description of Programming Concepts.

M.M. Bonsangue

- Member IPA, Dutch Graduate School Institute for Programming and Algorithmics.
- Member of programme committee of the fifth International Conference on Coordination Models and Languages, York, UK, April.
- Member of the organizing committee of the first International Symposium on Formal Methods for Components and Objects, November 5–8, Lorentz Center, UL.
- Member of the user commitee of the project EIF.3959 'Formal design of industrial safety-critical systems' funded by the Dutch Technological Foundation STW.

C.T.H. Everaars

- Member MSc. Committee G.F. Duivesteijn, TUD, October 4.

J.V. Guillen Scholten

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

C. Kupke

- Member of Dutch Research School OZSL.

A.B. Kurz

- Organiser and Programme Committee chair of the workshop Categorical Methods for Concurrency, Interaction, and Mobility (CMCIM 2002), Brno, Czech Republic, August.
- Programme Committee member of the workshop Coalgebraic Methods in Computer Science (CMCS 2002), Grenoble, France, April.

J.J.M.M. Rutten

- Professor of Theoretical Computer Science ('Foundations of Computer Science, esp. Coalgebra'), VU, since December 1, 2001.
- (Co)project leader of NWO/EW projects: ProMACS (Probabilistic Methods for the Analysis of Continuous Systems), COMOLO (Coalgebra and Modal Logic), COCON (Coalgebra and Control).
- Editor of Elsevier's 'Electronic Notes in Theoretical Computer Science'.
- Editor of Book Series 'Semantic structures in computation', Kluwer Academic Press Publishers.
- Chairman of the Steering Committee of the CMCS (Coalgebraic Methods in Computer Science) workshop series.
- 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 MFCS 2002 and CMCS 2002.
- Co-advisor of J. den Hartog: Probabilistic extensions of semantical models, October 17, VU. Thesis advisor: J.W. de Bakker, Co-advisor: E.P. de Vink.
- Member of the PhD committee of M.B. van der Zwaag, October 11, UvA.
- Member of the PhD committee of S. Andova, November 26, TUE.

L.W.N. van der Torre

- PhD committee member for C. Garion, Univ. Paul Sabatier, Toulouse, France.
- Programme committee member, GTDT 2002 workshop, co-located with the AAAI02 conference, Edmonton, Canada, July 28.
- Programme committee member, International Workshop on Regulated Agent-Based Social Systems: Theories and Applications (RASTA'02) at AAMAS 2002.

- Programme committee member, 9th International Workshop on Non-Monotonic Reasoning (NMR'2002), Toulouse, France, April 19–21.
- Sixth International Workshop on Deontic Logic in Computer Science (Deon02).
- Organizer EurAsian Workshop on Agents for Information Management at the EURASIA-ICT 2002 conference, Shiraz, Iran, October 29–31.
- Organizer session on argumentation, dialogue and decision at the 9th Intl. Workshop on Non-Monotonic Reasoning (NMR'2002), Toulouse, France, April 19–21.

P. Zoeteweij

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

Visitors

- J. Hughes (KUN), January 15. (Lecture: *A complete deductive calculus for (implications of) coequations*). Host: J.J.M.M. Rutten.
- N. Aoumeur (Univ. Magdeburg, Germany), January 23–24. Host: F.S. de Boer.
- Prof. D.M. Berry (Univ. Waterloo, Canada), February 27–March 1. Host: F. Arbab.
- Dr. V. Schmitt (Univ. Leicester, UK) April 2–4. (Lecture: *A gentle overview of categories and enriched categories*). Host: J.J.M.M. Rutten.
- Prof. F. Mavaddat (Univ. Waterloo, Canada), April 4–7. Host: F. Arbab.
- W. Delavaux (Adaptive Planet, B.V.), October 15: (Lecture: *Combining the Activator, Manifold, and .... A road to the future?*). Host: F. Arbab.
- Prof. J. Rosicky (Masaryk Univ., Brno, Czech Republic), September 29–October 4. Host: A.B. Kurz.
- A. Baltag (Oxford Univ., UK), November 27: (Lecture: *A Hoare Logic for Knowledge Programs*). Host: J.J.M.M. Rutten.
- H. Verhagen (Stockholm Univ., Sweden), December 24. Host: L.W.N. van der Torre.

Publications

Books and book chapters

F. Arbab, C. Talcott (Stanford Univ.) (eds.) (2002). *Coordination models and languages*, Proceedings of the 5^{th} International Conference, Coordination 2002, York, UK, April 2002, LNCS **2315**, ISBN 3-540-43410-0.

A. Kurz (ed.) (2002). *Proceedings of the workshop on Categorical Methods for Concurrency*, Interaction, and Mobility, **ENTCS 68**(1), Elsevier Science B.V., ISBN 0444514120.

B. Jacobs (KUN), J.J.M.M. Rutten (eds.) (2002). *Coalgebraic methods in computer science*. Special issue of Theoretical Computer Science **280**(1–2), Elsevier Science B.V., 1–200.

M. Dastani (UU) Z. Huang (VU) L. van der Torre (2002). Dynamic desires. S. Parsons, P. Gmytrasiewicz, M. Wooldridge (eds.). *Game Theory and Decision Theory in Agent-Based Systems*, **5** of Multiagent systems, Artificial Societies and Simulated Organizations, Kluwer.

Papers in refereed journals and proceedings

F. Arbab, F.S. de Boer, M. Bonsangue, J.V. Guillen Scholten (2002). MoCha, a middleware based on mobile channels. *Proceedings of COMPSAC 2002*, IEEE Computer Society Press.

F. Arbab, F. Mavaddat (Univ. Waterloo) (2002). Coordination Through Channel Composition. *Proceedings of Coordination 2002*, LNCS **2315**, 21–38.

E. Abraham-Mumm (CAU, Kiel),F.S. de Boer, W.P. de Roever (CAU, Kiel), M. Steffen (CAU, Kiel) (2002). Verification for Java's Reentrant Multithreading Concept. M. Nielsen, U. Engborg (eds.). *Proceedings of Foundations of Software Science and Computation Structures (FOSSACS)*, LNCS **2303**, Springer, 5–20.

R. Banach (Univ. Manchester) F. Arbab, G.A. Papadopoulos (Univ. Cyprus) J.R.W. Glauert (Univ. East Anglia) (2002). IWIM Semantics via Fibred Automata. *Proceedings of Formal Methods and Component Interaction*, ENTCS **66**(4), Elsevier Science.

F. Bartels (2002). GSOS for probabilistic transition systems (extended abstract). Lawrence Moss (ed.). *Proceedings of Coalgebraic Methods in Computer Science* (CMCS'02), **65**(1) ENTCS.

F.S. de Boer, C. Pierik (2002). Computer-aided specification and verification of annotated object-oriented programs. *Proceedings of Formal Methods for Open Object-based Distributed Systems* (FMOODS), Kluwer.

F.S. de Boer, M. Gabbrielli (Univ. Bologna) M.C. Meo (Univ. Aquila) (2002).

Proving correctness of Timed Concurrent Constraint Programs. M. Nielsen, U. Engborg (eds.). *Proceedings of Foundations of Software Science and Computation Structures* (FOSSACS), LNCS **2303**, Springer, 37–51.

M.M. Bonsangue, J.N. Kok, G. Zavattaro (Univ. Bologna) (2002). Comparing coordination models and architectures using embeddings, *Science of Computer Programming*, **46**(1–2), 31–69.

J. Broersen (UU), M. Dastani (UU), J. Hulstijn (UU), L. van der Torre (2002). Goal generation in the BOID architecture. *Cognitive Science Quarterly*, special issue on 'Desires, goals, intentions, and values: Computational architectures', **2**(3–4), 428–447, Autumn/Winter 2002.

J. Broersen (UU), M. Dastani (UU), L. van der Torre (2002). Realistic Desires. *Journal of Applied Non-Classical Logics* **12**(2), 287–308.

J. Broersen (UU), M. Dastani (UU), Z. Huang (VU), L. van der Torre (2002). Trust and commitment in dynamic logic. *Proceedings of The First Eurasian Conference on Advances in Information and Communication Technology* (EurAsia ICT 2002), Shiraz, Iran, October 29–31. LNCS **2510**, Springer, 677–684.

M. Dastani (UU), L. van der Torre (2002). An Extension of BDICTL with Functional Dependencies and Components. *Proceedings of 9th International Conference on Logic for Programming, Artificial Intelligence, and Reasoning* (LPAR'02), Tbilisi, Georgia, October 14–18, LNCS **2514**, Springer, 115–129.

M. Dastani (UU) L. van der Torre (2002). Specifying the Merging of Desires into Goals in the Context of Beliefs. *Proceedings of The First Eurasian Conference on Advances in Information and Communication Technology* (EurAsia ICT 2002), Shiraz, Iran, October 29–31, LNCS **2510**, Springer, 824–831.

M. Dastani (UU), L. van der Torre (2002). A classification of cognitive agents. W.D. Gray, C.D. Schunn (eds.). *Proceedings of 24th Annual Conference of the Cognitive Science Society* (Cogsci'02), Washington DC, Augustus 7–10, Lawrence Erlbaum Associates, Mahwah, New Jersey, 256–261.

M. Dastani (UU), L. van der Torre (2002). What is a normative goal? *Proceedings of International Workshop on Regulated Agent-Based Social Systems: Theories and Applications* (RASTA'02), Bologna, Italy, July 16.

M. Dastani (UU), L. van der Torre (2002). Decisions and games for BD agents. *Game Theoretic and Decision Theoretic Agents* (GTDT'02), Papers from the AAAI workshop, Technical Report WS-02-06, AAAI Press, 37–43.

M. Dastani (UU), L. van der Torre (2002). What is a Joint Goal? Games with Beliefs and Defeasible Desires. *Proceedings of 9th Intl. Workshop on Non-Monotonic Reasoning* NMR'2002, Toulouse, France, April 19–21. http://arxiv.org/abs/cs.MA/0207022.

J.V. Guillen-Scholten, F. Arbab, F.S. de Boer, M.M. Bonsangue (2002). A Channel-based Coordination Model for Components. *Proceedings of 1st International Workshop on Foundations of Coordination Languages and Software Architectures*, ENTCS **68**(3), Elsevier Science B.V.

J.V. Guillen-Scholten, F. Arbab, F.S. de Boer, M.M. Bonsangue (2002). Mobile Channels, Implementation Within and Outside Components. *Proceedings of Formal Methods and Component Interaction*, ENTCS **66**(4), Elsevier Science B.V.

A. Kurz, R. Hennicker (LMU, Munich) (2002). On institutions for modular coalgebraic specifications. *Theoretical Computer Science.* **280**, 69–103.

A. Kurz (2002). Logics Admitting Final Semantics. M. Nielsen, U. Engborg (eds.). *Proceedings of FOSSACS 2002*, LNCS **2303**, Springer, Berlin, 238–249.

A. Kurz, D. Pattinson (LMU, Munich) (2002). Definability, Canonical Models, Compactness for Finitary Coalgebraic Modal Logic. L. Moss (ed.). *Proceedings of Coalgebraic Methods in Computer Science* (CMCS'02), ENTCS **65**(1), Elsevier Science B.V.

A. Kurz, J. Rosicky (Masaryk Univ. Brno) (2002). Modal Predicates and Coequations. L. Moss (ed.). *Proceedings of Coalgebraic Methods in Computer Science* (CMCS'02), ENTCS **65**(1) Elsevier Science B.V.

J. Lang (CNRS+ Univ. Toulouse), L. van der Torre, E. Weydert (Univ. Saarbrücken) (2002). Utilitarian desires. *Autonomous Agents and Multi-Agent Systems*, **5**(3), 329–363.

J.J.M.M. Rutten (2002). Coinductive counting: bisimulation in enumerative combinatorics. L. Moss (ed.). *Proceedings of Coalgebraic Methods in Computer Science* (CMCS '02), ENTCS **65**, Elsevier Science B.V., 1–20.

W. de Vries (UU), F.S. de Boer, K. Hindriks (UU), W. van der Hoek (UU), J.-J.Ch Meyer (UU) (2002). A programming language for coordinating group actions. *From Theory to Practice in Multi-Agent Systems*, LNAI **2296**.

P. Zoeteweij (2002). A coordination-Based Framework for Parallel Constraint Solving. B.O'Sullivan (ed.). *ERCIM/CologNet Workshop on Constraint Solving and Constraint Logic Programming, Workshop Notes*. Available at http://www.cs.ucc.ie/ osullb/ercim2002. A revised version will be published in a 2003 LNAI volume of selected papers from the workshop.

CWI reports

SEN-R0203	SEN-R0206	SEN-R0216
SEN-R0224	SEN-R0221	SEN-R0222
SEN-R0230	SEN-R0232	

See page 170 for complete titles.

Other publications

F. de Boer, M. van der Heijden, P. Klint, J. Rutten (eds.) (2002). *Liber Amicorum Jaco de Bakker*, CWI, August (Partly in Dutch.)

Articles in unrefereed journals and proceedings

F. Arbab (2002). Compositional Connectors for Coordination of Components. *CWI Annual Report 2001*, CWI, 21–25.

Software developed

Tool-support for the specification and verification of Java programs. See http://www.cs.uu.nl/ cees/vft

Deliverables for projects

In the EU project OMEGA (see page 73):

- Kernel model for behaviour description (D1.1.1)
- Kernel model for architecture description (D1.1.2)
- OCL extensions (D1.2.1)
- Software development process and methodology (D3.1)
- Review and progress reports (D5.1 and D5.2)
- Organization of the first Mobi-J (FMCO 2002) workshop (D6.5)
- ArchiMate the following has been deliverabled.

State of the art in architecture frameworks and tools, ArchiMate phase 0, deliverable 2: https://doc.telin.nl/dscgi/ds.py/Get/File-22327, May 2002.

Concepts for Architectural Description, ArchiMate deliverable 2.2.1: https://doc.telin.nl/dscgi/ds.py/Get/File-24121, November 2002.

State of the art in architecture concepts and description, ArchiMate deliverable 2.1: https://doc.telin.nl/dscgi/ds.py/Get/File-24149, November 2002.

State of the Art in Architecture Support, ArchiMate deliverable 3.1: https://doc.telin.nl/dscgi/ds.py/Get/File-27882/ArchiMate_D3.1_State_of_the_art_in_Architecture_Support.pdf, December 2002.

Newsletters

M.M. Bonsangue (2002). Towards a type-theoretic interpretation of components. *Newsletter of the NVTI* **6**, (Dutch Association for Theoretical Computer Science) 13–21.

J.J.M.M. Rutten, M. Bruné, J.W. Klop (eds.) VU (2002). *Newsletter of the NVTI* **6**, 1–48.

Evolutionary Systems and Applied Algorithmics – SEN4

Mission

The SEN4 group Evolutionary Systems and Applied Algorithmics focuses on fundamental research and development into intelligent and adaptive systems, or computational intelligence. The theme focuses on the combination of two fields, consisting of computer science techniques and application fields:

1. Techniques concern intelligent computation: Evolutionary and multi-agent systems, adaptive algorithms, and neural networks;
2. Application fields concern: Economics, management, and e-societies (like e-business).

Important topics concern markets and market mechanisms (economics), negotiation, auctions, and social aspects (game theory), and optimization and classification (management). We give an overview of the above two distinctions from the viewpoint of agent systems in relation to e-business and economics and from the viewpoint of optimization and classification as applied in the SEN4 theme.

Agent systems: e-business and economics

The concept of software agents in computer science as well as the concept of societies of (human) agents in economics and social sciences yield important areas of research. In both cases, adaptive behaviour of agents, based on their own point of view ('bounded rationality') and reactive on their dynamic environment, is essential. An important aspect of adaptivity for an agent is the skill of learning. This is a growing field of research, important for both agent technology (how to build a really-learning agent) and economics (how to simulate learning agents).

In order to allow learning in agent systems, computational learning techniques are necessary. In SEN4, especially evolutionary systems, neural networks and adaptive algorithms are investigated, in order to build the internals of learning agents in e-commerce applications as well as to simulate markets and market mechanisms in economics and in e-commerce agent systems.

Focus areas are amongst others:

1. adaptive strategies for trading, like negotiations, auctions (game theory), and dynamic pricing; this concerns learning behaviour, especially for high-frequency trading;

2. design and simulation of market mechanisms for e-commerce;

3. simulation of markets in the fields of ACE and CAS (agent-based computational economics; complex adaptive systems; emergence).

These three fields are closely interrelated as different levels of abstraction, from microscopic behaviour (the learning software of an agent) to macroscopic behaviour (behaviour of markets consisting of adaptive agents).

Optimization and classification

More traditional fields are optimization and classification. In these areas, intelligent computation techniques are important and the subject of much research. Neural networks as well as evolutionary algorithms are particularly investigated with respect to classification problems and active learning. Special attention is given to spiking neural networks, which are novel types of neural networks. Application areas are e.g., remote sensing, data mining, profiling, and agent implementations.

Adaptive discrete algorithms as well as evolutionary algorithms are designed for e.g., decision making in dynamic environments or constraint optimization problems, like, on-line process management or quality of service in information technology.

Theme leader

Prof.dr.ir. J.A. La Poutré

Subthemes

Name	Leader
SEN4.1 – Evolutionary Algorithms	J.A. La Poutré
SEN4.2 – Neural Networks	J.A. La Poutré
SEN4.3 – Discrete Algorithms	J.A. La Poutré

In 2003 SEN4.2 and SEN4.3 will be merged.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Drs. F. Alkemade	1.0	PhD student	1999-10-01 till 2003-10-01	SEN4.1; EESEM	I.2, I.6, J.4
Drs. S.M. Bohte	1.0	PhD student	1998-01-15 till 2009-05-15	SEN4.2, SEN4.1; FRNN, ASTA	I.2, I.5, J.4
Dr.ir. D.D.B. van Bragt	0.9	researcher	1998-10-01 till 2002-12-01	SEN4.1; ASTA, DEAL, FREA	I.2, J.4
Drs. E.H. Gerding	1.0	PhD student	1999-10-01 till 2003-10-01	SEN4.1; ASTA, FREA	I.2, I.6, J.4
Dr. J.I. van Hemert	0.1	post-doc	2002-12-01 till 2004-12-01	SEN4.1; FREA, DEAL	F.2, G.1, I.2
Dr.ir. P.J. 't Hoen	1.0	post-doc	2001-03-01 till 2005-03-01	SEN4.1; DEAL, ASTA, FRNN	I.2, I.6
Drs. E. Kutschinski	0.1	PhD student	2000-11-01 till 2002-02-01	SEN4.1; ASTA	I.2
Prof.dr.ir. J.A. La Poutré (0.2 seconded to TUE)	1.0	theme leader	indefinite	SEN4.1, SEN4.2, SEN4.3; ASTA, EESEM, DEAL, FREA, FRNN, QSMM	F.2, I.2, I.6, J.4
Dr. C.D.D. Neumann (0.2 seconded to UT)	1.0	post-doc	1998-07-01 till 2002-12-31	SEN4.2, FS	58J, 60H, 91H, J.4
Dr. D.J.A. Somefun	1.0	post-doc	2001-01-01 till 2004-12-31	SEN4.1; ASTA, FREA	I.2, J.4

Seconded

Prof.dr. J.N. Kok (UL)	0.1	advisor	indefinite	SEN4.2; FRNN	I.2, I.5

Scientific report

Highlights

- F. Alkemade was awarded the participation in and a grant for the prestigious summer school 'Complex Systems' (1 month) at the Santa Fe Institute, USA.
- E.H. Gerding was awarded the participation in and a grant for the EXYSTENCE Thematic Institute on 'Complex Systems' (1 month) Italy.
- Two major projects were acquired, viz.,
  - DEAL: Distributed Engine for Advanced Logistics, funded by the E.E.T. program (Economy, Ecology, and Technology) via Novem. See also page 86.
  - CIM: Cybernetic Incident Management, funded as a CIC 'doorbraak'-project (CIC: 'Competing with ICT Competences'). Partners are Almende, TUD, VU, Group4Falck, and CMotions. For SEN4 the project will start by the end of 2003.
- R. van Stee received his PhD.
- J.A. La Poutré was appointed chair of the BNVKI (Belgium Association Netherlands for Artificial Intelligence).
- J.A. La Poutré was appointed in the editorial board of the new journal *Computational Management Science* (Springer-Verlag).

PhD research

Title	PhD research of F. Alkemade
Period	October 1999–October 2003
Leaders	J.A. La Poutré, H.M. Amman (TUE)
Funding	NWO

Progress report. Research was done on an agent-based model of information contagion in a network of consumers, where the spread of information on a social network is investigated. The network consists of consumers that are exposed to the introduction of a new product. Consumers decide whether or not to buy the product based on their own preferences, the decisions of their

neighbours in the social network and the advertisements they receive about the product. Specially, it addresses the effect of the topology of the social network on the success of the product introduction: Are some types of networks more difficult to penetrate than others? To investigate this, three different advertising scenarios are considered for the firms. This work was done with C. Castaldi (Sant'Anna School of Advanced Studies, Pisa).

Research was done on the fundamentals of agent-based computational economics (ACE), where elements from economics and computer science are combined. In this work, focus is on the relation between the evolutionary technique that is used and the economic problem that is modelled, in particular for learning in a Cournot-Nash (CN) model as in previous literature. It is shown that a relation between economic model and settings of the evolutionary techniques must be sufficiently uncoupled, in order to have the evolutionary algorithms work well and to get robust results. Alternative ways of designing and implementing this relation are given, yielding more robust and different results. This work was done with *La Poutré* and H.M. Amman.

Also, research was done on intermediaries in an Electronic Trade Network. This addressed the question whether trading of information goods in electronic commerce has significant impact on the role of intermediaries. The role of intermediaries in an electronic trade network is studied when an information good is traded over the network. The central question is whether the traditional reasons for the existence of intermediaries will still hold in electronic markets. Two aspects are especially considered: Information advantage and risk reduction. This is studied through agent-based evolutionary computer simulations and network economics, modelling trading relationships by graphs. Results show that the presence of intermediaries increases price stability in the market when there are frequent price changes. In this case, well-informed intermediaries can find a profitable niche and attract a substantial customer base. This work was done with *La Poutré* and H.M. Amman.

Title	PhD research of E.H. Gerding
Period	November 1999–November 2003
Leader	J.A. La Poutré
Funding	Telematics Institute

Progress report. The research was mainly performed as part of the ASTA project. The effect of outside opportunities on bilateral bargaining strategies was investigated, using evolutionary algorithms. The research on bargaining with outside opportunities was further extended. It was found that the bargaining strategies which evolved resulted in very different outcomes if players have additional opportunities to come to an agreement. Negotiations of a single opportunity were modelled using the ultimatum game. A rational strategy (using the sub-game perfect equilibrium) is for the proposer to claim the maximum surplus and the responder to accept. Interestingly, the opposite result is found if the players have additional opportunities, depending on certain game settings. These settings are the total number of opportunities and the number of samples. This work is done with *La Poutré*.

Other research concerned the ING business case in ASTA, where financial news information is bundled and priced via negotiations. A fundamental aspect of the research concerned finding appropriate negotiation protocols which give buyers of information an incentive to reveal some of their preferences. Also, a prototype (demonstrator) has been built for negotiation of information in this business case, in collaboration with ING and TNO. (CWI: *Gerding, Somefun, Bohte* and *La Poutré*.

Title	PhD research of S.M. Bohte
Period	May 1998–May 2002
Leader	J.A. La Poutré, J.N. Kok
Funding	CWI (basic)

Progress report. The work has focused on two areas: combinatorial computations with spiking neural networks and a literature study on the circumstances where precisely timed spikes are observed in biological systems, in order to yield possible application in computational settings.

Performing combinatorial computations with neural networks is a notoriously 'hard' problem, blamed on the inability of neural networks to deal with structured information. This type of problem is also referred to as 'the binding problem'. The challenge is to efficiently represent the 'binding' of one feature to another, and in particular simultaneously with other 'bound' objects in the activations of neurons in neural networks. Our work has focused on solving this problem using neural activity groups ('vectors') combined with the specific properties of spiking neural networks. This work has shown that in this way, up to four

similar feature combinations can be represented and detected simultaneously in a spiking neural network (in line with human perceptual performance). This work was done with *La Poutré* and *Kok*.

The literature study on the circumstances where biological systems are found to use precisely timed spikes (published in the PhD thesis) concluded that almost all reports share one important feature: the task the animal was facing required fast and precise actions. It was even reported that the same behavioural experiment, when slowed down, the neurons observed yielded much less precise spike-times. This behaviour is consistent with the spiking mechanism as observed in real neurons *in vitro*. This conclusion can provide a direction for investigating how a single artificial neural network can deal with external signals that may have inherent time-courses on different time scales (slow vs fast).

SEN 4.1 – Evolutionary Algorithms

Title	ASTA – Autonomous Systems of Trade Agents in E-Commerce
Period	September 1999–December 2003
Leaders	J.A. La Poutré, P.J. 't Hoen
Staff	E.H. Gerding, D.J.A. Somefun, D.D.B. van Bragt, S.M. Bohte
Funding	Telematics Institute (project)
Partners	TNO-TPD, ING, KPN Research

Progress report. Research was performed into the design and implementation issues of competitive electronic markets in a distributed agent framework. A specific implementation of an earlier system for allocating consumer attention space was extended and further enhanced, taking into account communication complexity, on-line learning, and asynchronicity. (*'t Hoen, Bohte, Gerding, La Poutré.*)

In addition, a further study was done on the problem of applying price discrimination with an on-line adaptive algorithm. In particular, a (multi-variable) derivative follower algorithm with an adaptive step-size was further investigated and experimented with. (*Van Bragt, Somefun, La Poutré.*)

Also, research was performed on on-line bundling and pricing of information goods, and on recommender systems, from an economic and ICT point of view. Main aspects were that dynamic bundling and pricing can enhance the value extracting capacity of an information broker, while recommender systems can enhance customer lock-in. Especially, combining dynamic bundling and pricing with recommender systems appears to be fruitful. First experiments were performed to show the additional value of the approach. (*Somefun, La Poutré.*)

Furthermore, research on multi-issue and one-to-many negotiation was performed in the ING business case. This focused on how, with the use of appropriate multi-issue bargaining strategies, efficient bargain outcomes can be realized. This addressed the design of a market place for sales of information bundles, especially for multi-issue negotiation concerning the quality of service and price for bundle constituents. Negotiations were designed to be executed in a one-to-many setting. The design involved economics (pricing) as well as computer science and market mechanism design issues. (*Gerding, Bothe, Somefun, La Poutré.*)

Other work within the ASTA project is described in the PhD research of *Gerding* on page 85, including the joint construction of a demonstrator for the ING business case.

Title	EESEM – Evolutionary Exploration Systems for Electronic Markets
Period	October 1999–September 2003
Leader	J.A. La Poutré
Staff	F. Alkemade, H.M. Amman (TUE)
Funding	NWO (project)
Partner	TUE

For the progress report we refer to the PhD work of F. Alkemade on page 84.

Title	DEAL – Distributed Engine for Advanced Logistics
Period	April 2002–2006
Leader	J.A. La Poutré
Staff	P.J. 't Hoen, D.D.B. van Bragt
Funding	E.E.T. (Novem) (project)
Partners	Almende, EUR, VU, Vos Logistics, Post Kogeko Transport Group, Groeneveld Group

Progress report. Work was performed on the development of robust, distributed market mechanisms as part of Multi-Agent Systems (MASs), for usage in the logistics of the transportation sector. In this work, on-line, decentralized auctions are used as model, where agents (representing trucks) bid for cargo in a MAS logistics setting. Bidding strategies were then studied, which were novel for such a large-scale setting.

In the setting, agents have the opportunity to unilaterally *decommit* from contracts. SANDHOLM et al. have formally shown that by incorporating this decommitment option the degree of Pareto efficiency of the reached agreements can increase as agents can escape from premature local minima by adjusting their contracts.

In a series of computer experiments for the above transportation settings, it is shown that significant increase in performance (profit) can be realized by a company with agents who can decommit loads. As a necessary precondition, decommitment is only a clearly superior strategy if an agent is close to the limit of its capacity. This is a new, general result for agents capable of handling simultaneous tasks. Furthermore, the increase in performance for the (abstract) model of the transportation sector can be seen as a lower bound for expected increased performance in practice. This claim was substantiated through experiments that show that the relative impact of a decommitment strategy increases with the complexity of the world. This work was done with *'t Hoen, Van Bragt, La Poutré.*

Title	FREA – Fundamental Research on Economic Agents and on Evolutionary Algorithms
Period	indefinite
Leader	J.A. La Poutré
Staff	D.D.B. van Bragt, E.H. Gerding, D.J.A. Somefun, P.J. 't Hoen, J.A. van Hemert
Funding	CWI (basic)
Partners	UL, Nutech Solutions GmbH

Progress report. Research was performed on constraint satisfaction using classical techniques and evolutionary computation. Specifically, an empirical study using methods from both fields to solve binary constraint satisfaction problems in order to determine which technique is most appropriate for certain amounts of difficulty of such problems is conducted. It was further compared how well these techniques perform under a scale-up of these problems. Moreover, a more in-depth study into evolutionary algorithms was conducted, where the deficiencies of these algorithms are explained by observing the subset of the problem space that is visited. (*Van Hemert* and T. Bäck (UL / Nutech Solutions GmbH).)

Real-life negotiations typically involve multiple parties with different preferences for the different issues and bargaining strategies which change over time. Such a dynamic environment (with imperfect information) was studied with a multi-population evolutionary algorithm (EA). Each population represents an evolving collection of bargaining strategies in our set-up. The bargaining strategies are represented by a special kind of finite automata, which require only two transitions per state. It is shown that such automata (with a limited complexity) are a suitable choice in a computational setting. Also, an EA is described which generates highly-efficient bargaining automata in the course of time. The 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. (*Van Bragt, La Poutré.*)

Also, fundamental research was performed on areas and problems occurring in other (externally financed) projects, like ASTA. In the FREA project, the more fundamental parts were addressed. These subjects therefore coincide with those mentioned there and are described in these projects. (*Van Bragt, Gerding, Sumefun, La Poutré.*)

SEN 4.2 – Neural Networks

Title	FRNN – Fundamental Research on Neural Networks
Period	1998–2002
Leader	J.A. La Poutré
Staff	S.M. Bohte, J.N. Kok, P.J. 't Hoen
Funding	CWI (basic)
Partner	UL

Progress report. Fundamental research was performed in the area of spiking neural networks. For the first part, we refer to the PhD work of *Bohte* on page 85.

Subsequently, initial research was done on the development of Reinforcement Learning rules for spiking neural networks. This work was concerned with deriving algorithms for changing the weights for single spiking neurons using Policy Gradient Reinforcement Learning concepts. This is work is in progress. (*Bohte.*)

Neural networks were also developed for use in a on-line learning agent-system, where the neural network calculates bids in an auction. The case of the auctioning of consumer attention space (in the ASTA project) was considered as the application. A basic solution was designed to learn bids as a function of a multi-dimensional input, which

characterizes the item to be auctioned. The approach was based on Radial Basis Function Networks, allowing local and simultaneous learning, which appeared important for this setting. (*'t Hoen, Bohte, La Poutré.*)

Title	FS – Financial Systems
Period	2001–December 2002
Staff	C.D.D. Neumann
Funding	CWI (basic)
Partner	UT

Progress report. The work on pricing of complex financial derivatives has been further 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. The research focused on two subjects, jump diffusion models and Markov functional models.

Jump diffusion models include jumps in the stochastic modelling of asset prices. 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.

Markov functional models aim to describe models containing a large number of assets using only a small number of stochastic factors. Such models are strongly constrained by no-arbitrage restrictions. They play an important role in pricing complex interest rate derivatives, such as Bermudean swaptions. Work is done based on the idea to use a subset of the assets as driving factors for the model. All other assets are to be regarded as derivative assets on this subset.

SEN 4.3 – Discrete Algorithms

Title	QSMM – Quality of Service for Multimedia Systems
Period	1999–2004
Leader	J.A. La Poutré
Staff	Vacancy
Funding	NWO (project)
Partners	Philips Research, TUE

This project was suspended due to a vacancy and will be resumed in 2003.

Societal aspects and knowledge transfer

Partners in public and private sector

- ASTA; see page 86.
- DEAL; see page 86.
- QSMM; see page 88.

Teaching activities

Course 'Distributed Software Architectures', especially for the part concerning agent systems: J.A. La Poutré (lecturer).

Other external contacts

Contacts exist also with the Telematics Institute, TUD, UM, Univ. College London, INRIA, Freiburg Univ., SICS, and Cornell Univ. Also, the trainee I. Vaishnavi of IIT New Delhi was supervised at SEN4.

Organization of conferences, workshops, courses, meetings

- SEN4 seminars (March 6,May 2,October 4, October 17,October 24, November 20, December 19).
- SEN4 Journal Club meetings (monthly).
- ASTA technical meetings (as often as needed).

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- 2nd Workshop on Computational Intelligence in Economics and Finance (CIEF 2002/JCIS 2002, Raleigh NC, USA, March 8–14: F. Alkemade (Lecture: *Boundedly Rational Agents Achieving Collusive Outcomes in the Cournot Game*, accepted for refereed proceedings).
- IEEE European Symposium on Artificial Neural Networks (ESANN) 2002, Brugge, Belgium, April 23–24: S.M. Bohte (Lecture: *Modeling efficient conjunction detection with spiking neural networks*, accepted for refereed proceedings).
- STT Conference Dealing with the Data Flood: Mining Data, Text, and Multimedia, The Hague, April 23: J.A. La Poutré (Invited presentation: *Trade Agents*).

- International Joint Conference on Neural Networks WCCI-IJCNN 2002, World Conference on Computational Intelligence, Honolulu, USA, May 12–17: S.M. Bohte (Invited presentation: *Implementations of efficient conjunction detection in spiking neural networks*, accepted for refereed proceedings).
- IEEE Conference on Evolutionary Computation WCCI-CEC 2002, World Conference on Computational Intelligence, Honolulu, USA, May 12–17: D.D.B. van Bragt (Invited presentation: *Co-evolving Automata Negotiate with a Variety of Opponents*, accepted for refereed proceedings).
- Workshop on Economics with Heterogeneous Interacting Agents WEHIA 2002, Trieste, Italy, May 30–June 1: E.H. Gerding (Invited presentation: *Multi-Issue Bargaining with Multiple Encounters*, accepted for refereed proceedings).
- Dagstuhl Seminar on Electronic Market Design, Dagstuhl, Germany, June 9–14: J.A. La Poutré (Invited presentation: *Competitive Market-Based Allocation of Consumer Attention Space: Conceptual System, Agent Architecture and Learning Software Agents*).
- Conference on Economics and Finance (CEF) 2002, Aix-en-Provence, France, June 27–29: D.D.B. van Bragt (Lecture: *A robust Algorithm for on-line Price Discrimination*), J.A. La Poutré (Lecture: *The Role of Information in an Electronic Trade Network*).
- Workshop on Agent-Mediated Electronic Commerce (AMEC) IV, Bologna, Italy, July 15: E.H. Gerding, P.J. 't Hoen (Lecture: *An extensible agent architecture for a competitive market-based allocation of consumer attention space*, accepted for refereed proceedings).
- ACM conference on Multi-Agent Systems (AAMAS), Bologna, Italy, July 16–19: E.H. Gerding, P.J. 't Hoen.
- ICT-Kenniscongres, The Hague, September 5–6: E.H. Gerding, S.M. Bohte, D.D.B. van Bragt, J.A. La Poutré (Lecture: *Demonstration of the ASTA software*).
- Financial Modeling and Optimization under Uncertainty, Munich, Germany, October 8–11: D.D.B. van Bragt.
- Belgium-Netherlands Artificial Intelligence Conference (BNAIC) 2002, Leuven, Belgium, October 21–22: E.H. Gerding, J.A. La Poutré, S.M. Bohte (Lecture: *Competitive Market Based Advertising*, accepted for proceedings).
- Quantitative Methods in Finance 2002, Cairns, Australia, December 9–13: C.D.D. Neumann (Lecture: *Discontinuous Markov Functionals in Term Structure Modeling, Local Scale Invariance and Term Structure Modeling*).

Working visits

- EXYSTENCE Thematic Institute on 'Complex Systems', Trieste, Italy, May 6–June 1: E.H. Gerding.
- Conference 'Amsterdam, Center of expertise', Beurs van Berlage, Amsterdam, May 8: C.D.D. Neumann.
- Lecture by P. Carr, UT, May 15: C.D.D. Neumann.
- Santa Fe Institute Complex Systems Summer School, Santa Fe Institute, Santa Fe, USA, June 9–July 6: F. Alkemade.

Project meetings

- DEAL Kick-off meeting, November 15, Rotterdam: J.A. La Poutré (Lecture: *Negotiations, Auctions, and Market Mechanisms in Agent Systems*), P.J. 't Hoen, S.M. Bohte.
- ASTA plenary meetings, monthly, CWI, J.A. La Poutré, E.H. Gerding, D.D.B. van Bragt, D.J.A. Somefun, S.M. Bohte.
- ERCIM HIT meeting, Nice, France, November 6: J.A. La Poutré.
- I-CARE plenary meetings, Utrecht, July 4 , July 17, November 21, December 18: J.A. La Poutré.

Other lectures

- Seminar Telematics Institute, February 25: J.A. La Poutré (Lecture: *Trade Agents*).
- I&T colloquium, TUE, May 3: J.A. La Poutré (Lecture: *Trading Agent Systems*).
- Algorithms Colloquium, UU, September 13: J.A. La Poutré (Lecture: *Competitive Market-Based Allocation by Learning Agents*).
- CWI in Bedrijf, CWI, October 18: S.M. Bothte (Lecture: *De Software Agent aan de Macht: van Krantenverkoper tot Kunstmatige Intelligentie*).

Memberships of committees and other professional activities

J.A. La Poutré

- Member of the Editorial Board of *Netnomics*, Journal for internet economics and e-commerce; Kluwer Science Publishers (since 1999).

- Member of the Editorial Board of *e-JEMED, the Electronic Journal of Evolutionary Modeling and Economic Dynamics* (since 2001).
- Member of the Editorial Board of *Computational Management Science (CMS)*, Springer-Verlag, new journal, to appear first in 2003 (since 2002).
- Chair of the BNVKI (the Belgium Association Netherlands for Artificial Intelligence) (since October 2002).
- Member of the program committee of the the Belgium-Netherlands Artificial Intelligence Conference, Kaatsheuvel, The Netherlands, November 1–2.
- Member of the program committee of the twelfth International World Wide Web Conference (WWW2003), section e-commerce, Budapest, Hungary.
- Member of the PhD committee of M. van Wezel, *Neural Networks for Intelligent Data Analysis*, March 7, UL.
- Member of the PhD committee of W.E. de Paepe, *Complexity Results and Competitive Analysis for Vehicle Routing Problems*, September 30, TUE.
- Member of the PhD committee of J.I. van Hemert, *Application of Evolutionary Computation to Constraint Satisfaction and Data Mining*, November 28, Leiden University.
- Leader of the consortium for the preparation of a project proposal for ICES-KIS (Bsik) funding: I-CARE, 'Intelligent Adaptive Systems for Health Care'.

Visitors

- Dr. M. de Kamps (UL), March 6. (Lecture: *Interaction between Feedforward and Feedback Information in the Visual Cortex*). Host: S.M. Bohte.
- I. Vaishnavi (IIT Delhi), May 13–August 1. Hosts: F. Alkemade, E.H. Gerding, J.A. La Poutré.
- Dr. R. van Stee (Univ. Freiburg), October 4. (Lecture: *Minimizing the Total Completion Time On-line on a Single Machine, using Restarts*). Host: J.A. La Poutré.
- T. Beielstein (Univ. Dortmund), October 17. (Lecture: *Threshold Selection, Hypothesis Tests, and DoE Methods and their Applicability to Elevator Group Control Problems Time*). Host: D.D.B. van Bragt.
- Dr. B. Langdon (Univ. College London GlaxoSmithKline) October 24. (Lecture: *Genetic Programming to Combine Machine Learning Classifiers in Drug Discovery*). Host: F. Alkemade.
- Dr. T. Heskes (KUN), November 20. (Lecture: *Bayesian Multi-task Learning for Distributing De Telegraaf*). Host: S.M. Bohte.
- K. Kannan (Carnegie Mellon Univ.), December 18–21. (Lecture: *Effect of Information Revelation Policies: A Game-Theoretic Analysis*). Host: D.J.A. Somefun.

Publications

Papers in refereed journals and proceedings

F. Alkemade, J.A. La Poutré (2002). Heterogeneous, boundedly rational agents in the Cournot Duopoly. R. Cowan, N. Jonard (eds.). *Heterogeneous Agents, Interactions and Economic Performance*, LNEMS **521**, Springer-Verlag, 3–17.

F. Alkemade, J.A. La Poutré (2002). Boundedly rational agents achieving collusive outcomes in the Cournot game. *Proceedings of the 2nd workshop on Computational Intelligence in Economics and Finance (CIEF2002/JCIS2002)*, 1143–1146.

S.M. Bohte, E.H. Gerding, J.A. La Poutré (2002). Spike-prop: error-backpropagation in multi-layer networks of spiking neurons. *Neurocomputing* **48**(1–4), 17–37.

S.M. Bohte, E.H. Gerding, J.A. La Poutré (2002). Competitive market-based allocation of consumer attention space. *Proceedings of the Fourteenth Belgium-Netherlands Artificial Intelligence Conference (BNAIC)*, 403–404.

S.M. Bohte, J.N. Kok, J.A. La Poutré (2002). Unsupervised classification in a layered RBF network of spiking neurons. *IEEE Trans. Neural Networks*, 426–435.

S.M. Bohte, J.N. Kok, J.A. La Poutré (2002). Modeling efficient conjunction detection with spiking neural networks. M. Verleysen (ed.). *Proceedings of the European Symposium on Artificial Neural Networks (ESANN) 2002*, D-Facto, 263–268.

S.M. Bohte, J.N. Kok, J.A. La Poutré (2002). Implementations of efficient conjunction detection in spiking neural networks. *Proceedings of International Joint Conference on Neural Networks (IJCNN)*, 1097–1103.

D.D.B. van Bragt, E. Gerding, J.A. La Poutré (2002). Equilibrium selection in alternating-offers bargaining models: The evolutionary computing approach. *Electronic Journal of Evolutionary Modeling and Economic Dynamics (e-JEMED)* **2**.

D.D.B. van Bragt, J.A. La Poutré (2002). Co-evolving automata negotiate with a variety of opponents. *Proceedings of the IEEE Congress on Evolutionary Computation 2002 (CEC 2002)*, IEEE Press **2**, Hawaii, USA, 1426–1431.

L. Epstein (School CMS, Hornliga, Israel), R. van Stee (2002). Minimizing the maximum starting time on-line. *Proceedings of the 10th European Symposium on Algorithms, ESA 2002*, LNCS **2461**, Springer-Verlag, 449–460.

P.J. 't Hoen, S.M. Bohte, E. Gerding, J.A. La Poutré (2002). Implementation of a competitive market-based allocation of consumer attention space. W. Walsh (ed.). *Proceedings of the 4th Workshop on Agent Mediated Electronic Commerce 2002*, LNCS **2531,** Springer-Verlag, 273–288.

S. Seiden (Lousiana Univ.), R. van Stee (2002). New bounds for multi-dimensional packing. *Proceedings of the 13th ACM-SIAM Symposium on Discrete Algorithms, SODA 2002*, SIAM Press, San Francisco, USA, 486–495.

S. Seiden (Lousiana Univ.), R. van Stee, L. Epstein (School CMS, Hornliga, Israel) (2002). New Bounds for variable-sized online bin packing. *Proceedings of 29th International Colloquium on Automata, Languages and Programming, ICALP 2002*, LNCS **2380**, Springer-Verlag, Malaga, Spain, 306–317.

R. van Stee, J.A. La Poutré (2002) Minimizing the total completion time on a single online machine, using restarts. *Proceedings of the 10th European Symposium on Algorithms, ESA 2002,* LNCS **2461**, Springer-Verlag, Rome, Italy, 872–883.

CWI reports

SEN-R0202	SEN-R0208	SEN-R0211
SEN-R0213	SEN-R0217	SEN-R0218
SEN-R0219	SEN-R0220	

See page 170 for complete titles.

Other publications

PhD thesis

R. van Stee (2002). *On-line scheduling and bin packing*, May, UL. Thesis advisor: Prof.dr. J.N. Kok. Co-advisor: Prof.dr.ir. J.A. La Poutré.

Articles in unrefereeed journals and proceedings

J.A. La Poutré (2002). Agent systems and emergent behaviour in economics and e-business. J. Meij (ed.). *Dealing with the Data Flood: Mining Data, Text, and Multimedia*, Stichting Toekomstbeeld der Techniek (STT), STT/Beweton, 176–182.

Software developed

As a result of the research conducted on multi-issue negotiation a software application was developed and implemented that demonstrates the use of the developed bargaining strategies. Moreover, in cooperation with TNO and ING, the developed software application was integrated into an agent-based application. (Gerding, Somefun, Bohte and La Poutré) .

Deliverables for projects

Several deliverables have been produced for the ASTA project.

- An Agent-Based Simulation for Market-based Consumer Attention Simulation (Gerding, La Poutré.)
- Bundling and Recommending Information Brokerage (Somefun, La Poutré.)
- Bargaining with Posterior Opportunities: An Evolutionary Social Simulation (Gerding, La Poutré.)
- Business Case Financial Information Brokerage (Benning, Somefun.)
- Automated Negotiation and Bundling of Information Goods: The Financial News Case. (Gerding, Somefun, Bohte, La Poutré.)

Patents

Pending patent: Allocation of Consumer Attention Spaces via Competitive Market-based Mechanisms. Bohte, Gerding, La Poutré, Driessen and Bomhof. Patent no. 75236, submitted July 2001.

MODELLING, ANALYSIS AND SIMULATION

General overview

Principal research area and mission

MAS (Modelling, Analysis and Simulation) is a mathematics cluster whose principal research area is *Applied and Numerical Mathematics*. The emphasis lies on partial differential equations with mathematical analysis, scientific computing and computational fluid dynamics as major activities across all three MAS themes. Smaller sized activities belong to the realms of control and system theory (discrete-event systems, hybrid systems, realization theory, system identification theory), to the realms of asymptotics and special functions with involvement in a major revision of the classical *Handbook of Mathematical Functions*, and to the realms of computational number theory (factoring large numbers) and discrete tomography.

Applications for MAS research are found everywhere in physics, life sciences, geosciences and environmental sciences, in engineering and in many industrial and technological fields. Ongoing trends in computer hardware with desktop performance in the gigaflop range further increase the demand for advanced modelling, analysis and simulation with applied and computational mathematics at the centre of interest. The cluster policy is to maintain a strong position in this rapid 'computational science' development. This requires a balance between long-lasting discipline-oriented and more short-term applied research with in particular an enduring attention for new challenges from applications. As a result, a considerable part of our current research is application-driven and to some extent this is reflected in the cluster's theme organization. As regards applications, theme MAS1 focuses on problems from the life sciences (biology and medicine), theme MAS2 on engineering and industrial problems, and the pilot theme MAS3 on problems from physics.

Application-driven research requires extensive contacts with technological institutes, government laboratories and industry. The theme reports list a wide variety of specific contacts and funded projects. Our external financial support was largely obtained from ICES-KIS 2, FOM, several EU projects, various NWO programmes such as Computational Science, STW, 'Wiskunde Toegepast' and NCF.

Cluster leader

Prof.dr. J.G. Verwer

Themes

Name	Leader
MAS1 – Applied Analysis and Scientific Computing	J.G. Verwer
MAS2 – Computing and Control	B. Koren
MAS3 – Nonlinear Dynamics and Complex Systems (pilot)	U.M. Ebert

Other items of interest

External contacts

Discipline-oriented research requires extensive contacts and joint work with university researchers. Details can be found in the theme reports. Several cluster members are part-time professor at a Dutch university: J.G. Verwer and P.W. Hemker are full professor of numerical analysis at the UvA, J.H. van Schuppen is full professor of applied analysis at the VU, B. Koren is full professor of computational fluid dynamics at the TUD, U.M. Ebert is full professor of physics at the TUE, and M.A. Peletier is associate professor (UHD) in applied analysis, also at the TUE.

In 2002, advisers to MAS from universities were Prof.dr. J. Hulshof (VU) for mathematical analysis (MAS1), Prof.dr. O. Diekmann (UU) and Prof.dr. H.V. Westerhoff (VU) for life-science applications

(MAS1), and Prof.dr.ir. P. Wesseling (TUD) and Prof.dr. B. van Leer (Univ. Michigan) for computational fluid dynamics (MAS2).

Highlights

Dr. U.M. Ebert and dr.ir. B. Koren were appointed full professor. Furthermore, four PhD students, E.H. van Brummelen, S.H. Cavallar, B. Lastdrager, and D. Lanser, completed their PhD research and dr. ir. J.E. Frank was awarded a VENI grant for his research proposal 'Geometric numerical methods for continuum mechanics'.

Regarding mathematical PDE analysis, an important event was the creation of the MAS1 subtheme 'PDEs at CWI'. In its present form, this subtheme started September 1, with one-day per week secondments of the professors A. Doelman (UvA), C.J. van Duijn (TUE), J. Hulshof (VU) and L.A. Peletier (UL). The main goal of 'PDEs at CWI' is to strengthen cooperations and to generate more research activity in mathematical PDE analysis at CWI and in the Netherlands.

Staff

- Staff directly managed by cluster leader
  - J. Kok
  - J. de Vries
- Applied Analysis and Scientific Computing – MAS1
  - J.G. Blom
  - O. Diekmann
  - A. Doelman
  - C.J. van Duijn
  - J.E. Frank
  - L'. Fraštia
  - I.A. Guerra
  - J. Hulshof
  - J.K. Krottje
  - L.A. Peletier
  - M.A. Peletier
  - N.N. Pham Thi
  - R. Planqué
  - B.P. Sommeijer
  - N.M. Temme
  - J.G. Verwer
  - H.V. Westerhoff
- Computing and Control – MAS2
  - K.J. Batenburg
  - D.P.L.D. Benden
  - G.F. Duivesteijn
  - L.C.G.J.M. Habets
  - B. Hanzon
  - P.W. Hemker
  - D. Jibetean
  - G. Kandoi
  - J. Komenda
  - B. Koren
  - B. Lastdrager
  - B. van Leer
  - M.R. Lewis
  - M. Nool
  - A. Mooij
  - W.A. Mulder
  - D.E.A. van Odyck
  - M. Petreczky
  - M.H. van Raalte
  - H.J.J. te Riele
  - J.H. van Schuppen
  - J. Wackers
  - P. Wesseling
- Nonlinear Dynamics and Complex Systems – MAS3
  - U.M. Ebert
  - W.H. Hundsdorfer
  - B.J. Meulenbroek
  - C.S. Montijn
  - A. Rocco
  - D. Sijacic
- Secretaries:
  - N. Mitrovic
  - S.J. van Dam

Applied Analysis and Scientific Computing – MAS1

Mission

The research within this theme focuses on the mathematical and numerical analysis of partial differential equations (PDEs). A minor activity is asymptotics for special functions. The nature of the research ranges from fundamental to practical and is for a considerable part application driven. All application

driven research activities emanate from new challenges from biology and medicine (life science applications), which are fields where mathematical modelling and scientific computing are rapidly becoming more and more important.

Regarding mathematical PDE analysis, an important event has been the creation of 'PDEs at CWI'. In its present form, this subtheme started September 1, 2002, with one-day a week secondments of the professors A. Doelman (UvA), C.J. van Duijn (TUE), J. Hulshof (VU) and L.A. Peletier (UL). The main goal of 'PDEs at CWI' is to strengthen cooperations and to generate more research activity in mathematical PDE analysis at CWI and in the Netherlands.

Theme leader

Prof.dr. J.G. Verwer

Subthemes

Name	Leader
MAS1.1 – PDEs in the Life Sciences	M.A. Peletier
MAS1.2 – PDEs at CWI	M.A. Peletier
MAS1.3 – Numerical Analysis of PDEs	J.G. Verwer
MAS1.4 – Asymptotics and Special Functions	N.M. Temme

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. P.J.F. Berkvens	1.0	researcher (NWO)	1998-06-01 till 2002-03-01	MAS1.2	33
Drs. J.G. Blom	1.0	researcher.	indefinite	MAS1.1	35, 65, 92
Dr.ir. J.E. Frank	1.0	researcher	indefinite	MAS1.1; MAS1.3	35, 65
L'. Fraštia MSc	1.0	post-doc	2002-02-01 till 2003-01-31	MAS1.1	35, 65, 92
I.A. Guerra Benavente MSc	1.0	PhD student	1998-06-01 till 2002-05-31	MAS1.2	35
Ir. J.K. Krottje	1.0	PhD student (NWO)	2001-04-01 till 2005-03-31	MAS1.1	35, 65, 92
Dr. M.A. Peletier	0.8	leader MAS1.1,1.2		MAS1.1; MAS1.2	35, 92
N.N. Pham Thi MSc	1.0	PhD student (NWO)	2002-09-01 till 2006-08-31	MAS1.1	35, 65, 92
Drs. R. Planqué	1.0	PhD student	2000-12-01 till 2004-11-30	MAS1.1	35, 92
Dr. B.P. Sommeijer	1.0	researcher	indefinite	MAS1.1	35, 65, 92
Dr. N.M. Temme	0.8	leader MAS1.4	indefinite	MAS1.4	33
Prof.dr. J.G. Verwer	0.6	cluster leader, theme leader, leader MAS1.3	indefinite	MAS1.1; MAS1.3	35, 65

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. O. Diekmann (UU)	0.2	advisor	2001-01-01 till 2004-12-31	MAS1.1	35
Prof.dr. A. Doelman (UvA)	0.2	researcher	2002-09-01 till 2007-09-01	MAS1.2	35

Prof.dr.ir. C.J. van Duijn (TUE)	0.2	researcher	2002-09-01 till 2007-09-01	MAS1.2	35
Prof.dr. J. Hulshof (VU)	0.2	researcher	2002-09-01 till 2007-09-01	MAS1.2	35
Prof.dr.ir. L.A. Peletier (UL)	0.2	researcher	2002-09-01 till 2007-09-01	MAS1.2	35
Prof.dr. H.V. Westerhoff (VU)	0.2	advisor	2001-01-01 till 2004-12-31	MAS1.1	35

Scientific report

Highlights

- Start of 'PDEs at CWI' (see MAS1.2) with the kick-off meeting on October 2.
- The VENI grant of J.E. Frank for his proposal 'Geometric numerical methods for continuum mechanics'.
- Completion of PhD thesis by D. Lanser (March 7) and B. Lastdrager (September 18).
- The International Workshop 'Innovative Time Integrators for PDEs' organized by MAS1, November 25–27, 40 participants.

PhD research

Title	PhD research of N.N. Pham Thi
Period	September 2002–August 2006
Leader	B.P. Sommeijer
Funding	NWO Computational Science

Progress report. The research of *Pham Thi* concerns the numerical solution of a class of integro-PDE systems which are used as models for forecasting phytoplankton concentrations in lakes and oceans. Pham Thi has used the initial period of her appointment to get acquainted with the problem and has begun to study the required numerical algorithms. See also the MAS1.1 project 'Microbial ecology, phytoplankton models'.

Title	PhD research of J.K. Krottje
Period	April 2001–March 2005
Leader	J.G. Verwer
Funding	NWO Wiskunde Toegepast

Progress report. The PhD project of *Krottje* concerns the development and analysis of numerical methods for a mathematical model for the outgrowth of axons from neurons in the nervous system. The model in use at this moment has been suggested by a cooperating group at the NIH (Netherlands Institute for Brain Research) and comprises a set of parabolic PDEs for attracting and repelling biochemical species coupled to gradient equations for the axon paths. First investigations of Krottje have dealt with maintenance of important analytical solution properties (bundling and debundling) in a numerical discretization. His results have been published in Report MAS-R0220. Currently, the emphasis is on a class of mesh-free methods which is believed to provide a flexible set-up for a future numerical software-package for the NIH. Specific results on these methods will be reported first half of 2003. See also the MAS1.1 project 'Neurobiology, modelling of axon growth'.

Title	PhD research of R. Planqué
Period	December 2000–November 2004
Leader	M.A. Peletier
Funding	CWI (Crossroads)

Progress report. 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, *Planqué* and *Peletier* 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 Masters thesis on defence strategies against cuckoo parasitism. This manuscript (Report MAS-R0224), joint with N. Britton, N. Franks and M.A. Peletier, has been published in *Bulletin of Mathematical Biology* **64**, 2002, 1045–1068. See also the MAS1.1 project 'Cell biology, rods and DNA'.

Title	PhD research of I.A. Guerra Benavente
Period	June 1998–May 2002
Leader	M.A. Peletier
Funding	CWI

Progress report. *Guerra Benavente*, with *Van Duijn* and *Peletier*, has continued the study of 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 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. In recent results self-similar blow-up solutions in three dimensions were shown to exist and be stable to perturbations. These results are published in *Guerra Benavente*'s PhD thesis (the defence takes place January 15, 2003 at the TUE). See also the MAS1.2 project 'Interacting stellar structures'.

MAS1.1 – PDEs in the Life Sciences

Within theme MAS1 this subtheme is the largest and is primarily application driven. The objective is mathematical modelling, mathematical and numerical analysis and numerical simulation, for life science applications. In 2002 the subtheme comprised six projects on applications from biology and medicine.

Title	Cell biology, ICES-KIS 2
Period	1999–2002
Leader	J.G. Blom
Staff	J.G. Blom, M.A. Peletier
Funding	ICES-KIS 2
Partners	UvA (SILS/IvI), VU (IMBW), B. Kholodenko (Thomas Jefferson Univ. Philadelphia)

Progress report. Within the framework of the ICES-KIS 2 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, UvA) and IMBW (the Institute for Molecular Biological Sciences, VU), extensive numerical experiments have been done for the phosphotransferase system (PTS). This research is under review for publication in *Biophysical Journal* (Report MAS-R0218, with an Appendix in Report MAS-R0228), and was presented in Bordeaux at the 10-th meeting, September 2002, of the International Study Group of Biological Thermodynamics, Control and Kinetics (BioThermoKinetics, BTK in short). This informal BTK study group is devoted to the quantitative understanding of the kinetics, thermodynamics and control of biological processes at the cellular level.

Further, in a theoretical study, *Peletier*, *Westerhoff* (UvA/VU) and B. Kholodenko (Thomas Jefferson Univ., Philadelphia) investigated the consequences of adding spatial diffusion for Metabolic Control Analysis. They showed that as a result of the additional scaling invariance a new form of a summation theorem could be derived, independent of the classical theorems. This work (Report MAS-R0226) has been submitted to *Biophysical Journal*.

Title	Cell biology, the silicon cell
Period	1999–2002
Leader	J.G. Blom
Staff	J.G. Blom, M.A. Peletier, L'. Fraštia
Funding	CWI, ICES-KIS 2
Partners	UvA (SILS/IvI), VU (IMBW), F. Otto (Univ. Bonn), D. Hilhorst (Univ. Paris-Sud), X. Chen (Univ. Pittsburgh), P. Fife (Univ. Utah)

Progress report. This project is related to the above ICES-KIS 2 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, UvA) 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 Univ. 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 (Report MAS-R0229, submitted).

Title	Cell biology, rods and DNA
Period	2000–2004
Leader	M.A. Peletier
Staff	M.A. Peletier, R. Planqué
Funding	CWI (Crossroads)
Partners	G.H. van der Heijden (Univ. College Londen), N. Britton (Univ. Bath), N. Franks (Univ. Bristol)

Progress report. See the PhD report of *Planqué* (page 95).

Title	Aqueous biology, biofilm project
Period	2000–2003
Leader	B.P. Sommeijer
Staff	M.A. Peletier, B.P. Sommeijer
Funding	EU
Partner	Aquatic Ecology and Ecotoxicology-group, UvA

Progress report. A biofilm is a thin layer composed of micro-algae, bacteria and their mucus. Biofilms occur in all natural rivers and lakes. Since natural biofilms act as high-tech conditioners for drinking water, they are frequently exploited by drinking-water companies to regulate organic matter content in the water. The role of CWI (*Peletier* and *Sommeijer*) in this project is to mathematically model a biofilm and to give advice on how to simulate various scenarios. For that purpose an existing software package (AQUASIM) is used. The biofilm schematized in the model is composed of two characteristic algal groups with different growth strategy and bacterial compartment. Also EPS (extracellular polymeric substances) and DOC (dissolved organic matter) have been taken into account, as well as external forces like grazing. A final report is in progress, jointly with the UvA Aquatic Ecology and Ecotoxicology-group.

Title	Microbial ecology, phytoplankton models
Period	2001–2005
Leader	B.P. Sommeijer
Staff	N.N. Pham Thi, B.P. Sommeijer, J.G. Verwer
Funding	NWO (Computational Science Program)
Partner	J. Huisman, Inst. of Biodiversity and Ecosystems Dynamics, UvA

Progress report. In close cooperation with J. Huisman we continued our research on phytoplankton dynamics and started a new NWO-granted PhD project within the Computational Science program (PhD student *Pham Thi*, as of September 1). The central research question is: Can we mathematically model and forecast the dynamics and species composition of phytoplankton communities. Models in this field take the form of integro-partial differential equations simulating dynamics in relation to mixing processes, species-specific vertical velocities (sinking or buoyancy), and competition. The 'integro-part' enters through the light intensity which is needed for photosynthesis and which is dependent on concentrations. In *J. Sea Research* **48** (2002), 83–96, Huisman and Sommeijer describe the numerical techniques used to solve the integro-PDEs and discuss some applications. In a second study we focused on sinking species. Since any phytoplanktoner needs light for its photosynthesis, sinking into the deep darkness does not seem to be a smart strategy for survival. However, the models predict that populations of sinking species may persist near the water surface if the turbulent mixing is at intermediate levels. These results have been published in *The American Naturalist* **159** (2002), 245–254. A third study concerns the dynamics in a stratified water column. The model shows that a viable population of sinking species can only sustain if the sinking velocity is less than a critical value. Furthermore, we showed that this maximal sinking velocity is inversely proportional to the turbidity of the water column. Both results are qualitatively and quantitatively supported by empirical data. Results were published in *Marine Ecology Progress Series* **244** (2002), 39–48. Currently we are working on competition models in combination with a model for nutrients. First results will appear in 2003.

Title	Neurobiology, modelling of axon growth
Period	2001–2005
Leader	J.G. Verwer
Staff	J.K. Krottje, J.E. Frank, J.G. Verwer
Funding	NWO (Wiskunde Toegepast)
Partners	A. van Ooyen, J. van Pelt (Netherlands Institute for Brain Research, NIH/KNAW)

Progress report. See the PhD report of *Krottje* (page 95).

MAS1.2 – PDEs at CWI

In its present form, this subtheme started September 1, 2002, with one-day per week secondments at CWI of the professors A. Doelman (UvA), C.J. van Duijn (TUE), J. Hulshof (VU) and L.A. Peletier (UL). The main goal is to generate more research activity in the analysis of PDEs at CWI and in the Netherlands by creating a 'hot spot' of PDE analysis at CWI. This will be achieved by strengthening cooperations in the field between the four universities and CWI. Activities in this subtheme will focus on joint seminars and joint research projects.

Title	Interacting stellar structures
Period	2001–2002
Leader	M.A. Peletier
Staff	I.A. Guerra Benavente, M.A. Peletier, C.J. van Duijn
Funding	CWI
Partners	P. Biler, T. Nadzieja (Univ. Wrocław)

Progress report. See the PhD report of *Guerra Benavente* (page 95).

Title	Textbook ODEs in PDEs
Period	2002–2004
Staff	C.J. van Duijn, L.A. Peletier
Funding	CWI

Progress report. With this textbook the authors plan to give a comprehensive account of the role of symmetry in partial differential equations with emphasis on self-similar and travelling wave solutions. The book will be amply provided with theory illustrated by numerous examples.

Title	Patterns in gravity-driven groundwater flow
Period	2002–2004
Leader	C.J. van Duijn
Staff	C.J. van Duijn
Funding	CWI
Partners	G.J. Pieters (TUE), P. Knabner (Univ. Erlangen), K. Johannsen (Univ. Heidelberg)

Progress report. A central issue in modelling gravity-driven groundwater flow is the derivation and mathematical analysis of the amplitude equations near the minimum of the stability boundary. This project aims at enhancing insight by studying specific patterns.

Title	Linearization in free boundary problems
Period	2002–2004
Leader	J. Hulshof
Staff	J. Hulshof
Funding	CWI
Partners	C.M. Brauner (Univ. Bordeaux), A. Lunardi (Univ. Parma), J.F. Ripoll (Stanford Univ.)

Progress report. Free boundary problems (FBPs) for partial differential equations appear in many applications in the exact sciences. The classical example is the Stefan problem for water-ice. Other applications involve cell boundaries, contact lines in thin, film flows, and flame fronts in combustion models. FBPs may appear as limits of (systems) of reaction-diffusion equations which have been studied extensively from a dynamical systems viewpoint. In this project we aim at a theory for FBPs which parallels that of reaction-diffusion equations: Linearization, Evans functions, rigorous nonlinear stability bifurcation analysis, etc. A main application is the thermo-diffusive model for combustion in dusty, gaseous mixtures, where the presence of dust accounts for nonlocal terms in the temperature equation. These are due to radiative effects which have a strong effect on flame temperatures and speeds.

Title	Spike hierarchy in the Gray-Scott Model
Period	2002–2004
Leader	A. Doelman
Staff	A. Doelman, L.A. Peletier
Funding	CWI
Partner	T.J. Kaper (Boston Univ.)

Progress report. In 1983 Gray and Scott proposed a system of two reaction-diffusion equations as a model system for understanding complex dynamics in chemical reactions, and the understanding of the formation of patterns such as the birth of multi-bump spikes and travelling fronts. In a joint project *Doelman*, *Peletier* and T.J. Kaper from Boston Univ. are studying a sequence of saddle-node bifurcations leading to a hierarchy of spikes with increasing complexity.

MAS1.3 – Numerical Analysis of PDEs

This subtheme is particularly concerned with numerical PDE analysis with a focus on theoretical aspects. An outstanding activity is the VENI project *Geometric numerical methods for con-*

tinuum mechanics granted in 2002 by NWO to J.E. Frank.

Title	Geometric numerical methods for continuum mechanics
Period	2002–2005
Leader	J.E. Frank
Staff	J.E. Frank
Funding	NWO Innovative Research Grant (VENI)
Partner	S. Reich (Imperial College of London)

Progress report. Geometric integration is a design philosophy for numerical modelling of discrete and continuum mechanics. The essential idea is that a numerical method should not simply approximate the exact solution in an asymptotic sense, but should also reproduce the fundamental qualitative features, independent of discretization parameters. Examples of such qualitative features are conservation laws, symmetries, limit sets, etc. Two articles by *Frank* and Reich on the application of geometric methods to problems in atmospheric dynamics have appeared this year in, respectively, *J. Comput. Phys.* **180**, 407–426, and in *Lecture Notes in Computational Science and Engineering* **26**, 131–142. A third is scheduled for publication in early 2003 in *BIT*. An NWO Innovative Research Grant (VENI) was awarded to *Frank* to support continued research on this topic through summer 2005. A 3-day workshop 'Innovative Time Integrators for Partial Differential Equations' was organized with geometric integration as one of the main topics. Further work on this project includes continued development of the methods for atmospheric dynamics and an investigation of multisymplectic methods for ferromagnetic materials. Publications on this work are being prepared for submission early 2003.

Title	Textbook
Period	2000–2003
Leader	J.G. Verwer
Staff	J.G. Verwer
Funding	CWI
Partner	W.H. Hundsdorfer (MAS3)

Progress report. This book describes numerical methods for partial differential equations (PDEs) coupling advection, diffusion and reaction terms. Hence it deals with methods for hyperbolic, parabolic and stiff and nonstiff ordinary differential equations. It emphasizes time-dependent transport-chemistry problems, describing e.g., the evolution of concentrations in environmental and biological applications. The authors are *Hundsdorfer* (MAS3) and *Verwer*. With the title 'Numerical Solution of Time-Dependent Advection-Diffusion-Reaction Equations', it will be published in 2003 by Springer-Verlag in their 'Springer Series in Computational Mathematics'.

MAS1.4 – Asymptotics and Special Functions

Title	Asymptotics and special functions
Period	1995–2005
Leader	N.M. Temme
Staff	N.M. Temme
Funding	CWI, NIST (Washington)
Partners	J.L. López (Univ. Pamplona), A. Gil and J. Segura (Univ. Madrid)

Progress report. Earlier work with R. Vidunas (Univ. Antwerp) on constructing numerical upper bounds for remainders of uniform asymptotic expansions has been completed (one paper has been published and Report MAS-R0225 has been accepted).

The research on asymptotic analysis (with López) concentrated on the construction of convergent expansions with asymptotic properties for a certain class of special functions. The method is based on multi-point Taylor expansions of analytic functions. The work has been reported in MAS-R0211 and two papers were submitted. Another accepted paper on asymptotics is Report MAS-R0209.

Algorithms in FORTRAN were written (with Gil and Segura) for the numerical evaluation of Airy functions and Scorer functions (published in Report MAS-R0213 and Report MAS-R0223 has been accepted). Another paper was written on the zeros of the Scorer functions (Report MAS-R0222, accepted for publication). Other accepted papers on this topic are Report MAS-R0205 and Report MAS-R0230.

Temme participated in the DLMF project (NIST), which concerns a complete revision of the Handbook of Mathematical Functions of Abramowitz and Stegun (revision of earlier written chapters and editorial work).

Societal aspects and knowledge transfer

Contract research

- DLMF project (NIST), see MAS1.4.

Teaching activities

- Course Parallel Scientific Computing & Simulation, UvA: B.P. Sommeijer.
- 'Stieltjesonderwijsweek Numerical Solution of Multiprocess-Multiscale Differential Equations', Lorentz Center, Leiden: J.G. Verwer.
- Short course 'Numerical Solution of Advection-Diffusion-Reaction Equations', Fields Institute of Mathematical Sciences, Toronto: J.G. Verwer.
- Multivariabele Analyse (Werktuigbouwkunde), TUE: M.A. Peletier.
- Mathematische Modellen in de Fysiologie (Biomedische Technologie), TUE: M.A. Peletier.

Organization of conferences, workshops, courses, meetings

- Forty-Second European Study Group with Industry (60 participants), CWI and UvA: February 18–22: M.A. Peletier, R. Planqué.
- Meeting An Afternoon on Numerical Methods for Geophysical Flows, CWI: March 8: D. Lanser (UT), J.G. Verwer.
- Crossroads colloquium, topic PDEs from the Life Sciences, CWI: April 16: J.G. Verwer, M.A. Peletier.
- PDE@CWI meetings, CWI: October 4, December 4: M.A. Peletier, A. Doelman, J. Hulshof.
- International Workshop Innovative Time Integrators for PDEs, 40 participants, 9 invited lectures, 2 from CWI: November 25–27: J.G. Blom (Lecture: *Continuum Modeling of Biological Membranes*), J.E. Frank (Lecture: *Multisymplectic treatment of the Landau-Lifshitz equation*). Organizers: J.G. Verwer, J.G. Blom, J.E. Frank, W.H. Hundsdorfer, B.P. Sommeijer.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Colloquium Leiden Morphology Center, January 30: M.A. Peletier (Invited lecture: *Buckling of Long Elastic Structures*).
- FDTD meeting, Philips Laboratories Eindhoven, February 20: J.G. Verwer (Invited lecture: *Splitting in Time Integration*).
- Workshop EU-BIOFILM project, Forschungszentrum Karlsruhe, Germany, March 18–19: B.P. Sommeijer (Lecture: *Modelling Phototrophic Biofilms with AQUASIM*).
- Nederlands Mathematisch Congres, Eindhoven: April 4–5: J.G. Verwer (Invited session lecture: *Splitting in Time Integration*).
- Crossroads colloquium CWI, April 16: J.G. Blom (Lecture: *PDEs in the Cell*), B.P. Sommeijer (Lecture: *Modelling the dynamics of phytoplankton*).
- Workshop Invariant and Symmetry-Preserving Algorithms for N-Body Simulation, Leicester, UK, April 25–26: J.E. Frank (Invited lecture: *The Hamiltonian Particle-Mesh Method and Numerical Results*).
- Conference on Scientific Computation Celebrating Gerhard Wanner's 60th Birthday, Geneva, Switzerland, June 26–29: J.E. Frank (Lecture: *A Finite Mass Approach for Advection-Diffusion-Reaction Equations*).
- European Conference on Mathematical and Theoretical Biology, Milano, Italy, July 2–6: R. Planqué.
- Summer School Applied Analysis, Enschede, July 10–14: R. Planqué.
- International Congress on Computational and Applied Mathematics, KU Leuven, Belgium, July 22–26: B.P. Sommeijer (Invited lecture: *Phytoplankton Dynamics, Competition for Light*).
- Workshop on Special Functions in the Digital Age, Institute for Mathematics and Its Applications (IMA), Minneapolis, July 22–August 2: N.M. Temme (Invited lecture: *Numerics of Special Functions*).
- Workshop on Special Functions, FoCM '02 meeting, Univ. Minnesota, Minneapolis, August 5–7: N.M. Temme (Lecture: *Two-point Taylor Expansions for Convergent Asymptotic*).
- SIAM Symposium on Computational Models and Simulation for Intra-Cellular Processes, Washington DC, USA, October 4–5: J.G. Blom (Lecture: *PDEs in the Cell*).
- CWI in Bedrijf, CWI, October 18: N.M. Temme (Lecture: *Abramowitz & Stegun: Na 40 jaar een totale revisie van dit 'Handbook of Mathematical Functions'*).

- Symposium 'Models in Microbiology', UvA, October 25: B.P. Sommeijer (Invited lecture: *Introducing Computational Fluid Dynamics in Microbial Ecology*).
- Second Annual Meeting of the Geometric Methods in GFD Network, Ashford, UK, December 16–18: J.E. Frank.

Working visits
- Univ. Bath, UK, January 7–9: M.A. Peletier (Lecture: *A Continuum Model for Lipid Bilayers*).
- Univ. College London, UK, March 4–15 and July 14–27: M.A. Peletier, R. Planqué.
- Imperial College of London, UK, April 22–24: J.E. Frank.
- NIST, Washington DC, May 21–23: N.M. Temme (Lecture: *New Software for a Class of Special Functions*).
- Univ. Paris-Sud, May 5–8: M.A. Peletier.
- Working visit to Univ. Bonn, May 15–17: M.A. Peletier (Lecture: *Buckling of Long Elastic Structures*).
- Visiting Fellowship, Univ. College London, August 1–31: M.A. Peletier.
- ENPC (Ecole Nationale des Ponts et Chaussées), Marne-la-Vallée, France, September 8–11: J.G. Verwer (Lecture: *Stabilized Runge-Kutta methods for parabolic equations*).
- Univ. Pública de Navarra, Spain, November 4–8: N.M. Temme (Lecture: *Asymptotics and Numerics of Special Functions*).

Project meetings
- Board meeting DLMF project ('Abramowitz and Stegun'), July 27–28, Univ. Minnesota, Minneapolis, USA: N.M. Temme.
- Kick-off meeting Computational Science program, NWO/EW, CWI, November 29: N.N. Pham Thi (Poster: *Phytoplankton Dynamics, the Struggle for Light*).

Other lectures
- Algemeen Natuurkunde Colloquium RUG, January 17: J.G. Verwer (Invited lecture: *New numerical PDE problems from computational biology*).
- Open Dag, CWI, October 20: R. Planqué (Lecture: *Waarom zit uw telefoonsnoer toch altijd in de knoop*).
- Staff colloquium Dept. Mathematics and Computer Science, RUG, February 11: J.G. Blom (Invited lecture: *The Silicon Cell: Towards Computing the Living Cell*).

Memberships of committees and other professional activities

J.E. Frank
- Co-organizer of the EU network CoRGI (Collaborative Research in Geometric Integration).

M.A. Peletier
- Associate professor of Applied Analysis, TUE.
- Co-organizer Forty-Second European Study Group with Industry.
- Associate editor of the *IMA Journal of Applied Mathematics*.
- Secretary and board member of the Wiskundig Genootschap.

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

N.M. Temme
- Editor *ZAMP*.
- Editor DLMF project: Revision of the *Handbook of Mathematical Functions* ('Abramowitz and Stegun').
- Member governing board Stieltjes Institute for Mathematics.
- CWI-coordinator for Dutch research schools in mathematics and computer science.
- Organizer CWI's monthly seminar *CWI Scientific Meetings*.

J.G. Verwer
- Full professor of Numerical Analysis, Korteweg-de Vries Institute, UvA.
- Senior Editor *APNUM* (Applied Numerical Mathematics).
- Member organizing committee Woudschoten Numerical Conference, Zeist, September 25–27.
- Member organizing committee 10th Seminar NUMDIFF – Numerical Solution of Differential and Differential-Algebraic Equations, Halle, Germany, September 8–11, 2003.
- Editor Proceedings 9th NUMDIFF Seminar, Halle, *APNUM* **42**, Issues 1–3, 1–487 (with B.P. Sommeijer, K. Strehmel, R. Weiner).

- Member advisory committee of CMUC (The Centre for Mathematics of the Univ. Coimbra, Portugal).
- CWI contact for the Flemish Research Network on Advanced Numerical Methods for Mathematical Modelling (WOG).
- Referent and committee member PhD thesis G. van den Heuvel, January 9, UL (*Resolvent conditions in the stability analysis of numerical processes for solving delay differential equations*).
- Committee member PhD thesis E.H. van Brummelen, February 8, UvA (*Numerical methods for steady free surface flows*).
- Committee member PhD thesis D.R. van der Heul, February 28, TUD (*A staggered scheme for nonconvex hyperbolic systems of conservation laws*).
- PhD thesis advisor D. Lanser, March 7, UvA (*Numerical methods for atmospheric flow and circulation problems*).
- Committee member PhD thesis A. Segers, April 2, TUD (*Data assimilation in atmospheric chemistry models using Kalman filtering*).
- PhD thesis advisor B. Lastdrager, September 18, UvA (*Numerical time integration on sparse grids*).

Visitors

- J.F. Williams (Univ. Bath, UK), February 23–30. Host: M.A. Peletier.
- D. Williamson (NCAR - Boulder, USA), March 5–11 (Invited lecture: *Time-versus process-split coupling of subgrid-scale parametrizations and dynamical cores in atmospheric general circulation problems*). Host: J.G. Verwer.
- D. Lanser (UT), March 8 (Invited lecture: *My first steps to an efficient numerical method for global atmospheric flow*). Host: J.G. Verwer.
- G.S. Stelling (TUD), March 8 (Invited lecture: *Numerical methods for non-hydrostatic free-surface flows*). Host: J.G. Verwer.
- A. Meister (Univ. Lübeck, Germany), April 15–17 (Invited lecture: *The thermoregulation of infants and its numerical sImulation*). Host: J.G. Verwer.
- J. Huisman (UvA), April 16 (Invited lecture: *Ups and downs: competition between phytoplankton species in relation to mixing processes*). Host: J.G. Verwer.
- P. Biler (Univ. Wrocław, Poland), May 25–31 Host: I.A. Guerra Benavente.
- J.L. López (Univ. Pública Navarra, Pamplona, Spain), August 15–30. Host: N.M. Temme.
- J. Segura (Univ. Carlos III de Madrid), August 20–September 15. Host: N.M. Temme.
- A. Gil (Univ. Autónoma de Madrid, Spain), August 20–September 15. Host: N.M. Temme.
- J. Cantarella (Univ. Georgia, USA), August 31–September 5. Host: R. Planqué.
- J.F. Williams (Univ. Bath, UK), November 25–December 3. Host: M.A. Peletier.
- F. Hamel (Univ. Marseille, France), December 3–5 (Invited lecture: *Global solutions and curved fronts for a KPP reaction-diffusion equation*). Hosts: A. Doelman, J. Hulshof.
- J.-M. Roquejoffre (Univ. Toulouse, France), December 3 (Invited lecture: *A nonlinear integral equation describing the propagation of a spherical flame: rigorous derivation*). Hosts: A. Doelman, J. Hulshof.

Publications

Books and book chapters

B.P. Sommeijer, J.G. Verwer, K. Strehmel (Univ. Halle), R. Weiner (Univ. Halle) (eds.) (2002). Proceedings of the Ninth Seminar on Numerical Solution of Differential and Differential-Algebraic Equations (NUMDIFF-9), September 4–9, 2000, Halle, Germany, *Appl. Numer. Math.* **42**, 1–488.

Papers in refereed journals and proceedings

J.B. van den Berg (Nottingham, UK), N. Davydova (UU), B. van de Fliert (UT), F. Peeters (VU), R. Planqué, H. van der Ploeg (UvA), G. Terra (NIOZ) (2002). Reconstruction of sea surface temperatures from the oxygen isotope composition of fossil planktic foraminifera. G.M. Hek (ed.). *Proceedings of the forty-second European study group with industry*, **51**, 91–120.

P.J.F. Berkvens, M.A. Botchev (UT) (2002). Parallel processing and non-uniform grids in global air quality modelling. B. Sportisse (ed.). *Proceedings 2-nd Int. Conf. on Air Pollution Modelling and Simulation*, April 9–12, 2001, Champs-sur-Marne, France, Springer Geosciences, 215–225.

P.J.F. Berkvens, M.A. Botchev (UT), M.C. Krol (UU), W. Peters J.G. Verwer

(2002). Solving vertical transport and chemistry in air pollution models. D.P. Chock, G.R. Carmichael (eds.). *IMA Volumes in Mathematics and its Applications* **130**, Atmospheric Modeling, Springer-Verlag, New York, 1–20.

Ch. Francke (UvA), H.V. Westerhoff, J.G. Blom, M.A. Peletier (2002). Flux control of the bacterial phosphoenolpyruvate:glucose phosphotransferase system and the effect of diffusion. *Mol. Biol. Rep.* **29**, 21–26.

J. Frank, G. Gottwald (Univ. Sydney), S. Reich (Imperial College of London) (2002). A Hamiltonian particle-mesh method for the rotating shallow water equations. *Meshfree Methods for Partial Differential Equations*, Lect. Notes in Comp. Science and Engn **26**. Springer-Verlag, 131–142.

J. Frank, S. Reich (Imperial College of London) (2002). A particle-mesh method for the shallow water equations near geostrophic balance. *J. Comput. Phys.* **180**, 407–426.

A. Gerisch (Univ. Halle), J.G. Verwer (2002). Operator splitting and approximate factorization for taxis-diffusion-reaction models. *Appl. Numer. Math.* **42**, 159–176.

P.J. van der Houwen, B.P. Sommeijer (2002). Parallel solution of a coupled flow and transport model for shallow water. *Int. J. Numer. Meth. in Fluids* **38**, 849–859.

P.J. van der Houwen, B.P. Sommeijer (2002). Approximate factorization in shallow water applications. *Proceedings of the 2001 ANODE workshop*, January 3–6, 2001, Auckland, New Zealand. *Numerical Algorithms* **31**, 337–360.

J. Huisman (UvA), M. Arrayás, U. Ebert, B.P. Sommeijer (2002). How do sinking phytoplankton species manage to persist? *The American Naturalist* **159**, 245–254.

J. Huisman (UvA), B.P. Sommeijer (2002). Population dynamics of sinking phytoplankton in light-limited environments: simulation techniques and critical parameters. *Journal of Sea Research* **48**, 83–96.

J. Huisman (UvA), B. Sommeijer (2002). Maximal sustainable sinking velocity of phytoplankton. *Marine Ecology Progress Series* **244**, 39–48.

A. Gil (Univ. Autónoma de Madrid), J. Segura (Univ. Carlos III de Madrid), N.M. Temme (2002). Computing complex Airy functions by numerical quadrature. *Numer. Algorithms* **30**, 11–23.

A. Gil (Univ. Autónoma de Madrid), J. Segura (Univ. Carlos III de Madrid), N.M. Temme (2002). Algorithm 822: GIZ, HIZ: Two Fortran 77 routines for the computation of complex Scorer functions. *ACM Trans. Math. Soft.* **28**, 436–447.

A. Gil (Univ. Autónoma de Madrid), J. Segura (Univ. Carlos III de Madrid), N.M. Temme (2002). Algorithm 819: AIZ, BIZ: Two Fortran 77 routines for the computation of complex Airy functions. *ACM Trans. Math. Soft.* **28**, 325–336.

M.C. Krol (UU), W. Peters (UU), P.J.F. Berkvens, M.A. Botchev (UT) (2002). A new algorithm for two-way nesting in global models: principles and applications. B. Sportisse (ed.). *Proceedings 2nd International Conference on Air Pollution Modelling and Simulation*, Champs-sur-Marne, France, Springer Geosciences, 225–235.

J.L. López (Univ. Pública de Navarra), N.M. Temme (2002). Two-point Taylor expansions of analytic functions. *Stud. Appl. Math* **109**, 297–311.

R. Planqué, N.F. Britton (Univ. Bath), N.R. Franks (Univ. Bristol), M.A. Peletier (2002). The adaptiveness of defense strategies against cuckoo parasitism. *Bull. Math. Biol.* **64**, 1045–1068.

J.G. Verwer, W. Hundsdorfer, J.G. Blom (2002). Numerical time integration for air pollution models. *Surveys on Mathematics for Industry* **10**, 107–174.

R. Vidunas (Univ. Antwerp), N.M. Temme (2002). Symbolic evaluation of coefficients in Airy-type asymptotic expansions. *J. Math. Anal. Appl.* **269**, 317–331.

CWI reports

MAS-R0201	MAS-R0203	MAS-R0204
MAS-R0205	MAS-R0208	MAS-R0209
MAS-R0211	MAS-R0213	MAS-R0216
MAS-R0218	MAS-R0220	MAS-R0222
MAS-R0223	MAS-R0224	MAS-R0225
MAS-R0226	MAS-R0228	MAS-R0229
MAS-R0230	MAS-R0231	

See page 171 for complete titles.

Other publications

PhD theses

D. Lanser (2002). *Numerical Methods for Atmospheric Flow and Circulation Problems.*

March 7, UvA. Thesis advisor: Prof.dr. J.G. Verwer.

B. Lastdrager (2002). *Numerical time integration on sparse grids.* September 18, UvA. Thesis advisor: Prof.dr. J.G. Verwer, co-advisor: prof.dr.ir. B. Koren.

Technical reports published elsewhere

E. Vermeulen (Natuur & Techniek), G. Hek (UvA), M. Nuyens (UvA), M. Peletier, R. Planqué, H. van der Ploeg (UvA), G. Terra (NIOZ), (2002). Het grote internationale eurodiffusie-experiment. *Natuur & Techniek* **1**(11), 22–25.

G. Hek (UvA), M. Nuyens (UvA), H. van der Ploeg (UvA), R. Planqué, E. Vermeulen (Natuur & Techniek)(2002). Het grote internationale eurodiffusie-experiment. *Natuur & Techniek* **11**, 56–62.

Computing and Control – MAS2

Mission

The theme Computing and Control is concerned with the numerical and system-theoretical analysis of complex applications in science and engineering, as well as with with their simulation and control. Numerical simulation enables the investigation of phenomena that are too dangerous, too expensive, too difficult, or simply impossible to be studied by real experiments. Control and system theory is of vital importance to modern society; many systems (medical, environmental, industrial, civil-infrastructural, military, etc.) heavily rely on it. Because there is no end in sight yet for the growth of computing power or algorithmic improvements in numerical mathematics and system theory, the potential benefits of computing and control are enormous. The challenge is the simulation, control, design and optimization of ever more realistic problems.

The major part of the current research in this theme is directed towards *fluid-flow* applications and *network* applications. Advanced numerical techniques for complex fluid-flow problems are developed presently for ship hydrodynamics, aircraft and spacecraft aerodynamics, and relativistic magnetohydrodynamics. Control and system theory is currently formulated for network problems from engineering and biology (traffic networks, wireless communication networks, and biochemical reaction networks.) New will be research on computational methods for the Maxwell equations; *computational electromagnetics.* To start, this new research will be combined with the fluid-dynamics work. A small, successful research activity in the theme, related to computational fluid dynamics when it comes to high-performance computing, is *computational number theory and data security.* In September, this subtheme was extended with a PhD project on discrete tomography, which has connections with number theory and parallel processing.

Theme leader

Prof.dr.ir. B. Koren

Subthemes

Name	Leader
MAS2.1 – Computational Fluid Dynamics	B. Koren
MAS2.2 – Computational Number Theory and Data Security	H.J.J. te Riele
MAS2.3 – Control and System Theory	J.H. van Schuppen

MAS2.1 is concerned with research issues related to the computation of fluid flows for various complex applications. In 2002 emphasis lay on the development of:

- numerical methods for the computation of free-surface flows,
- discontinuous Galerkin methods for convection-diffusion problems,
- discretizations of the equations of gasdynamics in special relativity, and
- the parallelization of (i) software for the incompressible Stokes equations, and (ii) sparse-grid software for scalar convection-diffusion equations.

In MAS2.2 number-theoretic algorithms are studied which have applications in cryptography and image reconstruction and require the help of fast computers, particularly parallel systems. In 2002 emphasis was on the study of algorithms for factoring large numbers as a continuous validation of the RSA cryptosystem, and on algorithms for the solution of discrete tomography problems.

MAS 2.3 carries out research on synthesis of control laws for control systems and on modelling, realization, and system identification of dynamic phenomena by dynamic systems.

In the year 2002 the research focus included:

1. control, realization, and quantization of piecewise-affine hybrid systems on polytopes;
2. decentralized failure diagnosis of discrete-event systems;
3. control of discrete-event systems with coalgebra, including decentralized discrete-event systems; and
4. algebraic methods for optimization with applications in system identification and control theory.

Staff

CWI employees

Name	**Fte**	**Function(s)**	**Period**	**Subthemes + projects**	**Classification (MSC or CR)**
Drs. K.J. Batenburg	0.6	PhD student	2002-09-01 till 2006-9-01	MAS2.2: NWO6	11-xx, 65-xx, 94A12
Drs. D.P.L.D. Benden	1.0	PhD student	2002-02-01 till 2003-01-31	MAS2.1: NWO3	65-xx
Prof.dr. P.W. Hemker	0.8	CWI Fellow	indefinite	MAS2.1: UvA, NWO1, NWO2, NWO3, NWO4, STW	35-xx, 39-xx, 41-xx, 65-xx
Ms. D. Jibetean MSc	1.0	PhD student	1999-04-15 till 2003-06-15	MAS2.3: SICA	93-xx
Dr. J. Komenda	1.0	post-doc	2001-05-01 till 2003-05-01	MAS2.3: CO-CON	93-xx
Prof.dr.ir. B. Koren	0.8	theme leader, leader MAS2.1	indefinite	MAS2.1: NWO1, NWO2, STW, NCF1, NCF2	65-xx, 76-xx
Drs. B. Lastdrager (0.5 fte MAS1)	0.5	PhD student	1998-12-01 till 2002-03-01	MAS2.1: NWO1	65-xx
Ir. M.R. Lewis	1.0	PhD student	1999-10-01 till 2003-10-01	MAS2.1: STW	65-xx, 76-xx
Ms. Drs. M. Nool	0.5	programmer	indefinite	MAS2.1: NCF1, NWO5	65-xx
Dr. D.E.A. van Odyck	1.0	post-doc	2001-10-01 till 2003-10-01	MAS2.1: NWO2	65-xx, 76-xx
Drs. M. Petreczky	1.0	PhD student	2002-08-01 till 2006-08-01	MAS2.3: CON-TROL	93-xx
Dr.ir. H.J.J. te Riele	1.0	leader MAS2.2	indefinite	MAS2.2: NWO5, NWO6	11-xx, 65-xx, 94A12
Prof.dr.ir. J.H. van Schuppen	0.8	leader MAS2.3	indefinite	MAS2.3: CON-TROL, CO-CON, CC, TRAFFIC, RESI, LIFESYS-TEMS, SICA	93-xx

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
G.F. Duivesteijn (TUD)	p.m.	trainee of Koren	2002-01-01 till 2002-08-31	MAS2.1	65-xx, 76-xx
Dr.ir. L.C.G.J.M. Habets (TUE)	0.2	researcher	1999-12-01 till 2002-12-31	MAS2.3: CONTROL, COCON, CC, RESI	93-xx
Dr. B. Hanzon (VU)	0.2	advisor	1999-05-01 till 2003-05-01	MAS2.3: SICA	93-xx
G. Kandoi (IIT or UvA)	1.0	trainee of Hemker	May 2002 till July 2002	MAS2.1	65-xx
Prof.dr. B. van Leer (Univ. Michigan)	p.m.	advisor	indefinite	MAS2.1: STW, NWO2	65-xx, 76-xx
A. Mooij (Hogeschool Utrecht)	1.0	trainee of Te Riele	2002-02-01 till 2002-07-15	MAS2.2: NWO5	11-xx, 65-xx
Dr. W.A. Mulder (Shell Rijswijk)	0.2	researcher	2001-05-01 till 2002-04-01	MAS2.1	65-xx
Ir. M.H. van Raalte (UvA)	1.0	PhD student	2000-12-01 till 2004-12-01	MAS2.1: UvA	65-xx, 76-xx
J. Wackers (TUD)	0.2	trainee of Koren	2002-03-01 till 2003-01-01	MAS2.1	65-xx, 76-xx
Prof.dr.ir. P. Wesseling (TUD)	p.m.	advisor	till 2003-01-01		

Scientific report

Highlights

- Completion of PhD theses: E.H. van Brummelen, S.H. Cavallar, B. Lastdrager.
- Appointment of Koren as full professor of Computational Fluid Dynamics at the TUD, Faculty of Aerospace Engineering.
- Approval of a research proposal on Computational Electromagnetics in the program IOP-EMVT (Innovatieve Onderzoeksprogramma's – Electromagnetische Vermogenstechniek).
- Formulation of a discrete-event system and verification of this system which is a model for the wireless local area network protocol IEEE 802.11.
- Start of project Control and Computation (EU.IST.CC), which is financed by the European Commission through the Information Societies Technology Program on 1 January, 2002.

PhD research

Title	PhD research of B. Lastdrager
Period	December 1998–February 2002
Leaders	J.G. Verwer, B. Koren
Funding	NWO

See report on project NWO1 (page 107).

Title	PhD research of D. Jibetean
Period	April 1999–April 2003
Leader	J.H. van Schuppen, together with B. Hanzon and Peetrs (UM)
Funding	NWO
Partners	INRIA Sophia-Antipolis, Univ. Maastricht and Cambridge

See report on project SICA (page 112).

Title	PhD research of M.R. Lewis
Period	October 1999–September 2003
Leader	B. Koren
Funding	STW
Partners	MARIN, Delft Hydraulics, Shell Amsterdam, TUD, Univ. Michigan

See report on project STW (page 108).

Title	PhD research of M.H. van Raalte
Period	December 2000–November 2004
Leader	P.W. Hemker
Funding	UvA

See report on project UvA (page 108).

Title	PhD research of D.P.L.D. Benden
Period	February 2002–February 2003
Leader	P.W. Hemker
Funding	NWO

See report on project NWO3 (page 107).

Title	PhD research of M. Petreczky
Period	August 2002–July 2006
Leader	J.H. van Schuppen
Funding	CWI

See report on project CONTROL (page 110).

Title	PhD research of K.J. Batenburg
Period	September 2002–August 2006
Leader	H.J.J. te Riele
Funding	NWO

See report on project NWO6 (page 110).

MAS2.1 – Computational Fluid Dynamics

Computational Fluid Dynamics (CFD) is of crucial importance to many processes in science and engineering. Still one of the most fruitful application areas of CFD is aircraft aerodynamics. To enable aircraft filled with tons of fuel and hundreds of passengers, to safely fly over our heads, a detailed knowledge, understanding and control of aerodynamics is of vital interest. Besides safe, aircraft must also be economical, quiet, etc.

CFD is well-established now in industrial research and development. Evidence for this is found in the *Journal of Computational Physics* and other, related top journals. The majority of papers in these journals are still CFD papers. At present, CFD starts to cooperate with other disciplines such as solid mechanics (computational fluid-structure interactions) and electromagnetism (computational magnetohydrodynamics). Much fundamental research is still required for these new, challenging cooperations.

Title	NWO1 – Sparse-grid methods for transport problems
Period	December 1998–February 2002
Leaders	J.G. Verwer, B. Koren
Staff	B. Lastdrager
Funding	NWO
Partner	SEN3 (Everaars)

Progress report. The research of *Lastdrager* was mainly focused on the application of sparse-grid algorithms to unsteady convection-diffusion problems. This work led to two journal publications and one conference proceeding. *Lastdrager* assisted *Everaars* (SEN3) in making a start with the distributed implementation of his sparse-grid software on a cluster of workstations, using the Manifold coordination language. This parallelization work was funded separately by NCF (see report on project NCF2 on page 109). Besides, *Lastdrager* studied a growth model from neurobiology i.e., growth of axons with finite physical dimensions. *Lastdrager* received his PhD degree at the UvA, on September 18.

Title	NWO2 – Computational magneto-hydrodynamics in special relativity
Period	October 2001–September 2003
Leader	B. Koren
Staff	D.E.A. van Odyck
Funding	NWO
Partners	UU, Univ. Michigan, FOM Rijnhuizen

Progress report. This research is focused on the development and implementation of a computational method for the relativistic magneto-hydrodynamic (RMHD) equations. The RMHD equations mainly have an astrophysical application. The project is a collaboration between CWI, the astrophysical department of the UU and FOM Rijnhuizen. As a first step, the special relativistic hydrodynamic (SRHD) equations were studied. In a CWI report a review of numerical SRHD was given and a one-dimensional shock tube problem was considered to investigate the performance of the Riemann solver applied. The AMRVAC code developed at FOM Rijnhuizen was extended with a Roe-Riemann solver to handle the SRHD equations. It was found that a large jump in the transversal velocity component at the contact discontinuity causes non-physical numerical solutions. This problem is being analyzed and fixes will be proposed and tested.

Title	NWO3 – *hp*-Adaptive methods for 3D convection dominated flows
Period	February 2002–February 2003
Leader	P.W. Hemker
Staff	D.P.L.D. Benden, P.W. Hemker
Funding	NWO
Partner	UvA

Progress report. In this project more-dimensional *hp*-self-adaptive solvers for convection-diffusion flows are studied. In this first year the emphasis was on strategies for mesh- and order-refinement, based on the coefficients approximating the unknown functions on a hierarchical base. An algorithm performing the *hp*-adaptive representation of 1D-functions of arbitrary smoothness was developed and analyzed. A report is in preparation.

Title	NWO4 – Numerical singular perturbation problems
Period	January 2001–December 2003
Leaders	P.W. Hemker, G.I. Shishkin
Staff	G.I. Shishkin, L.P. Shishkina, P.W. Hemker
Funding	NWO
Partners	KUN, Moscow State Univ., Russian Academy of Sciences, Steklov Institute of Mathematics

Progress report. In this project the longstanding cooperation between the Institute of Mathematics and Mechanics (IMM, Ural Branch RAS, Ekaterinburg, Russia) and CWI, on research concerning the development of efficient and robust numerical methods for singularly perturbed boundary value problems, was continued. Special numerical methods which converge ε-uniformly, including high-order accurate methods, have been considered for singularly perturbed parabolic and elliptic equations. Model problems for quasi-linear and linear ordinary differential equations were examined. Numerical techniques based on domain decomposition on overlapping subdomains were introduced and studied. New iterative methods for sequential and parallel computations are shown to be robust in the sense that their solutions converge ε-uniformly as the number of mesh points and the number of iterations increases, where the number of iterations required for convergence is independent of ε.

Title	STW – Development of a state-of-the-art Navier-Stokes solver for water flows around moving ships
Period	October 1999–September 2003
Leader	B. Koren
Staff	M.R. Lewis, B. Koren
Funding	STW
Partners	MARIN, Delft Hydraulics, Shell Amsterdam, TUD, Univ. Michigan

Progress report. This research is focused on the development of a computational method for the steady, incompressible Navier-Stokes equations that allow for free-surface water waves. *Lewis* finalized the implementation of an efficient solution method for steady free-surface Navier-Stokes flow problems for 3D hydrodynamics computations. The proposed method has been tested on a 3D hovercraft-type flow with varying degrees of complexity. The results revealed good convergence behaviour and accuracy for linear and mildly nonlinear cases. *Lewis* and *Koren* further improved the robustness of the method for highly nonlinear cases. A more relevant test case from the realm of numerical ship hydrodynamics, i.e., the computation of the wave pattern generated by an actual ship hull, was considered. Comparison of the computed results with experimental data showed fairly accurate correspondence, while the convergence behaviour still remained satisfactory. Secondly, a comparison study of different types of nonuniform meshes for the computation of layer solutions was initiated, with the aim of investigating their usefulness in a more practical application. The meshes considered are Shishkin-type meshes and stretched meshes.

Title	UvA – Discontinuous Galerkin methods and singularly perturbed problems
Period	December 2000–November 2004
Leader	P.W. Hemker
Staff	M.H. van Raalte, P.W. Hemker
Funding	UvA
Partner	UvA

Progress report. In this joint project with the UvA, the efficient solution of convection-diffusion problems by means of discontinuous Galerkin methods is studied. In 2002 the emphasis of the research was on the solution of the large linear systems that arise from high-order discretisation, by means of multigrid iteration. It was shown that a straightforward multigrid-strategy is optimally efficient, provided that the discrete operator is decomposed in point-wise blocks, whereas classical cell-wise blocks are useless. The problem was thoroughly analyzed for the case with cubic approximations, because it represents the canonical form to which all higher-order problems can be reduced. First the analysis was made for the 1D-case, where the principal ideas were developed. Then the case with 1D linear approximations was analyzed. This is a special case because of a possible instability that has to be suppressed by means of an additional penalty term. Finally, the analysis was made for 2D problems. The newly developed ideas were presented at the Seventh European Multigrid Conference, held in Hohenwart, Germany, in October.

In order to handle complex domains in combination with *hp*-adaptive discontinuous Galerkin methods on structured hexahedral grids, in December research was continued with a study on embedded boundary conditions.

Title	NCF1 – Parallel implementation of a state-of-the art, incompressible Navier-Stokes method
Period	December 2000–May 2002
Leader	B. Koren
Staff	M. Nool, B. Koren
Funding	NCF
Partner	TUD

Progress report. In this project, the parallelization of the least-squares spectral element formulation of the Stokes problem has been completed for structured incompressible flow problems. In addition, the extension to unstructured spectral element discretizations has been made. To get good portable programs which may run on distributed-memory multiprocessors, networks of workstations as well as shared-memory machines, MPI (Message Passing Interface) has been used.

Least-squares spectral element methods result in symmetric and positive definite systems of linear equations which can be solved in parallel by Conjugate Gradient. The parallelization of this kind of problems requires two different strategies, involving a rather complicated parallel conversion between the data. The numerical results confirm the good parallel properties of the element-by-element parallelization strategy. The combination of this strategy with the parallel Conjugate Gradient solver with diagonal preconditioning resulted in a good parallelizable code to solve incompressible flow problems.

Numerical simulations have been performed to validate the scalability of the different parts of the proposed method. This has been done by simulating several large-scale incompressible flow problems on the Cray T3E and the SGI Origin 3800, where the number of processors has been varied from 1 to over 100. The recent results indicate that the least-squares spectral element method is a powerful method for future numerical simulations of incompressible flow problems. Numerical experiments with a more effective preconditioning method (Additive Schwarz) show a substantial reduction in the number of iteration steps. The parallelization of this preconditioner is currently in progress.

Title	NCF2 – Parallel implementation of a sparse-grid method for time-dependent advection-diffusion-reaction problems
Period	December 2001–November 2002
Leader	B. Koren
Staff	C.T.H. Everaars (SEN3), B. Lastdrager, B. Koren
Funding	NCF
Partner	SEN3

Progress report. This research was focused on the parallelization of an existing sparse-grid method for time-dependent advection-diffusion problems from project NWO1. Starting point was Lastdrager's sequential ANSI-C program that was given a parallel/distributed structure through a coarse-grain restructuring, a cut-and-paste method. The glue code necessary in this cut-and-paste work was written in the coordination language Manifold. The resulting renovated software runs efficiently on modern parallel/distributed environments. A report is in preparation.

MAS2.2 – Computational Number Theory and Data Security

Many problems in number theory, e.g., the problem of finding the prime factors of a given large positive integer and the problem of finding the positive integer x for which $a^x \equiv b \bmod p$ where p is a given (large) prime and a and b are given positive integers, are at the basis of modern cryptosystems (RSA, resp. Diffie-Hellman key exchange). This is the main motivation for the study of such problems in this subtheme. In addition, a PhD study was started, in September, in discrete tomography because some algorithms used here (developed by Tijdeman and Hajdu) originate from number theory, and because large sparse matrices are involved which also occur in algorithms for factoring large numbers. So parallel processing techniques used in factoring algorithms are expected to be useful for handling the large matrices which arise in discrete tomography.

Title	NWO5–Factoring large numbers as validation of RSA
Period	January 1997–December 2006
Leader	H.J.J. te Riele
Staff	A. Mooij
Funding	NWO (basic & project funding)
Partners	UL, Univ. Bonn, P.L. Montgomery (Microsoft, Redmond)

Progress report. Montgomery has factored various numbers from the Cunningham table with help of his implementation of the Number Field Sieve, using the idle time of many workstations and PCs at CWI, and, for the parallel block Lanczos step of the NFS, SARA's parallel computer

'Teras'. In cooperation with prof.dr. J. Franke and dr. T. Kleinjung of the Univ. Bonn, *Montgomery* carried out the parallel linear algebra step for factoring the 190-digit number $3^{397} + 1$ with his block Lanczos code on SARA's Teras computer.

Mooij studied Montgomery's MPI (Message Passing Interface) implementation of his block Lanczos algorithm within the NFS, and optimized some parts of Montgomery's code for CWI's cluster of 16 AMD Athlon XP processors, by converting these parts into assembly code.

Together with H.C. Williams, *Te Riele* finished his computations of the class numbers of the real quadratic fields $\mathcal{Q}(\sqrt{p})$ for all the primes $p \equiv 1 \bmod 4$ below 2×10^{11} (Report MAS-R0215). The distribution of the computed class numbers agrees well with the distribution predicted by the so-called Cohen-Lenstra heuristics. As a by-product, a conjecture of Hooley concerning *sums* of the class numbers was verified.

Te Riele almost finished the survey paper on amicable numbers, written jointly with J.M. Pedersen, to be presented at the Conference in Number Theory in Honour of professor H.C. Williams, Banff (Alberta, Canada), May 24–30, 2003. One of the aims of this paper is to explain the developments which have led to the explosion of known amicable pairs, from about 1100 in 1972, to almost 3 million in 2002.

Title	NWO6 – Mathematical aspects of discrete tomography
Period	September 2002–August 2006
Leader	H.J.J. te Riele
Staff	K.J. Batenburg
Funding	NWO (project funding)
Partners	UL, Univ. Debrecen

Progress report. Starting point for this project is an algorithm of Hajdu and Tijdeman for the reconstruction of binary images from their projections. Already in his Masters thesis 'Analysis and optimization of an algorithm for Discrete Tomography', *Batenburg* has sped up a MATLAB implementation of this algorithm considerably. He has started his PhD study by rewriting his thesis in order to make it suitable for submission to the International Workshop on Combinatorial Image Analysis (Palermo, May 14–16, 2003). He also has started to improve Hajdu and Tijdeman's algorithm so that it can handle much larger problems than could be handled so far. In addition, *Batenburg* has carried out a pilot study of the possibilities to extend the algorithm of Hajdu and Tijdeman from binary images to images with more than two values at the lattice points.

MAS2.3 – Control and System Theory

Title	CONTROL – Control of hybrid systems
Period	December 1998–February 2007
Leader	J.H. van Schuppen
Staff	L.C.G.J.M. Habets, M. Petreczky, J.H. van Schuppen
Funding	CWI

Progress report. Research on this project is directly related to that of Project CC, see page 111.

With D. Liberzon (CSL, Univ. Illinois, Urbana-Champaign, IL, USA), *Van Schuppen* investigated the quantization of the control law for the control-to-facet problem of an affine system on a polytope. They formulated a sufficient condition for the existence of a control law with only a finite number of values which achieves the control objective of behaviour to the exit facet. A paper is in preparation.

With R.K. Boel (Univ. Gent, Belgium), *Van Schuppen* investigated decentralized failure diagnosis problems. The novel feature is that communication between decentralized diagnosers is specifically included in the model. Diagnosis of a telephone network developed by A. Benveniste (IRISA/INRIA, Rennes, France) and the wireless local area network protocol IEEE 802.11, are examples of such a model. The fundamental control and diagnosis problems include questions on when to communicate between diagnosers or controllers, what to communicate, and to whom to communicate in case of three or more controllers. An algorithm was formulated for the communication between two diagnosers. The results were submitted and presented at the International Workshop on Discrete Event Systems (WODES), at the Univ. Michigan, at a workshop at Queen's Univ. Kingston, Canada, and at the Univ. Toronto. The general problem of decentralized control with communication was posed as an open problem and presented at the International Symposium MTNS 2002.

With S.R. Sreenivas (CSL, Univ. Illinois, Urbana-Champaign, IL, USA), *Van Schuppen* formulated a model for the wireless local area network protocol IEEE 802.11. In such networks, this protocol is primarily used. There is no control theoretic model, no verification, and no con-

trol synthesis for this model. The model of the plant with the decentralized controller is in the form of a discrete-event system. A verification of a simple model of the system has been carried out with the program UMDES. Further research is needed for the model and for the control synthesis.

With P.R. Kumar and the graduate student K. Plarre (CSL, Univ. Illinois, Urbana-Champaign, IL, USA), *Van Schuppen* carried out research on a probabilistic model for information exchange in a wireless local area network.

Petreczky has made the first steps towards conducting research in the area of hybrid systems. He has studied literature relevant to the subject under the guidance of *Van Schuppen*. In order to obtain background knowledge in classical control and system theory he took a number of courses.

At the request of the research institute KEMA in Arnhem, a model was developed for control of electric power networks for planning purposes. The problem is motivated by the liberalization of the electric energy markets. During 2002 discussions on the problem took place with I. Hiskens (Univ. Illinois, Urbana-Champaign, IL, USA), P. Varaiya (Univ. California, Berkeley, CA, USA), and with J. Zaborsky (Washington Univ., St. Louis, MO, USA).

Title	COCON – Coalgebra and control
Period	May 2001–May 2003
Leader	J.H. van Schuppen
Staff	J. Komenda, J.H. van Schuppen
Funding	NWO
Partner	SEN3

Progress report. A framework has been developed for control of partially observed discrete-event systems with coalgebra. Coalgebra provides an alternative framework for control of discrete-event systems. The concept of bisimulation was developed by R. Milner, and was set into coalgebra by J.J.M.M. Rutten and others. Bisimulation is an equivalence relation on the state sets of partially observed discrete-event systems. The basic control theoretic properties like controllability, normality, observability and coobservability can be characterized by relations that are weakened versions of bisimulation. There is a generic procedure how to verify these different properties using corresponding relations.

Results obtained by *Komenda* concern: (1) the observability relation which, together with other conditions, forms an equivalent condition for the existence of a supervisor based on partial observations; (2) a relation corresponding to coobservability; (3) a theorem which provides an equivalent condition for the existence of a set of supervisors for decentralized control of discrete-event systems; and (4) new algorithms for computation of supremal normal or normal and controllable sublanguages, infimal closed observable superlanguages and observable sublanguages larger than the supremal normal sublanguage.

Komenda and *Van Schuppen* currently develop an extended framework for decentralized control. A coalgebraic framework for decentralized control yields new concepts, theorems, and algorithms as it already has done for centralized control.

Title	CC – Computation and Control
Period	January 2002–January 2005
Leader	J.H. van Schuppen
Staff	L.C.G.J.M. Habets, J.H. van Schuppen
Funding	European Commission (EU.IST.CC)
Partners	Verimag, Parades, ETH Zürich, Lund Univ. Technology, EDF, ABB

Progress report. *Habets* and *Van Schuppen* investigated the realization problem of piecewise-affine hybrid systems. They established an equivalent condition for reducibility of an affine system on a polytope by an affine map due to unobservability of the system. The results were presented at the International Symposium MTNS 2002 and at a meeting of project EU.IST.CC.

They have further for piecewise-affine systems on polytopes investigated the attraction domain of exit facets as part of the reachability problem. A report on this is in preparation.

A paper on control synthesis for the control-to-facet problem of an affine system on a polytope was revised and extended. The problem of partitioning a polytope into simplices was investigated and its complexity was analyzed. The results were presented at a meeting of project CC.

Though formally not part of Project CC, *Habets* in cooperation with C. Belta and George Pappas (Univ. Pennsylvania, Philadelphia, PN, USA), derived a control law for the control-to-facet problem for multi-affine systems on rectangles. An example to a biological system was treated. A paper was presented at the Conference on Decision and Control in December 2002.

Title	TRAFFIC – Control and modelling of motorway traffic
Period	1998–2002
Leader	J.H. van Schuppen
Staff	J.H. van Schuppen
Funding	CWI

Due to the sabbatical leave of *Van Schuppen*, no research was carried out on this project in 2002.

Title	RESI – Realization and system identification
Period	1998–2002
Leader	J.H. van Schuppen
Staff	L.C.G.J.M. Habets, J.H. van Schuppen, D. Jibetean
Funding	CWI
Partners	CBS, Univ. Illinois

Progress report. With J.M. van den Hof (CBS, formerly CWI), *Van Schuppen* wrote a tutorial article on system identification for the Encyclopedia of Life Support Systems. Contacts were maintained on the paper with C. Beck (Univ. Illinois, Urbana-Champaign, IL, USA).

With S. Meyn (CSL, Univ. Illinois, Urbana-Champaign, IL. USA), *Van Schuppen* has investigated the problem of system reduction for positive linear systems. An algorithm was formulated and proven to minimize the L_1 norm of the output function. A paper is in preparation.

With Mr. Cheng Tang (CSL, Univ. Illinois, Urbana-Champaign, IL. U.S.A.), Jan H. van Schuppen derived a formula for the divergence rate of the probability measures associated with the output processes of two Gaussian stochastic systems. A paper is in preparation.

Jibetean and *Van Schuppen* have investigated the system reduction problem for Gaussian stochastic systems with the divergence rate criterion, also called the Kullback-Leibler rate criterion. It was established that the problem can be reduced to a problem of infimization of a rational function. For this problem Jibetean has developed an algebraic method which was thus applied. Two examples were treated.

Title	LIFESYSTEMS – Control and system theory for biology
Period	2001–2009
Leader	J.H. van Schuppen
Staff	J.H. van Schuppen
Funding	CWI
Partners	VU, Univ. Illinois

Progress report. *Van Schuppen* has investigated the modelling, realization, and control of rational positive systems. Such systems arise as models of biochemical reaction networks. The research is carried out in cooperation with Prof. H.V. Westerhoff and B. Bakker (Dept. of Biology, VU). In the research of Bakker, a rational positive system arises as a model for the glycolysis of the bacterium *trypanosoma brucei*. Results address the mathematical formulation of the system, the realization problem, the graph relating the chemical compounds via the reactions, and control by medicine of the dynamic behaviour of the network. A paper is in preparation.

With B. Hajek and J. Alvarez (CSL, Univ. Illinois, Urbana-Champaign, IL, USA), *Van Schuppen* investigated a model for the flow in ion channels in cells in the human body. Mathematical properties of the partial stochastic differential equation were analyzed. Research on the problem is continued by the cooperators at UIUC. A meeting took place with the biochemist R. Eisenberg (Rush Medical College, Chicago, IL, USA) on the problems for the model.

Title	SICA – System Identification with Computer Algebra
Period	1999–2003
Leaders	B. Hanzon, J.H. van Schuppen
Staff	D. Jibetean, B. Hanzon, J.H. van Schuppen
Funding	NWO
Partner	UM

Progress report. Together with R.L.M. Peeters (UM) we investigated applications of techniques from constructive and computer algebra to several problems in the area of system identification, including optimal model order reduction, identifiability analysis and optimization problems arising in this field. Particular attention has been given to model reduction problems with respect to the H_2 norm and divergence rate criterion. Systems with uncertainties have been studied.

Externally financed networks

Title	SI – System Identification
Period	1998–March 1, 2003
Leader	J.H. van Schuppen
Staff	L.C.G.J.M. Habets, J.H. van Schuppen
Funding	EU (network)
Partners	Tech. Univ. Vienna (M. Deistler); Cath. Univ. Louvain-la-Neuve, Belgium (M. Gevers);

	INRIA Sophia Antipolis, France (L. Baratchart); IRISA, Univ. Rennes, France (J.-J. Fuchs); Univ. Cambridge, UK (J.M. Maciejowski); Istituto di Bioingegneria e Control, CNR, Padova (G. Picci); Royal Institute of Technology (KTH), Stockholm (A. Lindquist); Univ. Linköping, Sweden (L. Ljung)

Progress report. The financial means of the project are primarily for PhD students and postdocs. There are no financial means for actual joint research though the contacts of the project are used for this purpose. During 2002 the members of the subtheme remained in contact with the other teams of the project via meetings with individual researchers and via the annual ERNSI Workshop System Identification.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- NWO2; see page 107.
- STW; see page 108.
- NWO5; see page 109.
- CC; see page 111.
- RESI; see page 112.

Contacts with business and other organizations

- KEMA, Arnhem; see page 111.
- Parades, Rome, Italy; see page 111.

Teaching activities

- Capita course at UvA 'Advanced Scientific Computing': P.W. Hemker.
- Course Numerical Hydrodynamics, University of Amsterdam January–March: P.W. Hemker.
- Course Numerical Aircraft Aerodynamics II, TUD, January–March: B. Koren.
- Course Random Processes, Department of Electrical and Computer Engineering, Univ. Illinois, Urbana-Champaign, Illinois, USA, January–May: J.H. van Schuppen.
- Course Mathematical Control and System Theory, VU, September–December: J.H. van Schuppen with prof. A.C.M. Ran (VU).
- Onderwijsweek Numeriek Oplossen van Multiprocess-Multiscale-Differentiaalvergelijkingen, Thomas Stieltjes Institute for Mathematics, March 11–15: P.W. Hemker.
- Supervision of trainee from IIT New Delhi: P.W. Hemker.
- Supervision of trainee from the UvA (Kuut): P.W. Hemker.
- Supervision of trainees from TUD (Duivesteijn, Voort and Wackers): B. Koren.
- Supervision of trainee from Hogeschool Utrecht (Mooij): H.J.J. te Riele, M. Nool.

Other external contacts

- MAS2.2 has several source code licence agreements with companies in the Netherlands, USA, Germany and France allowing 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.H. Cavallar and B. Dodson.

  During 2002, the NFS source code has been made available for research purposes, on a non-commercial basis, to *four* other cooperating groups in the USA, Canada, Portugal, and the Netherlands, respectively.

Organization of conferences, workshops, courses, meetings

- EU/NSF-meeting, CWI, February 21: B. Koren.
- MAS-Seminar, CWI, February 25, March 25, June 17: P.W. Hemker, B. Koren, B. Lastdrager, M.R. Lewis, M. Nool, D.E.A. van Odyck, M.H. van Raalte, D.P.L.D. Benden, H.J.J. te Riele, J.H. van Schuppen.
- Seminars Rapid Changes in Complex Flows, CWI, April 11, November 13: B. Koren.
- Workshop on Factoring Large Numbers, CWI, June 4: H.J.J. te Riele.
- Meeting STW-project, CWI, September 3: B. Koren.
- CWI Seminar Control and System Theory, Fall, September–December, once every two weeks: J.H. van Schuppen. Topics: Geometric approach to linear systems and Binary Decision Diagram (BDD) algorithms.
- CWI Colloquium Control and System Theory, Fall, October–December, once every two weeks: J.H. van Schuppen.
- CFD-meetings at CWI (tri-weekly): B. Koren.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- CFD-Course, TUD, January 14–18: M. Nool.
- Workshop on Dependence structures in highly dimensional dynamical processes (organized by H.P. Wynn and A. di Bucchianico), Eindhoven, EURANDOM, January 31–February 1: B. Hanzon. (Lecture: *Algebraic optimization techniques for the estimation of zero-beta models*).
- Seminar Rapid Changes in Complex Flows, February 13 (FOM Rijnhuizen), April 11 (CWI), July 3 (UU), September 16 (FOM Rijnhuizen), CWI, November 13: P.W. Hemker, B. Koren (Lecture July 3: *Extension to Multi-D of a Riemann Solver for the Equations of Gasdynamics in Special Relativity*), D.E.A. van Odyck (Lecture February 13: *Numerical Relativistic Hydrodynamics*).
- Study Group Mathematics with Industry 2002, UvA, February 18: P.W. Hemker.
- Workshop Weighted Automata: Theory and Applications, Dresden, Germany, March 4–8: J. Komenda.
- Benelux Meeting, Houffalize, Belgium, March 26–28: D. Jibetean (Lectures: (1) *Linear Matrix Inequalities for Optimization of Rational Functions*; (2) *Global H2-approximation in state-space: a case study* (presented by a co-author)).
- Landelijke VGWM-dag, Jaarbeurs, Utrecht, March 21: M. Nool.
- 38e Nederlands Mathematisch Congres, TUE, April 4: P.W. Hemker.
- EIDMA Cryptography Working Group, Utrecht, April 12, October 4, December 13: H.J.J. te Riele (Lecture December 13: *Cryptography in quadratic number fields*).
- DIMACS Workshop Complexity in Biosystems, Rutgers Univ., Piscataway, NJ, USA, April 8–10: J.H. van Schuppen.
- Seminar with numerical mathematicians from Otto von Guericke Univ., Magdeburg, CWI, April 12: P.W. Hemker, B. Koren.
- AMIF 2002, Lisbon, April 17–20: B. Koren (Lecture: *Fixes for Solution Errors near Interfaces in Two-Fluid Flow Computations*).
- International Conference on Computational Science, Amsterdam, April 21–24: P.W. Hemker, M. Nool (Lecture: *Parallel Implementation of a Least-Squares Spectral Element Solver for Incompressible Flow problems*).
- EUROCRYPT 2002, Amsterdam, April 29–May 2: H.J.J. te Riele.
- Seminar CWI – UT Institute of Mechanics, CWI, May 28: P.W. Hemker (Lecture: *Multigrid for Discontinuous Galerkin Discretisation*), B. Koren (Lecture: *A Pressure-Invariant, Conservative Method for Two-Fluid Flows*).
- IFIP WG 2.5 Meeting and Workshop, Intel, Portland, Oregon USA, June 1–4: P.W. Hemker.
- North-American Workshop on Discrete-Event Systems, Queen's Univ., Kingston, Ontario, Canada, June 12 – 14: J.H. van Schuppen (Lecture: *Decentralized control and decentralized failure diagnosis for discrete-event systems with communication between controllers and diagnosers*).
- 5th International Meeting on High Performance Computing for Computational Science, VECPAR 2002, Tutorial: Performance Analysis and Prediction of Large-Scale Scientific Applications, Porto, Portugal, June 25: M. Nool.
- 5th International Meeting on High Performance Computing for Computational Science, VECPAR 2002, Porto, Portugal, June 26–28: M. Nool (Lecture: *A Parallel State-of-the-Art Least-Squares Spectral Element Solver for Incompressible Flow problems*).
- Third International Symposium on Finite Volumes for Complex Applications, Porquerolles, France, June 24–28: B. Koren (Lecture: *An Osher-Type and Level-Set Scheme for Two-Fluid Flow Computations*).
- 7th International Workshop on High Performance Optimization, Tilburg, The Netherlands, June 27–28: D. Jibetean.
- BAIL 2002, International Conference on Boundary and Interior Layers. Univ. Western Australia, Perth, July 8–12: P.W. Hemker.
- Second International Conference on Computational Fluid Dynamics (ICCFD2), Sydney, Australia, July 15–19: P.W. Hemker (Lecture: *Fixes for zeroth-order solution errors near two-fluid interfaces*), M.R. Lewis (Lecture: *Computation of 3D steady Navier-Stokes flow with free-surface gravity waves*).
- Workshop Advanced hybrid systems for networked control systems, part of the IFAC

World Congress 2002, Barcelona, Spain, July 21: J.H. van Schuppen (Lecture: *Research directions in control of hybrid systems and of discrete-event systems*).

- International Symposium on the Mathematical Theory of Networks and Systems (MTNS2002), Univ. Notre Dame, South Bend, IN, USA, August 12–16: D. Jibetean (Lecture: *Linear Matrix Inequalities for Global Optimization of Rational Functions and H2 Optimal Model Reduction*), J. Komenda (Lecture: *Coalgebra and supervisory control of discrete-event systems with partial observations*), J.H. van Schuppen (Lectures: (1) *Reduction of affine systems on polytopes*; (2) *Control and algebra – An introduction*; (3) *Decentralized control and failure diagnosis with communication between controllers and diagnosers*). J.H. van Schuppen was Chair person of first plenary session, session chair of a session, and participated in the meeting of the Steering Committee of MTNS.
- Intercity Number Theory Seminar, UL, September 13: H.J.J. te Riele.
- ERNSI Workshop System Identification, Le Croisic, France, September 23–25: L.C.G.J.M. Habets (Lecture: *Reduction of affine systems on polytopes*), B. Hanzon (Poster: *Optimal H2 model reduction in state-space: a case study* (joint work with D. Jibetean and R. Peeters)), and J.H. van Schuppen (Lecture: *ERNSI System identification and system theory*). Van Schuppen was chairman of the meeting of the Council of Team Leaders, and of a session.
- Woudschoten Conference on Numerical Mathematics, Woudschoten, September 25–27: D.P.L.D. Benden, P.W. Hemker, B. Koren, M.R. Lewis, M. Nool, M.H. van Raalte.
- Seminar in honour of the 65th birthday of professor J.J.H. Miller, Dublin, September 26–27: P.W. Hemker (Lecture: *A few remarks on numerical singular perturbation problems*).
- NWO-OTKA Workshop on Explicit algebraic number theory, Leiden, September 27–October 2, H.J.J. te Riele (Lecture October 2: *New class number computations and the Cohen-Lenstra heuristics*).
- 6th International Workshop on Discrete Event Systems, Zaragoza, Spain, October 2–4: J. Komenda (Lecture: *Computation of supremal sublanguages of supervisory control using coalgebra*), J.H. van Schuppen (Lecture: *Decentralized failure diagnosis for discrete-event systems with costly communication between diagnosers*). J.H. van Schuppen was chairman of a session.
- Seventh European MultiGrid Conference (EMG'02), Hohenwart , Germany, October 7–10: P.W. Hemker, M.H. van Raalte (Lecture: *Multigrid methods for discontinuous Galerkin discretisation*).
- Oriëntatiedagen Hoogleraren TUD, UL, Noordwijk, The Netherlands, October 9–10: B. Koren.
- NAKE Research Day 2002, Amsterdam, Dutch Central Bank, October 18: B. Hanzon (Lecture: *A Rational Probability Density Approach to Stochastic Volatility Estimation*).
- Preconditioning methods for optimal control and constrained optimization problems (PMOCCO'2002), Nijmegen, October 24–26: G.I. Shishkin (Lecture: *On conditioning of a Schwarz iterative method on overlapping subdomains for singularly perturbed convection–diffusion equations*), P.W. Hemker (Lecture: *Multigrid for discontinuous Galerkin discretization*).
- First International Symposium on Formal Methods for Objects and Components (FMCO2002), UL, November 7: J.H. van Schuppen.
- 52^{e} bijeenkomst Kontaktgroep Numerieke Stromingsleer, NLR, Amsterdam, November 8: M.R. Lewis.
- Lustrum Stieltjes Instituut 1992–2002, The Hague, November 15, H.J.J. te Riele.
- Najaarssymposium 2002 van het Wiskundig Genootschap: Wiskunde in breder verband, Nijmegen, November 22: H.J.J. te Riele (Lecture: *Toegepaste getaltheorie: de alomtegenwoordigheid van de priemgetallen*), M. Nool.
- Indefinite Symphony, Workshop on preconditioning methods for indefinite linear systems, TUE, December 9: M. Nool.
- 19th Annual Supercomputer User Meeting, SARA, Amsterdam, December 12: M. Nool.

Working visits

- Sabbatical leave at the Coordinated Sciences Laboratory, Department of Electrical and Computer Engineering, Univ. Illinois, IL, USA, January 1–June 30: J.H. van Schuppen (Lecture February 12: *Control and realization of piece-wise linear hybrid systems*).
- MARIN, Wageningen, The Netherlands (January 11, March 12, May 10, October 17 and 23): M.R. Lewis.

- Dr. R. Keppens, FOM Rijnhuizen, Nieuwegein February 6: M. Nool.
- Prof. P.R. Kumar, Coordinated Science Laboratory, UIUC, Urbana-Champaign, IL, USA, February 17–March 1 and April 22–May 5: J. Komenda (Lecture March 19: *Control of partially observed discrete-event systems using coalgebra*).
- ERCIM Executive Committee meeting, INRIA Sophia-Antipolis February 10–11; Vienna June 2–6: B. Koren.
- Philips Research Laboratory, Eindhoven, February 25: P.W. Hemker.
- Guest professorship at the Institute für Ökonometrie, Operations Research und System Theorie, Technische Univ. Wien, Vienna, Austria, March–June: B. Hanzon (Inaugural lecture March 11: *Algebraic optimization techniques for zero-beta CAPM and APT models*).
- Prof. D. Burkholder, Department of Mathematics, Univ. Illinois, Urbana-Champaign, IL, USA, March 7: J.H. van Schuppen.
- TLO/BGO-dag, Amsterdam, March 18: B. Koren.
- Prof. B. Poetscher, Institut für Statistik und Decision Support Systems, Univ. Vienna, Austria, April 15: B. Hanzon (Lecture: *State-space calculations for discrete probability densities*).
- Prof. S. Lafortune, Univ. Michigan in Ann Arbor, MI, USA, April 22: J. Komenda (Lecture: *Coalgebra and supervisory control of discrete-event systems*).
- Prof. Sri Namachivaya, Department of Aeronautics and Astronautics, Univ. Illinois, Urbana-Champaign, IL, USA, May 7: J.H. van Schuppen (Lecture: *Control of freeway traffic flow*).
- Institute of Advanced Studies, Vienna, Austria, May 7: B. Hanzon (Lecture: *Algebraic optimization techniques for zero-beta CAPM and APT models*).
- Prof. J. Rosenthal and prof. P. Antsaklis, Department of Mathematics of the Univ. Notre Dame, South Bend, Indiana, USA, May 8–9: J.H. van Schuppen (Lecture: *Control and realization of piecewise-linear hybrid systems*).
- Coalgebra Meeting, KUN, May 17: J. Komenda (Lecture: *Coalgebraic study of weak bisimulations of deterministic automata*).
- Prof. P. Varaiya, prof. S. Sastry, prof. V. Anantharam, dr. A. Puri, prof. J. Walrand, Department of Electrical Engineering and Computer Science of the Univ. California, Berkeley, CA, USA, May 15 – 19: J.H. van Schuppen.
- Prof. S. Lafortune and prof. D. Teneketzis, Department of Electrical Engineering and Computer Science of the Univ. Michigan, Ann Arbor, MI, USA, May 22–24: J.H. van Schuppen (Lecture: *Decentralized control and decentralized diagnosis for discrete-event systems with communication between controllers and diagnosers*).
- Dr. C.W. Oosterlee, Faculty of Information Technology and Systems, TUD, May 24: B. Koren.
- Prof. Th. de Jong, Faculty of Aerospace Engineering, TUD, May 29: B. Koren.
- Mathematics Department of the Univ. Illinois at Urbana-Champaign, IL, USA, May 28: J.H. van Schuppen (Lecture: *Stochastic realization and system identification*).
- Prof. H. Mukai, prof. B.J. Ghosh, prof. Tzi-Jong Tarn, prof. J. Zaborsky, Department of Systems Science and Mathematics, Washington Univ., St. Louis, MO, USA, May 29–30: J.H. van Schuppen (Lecture: *Control and realization of piece-wise linear hybrid systems*).
- EMVT, Philips Medical Systems, Best, June 13: P.W. Hemker.
- Prof. B. Francis, prof. R. Kwong, prof. W.M. Wonham, Department of Electrical and Computer Engineering, Univ. Toronto, Canada, June 17–18: J.H. van Schuppen (Lecture June 17: *Decentralized control and decentralized failure diagnosis for discrete-event systems with communication between controllers and diagnosers*; June 18: *Control and realization of piece-wise linear hybrid systems*).
- Prof. R.K. Boel, Univ. Gent, Belgium, September 9: J.H. van Schuppen.
- Prof. A.J.A. Vandenput, Faculty of Electrical Engineering, TUE, October 30: B. Koren, J. Wackers.
- Ir. M.M.J. Proot, Faculty of Aerospace Engineering, TUD, December 11: M. Nool.

Project meetings

- Meeting of Project CC, Lund, Sweden, May 22–23: L.C.G.J.M. Habets.
- Meeting of Advisory Committee of D. Jibetean, CWI, July 9: D. Jibetean, B. Hanzon, R. Peeters (UM), J.H. van Schuppen.
- STW meeting, September 3, CWI: B. Koren, M.R. Lewis.

- Meeting of the users committee of the STW Project Mobile communication, STW, Utrecht, September 18: J.H. van Schuppen.
- Meeting working group Computational Science and Engineering, TUD, September 23, October 21: B. Koren.
- Kick-off meeting IOP-EMVT, Ede, October 24: P.W. Hemker, B. Koren, J. Wackers.
- Meeting of Project CC, Ascona, Switzerland, October 29–31: J. H. van Schuppen (Lecture: *Control and system theory of hybrid systems*).
- Kick-off NWO-program Scientific Computing, CWI, November 29: P.W. Hemker.
- Kick-off meeting NWO-program Computational Science, CWI, November 29: P.W. Hemker, M.R. Lewis, M. Nool, D.E.A. van Odyck, H.J.J. te Riele.

Other lectures

- CWI in Bedrijf, CWI, October 18: J.H. van Schuppen (Lecture: *Systeem- en Regeltheorie met Toepassingen*).
- CWI Colloquium Control and System Theory, CWI, November 5: J.H. van Schuppen (Lecture: *Control and algebra - An introduction*).
- CWI Colloquium Control and System Theory CWI, November 11: J.H. van Schuppen (Lecture: *Protocol IEEE 802.11 - Modeling and control*).
- CWI Colloquium Control and System Theory, November 19: J. Komenda (Lecture: *Decentralized control of discrete-event systems with coalgebra*).

Courses

- Mathematical Models of Systems, Dutch Institute for Systems and Control (DISC), Fall 2002: M. Petreczky.
- Design Methods for Control Systems, Dutch Institute for Systems and Control (DISC), Winter 2002–2003: M. Petreczky.
- Mathematical Control and Systems Theory, Department of Mathematics, VU, Fall 2002: M. Petreczky.

Memberships of committees and other professional activities

P.W. Hemker

- Full professor Scientific Computing, UvA.
- Vice-chair Working Group 2.5 on Numerical Software, IFIP.
- Member of Science Committee, Thomas Stieltjes Institute for Mathematics.
- Member Steering group Amsterdam Centre for Computational Science, ACCS.
- Member Numerical Algorithms Group, NAG Inc.
- Associate editor *Computational Methods in Applied Mathematics*.
- Vice-chair International Program Committee, International Conference Computational Methods in Applied Mathematics, Minsk, Belarus, July 2003.
- Member Users Committee STW-project 'Development of a state-of-the-art Navier-Stokes solver for water flows around moving ships'.
- Thesis advisor E.H. van Brummelen, UvA, February 8.
- Member of PhD Committee D. Lanser, UvA, March 7.
- Member of PhD Committee B. Lastdrager, UvA, September 18.
- Member of MSc Committee A. Kuut, UvA, August 30.

B. Koren

- Full professor Computational Fluid Dynamics, TUD, Faculty of Aerospace Engineering (since May 1).
- Member Scientific Committee ECCOMAS CFD Conference, Rotterdam, 2006.
- Member ERCIM Executive Committee (until June 1).
- Member PhD Committee E.H. van Brummelen, UvA, February 8.
- Member MSc Committee J.M. Cnossen, TUD, Faculty of Aerospace Engineering, August 30.
- Member PhD Committee B. Lastdrager, UvA, September 18.
- Member MSc Committee G.F. Duivesteijn, TUD, Faculty of Aerospace Engineering, October 4.
- Referee of several scientific papers.

M. Nool

- Referee of paper for scientific journal.

H.J.J. te Riele

- Secretary of the Beeger Committee which selects and organizes the Beeger Lecture during the Nederlands Mathematisch Congres.
- Member of the Committee which made a bid (in December) 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 *Zentralblatt für Mathematik*, and referee of papers for various scientific journals.
- Chairman of the CWI - Library Committee.

J.H. van Schuppen

- Full professor in Applied Analysis at the Department of Mathematics, Faculty of Exact Sciences, VU (since 2000).
- Editor-in-Chief, journal *Mathematics of Control, Signals, and Systems* (since 1994).
- Series Co-Editor of Springer's Communication and Control Engineering Series, Springer Verlag London Ltd. (since January 2002).
- Member of Graduate School Dutch Institute for Systems and Control (DISC).
- Member of Graduate School Thomas Stieltjes Institute of Mathematics.
- Coordinator of the project System Identification which is financially supported by the European Commission through the Training and Mobility of Researchers Program, meeting on September 24 in Le Croisic, France.
- Chairman of Curatorium of the special chair in mathematical system theory and analysis at the VU.
- Chairman of Advisory Committee of the PhD student D. Jibetean, meeting on July 9.
- Member of reading committee of the PhD thesis of S. Bhulai, Department of Mathematics, VU.
- Member of Steering Committee of the International Symposia on the Mathematical Theory of Networks and Systems (MTNS), meeting August 14.
- Member of Program Committee of 13th IFAC Symposium on System Identification (SYSID2003) August 27–29, 2003, Rotterdam, The Netherlands.
- Member of Program Committee of IFAC Conference on the Analysis and Design of Hybrid Systems, ADHS03, Saint Malo, France, scheduled for June 16–18, 2003.
- Member of Program Committee of IFAC Workshop 'Logical-Dynamic Models of Controlled Processes', Irkutsk, Russia, scheduled for July 30–August 1, 2003.

Visitors

- A.A. Achterberg, J. Bergmans (UU), February 28. Host: B. Koren.
- B. Poonen (Univ. California at Berkeley), April 3–4, Beeger on April 4: (Lecture: *Integer and rational solutions to polynomial equations*). Host: H.J.J. te Riele.
- M.M.J. Proot (TUD), May 15. Host: M. Nool.
- The following five visitors presented a talk during the *Workshop on Factoring Large Numbers* on June 4 at CWI, P.L. Montgomery (Microsoft Research, Redmond, Ca, USA), June 2–7; J. Franke (Univ. Bonn, Germany) June 4; T. Kleinjung (Univ. Bonn, Germany), June 4; A.K. Lenstra (Citibank, Parsippany, NJ, USA and TUD), June 4; P. Leyland (Microsoft Research, Cambridge, UK), June 4. Host: H.J.J. te Riele.
- H.C. Raven (MARIN), June 10. Host: B. Koren.
- M.M.J. Proot (TUD), August 5. Host: B. Koren.
- B. van Leer (Univ. Michigan, USA), August 13. Host: B. Koren.
- D. Zwarts (Shell Rijswijk), August 27. Host: B. Koren.
- A. Pethő (Univ. Debrecen, Hungary), September 25–26. Host: H.J.J. te Riele.
- Ms. E. Abraham-Mumm, Institut für Informatik, Christian-Albrechts-Univ. Kiel, Germany, October 16 (Lecture: *Deductive verification of hybrid systems: Formalization and proof rules in PVS*). Hosts: M. Petreczky, J.H. van Schuppen.
- The following three visitors presented a talk during the *Intercity Number Theory Seminar* on October 18 at CWI: A. van der Poorten (Macquarie Univ. Sydney, Australia), October 18; Szabolcs Tengely (UL), October 18; H.W. Lenstra, Jr. (UL), October 18. Host: H.J.J. te Riele.

- L.P. Shishkina (IMM Ekaterinburg, Russia), October 15–November 15. Host: P.W. Hemker.
- G.I. Shishkin (IMM Ekaterinburg, Russia), October 15–November 15. Host: P.W. Hemker.
- H-G. Roos (TU Dresden, Germany), November 11–13. Host: P.W. Hemker.
- S. Houben (TUE), December 9. Host: P.W. Hemker.

Publications

Papers in refereed journals and proceedings

R.K. Boel (Univ. Gent, Belgium), J.H. van Schuppen (2002). Decentralized failure diagnosis for discrete-event systems with costly communication between diagnosers. *Proceedings 6th International Workshop on Discrete Event Systems* (WODES'02), IEEE Computer Society Press, IEEE, Los Alamitos, CA, USA, 175–181.

E.H. van Brummelen (MAS2 PhD-student until September 2001), A. Segal (TUD) (2002). Adjoint shape optimization for steady free-surface flows. *International Journal for Numerical Methods on Fluids,* **40**, 605–614.

J.H.C. Diris (UM), W.Th. Hermens (UM), P.W. Hemker, W.K. Lagrand (VU), C.E. Hack (VU), M.P. van Dieijen-Visser (UM) (2002). Pharmacokinetics of C1-inhibitor protein in patients with acute myocardial infarction. *Clinical Pharmacology & Therapeutics* **72**(5), 498–504.

L.C.G.J.M. Habets, J.H. van Schuppen (2002). Reduction of affine systems on polytopes. *Proceedings International Symposium MTNS2002,* Notre Dame, IN, USA.

P.W. Hemker, G.I. Shishkin (Russian Academy of Sciences, Ural Branch) L.P. Shishkina (2002). High-order time-accurate schemes for parabolic singular perturbation problems with convection. *Russian J. Numer. Anal. Math. Modelling* **17**(1), 1–24.

P.W. Hemker, G.I. Shishkin (Russian Academy of Sciences, Ural Branch) L.P. Shishkina (2002). High-order time-accurate schemes for singularly perturbed parabolic convection-diffusion problems with Robin boundary conditions. *Comp. Methods in Appl. Math.* **2**(1), 3–25.

P.W. Hemker, G.I. Shishkin (Russian Academy of Sciences, Ural Branch) L.P. Shishkina (2002). Defect correction high-order accurate schemes for parabolic singularly perturbed convection-diffusion problems. *Proceedings of the International Conference of Computational Mathematics*, Novosibirsk, 454–459.

P.W. Hemker, G.I. Shishkin (Russian Academy of Sciences, Ural Branch) I.V. Tselishcheva (2002). Parameter-uniform numerical methods for a class of quasilinear singularly perturbed convection-diffusion equations in a composed domain. *Proceedings of the International Conference of Computational Mathematics*, Novosibirsk, 460–466.

D. Jibetean, B. Hanzon (2002). Linear matrix inequalities for global optimization of rational functions and H2 optimal model reduction. *Proceedings International Symposium MTNS2002,* Notre Dame, IN, USA.

J. Komenda (2002). Coalgebra and supervisory control of discrete-event systems with partial observations. *Proceedings International Symposium MTNS2002,* Univ. Notre Dame, IN, USA.

J. Komenda (2002). Computation of supremal sublanguages of supervisory control using coalgebra. *Proceedings 6th International Workshop on Discrete Event Systems* (WODES'02), IEEE Computer Society Press, IEEE, Los Alamitos, CA, USA, 26–33.

B. Koren, M.R. Lewis, E.H. van Brummelen (TUD), B. van Leer (Univ. Michigan) (2002). Riemann-problem and level-set approaches for homentropic two-fluid flow computations. *Journal of Computational Physics,* **181**, 654–674.

B. Koren, M.R. Lewis, E.H. van Brummelen (TUD), B. van Leer (Univ. Michigan) (2002). An Osher-type and level-set scheme for two-fluid flow computations. R. Herbin, D. Kröner (eds.). *Proceedings of the Third International Symposium on Finite Volumes for Complex Applications*, Porquerolles, Hermes Penton, London, 583–590.

J.J.H. Miller (Trinity College, Dublin), G.I. Shishkin (Russian Academy of Sciences, Ural Branch), B. Koren, L.P. Shishkina (2002). Grid approximation of a singularly perturbed boundary value problem modelling heat transfer in the case of flow over a flat plate with suction of the boundary layer. S. Wang, N. Fowkes (eds.). *Proceedings of The International Conference on Boundary and Interior Layers - Computational and Asymptotic Methods*, Perth, Univ. Western Australia, Crawley, 13–22.

M. Nool, R. Keppens (FOM) (2002). AMRVAC: A Multidimensional Grid-Adaptive Magnetofluid Dynamics Code. *CMAM* **2**(1), 92–109.

M. Nool, M.M.J. Proot (TUD) (2002). Parallel implementation of a least-squares spectral element solver for incompressible flow problems. P. Sloot, C.J.K. Tan, J.J. Dongarra, A.G. Hoekstra (eds.). *Proceedings of the International Conference on Computational Science - ICCS 2002*, Amsterdam, LNCS **2329**, Springer, Berlin, 900–909.

M. Nool, M.M.J. Proot (TUD) (2002). A parallel, state-of-the-art, least-squares spectral element solver for incompressible flow problems. *Proceedings of VECPAR'2002 - 5th International Meeting on High Performance Computing for Computational Science*, Univ. Porto, Falcudade de Engenharia, FUEP, Portugal, 185–197.

J.H. van Schuppen (2002). Control and algebra – An introduction. *Proceedings International Symposium MTNS2002,* Univ. Notre Dame, IN, USA.

J.H. van Schuppen (2002). Decentralized control and decentralized failure diagnosis with communication between controllers and diagnosers. V.D. Blondel, A. Megretski (eds.). *Open Problem Book*, International Symposium MTNS2002, Univ. Notre Dame, IN, USA.

CWI reports

MAS-N0201	MAS-N0202	MAS-R0203
MAS-R0206	MAS-R0207	MAS-R0212
MAS-R0214	MAS-R0215	MAS-R0217
MAS-R0219	MAS-R0221	MAS-R0227
MAS-R0232		

See page 171 for complete titles.

Other publications

P.W.Hemker (2002). Multigrid, review of the book by U. Trottenberg, C. Oosterlee and A. Schüller. *SIAM Review* **44**, 145–146.

Interview with Koren in *De Ingenieur* **16**, 61.

PhD theses

E.H. van Brummelen (2002). *Numerical Methods for Steady Viscous Free-Surface Flows*, February 8, UvA. Thesis advisor: prof.dr. P.W. Hemker.

S.H. Cavallar (2002). *On the Number Field Sieve Factorisation Algorithm*, June 5, UL. Thesis advisor: prof.dr. R. Tijdeman. Co-advisors: dr.ir. H.J.J. te Riele, dr. P.L. Montgomery.

B. Lastdrager (2002). *Numerical Time Integration on Sparse Grids*, September 18, UvA. Thesis advisor: prof.dr. J.G. Verwer. Co-advisor: prof.dr.ir. B. Koren.

Nonlinear Dynamics and Complex Systems – MAS3

Mission

We investigate nonlinear dynamics and pattern formation in spatially extended systems. Mathematically speaking, patterns are generic solutions of (sets of) nonlinear PDEs which appropriately describe many phenomena in nature on a meso- and macroscopic level (cf. MAS1 and MAS2). MAS3 investigates fundamental questions (pulled fronts, reaction-advection-diffusion problems) and focuses more and more on electric discharges. On sufficiently large time and length scales, they can be described by reaction-advection-diffusion models for charged species that are coupled in an interesting threefold way to the Poisson-equation of electrostatics. In a way, this model is the 'Navier-Stokes-equation' of electric discharges. Discharges are characterized both by a great need of basic mathematical and physical research and by a wide range of technical applications. Research concerns analytical and numerical studies of the PDE system as well as the systematic derivation of effective models (moving interface, Ginzburg-Landau) on a larger length scale, comparison with systematic 'curiosity driven' experiments as well as thought exchange with industry.

Theme leader

Prof.dr. U.M. Ebert

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. U.M. Ebert	0.8	theme leader	indefinite	MAS3	35, 41, 58, 82, 92
Dr. W.H. Hundsdorfer	1.0	project leader	indefinite	MAS3	65, 35
Drs. B.J. Meulenbroek	1.0	PhD student	2001-11-01 till 2005-11-01	MAS3	35, 41, 58
Ir. C.S. Montijn	1.0	PhD student	2001-10-01 till 2005-10-01	MAS3	65, 35

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Dr. A. Rocco (FOM)	1.0	post-doc	2001-09-01 till 2003-03-01	MAS3	82, 35, 41, 58
Drs. D. Sijacic (FOM)	1.0	PhD student	2000-05-01 till 2004-05-01	MAS3	35, 41, 58, 65

Scientific report

Highlights

- Appointment U.M. Ebert as professor of physics at TUE in March 2002.
- First quantitative mechanism for branching of discharge channels (streamers) found, covered by *Nature, Physical Review Letters* and other media.
- Analytical reconstruction of this numerical observation with conformal mapping techniques.
- Submission of book on numerical analysis of reaction-advection-diffusion systems by W.H. Hundsdorfer and J.G. Verwer.
- Period doubling bifurcation in barrier discharge systems found.

PhD research

Title	PhD research of D. Sijacic
Period	May 2000–April 2004
Leader	U.M. Ebert
Funding	FOM

Progress report. The research of *Sijacic* is focused on spatio-temporal pattern formation in direct current driven systems where a gas discharge and a highly resistant semiconductor layer are sandwiched between two electrodes. In 2002, we submitted and published a paper with an extensive analytical and numerical investigation of the stationary solutions of the gas discharge layer. The study exhibited unexpected bifurcation structures in certain parameter ranges. *Sijacic* then has studied the spontaneous temporal oscillations of this system. The results rule out some previously suggested effective models of two-component reaction-diffusion type. In particular, *Sijacic* found some unexpected period doubling cascade that presently is under further investigation.

Title	PhD research of C.S. Montijn
Period	October 2001–September 2005
Leaders	W.H. Hundsdorfer, U.M. Ebert
Funding	NWO/FOM (Computational Science)

Progress report. The research of *Montijn* is focused on the numerical solution of pulled fronts and streamer discharges (see project STREAMERS). In a streamer, there are small spatial regions with steep ionization fronts. The natural choice for a numerical code hence seems to be one with adaptive grids or other types of local grid refinement. However, it turns out that such methods fail when applied to negative streamer fronts. This is because such fronts are so-called pulled fronts (see project PULLED), rather than the more familiar pushed or bistable fronts. The failure of adaptive grid methods is generic for such fronts. In this project we develop appropriate numerical strategies for numerical streamer simulations. A nested two-grid approach, based on physical strategies, has been developed. Numerical experiments concerning the avalanche-to-streamer transition and the streamer-branching transition are being conducted.

Title	PhD research of B.J. Meulenbroek
Period	November 2001–October 2005
Leader	U.M. Ebert
Funding	CWI

Progress report. The research of *Meulenbroek* is focused on applying conformal mapping methods to branching streamers. The previous numerical observation of branching streamers in models that contain both drift and diffusion contributions to the motion of the ionization front has raised a number of questions: Is the flattening of the streamer head at a certain stage due to diffusion or does a pure drift model exhibit the same transients? Can we confirm the physical-analytical nature of the branching instability? *Meulenbroek* has tested numerically that the sequence of transients is essentially the same in two-dimensional and three-dimensional models. Therefore we could focus on the analysis of the 2D case allowing the use of conformal mapping methods. Studying function theory and learning conformal mapping methods from post-doc *Rocco*. *Meulenbroek* has been able to adapt the method to the simplest approximation of our streamer problem and confirm by analytical calculation, that flattening and branching are generic features of this model.

Projects

Title	STREAMERS
Period	1998–2007
Leader	U.M. Ebert
Staff	A. Rocco, B.J. Meulenbroek, C.S. Montijn, W.H. Hundsdorfer
Funding	FOM, CPS, CWI, NWO/FOM (Computational Science)
Partners	E. van Veldhuizen and G.M.W. Kroesen (TUE)

Progress report. Our suggestion of the first quantitative mechanism for the spontaneous branching of discharge channels has drawn much attention in 2002, immediately after the publication of our first journal paper in *Physical Review Letters*. The discovery is based on numerical solutions combined with a physical-analytical interpretation of the observed branching instability. The initial steps were set by post-doc Arrayás Chaseta (since September 2001 at Univ. Juan Carlos II, Madrid), *Ebert* and *Hundsdorfer*. Meanwhile the investigation branches out to involve more researchers and more disciplines: Analysis, computations and experiments. Post-doc *Rocco* very systematically has extended the numerical investigations of Arrayás Chaseta and *Hundsdorfer* and we already published in another journal and in a proceedings paper in 2002. Eventually he has passed the numerical investigation to *Montijn* who has started to include adaptive grid methods, see PhD project *Montijn*. The numerical observations raise the question of a physical-analytical understanding. Certain aspects can be studied by conformal mapping methods. The first very succesful analytical steps were set by *Rocco*, *Meulenbroek* and *Ebert*, see PhD project *Meulenbroek*. Finally, *Ebert* has planned detailed experimental tests of the theoretical predictions together with E.M. van Veldhuizen and G. Kroesen at TUE. This has led to two proceedings papers and an experimental PhD project that will be started by T. Briels at TUE in spring 2003.

Title	BARRIER
Period	2000–2004
Leader	U.M. Ebert
Staff	D. Sijacic, W.H. Hundsdorfer
Funding	FOM
Partners	Group H.G. Purwins (Univ. Münster, Germany)

For progress report see PhD research *Sijacic* (page 121).

Title	NUMLED
Period	2002–2006
Leader	W.H. Hundsdorfer
Staff	C.S. Montijn, U.M. Ebert
Funding	NWO/FOM (Computational Science)

For progress report see PhD research *Montijn* (page 121). It comprises the numerical aspects of the projects STREAMERS and PULLED.

Title	STR-SC
Period	1999–2004
Leader	P.B. Rodin (guest)
Staff	U.M. Ebert, W.H. Hundsdorfer
Funding	FOM
Partner	I.V. Grekhov (Ioffe-Inst., St. Petersburg, Russia)

Progress report. We have investigated high-power semiconductor switches that are developed in St. Petersburg and used world-wide. They operate on the basis of ionization fronts which have much in common with streamer fronts. In 2002, we published two journal papers and one proceedings paper about the conventional and a proposed

new operation mode for these devices.

Title	NSADR, Textbook
Period	2000–2003
Staff	W.H. Hundsdorfer, J.G. Verwer (MAS1)
Funding	CWI

Progress report. This book describes numerical methods for partial differential equations (PDEs) coupling advection, diffusion and reaction terms. Hence it deals with methods for hyperbolic, parabolic and stiff and nonstiff ordinary differential equations. It emphasizes time-dependent transport-chemistry problems, describing, e.g., the evolution of concentrations in environmental and biological applications. The authors are *Hundsdorfer* and *Verwer*. With the title 'Numerical Solution of Time-Dependent Advection-Diffusion-Reaction Equations', it will be published in 2003 by Springer-Verlag in their 'Springer Series in Computational Mathematics'.

Title	REPT
Period	indefinite
Staff	U.M. Ebert
Partners	L. Schäfer (Univ. Essen, Germany), A. Baumgärtner (Forschungszentrum Jülich, Germany)

Progress report. The diffusion of long macromolecules through an environment of obstacles is of great interest both in chemistry and in biology. Based on a previously developed model, *Ebert,* Schäfer and Baumgärtner have continued their long-lasting collaboration on this subject. In 2001/02 they studied the dynamic structure function of reptating long chains both analytically and through Monte Carlo simulations. This function is easy to measure experimentally, but difficult to calculate. They submitted two long papers in 2002, one was published in 2002, the other one is under review.

Title	PHYTO
Period	indefinite
Staff	U.M. Ebert
Partners	M. Arrayás Chaseta (Univ. Juan Carlos II, Madrid), J. Huisman (UvA), B.P. Sommeijer (MAS1), N.M. Temme (MAS1)

Progress report. A contribution of MAS3 to the analytical investigation of phytoplankton models was published in *The American Naturalist* in 2002, a previous paper appeared in *Bull. Math. Biol.* in 2001.

Title	PULLED
Period	indefinite
Staff	U.M. Ebert
Partner	W. van Saarloos (UL)

Progress report. This topic has delivered a number of papers, invitations and recognition in the past. Two journal papers and one for the general public were published in 2002. Some previously derived analytical results will be submitted in 2003. See also the related numerical project NUMLED and some of the papers published by *Rocco*.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

REPT; see page 123.

Organization of conferences, workshops, courses, meetings

- W.H. Hundsdorfer organized the monthly 'MAS Seminar' at CWI.
- Workshop 'Innovative Time Integration', Amsterdam, November 25–27. Organizing Committee: J.G. Verwer, J.E. Frank, J.G. Blom, W.H. Hundsdorfer, B.P. Sommeijer.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Scientific meeting Stat. Fysica, Lunteren, January 24–25: A. Rocco (Talk: *Spontaneous branching of negative streamers in homogeneous fields*), D. Sijacic, U.M. Ebert (Poster: *Pattern formation in DC 'barrier' discharges: stationary and oscillatory solutions*), B.J. Meulenbroek, C.S. Montijn.
- Scientific meeting Plasma Fysica, Lunteren, March 12–13: U.M. Ebert, A. Rocco (Poster: *Spontaneous branching of anode directed streamers*), B.J. Meulenbroek.
- International workshop 'Nonlinear Phenomena in Science', Lorentz Center, Leiden, March 18–28: B.J. Meulenbroek.
- Conference 'Fronts, fluctuations and growth', Ann Arbor, Michigan, May 19–24: U.M. Ebert

(Invited talk: *The universality class of pulled fronts*).
- NWO-Symposium on Nonlinear Systems, Enschede, May 23–24: A. Rocco (Invited talk: *Spontaneous branching of negative streamers in homogeneous fields*), B.J. Meulenbroek, C.S. Montijn, D. Sijacic.
- Conference on Scientific Computing, Geneva, June 26–29: W.H. Hundsdorfer (Keynote lecture: *Monotonicity-preserving linear multistep methods*).
- 16th ESCAMPIG and 5th ICRP Joint Conference Grenoble, July 14–18: U.M. Ebert (Poster: *A mechanism for streamer branching*).
- Scientific meeting of research school CPS, 's Hertogenbosch, The Netherlands, September 17: U.M. Ebert (Talk: *Spontaneous branching of streamer discharges*).
- Final Conference SFB 237, Colmar, France, September 23–27: U.M. Ebert (Invited talk: *Pulled fronts - a universality class in nonlinear dynamics*).
- Woudschoten Numerical Analysis Conference, Zeist, September 25–27: W.H. Hundsdorfer.
- Workshop 'Innovative Time Integration', Amsterdam, November 24–27: W.H. Hundsdorfer (Invited talk: *Monotonicity-preserving linear multistep methods).*
- Kick-off meeting NWO-program Computational Science, CWI, November 29: C.S. Montijn, W.H. Hundsdorfer, U.M. Ebert, A. Rocco (Poster: *A numerical investigation of growing and branching spark channels*).
- Wetenschappelijke FOM-dagen Gecondenseerde Materie, Veldhoven, The Netherlands, December 17–18: B.J. Meulenbroek, U.M. Ebert, D. Sijacic (Poster: *Spontaneous branching of discharge channels*).

Working visits
- Univ. Essen, January 3: U.M. Ebert.
- Univ. Münster, August 27: U.M. Ebert.

Project meetings
- U.M. Ebert, project session for a FOM-program in the field of low temperature plasmas, brainstorming session, TUE, August 26; workshop, TUE, November 21.

Other lectures
- Seminarium Computional Science, UvA, January 18, U.M. Ebert (Talk: *Pattern formation in electric discharges*).
- CWI-Magdeburg meeting, Amsterdam, April 12: W.H. Hundsdorfer (Talks: *Monotonicity-preserving linear multistep methods* and *Numerical simulation of gas-discharge*).
- Workshop CWI-TU Twente, CWI, May 28: A. Rocco (Talk: *Spontaneous branching of negative streamers in homogeneous fields*).
- Joint seminar TUE and Philips, June 13: U.M. Ebert (Talk: *Branching of Corona Streamers*).
- Seminar Univ. Sevilla, Spain, September 13: U.M. Ebert (Talk: *Spontaneous branching of streamer discharges*).
- CWI in Bedrijf, CWI, October 18: U.M. Ebert (Talk: *Vertakkende vonken – de dynamica van de elektrische doorslag*).
- Monthly Evening Colloquium of Natuurkundig Gezelschap Utrecht, December 10: U.M. Ebert (Talk: *Vertakkende vonken – de dynamica van de elektrische doorslag*).
- 'General Physics Seminar' FOM-Instituut voor Plasmafysica Rijnhuizen, December 12: U.M. Ebert (Talk: *Spontaneous branching of discharge streamers*).

Courses
- Stieltjes onderwijsweek 'Numeriek oplossen van multiprocess-multiscale differentiaalvergelijkingen', Lorentz Center, Leiden, March 11–15: C.S. Montijn, D. Sijacic.
- PhD student-school on Statistical Physics and Theory of Chronologiscally Condensed Matter, Nijmegen, May 13–17: B.J. Meulenbroek, D. Sijacic.

Memberships of committees and other professional activities

U.M. Ebert
- Part-time professor of physics at TUE, since March 2002.
- Leader of FOM-workgroup FOM-C01 with FOM employees Rocco, Rodin and Sijacic, since 1999.
- Member of Steering Committee of research school 'Centrum voor Plasmafysica en Stralingstechnologie' (CPS) and leader of CWI group of the research school, since 1999.
- Member NWO-EW-VENI-Committee for application, February 15 and September 1.
- Member PhD committee A. Reitsma, TUE, September 3.
- Referee and member PhD committee C. Soria, Sevilla, Spain, September 13.

W.H. Hundsdorfer

- Member reading and PhD committee T. van Noorden, VU, June 18.

Visitors

- P.B. Rodin (TU Berlin), January 7–18. Host: U.M. Ebert.
- J. Jaffré (INRIA Roquencourt), October 29–31. Talk: *On the upstream mobility flux for multiphase flow in porous media.* Host: W.H. Hundsdorfer.
- J. Roberts (INRIA Roquencourt), October 29–31. Talk: *Numerical modelling of flow in porous media with faults.* Host: W.H. Hundsdorfer.

Publications

Papers in refereed journals and proceedings

M. Arrayás (Univ. Juan Carlos II, Madrid), U.M. Ebert, W.H. Hundsdorfer (2002). Spontaneous branching of anode-directed streamers between planar electrodes. *Phys. Rev. Lett.* **88**, 174502, 4 pages.

A. Crisanti (Univ. Roma), F. Ritort (Univ. Roma), A. Rocco, M. Sellitto (Univ. Roma) (2002). Is the Stillinger and Weber decomposition relevant for coarsening models? *J. Phys.: Condens. Matter* **14**, 1523–1537.

U.M. Ebert, W.H. Hundsdorfer (2002). Reply to A.A. Kulikovsky. *Phys. Rev. Lett.* **89**.

U.M. Ebert, A. Rocco, W.H. Hundsdorfer, M. Arrayás (Univ. Juan Carlos II, Madrid) (2002). A mechanism for streamer branching. *Proceedings of the ESCAMPIG 16*$^{\text{th}}$ *- ICRP 5*$^{\text{th}}$ *(Joint European-Japanese Conference on Gas Discharges)*, Grenoble, France, 103–104.

U.M. Ebert, W. van Saarloos (UL), L.A. Peletier (UL) (2002). Universal algebraic convergence in time of pulled fronts: the common mechanism for difference-differential and partial differential equations. *Eur. J. Appl. Math.* **13**, 53–66.

J. Huisman (UvA), M. Arrayás (Univ. Juan Carlos II, Madrid), U.M. Ebert, B. Sommeijer (2002). How do sinking phytoplankton species manage to persist? *The American Naturalist* **159**, 245–254.

W.H. Hundsdorfer (2002). Accuracy and stability of splitting with stabilizing corrections. *Appl. Num. Math.* **42**, 213–233.

A. Rocco, J. Casademunt (Univ. Barcelona), U.M. Ebert, W. van Saarloos (UL) (2002). Diffusion coefficient of propagating fronts with multiplicative noise. *Phys. Rev. E* **65**, 012102.

A. Rocco, L. Ramírez-Piscina (Univ. Barcelona), J. Casademunt (Univ. Barcelona) (2002). Kinematic reduction of reaction-diffusion fronts with multiplicative noise: Derivation of stochastic sharp-interface equations. *Phys. Rev. E* **65**, 056116, 14 pages.

A. Rocco, U.M. Ebert, W.H. Hundsdorfer (2002). Branching of negative streamers in free flight. *Phys. Rev. E* **66**, 7035102 (R), 4 pages.

P.B. Rodin (CWI and TU Berlin), U.M. Ebert, W.H. Hundsdorfer, I.V. Grekhov (Ioffe-Inst., St. Petersburg) (2002). A novel type of power picosecond semiconductor switches based on tunneling-assisted impact ionization fronts. *Proceedings of Int. Power Modulator Conf.*, Hollywood, California, USA, 4 pages.

P.B. Rodin (CWI and TU Berlin), U.M. Ebert, W.H. Hundsdorfer, I.V. Grekhov (Ioffe-Inst., St. Petersburg) (2002). Tunneling-assisted impact ionization fronts in semiconductors. *J. Appl. Phys.* **92**, 958–964.

P.B. Rodin (CWI and TU Berlin), U.M. Ebert, W.H. Hundsdorfer, I.V. Grekhov (Ioffe-Inst., St. Petersburg) (2002). Superfast fronts of impact ionization in initially unbiased layered semiconductor structures. *J. Appl. Phys.* **92**, 1971–1980.

L. Schäfer (Univ. Essen), U.M. Ebert, A. Baumgärtner (Forschungszentrum Jülich) (2002). The coherent scattering function in the reptation model: Analysis beyond asymptotic limits. *Phys. Rev. E* **65**, 061505.

D. Sijacic, U.M. Ebert (2002). Transition from Townsend to glow discharge: subcritical, mixed or supercritical characteristics. *Phys. Rev. E* **66**, 066410, 4 pages.

A. Torcini (Univ. Roma), A. Vulpiani (Univ. Roma), A. Rocco (2002). Front propagation in chaotic and noisy reaction diffusion systems: A discrete-time map approach. *Eur. Phys. J. B* **25**, 333–343.

E.M. van Veldhuizen (TUE), W.R. Rutgers (TUE), U.M. Ebert (2002). Positive and negative pulsed corona in argon. *Proceedings of Hakone* **8**, Pühajärve, Estonia, 5 pages.

E.M. van Veldhuizen (TUE), W.R. Rutgers (TUE), U.M. Ebert (2002). Branching of

streamer type corona discharge. *Proceedings of the XIVth Int. Conf. Gas Discharges and Appl.*, Liverpool, UK, 4 pages.

J.G. Verwer, W.H. Hundsdorfer, J.G. Blom (2002). Numerical time integration for air pollution models. *Surv. Math. Ind.* **10**, 107–174.

CWI reports

MAS-R0202 MAS-R0210

See page 171 for the complete titles.

Electronic reports

A. Baumgärtner (Forschungszentrum Jülich, Germany), U.M. Ebert, L. Schäfer (Univ. Essen) (2002). The Coherent Scattering *Function in the Reptation Model: Simulations Compared to Theory.*
http://xxx.lanl.gov/abs/cond-mat/0203218

B. Coluzzi (CEA-Saclay, Gif/Yvette, France), A. Crisanti (Dept. Physics, Univ. Rome), E. Marinari (Dept. Physics, Univ. Rome), F. Ritort (Dept. Physics, Univ. Barcelona), A. Rocco (2002). *A New Method to Compute the Configurational Entropy in Spin Glasses.*
http://xxx.lanl.gov/abs/cond-mat/0105391

Other publications

U. Ebert (2002). Pattern forming systems: Universal and specific. *Annual Report CWI 2001*, 27–33.

U. Ebert (2002). A simple model for spark branching. *ERCIM News* **50**, cover page and p. 43.

U. Ebert (2002). Algebraic convergence of pulled fronts. *ERCIM News* **50**, 53.

M. van de Ven (TUE), U. Ebert (2002). 'Ik wil ergens een streep onder kunnen zetten', TUE Cursor, (http://www.tue.nl/cursor/bastiaan/jaargang44/cursor20/rubrieken/R_M_intervieuw.htm).

M.T. Westra (FOM), U. Ebert (2002). Zicht op de bliksem. *Nederlands Tijdschrift voor Natuurkunde* **68**, 244–247.

INFORMATION SYSTEMS

General overview

Principle research area and mission

The research activities are focused on various aspects of information systems: From theory inspired investigation into the nature of new computing paradigms; prototyping novel visualization techniques on concrete applications and devices; methods and models for narrative story telling over multimedia stores, to management of large multimedia datastores with probabilistic query processing features.

All research activities seek a balance between application inspired problems, the accompanying software architectures and experimentation, and the scientific modelling and analysis of the solutions invented.

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. 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. Likewise, the activities in INS2 on human-computer interaction is closely aligned with the CWI spin-off Epictoid. Another important outlet of the knowledge acquired is through active participation in International Standardization committees as 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). 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 universities.

Cluster leader

Prof.dr. M.L. Kersten

Themes

Name	Leader
INS0 – Standardization and Knowledge Transfer	M.L. Kersten
INS1 – Data Mining and Knowledge Discovery	M.L. Kersten
INS2 – Multimedia and Human-Computer Interaction	H.L. Hardman
INS3 – Visualization	R. van Liere
INS4 – Quantum Computing and Advanced Systems Research	P.M.B. Vitányi

The activities in INS1 are focused on multimedia information systems. The key scientific challenge is to bridge the gap between information retrieval based on probabilistic reasoning and database technology to achieve efficient and effective architectures. The activities in data-mining techniques are gradually reduced.

Much of the work in 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.

INS3 primarily deals with interactive scientific and information visualization using the Personal Space Station and visualization algorithms for bio-informatics.

The core of theoretical investigations into new computing paradigms, complexity theory and learning theory, and new machines – Quantum Computing – is undertaken in theme 4.

The remaining activities are projects geared at knowledge transfer towards research and industrial communities.

Highlights

- P.M.B. Vitányi was appointed CWI Fellow for his many years of inspirational and productive research. H.M. Buhrman succeeded him as theme leader of INS4.
- Development of the world's fastest algorithm for DNA database and protein-to-protein mapping algorithm, called *PatternHunter* by J.T. Tromp.
- D.J.N. van Eijck, chairman of the VSNU visiting committee for Artificial Intelligence.
- Four PhDs were successfully defended by (former) INS members: P.A. Boncz, A.R. Schmidt, S. Manegold, W.K. van Dam.
- INS members participated in the PCs of 37 international workshops and conferences.
- INS members act as editors in 18 international scientific journals.

Staff

- Standardization and Knowledge Transfer – INS0
  - D.J.N. van Eijck
  - M. Hazewinkel
  - I. Herman
  - A.R. Hollaar
  - M.L. Kersten
  - S. Pemberton
- Data Mining and Knowledge Discovery – INS1
  - A.R. van Ballegooij
  - P.A. Boncz
  - M.H.M. van Dinther
  - T. Ianeva
  - A. Jančařiková
  - M.L. Kersten
  - J.A. List
  - S. Manegold
  - K.S. Mullender
  - N.J. Nes
  - G. Ramirez Camp
  - A.R. Schmidt
  - A.P.J.M. Siebes
  - M. Srivastava
  - Z.R. Struzik
  - C. Treijtel
  - A.P. de Vries
  - T.H.W. Westerveld
  - M.A. Windhouwer
  - M.K. Zukowski
- Multimedia and Human-Computer Interaction – INS2
  - S. Bocconi
  - P.M.E. De Bra
  - K.I. Falkovych
  - J.P.T.M. Geurts
  - H.L. Hardman
  - F.-M. Nack
  - H. Noot
  - J.R. van Ossenbruggen
  - L.W. Rutledge
  - Zs.M. Ruttkay
- Visualization – INS3
  - B.R. Boschker
  - A.J. Jansen
  - W.C. de Leeuw
  - R. van Liere
  - J.D. Mulder
  - O.H.G.M. Reynhout
  - A.J. van Rhijn
  - J.J. van Wijk
- Quantum Computing and Advanced Systems Research – INS4
  - H.M. Buhrman
  - R.L.C. Cilibrasi
  - M.G. de Graaf
  - F. Green
  - P.D. Grünwald

- H. Klauck
- T.J. Lee
- R. Manniesing
- T.T.R. Roos
- R.S. Špalek
- J.T. Tromp
- P.M.B. Vitányi
- R.M. de Wolf

- Secretary:
  - M.W.A. Hegt

Standardization and Knowledge Transfer – INS0

Mission

The mission of the group is to stimulate dissemination and take-up scientific results through concerted actions with e.g., standardization committees. Furthermore, small-scale individual projects in the area of digital libraries are supported pending a better embedding in or outside the institute.

Theme leader

Prof.dr. M.L. Kersten

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. D.J.N. van Eijck	1.0	researcher	indefinite	Applied Logic	I.2.3, I.2.4, I.2.7, F.3.1, F.3.2, F.4.1, F.4.2
Dr. M. Hazewinkel	1.0	researcher	indefinite	TRIAL, MKM-net	05E, 16W30, 68T30, 68T50
Dr. I. Herman	1.0	researcher	indefinite	W3C activities	D.2.11, H.1.2
Prof.dr. M.L. Kersten	0.2	theme leader	indefinite	INS0	H.2.4, H.2, E.1, E.5
S. Pemberton	1.0	researcher	indefinite	W3C activities	D.2.11, H.1.2

Scientific report

Highlights

- Establishment of W3C Offices in South Korea, Singapore, and Finland.
- D.J.N. van Eijck chaired the VSNU Visiting Comittee on AI in the Netherlands.

Projects

Title	W3C
Period	1998 till today
Leader	I. Herman
Staff	I. Herman, S. Pemberton, F.A. Roos
Funding	W3C
Partners	Other W3C members

Progress report. Since 1998, CWI is hosting the local W3C Office in the Netherlands (Benelux since June 2002) and since 2001 *Herman* is the coordinator of all local offices world-wide. These community activities are supported by deep involvement in the W3C standardization activities, such as XHTML, SMIL, SYMM and XML-benchmarking. *Herman* is head of W3C Offices and *Pemberton* chair of the HTML and Forms Working Groups. CWI's involvement in W3C provides a knowledge-transfer path and feedback loop for our research in multimedia (see also INS2).

Title	Applied logic
Period	indefinite
Leader	D.J.N. van Eijck
Staff	D.J.N. van Eijck
Funding	CWI
Partners	UvA, UU

Progress report. In the area of applied logic we seek new methods and techniques to improve educational material supported by automatic the-

orem provers. Dynamic and epistemic logic are part of the theoretical foundations of information processing. Central notions are state and state transition, information update, and information change. These notions are also central in a set of innovative textbooks in the area of Reasoning and Computation under development by *Van Eijck* together with researchers at the UvA and UU. *Van Eijck* implemented a theorem prover for hybrid logic based on tableaux. Hybrid logic, the result of a mixture of modal logic with operator binding from first order logic, has decidable subfragments that are more expressive than modal logic yet more amenable to algorithmic processing than first order logic. With J. Heguiabehere (UvA), *Van Eijck* worked on programming with dynamic logic, and with R. Nouwen (UU) on quantification and reference in natural language semantics.

Title	TRIAL SOLUTION
Period	February 2000–May 2003
Leader	M. Hazewinkel
Staff	M. Hazewinkel, C.L. Blom (SEN3), J. de Vries (MAS) (until July 1)
Funding	EU project
Partners	About ten among which Springer-Verlag

Progress report. In the area of Digital Libraries we focus on the intricate problems of assigning 'key phrases' to slices of mathematic publications. These phrases form the basis for improved indexing of the fast body of mathematical literature, as undertaken by Hazewinkel in his quest to develop an encyclopedia of mathematics. During this year the following deliverables were produced: Index with MSC2000 classifications for 'Bronstein, Taschenbuch der Mathematik', Automatic keyphrase assignment system for a sliced text (together with test material), and a survey paper 'Dynamic stochastic models for indexes and thesauri, identification clouds, and information storage and retrieval'.

Title	MKMnet (Mathematical Knowledge Management)
Period	September 2002–November 2003
Leader	M. Hazewinkel
Staff	M. Hazewinkel, C.L. Blom (SEN3)
Funding	EU network
Partners	Various universities and NAG

Progress report. The kick-off meeting was in Bath (UK) in September 2002. M. Hazewinkel was named chairman of the network. The manager is J. Davenport (Bath Univ.). The first deliverables are due in February 2003.

Societal aspects and knowledge transfer

Standardization activities

- Chairman of the W3C Offices: I. Herman.
- Chairman of W3C XHTML and Forms working groups: S. Pemberton.

Teaching activities

- Tutorial on 2D Web Graphics, Web3D 2002 Symposium, Tempe, Arizona, USA, February 25: I. Herman.
- Tutorial on 2D Web Graphics, ISOC.NL course, The Hague, March 28: I. Herman.
- Tutorial *Styling the new Web*, at CHI 2002, Minneapolis, April 2: S. Pemberton.
- Language Technology course at UU, Spring 2002 (with M. Moortgat): D.J.N. van Eijck.
- Reasoning, Representation and Computation course at UvA, Spring 2002: D.J.N. van Eijck.
- Theoretical Linguistics course at UU, Fall (with T. Reinhart): D.J.N. van Eijck.
- Implementing Theta Theory, Uil-OTS colloquium, Fall: D.J.N. van Eijck.
- Tutorial *Computational Semantics, Type Theory and Functional Programming*, 7th Symposium on Logic and Language, Pecs, Hungary, August 26, 27, 29: D.J.N. van Eijck.
- Tutorial on 2D Web Graphics, Sankt Augustin, Germany, October 16: I. Herman.

Projects with partners in public and private sector

- W3C activities; see page 129.
- TRIAL; see page 130.
- MKMnet; see page 130.

Other external contacts

- Van Eijck is part of an initiative by Amsterdam University Press to develop *Exact in Context*, a series of innovative books on the exact sciences for use in Dutch secondary schools. The first volume in the series, written by Van Eijck with his former PhD student M. Pauly and coworkers from the UvA, was published in March 2002.

Organization of conferences, workshops, courses, meetings

- Organizer of the Dutch Graduate School in Logic Schoolweek 2002, October 14–18: D.J.N. van Eijk (with E. Hoogland).

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- IWAP2002 (international workshop on applied probability), Caracas, Venezuela, January 13–22: M. Hazewinkel (Invited plenary lecture: *Probabilistic models for dynamic thesauri*).
- W3C Technical Plenary, Cannes, February 27: S. Pemberton (Lecture: *Last Call*).
- Computational Linguistics Colloquium, Utrecht, March 22: D.J.N. van Eijck (Lecture: *Quantification and Reference*).
- W3C.de Day "Cross Media Publishing", Bonn, April 11: S. Pemberton (Lecture: *Xhtml, XForms, and device independence*).
- WWW2002, Hawaii, May 8–11: S. Pemberton (Lectures: *Xforms: an overview* May 10, *Xforms for developers* May 11).
- W3C Interop tour, Vienna, May 28: S. Pemberton (Lecture: *HTML, the great integrator*).
- Conference on (Preferably) non-lexical semantics, Paris, June 14: D.J.N. van Eijck (Lecture: *Quantification and Reference in Incremental Processing*).
- SIGCHI.nl Conference, Ede, The Netherlands, June 19: S. Pemberton.
- 8-th International meeting on Probability and Mathematical Statistics, Vilnius, June 23–29: M. Hazewinkel (Lecture: *Dynamic probabilistic indexes and thesauri*).
- Probabilistic models for evolving classification structures, Graduate level, Vilnius Univ., July 1–10: M. Hazewinkel.
- SVG Open Conference, Zürich, July 16: I. Herman (Lecture: *SVG Linearization and Accessibility*).
- Third International Algebra meeting., Krasnoyarsk, August 4–10: M. Hazewinkel (Invited plenary lecture: *The primitives of the Hopf algebra of noncommutative symmetric functions and applications*).
- 7th Symposium on Logic and Language, Pecs, Hungary, August 28: D.J.N. van Eijck (Invited talk: *Context and the Composition of Meaning*).
- Web Services Conference, Hong Kong, September 2: I. Herman (Keynote lecture: *Semantic Web - and Evolution for the Future*).
- Meeting in honour of Z. Borewicz, St. Petersburg, September 16–24: M. Hazewinkel (Plenary invited lecture: *Noncommutative symmetric functions and their applications*).
- XML Day, Brussels, October 2: S. Pemberton (Keynote: *XML: what's in it for your website*).
- XML Day, Amsterdam, October 3: S. Pemberton (Keynote: *XML: what's in it for your website*).
- XML Day, Copenhagen, October 10: S. Pemberton (Keynote: *XML: what's in it for your website*).
- W3C Document Formats Domain, Grenoble, October 15–17: S. Pemberton.
- User Interfaces For All, Paris, October 24–25: S. Pemberton (Keynote: *The Kiss of the Spiderbot*).
- Usability and the Web workshop, Gaithersburg, USA, November 4–5: S. Pemberton (Lecture: *The User and the Web*).
- SURFnet Relatiedagen 2002, Egmond aan Zee, November 12: I. Herman (Invited talk: *An Overview of W3C XML Technologies*).
- Meeting in honour of Anders Lindquist, Stockholm, November 15–17: M. Hazewinkel (Plenary lecture: *Chen-Fox-Lyndon factorization over partially ordered sets*).

Working visits

- ETRI, Daejeon, South Korea (to establish a W3C Office), January 24–25: I. Herman.
- EDI and Nanyang Politechnic, Singapore (to establish a W3C Office), January 27: I. Herman.
- DMI, Tampere, Finland (to establish a W3C Office), April 5: I. Herman.
- TRIAL evaluation meeting, Luxembourg, February 2–April 2: M. Hazewinkel. (Lecture: *Structure of an automatic keyphrase assigner*).
- Kickoff meeting MKMnet, Bath, September 13–15: M. Hazewinkel.
- W3C Advisory Committee meeting, Boston, November 18–20: S. Pemberton.
- SIGCHI Executive Committee Meeting, Seattle, July 12–14: S. Pemberton.

Project meetings

- W3C AC Meeting, Hawaii, May 5–6: I. Herman.
- W3C AC Meeting, Boston, November 19–20: I. Herman.
- W3C Offices' meeting, Boston, December 9–10: I. Herman.
- Question-How face to face and project meetings, June 10, September 13: I. Herman.
- KT workshop (FP6), Luxembourg, May 14–17: M. Hazewinkel (Short presentation of TRIAL SOLUTION and the idea of Identification clouds).

Other lectures

- Seminar in ETRI, Daejeon, South Korea January 25: I. Herman (*Overview of W3C*).
- IDA, Singapore, January 28: I. Herman (*A Tour Around W3C XML Recommendatations*).
- W3C.DE-Arbeitstreffen: Cross Media Publishing, Sankt Augustin, Bonn, Germany, April 11: I. Herman (*W3C - Why and How*).
- W3C Korean Office Opening, Daejeon, South Korea, April 19: I. Herman (*Overview of XML Related Recommendations*).
- W3C Interop Tour events in Paris (May 21) and Vienna (May 28): I. Herman (*Interoperability of W3C XML Technologies*).
- XML Days Europe series, Amsterdam, October 3: I. Herman *Semantic Web - and Evolution for the Future*).
- Hungarian W3C Office Opening event, Budapest, October 24: I. Herman (*Introduction to the Semantic Web*).
- Finnish W3C Office Opening event, October 11: I. Herman (*2D Web Graphics: SVG*).
- The Hopf algebra of noncommutative symmetric functions, its dual (the quasisymmetric functions), and its primitives, Colloquium lecture, Johns Hopkins Univ., February 14: M. Hazewinkel.
- BayCHI, Palo Alto, USA, September 10: S. Pemberton (*The Kiss of the Spiderbot*).

Memberships of committees and other professional activities

D.J.N. van Eijck

- Advisor of PhD student J. Heguiabehere from UvA.
- Scientific Director of Dutch Research School in Logic (since Spring 1997, until November 2002).
- Professor of Logical Aspects of Computational Linguistics, UU (since December 1990).
- Secretary of the Dutch Society for Logic (VvL).
- Member of the PhD committee R. Moot, UU, February 1.
- Member of the PhD committee S.P. Luttik, VU, April 3.
- Member of the PhD committee M. Janssen, UU, June 7.
- Member of the PhD committee R. Bernardi, UU, June 19.
- Member of the PhD committee M. Bognar, VU, November 26.
- Chairman of the VSNU visiting committee for Artificial Intelligence, Fall 2001 and Spring 2002.

I. Herman

- Vice-chairman of the Eurographics Association.
- Member of IFIP TC6 Working group (Internet Application Engineering).
- Member of International World Wide Web Conference Committee (IW3C2).
- Member of the editorial board of *Computer Graphics Forum.*
- Board member of Accessibility.nl (managed by the Bartiméus Institute).

M. Hazewinkel

- Managing Editor book series: Mathematics and Its Applications, Kluwer Academic Publishers, since 1977.
- Managing Editor *Acta Applicandae Mathematicae*, Kluwer Academic Publishers, since 1983.
- Managing Editor Encyclopaedia of mathematics, Kluwer Academic Publishers; Vols 1–10, 1988–1994; first update volume, 1997; CDROM version, 1998; second update volume 2000 (Volume 12); third update volume 2001 (Volume 13).
- Managing Editor Handbook of Algebra, Elsevier; first volume 1996, volume 2: 2000; volume 3: 2003.
- Manager (coordinator) INTAS projects 97–0808 (1998–2002), 97–0804 (1999–2002).
- Member Council of Scientists INTAS, September 1999–September 2002.
- Member Steering committee ESF program on Noncommutative Geometry, 2000–2004.

- Member Mathematical Knowledge Management consortium, September 2001.
- Member organizing and program committee 'Borewicz conference', St. Petersburg, September 16–24.
- Member program committee MKM 2003, Bologna, February 2003.

S. Pemberton

- Editor in Chief, *ACM Interactions*.
- Member of Executive Committee, *ACM SIGCHI*.
- Chair W3C HTML Working Group, Cannes, France, February 25–26.
- Chair W3C HTML Working Group, Copenhagen, Denmark, June 3–7.
- Chair W3C HTML Working Group, Palo Alto, USA, Sepember 9–13.
- Chair W3C HTML Working Group, San Diego, USA, October 28–November 1.
- W3C Usability and Web Workshop, Gaithersburg, USA, November 4–5.

Visitors

- Dr. A. Kazbaras (Univ. Vilnius, Lithuania), February 24–March 3. Host: M. Hazewinkel.
- Dr. Rimas Maliukevicius (Univ. Vilnius, Lithuania), February 24–March 3. Host: M. Hazewinkel.
- Dr. Peter Malyshev (Univ. Kiev, Ukraine), April 7–17. Host: M. Hazewinkel.

Publications

Books and book chapters

D.J.N. van Eijck, J. Jaspars, J. Ketting, M. Pauly (2002). *Denkende Machines: Computers, rekenen, redeneren*, Amsterdam Univ. Press. ISBN: 90-5356-569-8.

D.J.N. van Eijck, J. Jaspars, J. Ketting, M. Pauly (2002). *Denkende Machines: Computers, rekenen, redeneren – Docentenhandleiding*, Amsterdam Univ. Press. ISBN 90-5356-583-3.

M. Hazewinkel (2002). *Encyclopaedia of Mathematics, Supplement* **3**(13).

M. Hazewinkel (2002). 37 articles for Supplement 3 of *Encyclopaedia of Mathematics* **13**.

Papers in refereed journals and proceedings

D.A. Duce, F.R.A. Hopgood, I. Herman (2002). Web 2D Graphics: State-of-the-Art. *Computer Graphics Forum* **21**(1), 43–65.

D.J.N. van Eijck (2002). Reference Resolution in Context. M. Theune, A. Nijholt, H. Hondorp(eds.). *Computational Linguistics in the Netherlands 2001; Selected Papers from the Twelfth CLIN Meeting*, Rodopi, 89–103.

I. Herman, D. Dardailler (2002). SVG Linearization and Accessibility. *Computer Graphics Forum* **21**(4), 777–786.

M. Hazewinkel (2002). Index Journal of logic programming volumes 1–46. *J Logic and Algebraic Programming* **50**(1–2), 1–103.

M. Hazewinkel (2002). Dialogue mediated information retrieval, automatic keyphrase assignment and identification clouds. *Proceedings on Crimea 2002*. Ninth international conference. Libraries and associations in a transient world, 712–721.

S. Pemberton (2002). Electric IP. *ACM Interactions* **9**(1).

S. Pemberton (2002). Choose one: fast, correct, or pleasurable. *ACM Interactions* **9**(2).

S. Pemberton (2002). Go Away! *ACM Interactions* **9**(4).

S. Pemberton (2002). A pixel is not a point. *ACM Interactions* **9**(2).

Other publications

D.J.N. van Eijck, J. van de Craats (UvA), F. van Eynde (Univ. Leuven), G. Kempen, C. Witteveen (TUD) (2002). *De Onderwijsvisitatie Kunstmatige Intelligentie*, VSNU Report, Utrecht, 135 pp.

M. Hazewinkel (2002). *Dynamic Stochastic Models for Indexes and Thesauri, Identification Clouds, and Information Retrieval and Storage*, Deliverable TRIAL SOLUTION.

M. Hazewinkel (2002), *Book review*: B. Yandell (2002). *The honours class*. A. K. Peters. *History of logic and philosophy*.

M. Hazewinkel, (2002). Idiosyncratic remarks by a bibliomaniac 7. Semipopular writing. *Acta Appl. Math.* **74**, 113–116, bookreview.

S. Pemberton (2002). *Websites and diversity*, Radio interview Teleac Telescoop, May 29.

S. Pemberton (2002). *The kiss of the spiderbot*, Radio interview Teleac Telescoop, October 30.

S. Pemberton et al. (2002). *XHTML 1.0 The Extensible HyperText Markup Language* (Sec-

ond Edition), *A Reformulation of HTML 4 in XML 1.0*, W3C Recommendation.

Software developed

HyLoTab — Tableau-based Theorem Proving for Hybrid Logics, Jan van Eijck. Available from `http://www.cwi.nl/~jve/hylotab`

Reasoning, Computation and Representation using Haskell, Haskell programs and modules, Jan van Eijck (with Kees Doets). Available from `http://www.cwi.nl/~jve/rcrh`

Data Mining and Knowledge Discovery – INS1

Mission

The mission of the group is to simplify and improve data management and information analysis in high-demanding application areas, such as multimedia and knowledge discovery. This is realized through the combined expertise in the area of database architectures, multimedia information retrieval, and data mining algorithms. The approach is based on concurrent progress in the development of models, algorithms, techniques, and experimental software platforms. Knowledge transfer is focused on dissemination of the leading platform, MonetDB, which is used in a spin-off company since 1996 and is currently prepared for the open source community.

Theme leader

Prof.dr. M.L. Kersten

Subthemes

Name	Leader
INS1.1 – Data Mining	A.P.J.M. Siebes
INS1.2 – Multimedia Databases	A.P. de Vries
INS1.3 – Database Architectures	P.A. Boncz

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Drs. A.R. van Ballegooij	1.0	PhD student	1999-10-01 till 2003-09-30	INS1.2: MIA	H.3.1, H.3.3
Dr. P.A. Boncz	1.0	researcher, leader INS1.3	indefinite	INS1.2: MIA AmbientDB	H.2.4, H.2, E.1, E.5
Ing. M.H.M. van Dinther	0.1	programmer	2002-08-01 till 2002-08-31	INS1.3	H.2.4, H.2, E.1, E.5
Prof.dr. M.L. Kersten	0.6	theme leader	indefinite	INS1.2: MIA AmbientDB INS1.3: MIA	H.2.4, H.2, E.1, E.5
Drs. J.A. List	1.0	PhD student	2000-11-01 till 2004-10-31	INS1.2: MIA	H.3.1, H.3.3
Dr. S. Manegold	1.0	researcher	1997-10-01 till 2003-09-30	INS1.3: MIA	H.2.4, H.2, E.1, E.5
Drs. K.S. Mullender	1.0	programmer	indefinite	INS1.3	H.2.4, H.2, E.1, E.5
Dr. N.J. Nes	1.0	researcher	indefinite	INS1.3: MIA	H.2.4, H.2, E.1, E.5
Dr. A.R. Schmidt	1.0	researcher	1999-01-01 till 2003-12-31	INS1.2: DMW	H.2

Dr. Z.R. Struzik	1.0	researcher	indefinite	INS1.1	H.2.8, I.1.5
Ir. C. Treijtel	1.0	PhD student	2002-02-01 till 2004-01-31	INS1.3	H.2.4
Dr.ir. A.P. de Vries	1.0	researcher, leader INS1.2	1999-12-16 till 2003-12-31	INS1.2: MIA	H.3.1, H.3.3
Ir. T.H.W. Westerveld	0.4	PhD student	2002-09-01 till 2004-08-31	INS1.2: Waterland	H.3.1, H.3.3
Drs. M.A. Windhouwer	1.0	PhD student	indefinite	INS1.2: Acoi, Waterland	H.3.1

Seconded

Name	**Fte**	**Function(s)**	**Period**	**Subthemes + projects**	**Classification (MSC or CR)**
T. Ianeva, MSc (Univ. Valencia)	0.3	student	2002-10-01 till 2002-12-31	INS1.2: MIA	H.3.1, H.3.3
A. Jančařiková (VU, Karel Univ.)	0.3	MSc student	2002-12-01 till 2003-05-31	INS1.3	H.2
G. Ramirez Camp	0.3	MSc student	2002-10-01 till 2003-02-28	INS1.2	H.3.1
Prof.dr. A.P.J.M. Siebes (UU)	1.0	advisor, leader INS1.1	indefinite	INS1.1	H.2.8
M. Srivastava (IIT)	0.3	MSc student	2002-05-14 till 2002-07-17	INS1.3	H.2.4
M.K. Zukowski (VU)	0.8	MSc student	2002-01-01 till 2002-05-31	INS1.3	H.2.4

Scientific report

Highlights

Highlights of 2002 were three PhD theses. Those of Boncz and Manegold are the culmination of a multiyear activity in the design and implementation of a new database kernel, called Monet. The thesis of Schmidt has resulted in world-wide visibility in the assessment of XML storage and query processing techniques.

PhD research

Title	PhD research of P.A. Boncz
Period	July 2001–June 2002
Leader	M.L. Kersten
Funding	MIA project
Partner	UvA

Progress report. *Boncz* finished his PhD thesis on the Monet system in May. He investigated new directions in DBMS architecture to better address the needs of query-intensive database applications (like OLAP, data mining, XML query processing and multimedia retrieval) on modern hardware. The final contribution to the thesis was a new cache-conscious join projection algorithm, called radix-recluster. The finalization thesis, which is a full reference to the Monet system, forms the crown on the last six years of research into DBMS architecture at INS1, and over those years has led to a string of papers in the best and highly selective database publications (EDBT'96, ICDE'98, VLDB'98/'99/'00/'02, SIGMOD'02, VLDB Journal'99/'00, IEEE TKDE'02).

Title	PhD research of A.R. van Ballegooij
Period	October 1999–October 2003
Leaders	A.P. de Vries, M.L. Kersten
Funding	MIA project
Partners	UvA, UT

Progress report. In the first part of 2002, *Van Ballegooij* has specialized his research direction from general multimedia search in a database context to the concrete topic of efficient array support in a relational database. Through offering efficient support for array structures and array processing, we expect to make database systems (MonetDB specifically) more suitable and accesible for scientific users, multimedia retrieval system developers in particular. This year's progress included the development of a prototype system, and active participation in the CWI effort for the video track at TREC.

Title	PhD research of J.A. List
Period	November 2000–November 2004
Leaders	A.P. de Vries, M.L. Kersten
Funding	MIA project
Partners	UvA, UT

Progress report. During 2002, the core of *List*'s research has been the participation in INEX 2002, the Initiative for the Evaluation of XML Retrieval, organized by the DELOS Network of Excellence for Digital Libraries. Our research for this initiative focused on:

1. An efficient storage and manipulation mechanism for XML documents.

2. The implementation of a retrieval model where we map additional dimensions of relevance to (possibly) structural properties of documents and use these additional dimensions in retrieval.

The system has been implemented on top of a research database kernel, MonetDB.

Title	PhD research of S. Manegold
Period	October 1997–December 2002
Leader	M.L. Kersten
Funding	MIA project
Partner	UvA

Progress report. In November, *Manegold* finished his PhD thesis, which studies performance modelling of main-memory database systems on the level of cache and CPU resource usage found in modern hardware (hierarchical memory systems and super-pipelined CPUs). Also this year, his work on making such modelling easier using high-level pattern descriptions of algorithm-kernels was published in VLDB'02. The work for his thesis has clearly advanced the state of the art in database query processing. Together with his earlier work, it demonstrated the feasibility of highly accurate prediction of overall database performance on the basis of modelled values of detailed hardware events (cache misses, branch mis-predictions), together with work on making such models hardware platform independent by developing automatic techniques to discover the main characteristics of a hardware architecture (cache and TLB levels), and calibrating the cost of the related events. It has resulted in 15 refereed papers in the database community.

Title	PhD research of A.R. Schmidt
Period	January 1999–December 2002
Leader	M.L. Kersten
Funding	Telematics Institute
Partners	Telematics Institute, Microsoft, BEA, FhG

Progress report. Schmidt finished his PhD research on XML processing in a database system in 2002. Tangible results are the development in organizing and publication of the first XQUERY benchmark. This benchmark received wide publicity in the database community and is considered one of the leading measurement tools for XML enhanced database engines. The impact of XML on the query processor architecture has been studied in close cooperation with the SQL server group of Microsoft.

Title	PhD research of C. Treijtel
Period	February 2002–February 2006
Leaders	P.A. Boncz, M.L. Kersten
Funding	CWI
Partner	Philips NatLab

Progress report. Treijtel started his PhD track in February 2002. His work in the new AmbientDB project focuses on the study of multi-wavefront query processing techniques in ad hoc peer-to-peer networks in a heterogeneous mix of mobile and static nodes with widely varying capabilities. In this context, he also participated in the series of workshops held with Philips NatLab (SIG on Organic Databases). First publications of his work are in preparation and are expected to materialize in 2003.

Title	PhD research of T.H.W. Westerveld
Period	August 2002–August 2004
Leaders	A.P. de Vries, F. de Jong (UT)
Funding	Waterland project
Partner	UT

Progress report. Since September 2002, *Westerveld* worked on the Waterland project. His research focuses on the use of probabilistic models for retrieval from generic multimedia collections (text, images and video). The models are not only used to return a ranked list of (multimedia) documents for a users query, but they can also help a user to better specify an information need. Furthermore, the use of the models for (semi-) automatic annotation of multimedia objects is investigated. The probabilistic mod-

els have been evaluated at TREC's video track (a video retrieval benchmark) and results are published in the TREC proceedings as well as in the *EURASIP Journal on Applied Signal Processing*. Careful analysis of the results gave insight into the qualities and limitations of the models under study, as well as new pointers for future research.

Title	PhD research of M.A. Windhouwer
Period	June 1998–December 2003
Leader	M.L. Kersten
Funding	Telematics Institute (DMW project)
Partner	UT

Progress report. *Windhouwer* worked on the Acoi system architecture and its theoretical foundation: Feature grammars. In 2002 he rewrote the systems kernel, the Feature Detector Engine, and provided a more solid formal basis in the form of feature grammar systems – a specific instantiation of cooperating distributed grammar systems. The system plays a major role in the Digital Media Warehouses demonstrator, which was further stabilized, distributed on CD-Rom to various partners, and made available on the Web.

INS1.1 – Data Mining

Title	Knowledge discovery
Period	June 1998–August 2003
Leader	A.P.J.M. Siebes
Staff	A.P.J.M. Siebes, Z.R. Struzik
Funding	CWI
Partner	UU

Progress report. Work on data mining increasingly focuses on analysis of time series and sequential data in medicine (physiological time series). The approach taken is to deploy wavelet analysis on concrete medical and economic time series.

INS1.2 – Multimedia Databases

Title	AmbientDB
Period	February 2002–2007
Leader	P.A. Boncz
Staff	P.A. Boncz, M.L. Kersten, C. Treijtel, A. Jančařiková
Funding	CWI
Partners	Philips NatLab, CTIT (UT)

Progress report. AmbientDB is a new project that investigates database architecture in the emerging field of P2P databases. P2P databases are characterized by being composed from ad-hoc networks of possibly many devices that share some (parts of a) common schema and want to manage structured data over many such devices. Possible applications are in networks of distributed environmental sensors but also in the 'ambient intelligent' home and work environments, where many miniaturized wireless devices cooperate pro-actively to meet the wishes and the demands of end-users.

This research is done in cooperation with the Information Technology group of E. Dijkstra at Philips NatLab. In 2002, a Special Interest Group was organized between INS1 and Philips NatLab, consisting of a cycle of seven workshops each attended by 10–15 people. These contacts resulted in the embedding of the Philips and CWI joint activities in the ICES-KIS 3 MultimediaN proposal, as well as the possible preparation of an EU 6th FP IP.

AmbientDB is still evolving with research going on into P2P query processing and P2P networking protocols that can support the needs of database applications. Future research activities are expected in the area of P2P transaction processing and schema integration (the latter in cooperation with CTIT).

In the context of AmbientDB, the contacts with Philips NatLab led to three external PhD candidates (A. Sinitsyn, A. Kobzhev and P. Kourzanov) starting up their PhD tracks in 2003 there, under guidance of *Boncz*.

Title	DMW
Period	May 1998–May 2002
Leader	A.P. de Vries
Staff	A.P. de Vries, M.A. Windhouwer, M.L. Kersten
Funding	Telematics Institute
Partners	Telematics Institute, CTIT

Progress report. The Digital Media Warehouses project finished in May this year. The specific focus in the final project year has been the consolidation of the project results, in particular through knowledge transfer to ongoing TICO projects. This goal has been implemented by improving the existing demonstrator significantly, resulting in a stable version distributed on CD-Rom and made available on the Web, and the production of an Acoi tutorial. Summarizing, the project has resulted in over thirty publications as well as a succesful demonstrator showcased at several conferences.

Title	MIA/IR
Period	1999–2003
Leader	A.P. de Vries
Staff	A.P. de Vries, N.J. Nes, S. Manegold, M.L. Kersten, A.R. van Ballegooij, J.A. List
Funding	ICES-KIS MIA
Partners	UvA, UT, Data Distilleries

Progress report. The information retrieval (MIA/IR) project is part of the ICES-KIS MIA project, which addresses the technological and scientific issues stemming from multimedia applications. *Nes* provided support for application development on top of MonetDB, such as extensive experimentation for k-NN algorithms. The remaining activities are summarized in the PhD progress reports.

Title	Waterland
Period	June 1998–December 2003
Leader	A.P. de Vries
Staff	A.P. de Vries, M.A. Windhouwer, T.H.W. Westerveld
Funding	Senter
Partners	Telematics Institute, CTIT, TNO-TPD, NOB, NOS

Progress report. The Waterland project focuses on semi-automatic techniques for metadata extraction in the digital production of media. *Windhouwer* worked on this project when DMW was finished, and *Westerveld* joined CWI on this project. Main activity on the project was carried out as part of their PhD research. For the Waterland project, the connection between the feature grammar engine and Matlab has been improved, and a start was made to steer the TREC video indexing process using the Acoi architecture.

Title	CIRQUID
Period	June 1998–December 2003
Leader	A.P. de Vries
Staff	A.P. de Vries, G. Ramirez Camp
Funding	NWO
Partner	CTIT

Progress report. The CIRQUID project bridges the gap between structured query capabilities and relevance-oriented querying. Current techniques for XML querying, originating from the database field, do not support relevance-oriented querying. On the other hand, techniques for ranking documents, originating from the information retrieval field, typically do not take document structure into account. The project will realize flexible and transparent integration of information retrieval functionality in a database query engine, enabling exciting new ways to combine document structure and content. The project started in October, but CWI candidate will start March 2003.

INS1.3 – Database Architectures

Title	MIA/MonetDB
Period	1993–indefinite
Leader	P.A. Boncz
Staff	P.A. Boncz, S. Manegold, N.J. Nes, M.L. Kersten, M.K. Zukowski, K.S. Mullender, M.H.M. van Dinther
Funding	ICES-KIS MIA
Partners	UvA, UT, Data Distilleries

Progress report. The database architecture project MIA/MonetDB is part of the ICES-KIS MIA project, which addresses the technological and scientific issues stemming from multimedia applications. *Nes* developed the first implementation of the SQL-3 frontend for MonetDB, which is considered an essential ingredient for wide-spread knowledge dissemination. *Kersten* continued the development of the MonetDB 5.0 version, addressing the issues of a concise and flexible abstract machine interface for database processing.

Mullender joined the team as of April 1. He is responsible for securing and improving the code base for the open-source community. During the summer, *Van Dinther* joined him and prepared the first implementation of an ODBC interface.

Zukowski (VU) finished his MSc final term assigment on cache-conscious query processing on SMP machines, which among others yielded interesting parallel variants of the radix-decluster algorithm for cache-conscious join projections. This work will be published at a future time.

Fall 2002, work was started on a successor system of MonetDB temporarily dubbed 'Times 100' which focuses on redefining all crucial database operators in a vectorized manner such that superscalar wide-issue CPUs like Itanium2 can achieve optimal IPC (instructions per cycle), by removing the artifical ordering dependencies imposed by conventional programming languages from query algebra implementations and using techniques like predication to make execution paths highly predictable.

The remaining activities are reported under the PhD sections above.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- AmbientDB; see page 137.
- DMW; see page 137.
- MIA; see page 137.
- Waterland; see page 138.
- CIRQUID; see page 138.

Teaching activities

- SIKS PhD course on 'Databases', Driebergen, The Netherlands, May 15: A.P. de Vries.
- SIKS PhD course on 'Database Architectures', Driebergen, The Netherlands, May 15: P.A. Boncz.
- SIKS PhD course on 'Information Retrieval', Leuven, Belgium, December 13: A.P. de Vries.

Other external contacts

- Special Interest Group on Organic Databases, Philips NatLab, Eindhoven, April–December: P.A. Boncz, M.L. Kersten, C. Treijtel, K.S. Mullender.

Organization of conferences, workshops, courses, meetings

P.A. Boncz co-organized the course 'Database Architecture' at UU (with H. Philippi).

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- ECIR workshop, Glasgow, UK, February 24–25: A.P. de Vries.
- Fractal 2002: Complexity and Fractals in Nature 7th International Multidisciplinary Conference, Granada, Spain, March 17–20: Z.R. Struzik (Lecture: *Cumulative effective Hölder exponent based indicator for real time fetal heartbeat analysis during labour*).
- The 20th Meeting of Special Interest Group of Japan Society of Medical Electronics and Biological Engineering: Signal Processing for Measurement and Interpretation of Biological Functions, Tokyo Univ., Japan, March 29: Z.R. Struzik (Invited talk: *Wavelets and Heartbeat – analysis of scaling, patterns and non-stationarity with wavelet transform*).
- Database Congres, Amsterdam, April 5: M.L. Kersten (Lecture: *Main-memory database systems*).
- ACM Sigmod conference, Madison, Wisconsin, USA, June 3–6: M.L. Kersten, N.J. Nes, A.P. de Vries (Lecture: *Efficient k-NN search on vertically decomposed data*).
- SQL Server Seminar, Microsoft Cambridge Research, Cambridge, UK, June 24–26: S. Manegold, M.L. Kersten (Lecture: *A shoppinglist for the Monet database kernel*).
- IPI-PAN, Warsaw, Poland, June 29: Z.R. Struzik (Invited talk: *Wavelets and Heartbeat – analysis of scaling, patterns and non-stationarity with wavelet transform*).
- CLEF workshop, Rome, August 18–20: A.P. de Vries.
- First VLDB Workshop on Efficiency and Effectiveness of XML Tools, and Techniques (EEXTT2002), Hong Kong, August 19: A.R. Schmidt (Lecture: *Assessing XML data management with XMark*).
- VLDB02, Hong Kong, August 20–23: S. Manegold (Lecture: *Generic database cost models for hierarchical memory systems*), M.L. Kersten, P.A. Boncz, A.R. Schmidt (Lecture: *XMark: A Benchmark for XML Data Management*).
- Bali, Indonesia, August 28–31: Z.R. Struzik (Invited talk: *Is the economy constantly in labour? – A far-reaching comparison between financial time series and fetal heart rhythm during labour*).
- ICT-Kenniscongres, The Hague, September 5–6: M.L. Kersten (Lecture: *The holy grail of digital libraries*).
- DIMACS Workshop on Video Mining, Rutgers Univ., Piscataway, New Jersey, USA, November 4–6: A.P. de Vries (Invited talk: *Video data management*).
- Probing Human Mind through Ecological/ Continuous Behavioral Monitoring, November 11: Z.R. Struzik (Invited talk: *Reasoning from non-stationarity*).
- The Second Nikkei Symposium on Applications of Econophysics, Tokyo, Japan, November 12–14: Z.R. Struzik (Invited talk: *On the completeness of financial time series*).
- TREC meeting, Gaithersburg, USA, November 18: T.H.W. Westerveld, A.R. van Ballegooij.
- Dagstuhl Workshop on Intelligent XML Search, Germany, December 1–4: S. Manegold, M.L.

Kersten (Lecture: *XML=CSV*), M.A. Windhouwer (Lecture: *Feature grammar systems: Incremental maintenance of indexes to digital media warehouses*).
- Schloss Dagstuhl, Wadern, Germany, December: J.A. List (Lecture: *CWI At INEX 2002*).
- 3rd Dutch-Belgian IR Workshop (DIR 2002), Leuven, Belgium, December 6: J.A. List (Lecture: *XML-IR: Coverage as a part of Relevance*), A.P. de Vries.

Working visits
- Tokyo Univ. (2 times), Educational Physiology Laboratory, Graduate School of Education, Tokyo, Japan, March 27–April 2, November 11: Z.R. Struzik. Host: Prof. Y. Yamamoto.
- Kyoto Univ. (2 times), Research Center for Earthquake Prediction, Disaster Prevention Research Institute, April 2–5, November 21: Z.R. Struzik.
- IFIP 2.6 meeting, Lausanne, Switzerland, May 15–17: M.L. Kersten.
- IBM Almaden, TREC video preparation meeting, USA, May 27: A.P. de Vries.
- Univ. Syracuse, Brown paper bag talk, May 31: A.P. de Vries.
- IPI-PAN Poland Institute of Computer Science, Polish Academy of Sciences (IPI-PAN), Warsaw, Poland, June 29: Z.R. Struzik. Host: Prof.dr. hab J. Koronacki.
- INRIA Rocquencourt for the organizing workshop for the AIR@HOME Network Of Excellence under preparation for the first call of EC 6th FP, December 2–3: P.A. Boncz.

Project meetings
- ToKeN2000 Project Workshop, CWI, February 8: M.L. Kersten, M.A. Windhouwer.
- Organic Database Project Meetings, Philips NatLab: P.A. Boncz, M.L. Kersten, C. Treijtel, K.S. Mullender. Philips hosts: H. van Gageldonk, W. Fontijn.
- MultimediaN preparatory meetings at CWI, TNO, UvA, TUD, UT: M.L. Kersten.

Memberships of committees and other professional activities

A.P. de Vries
- Supervision of MSc theses: M. Srivastava, G. Ramirez Camp.
- Program Committee Member for ECIR 2002, March 25–27, Glasgow.
- Program Committee Member for SIGIR 2002, Tampere, Finland.
- Member for NWO IMIX program committee.
- Reviewer for *ACM Multimedia, ACM Transactions on Information Systems, Journal of Information Retrieval, VLDB, SIGMOD.*

P.A. Boncz
- Supervision of MSc theses: M.K. Zukowski, A. Jančařiková.
- Program Committee Member for EDBT'02, March 24–28, Prague.
- Reviewer for VLDB'02 and SIGMOD'02 conferences.

M.L. Kersten
- Professor of computer science at UvA (1993–).
- Program Committee Member ICDE, San Jose, USA, February.
- Program Committee Member ECDL'2002, Rome, Italy, July.
- Program Committee Member IDEAS, Edmonton, Canada, July.
- Program Committee Member IDEAL, Manchester, UK, August.
- Program Committee Member VLDB'02, Hong Kong, August 20–23.
- Program Committee Member WISE'2002, Singapore, December.
- Member editorial board *The VLDB Journal*, Springer-Verlag (1996–).
- Member editorial board *Distributed and Parallel Databases* (1993–).
- Member of the VLDB Endowment Executive Board.
- Co-founder and non-executive board member Data Distilleries B.V., Amsterdam.
- Member Scientific Advisory Board GMD/IPSI, Darmstadt, Germany.
- Member Scientific Advisory Board Helsinki Institute for Information Technology, Finland.
- Member board Amsterdam New Media Association (ANMA).

Z.R. Struzik
- Program Committee Member for DEXA'02, September 2–6, Aix-en-Provence, France.
- Member organization IASTED Technical Committee on Information Systems (2001–2004).

- Member organizing committee Econophysics of Emerging Markets, Warsaw, Poland, 2004.
- Member editorial board Fractals.

Visitors

- T. Penzel (Marburg Univ.), April 18. Host: Z.R. Struzik.
- T. Norgall (Fraunhofer Inst., Germany), April 18. Host: Z.R. Struzik.
- M. Hagendoorn (Max Plank Inst. Saarbrücken), May 14 (Lecture: *Simple and efficient Nearest-Neighbor search*). Host: A.P. de Vries.
- P. Valduriez (INRIA Rocquencourt), May 29–30. Host: M.L. Kersten.
- N. Mamoulis (Hong Kong Univ.), July, working on ACM TODS paper. Host: A.P. de Vries.
- A. Orlowski (SGGW/IF-PAN, Warsaw), September 4–10. Host: Z.R. Struzik.
- P. Bernstein (Univ. Washington, Microsoft Research), November 5–7 (Lecture: *Generic Model Management – A Database Infrastructure for Schema Manipulation*). Host: M.L. Kersten.
- D. DeWitt (Univ. Wisconsin), December 14–17 (Lecture: *Database Research at Wisconsin Un*). Host: M.L. Kersten.
- G. Weikum (Univ. Saarbrücken), December 16–17 (Lecture: *Database Research at Saarbrücken*). Host: M.L. Kersten.

Publications

Papers in refereed journals and proceedings

J.A. List, A.P. de Vries (2002). XML-IR: Coverage as a part of Relevance. *Proceedings of the 3rd Dutch-Belgian IR Workshop*, (DIR 2002), Leuven, Belgium, 7–12.

S. Manegold, P.A. Boncz, M.L. Kersten (2002). Generic database cost models for hierarchical memory systems. *Proceedings of the International Conference on Very Large Databases*, (VLDB), Hong Kong, China, 191–202.

S. Manegold, P.A. Boncz, M.L. Kersten (2002). Optimizing main-memory join on modern hardware. *IEEE Transactions on Knowledge and Data Eginieering*, (TKDE) **14**(4), 709–730.

F. Nack, M.A. Windhouwer, L. Hardman, E. Pauwels, M. Huijberts (2002). The role of high-level and low-level features in style-based retrieval and generation of multimedia presentations. *The New Review of Hypermedia and Multimedia* **7**, 39–65.

A.H. Salden (Telematics Institute), F. Aldershoff (Telematics Institute), S. Iacob (Telematics Institute), R. Otte (Telematics Institute), M.A. Windhouwer (2002). Web-enabled advanced multimedia systems. *Proceedings of the International Workshop on Multimedia Signal Processing*, (MMSP), St. Thomas, US Virgin Islands, 117–120.

A.R. Schmidt, F. Waas (Microsoft Research, USA), M.L. Kersten, M.J. Carey (BEA Systems, USA), I. Manolescu (INRIA Roquencourt, France), R. Buss (FhG-IPSI, Germany) (2002). XMark: A benchmark for XML data management. *Proceedings of the International Conference on Very Large Database*, (VLDB), Hong Kong, China, 974–985.

A.R. Schmidt, F. Waas (Microsoft Research, USA), M.L. Kersten, M.J.Carey (BEA Systems, USA), I. Manolescu (INRIA Roquencourt, France), R.Buss (FhG-IPSI, Germany) (2002). Assessing XML data management with XMark. *First VLDB Workshop on Efficiency and Effectiveness of XML Tools, and Techniques*, (EEXTT2002), Hong Kong, China.

A.R. Schmidt (2002). Doctoral poster: Processing XML in Database Systems. *Proceedings of the International Conference on Very Large Database*, (VLDB), Hong-kong, China. 974–985.

A.R. Schmidt, M.L. Kersten (2002). Bulkloading and maintaining XML documents. *Proceedings of the ACM Symposium on Applied Computing*, (SAC), Madrid, Spain, 407–412.

A.P.J.M. Siebes, Z.R. Struzik (2002). Complex data: mining using patterns. *Proceedings of ESF Exploratory Workshop on Pattern Detection and Discovery in Data Mining*, Imperial College, London, UK, Invited contribution.

A.F. Smeaton (Univ. Dublin), P. Over (NIST, USA), C.J. Costello (Johns Hopkins Univ.), A.P. de Vries, D. Doermann (Johns Hopkins Univ.), A. Hauptmann (Carnegie Mellon Univ.), M.E. Rorvig (Univ. North Texas), J.R. Smith (T.J. Watson Inst.), L. Wu (Fudan Univ. Shanghai) (2002). The TREC2001 Video Track: Information Retrieval on Digital Video Information. *Research and Advanced Technology for Digital Libraries, Proceedings 6th European Conference*, ECDL 2002, Rome, Italy, 266–275.

A.P. de Vries, N. Mamoulis (Hong Kong Univ.), N.J. Nes, M.L. Kersten (2002). Efficient k-NN search on vertically decomposed data. *Proceedings of the ACM SIGMOD International*

Conference on Management of Data, Madison, WI, USA, 322–333.

Z.R. Struzik, A.P.J.M. Siebes (2002). Wavelet transform based multifractal formalism in outlier detection and localisation for financial time series. *Physica A: Statistical Mechanics and its Applications* **309**(3–4), 388–402.

Z.R. Struzik, W.J. van Wijngaarden (AMC, Amsterdam), R. Castelo (UU) (2002). Reasoning from non-stationarity. *Physica A: Statistical Mechanics and its Applications* **314**(1–4), 245–254.

Z.R. Struzik, W.J. van Wijngaarden (AMC, Amsterdam) (2002). Cumulative effective Hölder exponent based indicator for real time heartbeat analysis during labour. M.M. Novak (ed.). *Emergent Nature: Fractals 2002*, World Scientific, Singapore, 45–55.

CWI reports

INS-R0203 INS-R0206 INS-R0208

See page 173 for complete titles.

Other publications

PhD theses

P.A. Boncz (2002). *A Next-Generation DBMS Kernel for Query-Intensive Applications*, UvA, May 31. Thesis advisor: Prof.dr. M.L. Kersten.

A.R. Schmidt (2002). *Processing XML in Database Systems*, UvA, November 7. Thesis advisor: Prof.dr. M.L. Kersten.

S. Manegold (2002). *Understanding, Modeling, and Improving Main-Memory Database Performance*, UvA, December 17. Thesis advisor: Prof.dr. M.L. Kersten.

Masters thesis

M. Zukowski. *Parallel Query Execuction in Monet on SMP Machines*, VU.

Miscellaneous publications

W. Fontijn (Philips), P.A. Boncz. *Report of The Special Interest Group on Organic Databases*, Philips NatLab Report.

M. Petkovic (UT), M.A. Windhouwer, R. van Zwol (UT), H.E. Blok (UT), P.M.G. Apers (UT), M.L. Kersten, W. Jonker (UT). Content-based Video Indexing for the Support of Digital Library Search. *Proceedings of the IEEE International Conference on Data Engineering*, (ICDE), San Jose, California, USA, February. Technical Demonstration.

Software developed

In October, the MonetDB system was placed in open-source at `sourceforge.net/projects/monetDB`, with a formal announcement of a first official first release planned for Spring 2003.

Multimedia and Human-Computer Interaction – INS2

Mission

The group's strengths lie in its knowledge of multimedia, hypermedia, and Web technology. The past year saw this area of interest broadened with the emergence of the Semantic Web. Our long-term focus on automated hypermedia presentation generation now incorporates semantically-encoded knowledge as this process input. This allows the authoring of document content in terms of more abstract models of author intent. It also broadens the scope of style and its processing, giving end-users and designers more flexibility in specifying how they wish to have certain categories of semantically-encoded documents presented to them. A strong component of the multimedia interfaces we develop lies in providing a human face for the computer's communication with its user. Our CharToon program interface provides a computer-generated anthropomorphic face with emotional expression to facilitate the user's identification with it.

Theme leader

Prof.dr. H.L. Hardman

Subthemes

Name	Leader
INS2.1 – Semantics and Hypermedia Processing	H.L. Hardman
INS2.2 – Social User Interfaces	Zs.M. Ruttkay

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Ir. S. Bocconi	1.0	PhD student	2000-01-01 till 2005-12-31	INS2.1: I2RP	H.5.4, H.5.1, I.7.2
K.I. Falkovych, MSc	1.0	PhD student	2002-11-01 till 2002-12-31	INS2.1: CHIME	H.5.4, H.5.1, I.7.2
Drs.ing. J.P.T.M. Geurts	1.0	PhD student	2002-06-01 till 2006-05-31	INS2.1: NASH	H.5.4, H.5.1, I.7.2
Prof.dr. H.L. Hardman	0.8	theme leader, leader INS2.1	indefinite	INS2.1: NASH, I2RP, Topia	H.5.4, H.5.1, I.7.2
Dr. F.-M. Nack	1.0	researcher	2000-02-01 till 2006-01-31	INS2.1: Dynamo, OntoWeb, CHIME	H.5.4, H.5.1, I.2.4, I.4, I.7.2
Drs. H. Noot	1.0	programmer	indefinite	INS2.1: Epictoid	H.5.1, I.3.7, J.4, J.5
Dr. J.R. van Ossenbruggen	1.0	researcher	indefinite	INS2.1: NASH	H.5.4, H.5.1, I.7.2
Dr. L.W. Rutledge	1.0	researcher	indefinite	INS2.1: MIA, Topia, W3C AC	H.5.4, H.5.1, I.7.2
Dr. Zs.M. Ruttkay	1.0	programmer, leader INS2.2	2001-03-16 till 2004-03-15	INS2.1: Epictoid	H.5.1, I.3.7, J.4, J.5

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. P.M.E. De Bra	0.2	researcher	indefinite	INS2.1: Dynamo, NASH	H.5.4, H.5.1, I.7.2

Scientific report

PhD research

Title	PhD research of S. Bocconi
Period	January 2002–December 2006
Leader	H.L. Hardman
Funding	NWO (ToKeN2000/I^{2}RP project)

Progress report. This thesis work is concerned with the reuse of existing multimedia information in the automatic generation of multimedia presentations. Reuse here means recreating a context in the presentation for different information items that were created for different purposes resulting in a coherent presentation structure. The main problem lies in the fact that it is hard for a machine to detect whether a particular generated presentation can communicate the message it was designed for and particularly whether it communicates something that was not intended to communicate. The initial approach taken is to investigate the use of discourse and narrative structures to make a coherent story out of a collection of data. Emerging Semantic Web technology is used.

Title	PhD research of K.I. Falkovych
Period	November 2002–October 2006
Leaders	H.L. Hardman, F.-M. Nack
Funding	NWO (ToKeN2000/CHIME project)

Progress report. This thesis work began in November. This PhD is expected to follow up Masters thesis work on the mapping between

Semantic Web languages RDFS and OWL and Unified Modelling Language (UML). Additional research was begun in multimedia presentation generation area, in particular in user modelling for multimedia environment and aspects of interactive interfaces.

Title	PhD research of J.P.T.M. Geurts
Period	June 2002–May 2006
Leaders	H.L. Hardman, J.R. van Ossenbruggen
Funding	NWO (NASH project)

Progress report. This thesis work started in June, it continues work performed at DSTC, Australia, concerning semantic inferencing on Dublin Core metadata. This resulted in a paper at ECDL 2002 and a demo at 'CWI in Bedrijf' and the ICT Kenniscongres. In addition, this work implemented Hypermedia Formatting Objects (HFO's) within the Cuypers system. This topic forms a potential contribution to the process of automatic generation of multimedia presentations, and consequently to Cuypers, of which the architecture is the current primary topic for this thesis.

INS2.1 – Semantics and Hypermedia Processing

Title	Dynamo
Period	February 2000–January 2004
Leader	F.-M. Nack
Funding	NWO
Partners	TUE, Philips Research

Progress report. The main goal of the project is to increase the level of automated adaptation of varying user and system characteristics during the process of creating hypermedia presentations. User adaptation might cover such things as the current state of knowledge of the user, the task the user is involved in and characteristics and preferences of the user. Adaptation at the system level includes accounting for the end-user system the presentation will be played on, the network bandwidth between the server generating the source document, the servers supplying the media items and the hardware at the client's side. Although the role of CWI is finished, *Hardman* continues work representing TUE.

Title	MIA/IR – Multimedia Information Analysis
Period	July 1999–December 2002
Leader	A.P. de Vries (INS1)
Staff	L.W. Rutledge
Funding	ICES-KIS MIA
Partners	UvA, UT, Data Distilleries

Progress report. The MIA project aims at true multimedia analysis of multimedia documents composed of digital text, picture and/or video. At the confluence of text-, picture- and video-analysis, data visualization, and multimedia data storage, the MIA project aims to provide the technology for the digital library age. INS2.1's contribution was the use of multimedia standards and their tools in the project.

Title	NASH – Networked Adaptive Structured Hypermedia
Period	June 2002–May 2004
Leader	P.M. De Bra
Staff	P.M. De Bra, J.P.T.M. Geurts, H.L. Hardman, J.R. van Ossenbruggen
Funding	NWO
Partner	TUE

Progress report. The NASH project is a result of the identification (and partitioning) of research problems by the joint research teams of TUE and CWI who are collaborating in NWO, ITEA and W3C projects related to the generation of hypermedia interfaces for semi-structured multimedia information. Besides the applicants, the two whole research teams will be working together with the NASH researchers to complete the networked adaptive structured hypermedia generation framework, involving all three aspects mentioned above.

Title	OntoWeb – Ontology-based information exchange for knowledge management and electronic commerce (Network of Excellence)
Period	June 2001–May 2004
Leader	F.-M. Nack
Staff	F.-M. Nack
Funding	IST
Partners	Too numerous to mention (see http://ontoweb.aifb.uni-karlsruhe.de/Organisations/)

Progress report. Our contribution describes the current state of the art on representing the four

essential conceptual facets of a multimedia unit, namely the form and substance of content and the form and substance of its expression, and points to the still unsolved problems regarding the syntax for media semantics. We first provide a brief overview of the general features of the MPEG-7 standard and its different parts. This serves as a description of the state of the art in content description for audio-visual media. We then analyze the ability of one of these parts for its capability to define structures for describing media semantics. We describe the problems of two currently conflicting MPEG-7 representations of expression-based media semantics, which should be equivalent. We then discuss high-level aspects of media semantics, namely the general problems of an ontology for media semantics. Finally, we talk about the problems of applying the theoretical concepts to real applications. The project deliverable was published as technical report INS-R0204.

Title	I^2RP – Intelligent Information Retrieval and Presentation in public historical multimedia databases
Period	2002–2005
Leader	H.L. Hardman
Staff	H.L. Hardman, S. Bocconi, K. Czajka, K. Schwarz, S.E. Little
Funding	NWO
Partners	ToKeN2000, Rijksmuseum Amsterdam, KI/RUG, IKAT/UM, UL

Progress report. The work of CWI focuses on the presentation aspects of personalized, media-centric hypermedia-interfaces. The Cuypers proof-of-concept prototype, constructed in the first phase of ToKeN2000, currently focuses on the adaptation of hypermedia presentations to various end-user devices such as a desk-top computer, a hand-held device or a mobile phone. This device-driven approach was developed to validate our constraint-driven approach to hypermedia presentation generation. In the following phase of ToKeN2000, the device-driven approach will be integrated with a more user-centric approach, based on explicit user profile information. In order to adapt hypermedia presentations to an individual user's task and preferences, adequate user models need to be developed. Research to address this issue will be carried out in cooperation with KI/RUG in the context of the Optima project.

Title	CHIME – Cultural Heritage in an Interactive Multimedia Environment
Period	November 2002–October 2004
Leader	H.L. Hardman
Staff	K.I. Falkovych, F.-M. Nack
Funding	NWO
Partner	ToKeN2000

Progress report. The goal of the CHIME project is to investigate the use of semantic models for tailoring the presentation of cultural information extracted from existing repositories to different types of users. While database query and full text search interfaces are able to provide access to the information, they do not take into account the richness of expression of multiple media types. In this project we will build on the presentation generation framework developed in previous ToKeN2000 work and focus on the user and domain modelling aspects, paying particular attention to the knowledge representation problems introduced by multimedia aspects. Research in the project will concentrate on the creation of ontological descriptions of the domain which can be revealed in different levels of detail to different users, on the creation of user profiles to facilitate both this process and the hypermedia presentation generation process. Experience gained in the use of the user profiles and domain ontologies during the presentation generation process can then feed back into their development.

Title	Question How
Period	September 2001–September 2003
Leader	H.L. Hardman
Staff	J.R. van Ossenbruggen, F.-M. Nack
Funding	EU/IST, ERCIM

Progress report. The Question How project integrated Dublin Core technologies into our experimentation platform Cuypers. This enables the processing of available metadata using standard Web tools during presentation generation. The project also added the generation of SMIL presentations with rich and systematic annotations about the intended function and semantics of the presentation.

Title	Topia – Topic-based Interaction with Archives
Period	June 2002–December 2002
Leader	M. Veenstra (Telematics Institute)
Staff	H.L. Hardman, L.W. Rutledge
Funding	Telematics Institute
Partner	Telematics Institute

Progress report. The Topia project explored the discourse-driven generation of hypermedia presentation from semantically annotated media archives. A demonstrator was made using the Rijksmuseum data store generated as part of the Cuypers system. This result demonstrates the complete process chain from semantics through discourse to meaningful and coherent multimedia presentations. A conference submission contains the results of the project. The project will be continued and expanded in 2003 with IBM as an additional partner.

INS2.2 – Social User Interfaces

Title	Epictoid
Period	2002
Leader	Zs.M. Ruttkay
Staff	Zs.M. Ruttkay, H. Noot
Funding	Epictoid
Partner	Epictoid

Progress report. We have extended the scope of our work beyond facial animation in two ways. One is the addition of hand gestures. Another is zooming to the micro-control and effects of facial expressions. In both cases, the major goal was to produce individual and styled expressions. We also upgraded CharToon, extending its repertoire and extending it with a high-level scripting language.

Societal aspects and knowledge transfer

Projects with partners in private and public sector

- Epictoid; see page 146.
- Dynamo; see page 144.
- MIA/IR; see page 144.
- OntoWeb; see page 144.
- I^2RP; see page 145.
- Topia; see page 146.

Teaching activities

- Lecture on *Structured Documents for the Web*, Seminar Modern Information Systems (2001–2002), TUE, January 8: J.R. van Ossenbruggen.
- Lecture on *Semantic Web, part I*, Seminar Modern Information Systems (2001–2002), TUE, January 15: H.L. Hardman.
- Lecture on *Semantic Web, part II; Hypermedia Presentation Generation*, Seminar Modern Information Systems (2001–2002), TUE, January 29: J.R. van Ossenbruggen.
- Half-day lecture on *SMIL 2.0: Interactive Multimedia on the Web*, User System Interaction (USI) training program at Stan Ackermans Institute (SAI), TUE, February 6: L.W. Rutledge.
- Half-day tutorial on *SMIL 2.0: Interactive Multimedia on the Web*, Katholieke Univ. Leuven, Belgium, February 9: L.W. Rutledge.
- Full-day tutorial on *SMIL 2.0: Interactive Multimedia on the Web* at the Eleventh International World Wide Web Conference (WWW2002), Honolulu, Hawaii, May 7: L.W. Rutledge.
- Half-day lecture on *SMIL 2.0: Interactive Multimedia on the Web*, Basic courses: *Databases and Interactive Systems*, Dutch research school for Information and Knowledge Systems (SIKS), Driebergen, The Netherlands, May 15: L.W. Rutledge.
- Full-day tutorial on *SMIL 2.0: Interactive Multimedia on the Web* at ACM Hypertext 2002 (HT02), College Park, Maryland, June 11: L.W. Rutledge.
- Half-day tutorial on *SMIL 2.0: Interactive Multimedia on the Web* at ACM Multimedia 2002 (MM02), Juan-les-Pins, France, December 2: L.W. Rutledge.
- Lecture on *Multimedia on the Web*, Seminar Modern Information Systems (2002–2003), TUE, December 10: H.L. Hardman.
- Lecture on *Semantic-Driven Multimedia Presentations* at SIKS course *Information and Organization* and *Information Retrieval*, Vught, The Netherlands, December 13: H.L. Hardman.

Other external contacts

- Special Interest Group on the Semantic Web, Philips NatLab, Eindhoven, June 9–December 16: S. Bocconi.

Organization of conferences, workshops, courses, meetings

- Organizer of theme meeting 'Semantic Web', Werkgemeenschap Informatiewetenschap, Utrecht, June 7: H.L. Hardman.
- Co-organizer of the First International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS02) Workshop on 'Embodied conversational agents - let's specify and evaluate them!', Bologna, July 16–17: Zs.M. Ruttkay.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- Werkgemeenschap voor Informatie- en Communicatietheorie in de Benelux (WIC) IEEE Benelux Section, Midwinter Meeting 2002 on Multimedia Retrieval, TUE, January 14: F.-M. Nack (Invited talk: *Standardization Efforts in the area of Multimedia Retrieval: Is MPEG-7 the final solution?*).
- Seventh E3 Concertation Meeting VHML Workshop, Brussels, February 6: H. Noot, Zs.M. Ruttkay.
- W3C Workshop on Delivery Context, W3C/-INRIA, Sophia-Antipolis, March 4–5: H.L. Hardman, J.R. van Ossenbruggen (Talk: *Towards Semantic Web Document Engineering*).
- European Workshop on Culture and Technology, Fattoria di Celle, Pistoia, Italy, March 22–24: H.L. Hardman.
- The Animating Expressive Characters for Social Interaction (AECSI03) Symposium at the Artificial Intelligence and the Simulation of Behaviour (AISB02) Convention, Imperial College, London, April 3–5: Zs.M. Ruttkay (Accepted paper: *Exercises of style for virtual humans*).
- Fraunhofer-CWI Workshop, CWI, April 19: H. Noot, L.W. Rutledge, Zs.M. Ruttkay (Invited talk: *Scripted facial animation*).
- New Directions in ICT Conference, Telematics Institute, April 24: L.W. Rutledge.
- Semantic Web Workshop, WWW2002, Honolulu, Hawaii, May 7: H.L. Hardman, J.R. van Ossenbruggen (Accepted paper: *Smart Style on the Semantic Web*).
- Eleventh International World Wide Web Conference (WWW2002), Honolulu, Hawaii, May 7–11: H.L. Hardman, J.R. van Ossenbruggen, L.W. Rutledge.
- The First Hungarian Computer Graphics Conference, Budapest, May 28–29: Zs.M. Ruttkay (Accepted paper: *Cartoon talking heads*).
- SIG Semantic Web meeting, Philips, Eindhoven, June 6: S. Bocconi (Invited talk: *The Semantic Web and Multimedia*).
- Theme meeting 'Semantic Web', Werkgemeenschap Informatiewetenschap, Utrecht, June 7: H.L. Hardman, S. Bocconi.
- First International Semantic Web Conference (ISWC 2002), Sardinia, June 9–12: J.R. van Ossenbruggen.
- The Thirteenth ACM Conference on Hypertext and Hypermedia (Hypertext 2002), College Park, Maryland, June 11–15: L.W. Rutledge.
- The First International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS02) Workshop on 'Embodied conversational agents - let's specify and evaluate them!', Bologna, July 16–17: H. Noot, Zs.M. Ruttkay (Accepted paper: *Evaluating ECAs – What and how?*).
- The Second International Workshop on Narrative and Interactive Learning Environments (NILE2002), Edinburgh, August 6–9: L.W. Rutledge (Accepted paper: *Towards Generating Balanced Narrative Hierarchies for Maintaining User Orientation*).
- The Second Conference on Computational Semiotics for Games and New Media (COSIGN 2002), Augsburg, September 2–4: F.-M. Nack (Accepted paper: *Denotative and Connotative Semantics in Hypermedia: Proposal for a Semiotic-Aware Architecture*).
- ICT-Kenniscongres, The Hague, September 6: H.L. Hardman (Invited talk: *Semantics for Multimedia Presentations on the Web*), S. Bocconi, J.P.T.M. Geurts (Demo: *Cuypers*).
- 6th European Conference on Research and Advanced Technology for Digital Libraries, Pontifical Gregorian Univ., Rome, September 16–18: S.E. Little, J.P.T.M. Geurts (Accepted paper: *Dynamic Generation of Intelligent Multimedia Presentations through Semantic Inferencing*).
- Gigaport Workshop, De Waag, Amsterdam, October 17: L.W. Rutledge (Invited talk: *SMIL 2.0: Interactive Multimedia for the Web*).
- CWI in Bedrijf, CWI, October 18: H.L. Hardman (Invited talk: *Semantic driven multimedia presentations*).

- Information Day – Interface and Knowledge Technologies, Luxemburg, October 23–24: H. Noot (Invited talk: *Embodied conversational agents and interactive presenter kits*).
- The Computer and Automation Research Institute of the Hungarian Academy of Sciences (MTA SZTAKI), October 30: Zs.M. Ruttkay (Invited talk: *Reactive Facial Animation*).
- Startsymposium 'Tussen Brein en Bewustzijn', Wetenschapsmuseum NEMO, November 1: K. Schwarz.
- The Computer and Automation Research Institute of the Hungarian Academy of Sciences (MTA SZTAKI), November 20: Zs.M. Ruttkay (Invited talk: *Exercises of Style*).
- ACM Multimedia (MM02), Juan-les-Pins, December 1–6: H.L. Hardman, F.-M. Nack, L.W. Rutledge.

Working visits

- V2_, Rotterdam, June 5: H.L. Hardman, S. Bocconi, M. Caceres, A.A.E. Corsini, G. Katariya, F.-M. Nack, J.R. van Ossenbruggen (Invited talk: *Smart Style on the Semantic Web*), L.W. Rutledge, P. Schmitz.
- Univ. Roma La Sapienza, July 15: Zs.M. Ruttkay.
- Computer and Automation Research Institute of the Hungarian Academy of Sciences (MTA SZTAKI), Budapest, September 15–December 31: Zs.M. Ruttkay.
- V2_, Rotterdam, December 11: H.L. Hardman, S. Bocconi, J.P.T.M. Geurts, A.S.K. Manniesing, S.E. Little (Invited talk: *Cuypers Meets Users: Implementing a User Model Architecture for Multimedia Presentation Generation*), F.-M. Nack, J.R. van Ossenbruggen, L.W. Rutledge.

Project meetings

- ToKeN2000 Project Workshop, CWI, February 8: H.L. Hardman, S. Bocconi, J.R. van Ossenbruggen.
- ERCIM E-Learning WG meeting, Nice, February 11–12: Zs.M. Ruttkay (Invited talk: *Styled characters with scripts*).
- W3C Advisory Committee (W3C AC) Meeting, Honolulu, Hawaii, May 5–7: L.W. Rutledge.
- GMD FP6 EoI meeting, Bonn, May 22: H. Noot.
- CWI-TUE Project meeting, Utrecht, July 4: H.L. Hardman, F.-M. Nack, J.R. van Ossenbruggen (Invited talk: *Cuypers: Smart Style on the Semantic Web*).
- Topia Project Meetings, Telematics Institute, Enschede, July 8 and August 30: L.W. Rutledge.
- Topia Project Meeting, CWI, October 7: H.L. Hardman, L.W. Rutledge.
- I^2RP Project Meeting, CWI, November 4: H.L. Hardman, S. Bocconi (Invited talk: *Discourse Driven Hypermedia Presentation*), J.R. van Ossenbruggen.
- Topia Project Meeting, Telematics Institute, November 25: H.L. Hardman, L.W. Rutledge.
- Representatives of the Optima project I^2RP, Groningen, November 14: K. Schwarz, S.E. Little.
- W3C Advisory Committee (W3C AC) Meeting, Cambridge, MA, November 18–20: L.W. Rutledge.

Courses

- SIKS/Ontoweb Master Class *Logical Foundation of the Semantic Web*, Amsterdam, April 10: H.L. Hardman, S. Bocconi, M. Caceres, A.A.E. Corsini, K. Czajka, O. Rosell Martinez, J.R. van Ossenbruggen.
- IETF Masterclass *Steve Deering over IPv6*, Amsterdam, April 18: S. Bocconi.
- Course *Databases and Interactive Systems*, Driebergen, May 13–17: S. Bocconi.
- Course *The Semantic Web*, Zeist, May 27–28: S. Bocconi.
- DELOS Summer School 2002 on Digital Libraries, Pisa, July 8–12: S. Bocconi.
- Masterclass on Human Computer Interaction, Amsterdam, August 27: H.L. Hardman, S.E. Little, S. Bocconi.
- SIKS course *Information and Organization* and *Information Retrieval*, Vught, The Netherlands, December 9–13: S. Bocconi, J.P.T.M. Geurts, K.I. Falkovych.

Memberships of committees and other professional activities

H.L. Hardman

- Professor in computer science at TUE, since 2001.
- Supervision of S.G. Loeber (PhD student since March 2000) as part of cooperation with TUE.

- Supervision of Masters thesis at UvA for J.P.T.M. Geurts, *Constraints for Multimedia Presentation Generation*, February 6.
- Supervision of Nigten (PhD student at Central St. Martin's Institute, London since 2002) in collaboration with V2_ (institute for the Instable Media, Rotterdam).
- Program Committee Member for the Hypermedia track of the Eleventh International World Wide Web Conference (WWW2002), Honolulu, Hawaii, May 7–11.
- Program Committee Member for the First International Semantic Web Conference (ISWC 2002), Sardinia, June 9–12.
- Program Committee Member for the Second International Conference on Adaptive Hypermedia and Adaptive Web Based Systems (AH2002), Málaga, May 29–31.
- Supervision of Masters thesis at Univ. Catalonia for O. Rosell Martinez, *Design dependencies within the automatic generation of hypermedia presentations*, June 30.
- Second advisor of PhD thesis at TUE for Hongjing Wu, *A Reference Architecture for Adaptive Hypermedia Applications*, November 8.
- Reviewer for *The Journal of Personalization Research Special Issue on User Modeling and Personalization for Television.*
- Reviewer for *Computing Reviews.*
- Reviewer for *IEEE Multimedia.*
- Reviewer for *Transactions of the IEEE Transactions on Systems, Man, and Cybernetics.*
- Member of the Association for Computing Machinery (ACM) and its Special Interest Groups on Hypertext, Hypermedia and the Web (SIGWEB) and Multimedia (SIGMM).
- Member of the British Computing Society (BCS).

F.-M. Nack

- Program Committee Member for the Thirteenth ACM Conference on Hypertext and Hypermedia (Hypertext 2002), College Park, Maryland, June 11–15.
- Supervision of Bachelor's thesis for K. Czajka, *Design of Interactive and Adaptive Interfaces to Exploit Large Media-Based Knowledge Spaces in the Domain of Museums for the Fine Arts*, June 14.
- Program Committee Member for the Second International Workshop on Narrative and Interactive Learning Environments (NILE 2002), Edinburgh, August 6–9.
- Reviewer for the Second Conference on Computational Semiotics for Games and New Media (COSIGN 2002), Augsburg, September 2–4.
- Supervision of Bachelor's Thesis at Univ. Applied Science, Darmstadt for T. Schlenkhof, *Vom Informationsmanagement zum Wisensmanagement*, September 25.
- Examiner of PhD thesis at Curtin Univ., Perth, Australia for B. Adams, *Mapping the semantic landscape of film: Computational extraction of indices through film grammar*, December.
- Reviewer for ACM Multimedia (MM02), Juanles-Pins, December 1–6.
- Chair of panel *Media Semantics: Who Needs It and Why?* at ACM Multimedia (MM02), Juanles-Pins, December 5.
- Reviewer for *IEEE Multimedia.*
- Reviewer for *IEEE Intelligent Systems.*
- Reviewer for *ACM Multimedia Systems.*
- Reviewer for *International Journal of Continuing Engineering Education and Life Long Learning (IJCEELL).*
- Peer reviewer for the EU project CULTOS.
- Editor of the Media Impact Column of *IEEE Multimedia journal.*
- Contact in OntoWEB (Ontology-based information exchange for knowledge management and electronic commerce) project.
- Member of the ISO/IEC JTC1/SC29/WG11 group developing the Moving Picture Experts Group Multimedia Content Description Interface (MPEG-7) Description Definition Language (DDL).
- Member of the Association for Computing Machinery (ACM) and its Special Interest Groups on Multimedia (SIGMM), Hypertext, Hypermedia and the Web (SIGWEB) and Computer-Human Interfaces (SIGCHI).

H. Noot

- Member of the Association for Computing Machinery (ACM) and its Special Interest Group on Graphics (SIGGRAPH).

J.R. van Ossenbruggen

- Supervision of Masters thesis at UvA for J.P.T.M. Geurts, *Constraints for Multimedia Presentation Generation*, February 6.
- Program Committee Member for the Semantic Web track of the Eleventh International World Wide Web Conference (WWW2002), Honolulu, Hawaii, May 7–11.
- Referee for the First International Semantic Web Conference (ISWC 2002), Sardinia, June 9–12.
- Reviewer for the Thirteenth ACM Conference on Hypertext and Hypermedia (Hypertext 2002), College Park, Maryland, June 11–15.
- Supervision of Masters thesis at Univ. Catalonia for O. Rosell Martinez, *Design dependencies within the automatic generation of hypermedia presentations*, June 30.
- Reviewer for the First International Workshop on Web Semantics at the Thirteenth International Conference on Database and Expert Systems Applications (DEXA 2002), Aix-en-Provence, September 2–6.
- Affiliate member of the Institute of Electrical and Electronics Engineers (IEEE) Computer Society.
- Member of the Association for Computing Machinery (ACM) and its Special Interest Group on Hypertext, Hypermedia and the Web (SIGWEB).

L.W. Rutledge

- Program Committee Member for the Multimedia track of the Eleventh International World Wide Web Conference (WWW2002), Honolulu, Hawaii, May 7–11.
- Chair of the Doctoral Consortium of the Thirteenth ACM Conference on Hypertext and Hypermedia (Hypertext 2002), College Park, Maryland, June 15.
- Reviewer for the Thirteenth ACM Conference on Hypertext and Hypermedia (Hypertext 2002), College Park, Maryland, June 11–15.
- Reviewer for the Workshop on XML in Digital Media (XMLinDM'02) at the Eighth International Conference on Distributed Multimedia Systems (DMS'2002) San Francisco, California, September 26–28.
- Program Committee Member for the Eighth Brazilian Symposium on Multimedia and Hypermedia Systems (SBMIDIA 2002), Fortaleza, Brazil, October 7–10.
- Program Committee Member for the ACM Symposium on Document Engineering (DocEng 2002), McLean, Virginia, USA, November 8–9.
- Reviewer for ACM Multimedia (MM02), Juanles-Pins, December 1–6.
- Program Committee Member for the Ninth International Conference on Multi-Media Modeling, Taiwan, January 7–10, 2003.
- Reviewer for SMIL Europe 2003, Paris, February 12–14, 2003.
- Reviewer for the *Journal of Digital Libraries*.
- Reviewer for the *IEEE Transactions on Multimedia*.
- Reviewer for the *New Review of Hypermedia and Multimedia*.
- Member of the Association for Computing Machinery (ACM) and its Special Interest Groups on Hypertext, Hypermedia and the Web (SIGWEB) and Multimedia (SIGMM).
- Member of W3C Advisory Committee.

Zs.M. Ruttkay

- Supervision of Masters thesis at VU for V. van Moppes, *Emotional Speech Markup Language*, October.
- Program Committee Member for the Virtual Conversational Characters: Applications, Methods, and Research Challenges Workshop at Human Factors 2002 (HF2002), Melbourne, Australia, November 25–27.
- Member of the Association for Computing Machinery (ACM) and its Special Interest Group on Graphics (SIGGRAPH).
- Member of the John von Neumann Computer Society (NJSZT).

Visitors

- K. Czajka (Univ. Applied Science, Darmstadt), start of year–April 1. Host: F.-M. Nack.
- O. Rosell Martinez (Univ. Catalonia), start of year–June 1. Host: J.R. van Ossenbruggen.
- M. Caceres (Queensland Univ. Technology), Australia, start of year–July 1. Host: F.-M. Nack.
- N. Dimitrova and L. Nikolovska (Philips Research), January 17. Host: F.-M. Nack.
- A.A.E. Corsini, student, February 1–August 1. Host: H.L. Hardman.

- V. van Moppes (VU), February 1–August 1. Host: Zs.M. Ruttkay.
- U. Spierling (FHG), February 5. Host: F.-M. Nack.
- S. Mozziconacci, February 18. Host: Zs.M. Ruttkay.
- P. King (Univ. Manitoba, Canada), March 27. Talk: *Two models for the formal specification of temporal constraints in multi-media documents.* Host: H.L. Hardman.
- G. Katariya (IIT Internship), May 11–July 24. Host: J.R. van Ossenbruggen.
- P. Schmitz (Ludicrum), May 26–June 28. Host: H.L. Hardman.
- P. King (Univ. Manitoba, Canada), June 16–17. Host: H.L. Hardman.
- S.E. Little (Distributed Systems Technology Centre DSTC, Australia), August 1–December 20. Host: H.L. Hardman.
- S. Beard (Curtin Univ. Technology, Australia), August 13. Talk: *Virtual human markup language.* Host: Zs.M. Ruttkay.
- Y. Bachvarova (Univ. Lausanne), August 21. Host: H.L. Hardman.
- A.S.K. Manniesing (TUD), September 1–end of year. Host: F.-M. Nack.
- K. Schwarz (Univ. Applied Science, Darmstadt), October 14. Host: F.-M. Nack.
- M. Davis (Univ. California at Berkeley), December 10. Talk: *Towards computational media: Metadata for media automation and reuse.* Host: F.-M. Nack.

Publications

Books and book chapters

F.-M. Nack (2002). From ontology-based semiosis to computational Intelligence - The Future of Media Computing. C. Doria, S. Venkatesh (eds.). *Media Computing Computational Media Aesthetics*, ISBN 1-4020-7102-7, Kluwer Academic Publishers, 159–196.

Papers in refereed journals and proceedings

E. Krahmer (UT), Zs.M. Ruttkay, M. Swerts (TUE), W. Wesselink (TUE) (2002). Perceptual evaluation of audiovisual cues for prominence. *Proceedings of the Seventh International Conference on Spoken Language Processing (ICSLP–2002)*, 1933–1936.

E. Krahmer (UT), Zs.M. Ruttkay, M. Swerts (TUE), W. Wesselink (TUE) (2002). Pitch, eyebrows and the perception of focus. *Proceedings of Speech Prosody 2002*, 443–446.

C. Lindley (CSIRO, NSW, Australia), F.-M. Nack, E. Andre (Univ. Saarbrücken) A. Clark (Tinnet, UK) G. Mitchell (Univ. East London), C. Fencott (Univ. Teesside, UK) (2002). The emergence of the Labyrinth: The intrinsic computational aesthetic form. *Proceedings of the Second Conference on Computational Semiotics for Games and New Media (COSIGN02)*, 3–6.

S.E. Little (DSTC, Australia), J.P.T.M. Geurts, J. Hunter (Univ. Queensland) (2002). Dynamic generation of intelligent multimedia presentations through semantic inferencing. *Proceedings of the Sixth European Conference on Research and Advanced Technology for Digital Libraries*, Springer-Verlag, 158–189.

S.G. Loeber (TUE), L.M. Aroyo (TUE), L. Hardman (2002). An explicit model for tailor-made eCommerce web presentations. *Proceedings of the Workshop on Recommendation and Personalization in eCommerce at the 2nd International Conference on Adaptive Hypermedia and Adaptive Web Based Systems*, 8 pages.

F.-M. Nack (2002). Media information spaces – A semantic challenge. *IEEE Intelligent Systems* **17**(1), 81–83.

F.-M. Nack, L. Hardman (2001). Denotative and connotative semantics in hypermedia: Proposal for a Semiotic-Aware Architecture. *New Review of Hypermedia and Multimedia* **7**, 7–37 (revision of technical report INS-R0202).

F.-M. Nack, M. Windhouwer, L. Hardman, E. Pauwels, M. Huijberts (2001). The role of high-level and low-level features in style-based retrieval and generation of multimedia presentations. *New Review of Hypermedia and Multimedia* **7**, 39–65.

J.R. van Ossenbruggen, L. Hardman (2002). Smart style on the semantic web. *Proceedings of the Semantic Web Workshop at Eleventh International World Wide Web Conference (WWW2002)* (revision of technical report INS–R0201).

J.R. van Ossenbruggen, H.L. Hardman, L.W. Rutledge (2002). Hypermedia and the semantic web: A research agenda. *Journal of Digital Information* **3**(1) (revision of technical report INS–R0105).

L.W. Rutledge, S. Iacob (Telematics Institute) (2002). Towards generating balanced

narrative hierarchies for maintaining user orientation. *Proceedings of the Second International Workshop on Narrative and Interactive Learning Environments (NILE2002)*, 30–37.

Zs.M. Ruttkay, C. Doorman (VU), H. Noot (2002). Evaluating ECAs – What and how? *Proceedings of the First International Joint Conference on Autonomous Agents and Multi-agent Systems (AAMAS02) Workshop on 'Embodied conversational agents - let's specify and evaluate them!'*.

Zs.M. Ruttkay, C. Pelachaud (Univ. de Paris) (2002). Exercises of style for virtual humans. *Proceedings of the Animating Expressive Characters for Social Interaction (AECSI03) Symposium at the Artificial Intelligence and the Simulation of Behaviour (AISB02) Convention*, 85–90.

Zs.M. Ruttkay, H. Noot (2002). Cartoon talking heads. *Proceedings of the First Hungarian Computer Graphics Conference*, 2–9.

A.W.M. Smeulders (UvA), L. Hardman, G. Schreiber (UvA), J.-M. Geusebroek (TUE) (2002). An integrated multimedia approach to cultural heritage e-documents. *Proceedings of the Fourth International Workshop on Multimedia Information Retrieval at ACM Multimedia 2002.*

CWI reports

INS-R0201 INS-R0202 INS-R0204 INS-R0205

See page 173 for complete titles.

Other publications

Masters theses

C. Doria (T.J. Watson Inst.), A. Mauthe (Lancaster Univ.), F.-M. Nack, L.W. Rutledge, T. Sikora (TU Berlin), H. Zettl (USA) (2002). Media semantics: Who needs it and why (Panel Session). *Proceedings of the Tenth ACM International Conference on Multimedia (MM02)*, 580–583.

J.P.T.M. Geurts (2002). *Constraints for Multimedia Presentation Generation.* UvA, February 6. Thesis advisors: J.R. van Ossenbruggen, H.L. Hardman.

O. Rosell Martinez (2002). *Design Dependencies within the Automatic Generation Of hypermedia Presentations*, Technical Univ. Catalonia, June 30, Thesis advisors: J.R. van Ossenbruggen, H.L. Hardman (also published as technical report INS-R0205).

V. van Moppes (2002). *Emotional Speech Markup Language*, VU, October. Thesis advisor: Zs.M. Ruttkay.

Diploma theses

K.Czajka (2002). *Design of Interactive and Adaptive Interfaces to Exploit Large Media-based Knowledge Spaces in the Domain of Museums for the Fine Arts.* Univ. Applied Science, Darmstadt, June 14. Thesis advisor: F.-M. Nack.

Articles in unrefereed journals and proceedings

F.-M. Nack (2002). Pictures at an exhibition. *IEEE MultiMedia* **9**(2), 14–17.

J.R. van Ossenbruggen, H.L. Hardman (2002). Hypermedia presentation generation on the semantic web. *ERCIM News* **51**, 36.

L.W. Rutledge (2002). SMIL 2.0 implementation overview. *interChange – Newsletter of the International SGML/XML Users' Group* **8**(1), 20–24.

Software developed

INS2.1 developed the Cuypers research prototype system (`http://www.cwi.nl/media/cuypers/`) to experiment with the generation of Web-based presentations as an interface to semi-structured multimedia databases. Cuypers differs from XSL-based transformations in that it explores a set of abstractions, both on the document and on the presentation level, that are geared toward interactive, time-based and media centric presentations, rather than presentations that are based on text-flow.

Van Ossenbruggen supervised development work to extend the system. To experiment with RDF encoded knowledge from the Semantic Web, he implemented an interface to the Sesame RDF storage and querying engine. For the Question How project, Van Ossenbruggen and Bocconi realized a Dublin Core annotation generation module for Cuypers. In addition to the demonstrator based on the Rijksmuseum repository, Geurts developed a demonstrator based on Open Archive Initiative repositories. Geurts also improved the semantic preprocessing of the input by implementing a module that builds semantic graphs using inference rules and Dublin Core metadata in the media items. Bocconi started on a Cuypers module that supports discourse driven presentation generation. Little started on a Cuypers module that is able to make trade offs between conflicting interests between the preferences of the provider and the end-user. Manniesing (in-

tern) started on a Cuypers module for intelligent selection of color schemes.

Rutledge developed a demonstrator for the Topia project in collaboration with the Telematics Institute. The demonstrator generated timed multimedia presentations based on the Rijksmuseum repository. It combines the use of RDF-based semantic processing with efficient XSLT-based syntactic transformations.

For the Question How project, Van Ossenbruggen and Bocconi realized a Dublin Core annotation generation module for Cuypers. They also enhanced Cuypers to include Dublin Core information in its output.

INS2.2 developed and implemented the GESTYLE language. This XML-based markup language makes it possible to define non-verbal style of embodied conversational agents, and generate appropriate gesturing automatically, by interpreting high-level meaning tags in text to be spoken by the ECA. INS2.2 also designed and implemented (in the framework of the stage project of (V. van Moppes, VU) a markup language to produce expressive synthesized speech. A commercial TTS system was adopted in the framework of cooperation with MindMaker.

Visualization – INS3

Mission

Visualization and 3D user interfaces have rapidly become an important research area. It clearly has a multidisciplinary character, intersecting various disciplines in computer science (in particular computer graphics and user interfaces) and mathematics (in particular numerical mathematics and statistics), and also has connections with research in perception and industrial design.

Until recently, research in scientific visualization and 3D user interfaces was oriented towards the ad hoc development of working prototypes. In the excitement over the obvious benefits, few questions were asked about the nature of perceived information and how well the human visual system actually performs. Because visualization and virtual reality are new, emerging disciplines, the lack of structure is not surprising, but their development is necessary and offers significant opportunities.

The mission of the pilot 'Visualization' is to obtain a better understanding of the methodologies and formalisms involved in building and engineering interactive visualization systems. An important aspect is the application and evaluation of these systems in real world applications.

The pilot INS3 was successfully evaluated in 2002 and was continued as a research theme in 2003. The new name is 'Visualization and 3D Interfaces'.

Theme leader

Dr.ir. R. van Liere

Subthemes

Name	Leader
INS3.1 – Data Visualization	R. van Liere
INS3.2 – 3D User Interfaces	J.D. Mulder

INS3.1 is concerned with researching interactive scientific visualization issues in the area of time dependent data sets and the exploration of multidimensional information spaces. This research is combined with the development of algorithms arising in projects from the Dutch *living cell* initiative.

INS3.2 is concerned with applying virtual reality technology to cost effective and ergonomical 3D desktop user interfaces. 3D visual and tangible interfaces are the key research focus. This research is combined with the engineering of prototype desktop solutions together with several affiliated research groups.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Drs. B.R. Boschker	0.2	PhD student	2002-11-01 till 2006-11-01	INS3.2	I.3.2, I.3.3
A.J. Jansen	0.6	programmer	2002-5-01 till now	INS3.2	I.3.2, I.3.3
Dr.ir. W.C. de Leeuw	1.0	researcher	indefinite	INS3.1	I.3.2, I.3.3
Dr.ir. R. van Liere	0.8	theme leader, leader INS3.1	indefinite	INS3.1, INS3.2	I.3.2, I.3.6
Dr. J.D. Mulder	1.0	researcher, leader INS3.2	2001-05-01 till 2005-05-01	INS3.2	I.3.2, I.3.3
O.H.G.M. Reynhout	0.7	student	2002-4-01 till 2002-12-31	INS3.2	I.3.2, I.3.3
Ir. A.J. van Rhijn	0.8	PhD student	2002-03-01 till 2006-03-01	INS3.2	I.3.2, I.3.3

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. J.J. van Wijk (TUE)	p.m.	advisor	indefinite	INS3.2	I.3.2, I.3.3, I.3.2.6

Scientific report

Highlights

- Positive evaluation of INS3 from pilot to research theme. New name: Visualization and 3D Interfaces.
- New algorithms for motion analysis of time dependent 3D confocal data.
- Construction of the Personal Space Station, a prototype near-field virtual reality environment.
- New algorithm for optical tracking based on projection invariant patterns under controlled lighting conditions.
- Development of low cost optical head tracking system under office lighting conditions.
- Demonstration of Personal Space Station at SuperComputing 2002, Baltimore, USA.
- Personal Space Station in the *Wetenschapsbijlage* of the Volkskrant; 28 September 2002.

PhD research

Title	PhD research of A.J. van Rhijn
Period	March 2002–March 2006
Leader	J.D. Mulder
Funding	CWI

Progress report. The research of *Van Rhijn* is focused on the study of 3D interactive techniques in a near-field virtual reality environment. *Van Rhijn* has prototyped a generic device which will provide a basis for the design, application and evaluation of direct 3D interaction techniques in VR. Current research is aimed at the low level technical requirements in a Personal Space Station environment. These include the study of techniques that deal with noise reduction and predication in optical tracking.

Title	PhD research of B.R. Boschker
Period	November 2002–November 2006
Leader	J.D. Mulder
Funding	CWI

Progress report. The research of *Boschker* is focused on collaboration in a shared near-field workspace. *Boschker* is in the progress of surveying the field.

INS3.1 – Data Visualization

Microscopy has always been an essential component in biological and biomedical research. Confocal and deconvolution microscopes now are routine equipment in many laboratories. The application of interactive graphics techniques allow for the analysis of high-volume 3D-images of biological objects, such as protein, cells and tissues. These imaging techniques will continue to evolve, as a broad field of bioscientists are now moving into the imaging of living cells.

The work in INS3.1 addresses the problems arising when visualizing time dependent data sets

of living cells acquired by confocal microscopes.

Title	BIO-VR – Virtual Reality for Cell Biology
Period	January 2000–December 2002
Leader	R. van Liere
Staff	R. van Liere, W.C. de Leeuw
Funding	ICES-KIS II
Partner	SILS – Swammerdam Institute for Life Sciences, UvA

Progress report. The aim of this multi-disciplinary project is to develop the hardware and software for an advanced virtual reality desktop environment for conveying research results produced in the context biological microscopic imaging. The deliverable will be a hardware and software platform for cell biological visualization. This platform will be installed at the SILS.

Work is under way to develop a low cost and ergonomic virtual environment which can be used for scientific visualization. The design of this environment is unique in two ways: It is built from low-cost commodity building blocks and the ergonomics of the environment allows it to be used in normal office working conditions.

The purpose of this project proposal is to enhance the prototype virtual environment and to implement the software to allow interactive analysis of time dependent biological data sets. These activities have continued to strengthen the synergism between the cell biology group at SILS and INS3.1. *Van Liere* and *De Leeuw* continued their research in scientific visualization to provide visual presentations of structural characteristics of cell data. This project addresses the role of virtual reality in gaining insight in these presentations. Perceiving structural characteristics of cell data is enhanced by using virtual reality technology. The advantage of virtual reality is particularly apparent in the exploration phase of the analysis when the behaviour of the underlying biological processes is not a priori known.

Title	Motion estimation in time dependent volume data
Period	April 2001–April 2003
Leader	R. van Liere
Staff	R. van Liere, W.C. de Leeuw
Funding	ICES-KIS II
Partner	SILS

Progress report. A second cell biology-related research theme is the development of techniques for the analysis of time dependent volume data. The approach taken in this project is to compute a time dependent vector field representing the movement of the data from a sequence of volume data sets. Two techniques have been studied; rigid block matching technique and a technique that is based on mass conservation in a continuum. Both techniques have been applied to study the process of chromatin decondensation during formation of the cell nucleus of a newly formed cell.

The research in the project is coordinated by *Van Liere*, in collaboration with prof. Van Driel at the SILS.

INS3.2 – 3D User Interfaces

Title	PSS – Personal Space Station
Period	April 2001–April 2005
Leader	J.D. Mulder
Staff	J.D. Mulder, A.J. van Rhijn, A.J. Jansen, R. van Liere, O.H.G.M. Reynhout
Funding	ICES-KIS II
Partners	SILS, TUE

Progress report. In 2001, *Mulder* and *Van Liere* developed a prototype version of a near-field virtual environment, the Personal Space Station (PSS). This environment will be used as a vehicle to design, apply and evaluate new direct 3D interaction techniques in Virtual Reality. In 2002, work on the PSS continued in the development of two new algorithms for optical tracking and the construction of task dependent interaction devices.

Mulder, Jansen and *Van Rhijn* developed an affordable optical head tracking system for desktop VR environments. The generic and specific head tracking requirements for these types of environments have been defined, as well as the relaxations such environments put on head tracking systems.

Van Liere and *Mulder* developed a new optical tracker algorithm using invariant properties of marker patterns to efficiently identify and reconstruct the pose of these interaction devices.

Van Rhijn developed a cubic device with sliders attached to it. The optically tracked device will be used to study and evaluate high level interaction in direct 3D user interaction in VR.

Reynhout developed a new scheme for correcting heavily distorted images acquired from cameras with very wide angle lenses.

Title	JSS – Joint Space Station
Period	January 2001–November 2006
Leader	J.D. Mulder
Staff	J.D. Mulder, B.R. Boschker
Funding	ICES-KIS II
Partners	SILS, TUE

Progress report. *Mulder* developed an initial prototype of the Joint Space Station, a new concept for collaborative Virtual and Augmented Reality with a shared physical workspace. It is constructed out of multiple, single-user near-field Virtual or Augmented Reality stations using mirror-based displays. The JSS will be used as a vehicle to study collaboration in a shared VR/AR environment.

Boschker started his PhD work in this area.

Societal aspects and knowledge transfer

External contacts

- A prototype version of the PSS was installed at three national research institutes; TUE WINS, TUE BMT and TUE USS.

Organization of conferences, workshops, courses, meetings

- ICT-Kenniscongres, The Hague, September 5–6: J.D. Mulder, R. van Liere (PSS Demonstration).
- SuperComputing 2002, Baltimore, USA, November 16–22: J.D. Mulder (PSS Demonstration).

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- 2002 IEEE International Symposium on Biomedical Imaging, Washington DC, July 7–10: W.C. de Leeuw.
- IEEE Visualization 2002, Boston (MA), October 27–November 1: W.C. de Leeuw.
- SuperComputing 2002, Baltimore, USA, November 16–22: J.D. Mulder.
- ICT-Kenniscongres, The Hague, September 5–6: R. van Liere.
- Immersive Computer Interaction, IPO, Eindhoven, May 3: J.D. Mulder.
- Laval Virtual, Virtual Reality International Conference, VRIC 2002, Laval, France, June 19–21: J.D. Mulder.

Other lectures

- Invited lecture at Philips NatLab, February 15: R. van Liere.
- CWI Scientific meeting, February 22: J.D. Mulder (Lecture *The Personal Space Station*).

Memberships of committees and other professional activities

R. van Liere

- Part-time associate professor at TUE (0.2 fte).
- Member of Program Committee of EG/IEEE VisSym 2002, May 27–29, Barcelona.
- Member of Program Committee of IPT/EGVE 2002, June 1–3, Barcalona Boston.
- Member of Program Committee of IEEE Visualization 2002, Boston, October 27–November 1.

Visitors

- S. Oomes (Eccentric Vision), March 20. Host: R. van Liere.
- L. Koymans (Center for Molecular Design, Janssen Research Foundation), November 15. Host: R. van Liere.

Publications

Books and book chapters

W.C. de Leeuw, R. van Liere (2002). Visualization of Multidimensional Data using Structure Preserving Projection Methods. F.H. Post, G.M. Nielson, G.-P. Bonneau (eds.). *Data Visualization: The State of the Art*, Kluwer Academic Publishers. ISBN 0-7803-7585-8; IEEE catalog number O2Ex608BC.

Papers in refereed journals and proceedings

W.C. de Leeuw, R. van Liere (2002). BM3D: Motion Estimation in Time Dependent Volume Data. *Proceedings IEEE Visualization 2002*, Boston, USA, 427–434.

R. van Liere, W. de Leeuw, J. Mulder, P. Verschere, A.Visser, E. Manders, R. van Driel (2002). Virtual Reality in Biological Microscopic Imaging. *Proceedings 2002 IEEE International Symposium on Biomedical Imaging*, Washington DC (USA), July 7–10.

J.D. Mulder, R. van Liere (2002). The Personal Space Station: Bringing Interaction Within Reach. *Proceedings of the Virtual Reality International Conference, VRIC 2002*, Laval, France, June 19–21, 73–81.

Other publications

Software developed

- *PVR:* a portable virtual reality application programming library: J.D. Mulder and R. van Liere.
- *BM3D:* a motion estimation technique for time dependent volume data: W.C. de Leeuw.

Newsletters

- Denkbeeldige moleculen onder handbereik, *Volkskrant Wetenschapsbijlage*, September 28.
- *Technisch Weekblad* **33**(42), October 21.
- *Automatisering Gids*, October 18.

Quantum Computing and Advanced Systems Research – INS4

Mission

There is great progress and opportunities in nonclassical computational technologies and algorithmics by exploiting novel computational aspects of physical phenomena, using nonclassical algorithms, or using classical algorithms in a nonclassical manner. Key issues are Feasibility of Technology and Efficiency of Algorithms, and Theoretical Basics. Novel technologies comprise coherent quantum mechanical and reversible low-energy computing.

Quantum information processing is the intersection of quantum mechanics and computer science. It tries to improve on classical computers and classical complexity bounds by making use of quantum mechanical phenomena. After Peter Shor's 1994 discovery of efficient quantum algorithms for factoring and the discrete log (threatening current 'classical' cryptography), the field has grown explosively and is now one of the hottest subfields of both computer science and physics.

Novel aspects of classical algorithms include distributed networking, security, genomics algorithmics and automatic learning by compression.

The work programme in quantum algorithmics includes the design and analysis of new algorithms in communication and the 'black box' model, and development of new tools to establish complexity bounds of such algorithms. We plan to test such algorithms collaborating with experimental groups in the USA and recently also in the EU (viz., the RESQ project). In reversible computing we develop new reversible simulations that use less time and memory simultaneously than any currently known algorithm. In machine learning we continue our work on algorithmic minimal sufficient statistics and minimal description length learning (MDL). Applications of algorithmic information theory, (also known as Kolmogorov complexity) in mathematics and algorithms are investigated and consolidated. A new research strain (for the moment part of INS4.3) is planned in theoretical analysis and applications of computational genomics. In particular in sequencing, analyzing genomic material in secondary and tertiary structure. For more information, see http://www.cwi.nl/ins4 (INS4).

Theme leader

Prof.dr.ir. P.M.B. Vitányi

Subthemes

Name	Leader(s)
INS4.1 – Quantum Computing	H.M. Buhrman
INS4.2 – MDL Learning and Algorithmic Statistics	P.M.B. Vitányi, P.D. Grünwald
INS4.3 – Advanced Algorithms, Systems and Genomics	P.M.B. Vitányi, H.M. Buhrman

INS4.1 studies algorithms and systems based on quantum mechanical principles. This work is exploratory research dealing with quantum algorithmics, quantum communication complexity, quantum

information theory. Together with similar groups in Europe and the USA, CWI's work is aimed at making the realization of practical quantum computation possible.

INS 4.2 addresses a range of issues related to machine learning and statistical inference, both theoretically and practically. It studies the relation between data compression and generalization properties and prediction, for example in the sense of the 'minimum description length' paradigm–basically a formal version of Occam's Razor.

INS 4.3 develops principles and algorithms for distributed and parallel systems. Moreover, it identifies limitations and possibilities of future systems by exploiting fundamental mathematical techniques of complexity theory. A major part of the work is on computational genomics, phylogeny, and clustering.

Staff

CWI employees

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. H.M. Buhrman	0.8	leader INS4.1, co-leader INS4.3	indefinite	INS4.1: QAIP INS4.3	E.4, F.1, F.2, H.3, I.2, I.5
Drs. W.K. van Dam	1.0	PhD student	till 2002-03-01	INS4	E.4, F.1, F.2, H.3, I.2, I.5
Drs. M.G. de Graaf	1.0	PhD student	2001-08-01 till 2005-08-01	INS4.1:; QAIP	E.4, F.1, F.2, H.3, I.2, I.5
Dr. P.D. Grünwald	1.0	co-leader INS4.2	indefinite	INS4.2: UL, NEUROCOLT II	E.4, F.1, F.2, H.3, I.2, I.5
Drs. H.P. Röhrig	1.0	PhD student	1998-11-01 till 2003-10-31	INS4.1: QC	E.4, F.1, F.2, H.3, I.2, I.5
Dr. H. Klauck	1.0	researcher	2000-09-01 till 2002-09-01	INS4.1: QUIP, QAIP	E.4, F.1, F.2, H.3, I.2, I.5
Drs. R. Manniesing	1.0	PhD student	2000-11-01 till 2002-06-01	INS4.3: ACAA	E.4, F.1, F.2, H.3, I.2, I.5
Drs. R.S. Špalek	1.0	PhD student	2002-09-01 till 2006-09-01	INS4.1; QAIP: NWO	E.4, F.1, F.2, H.3, I.2, I.5
Dr. J.T. Tromp	1.0	researcher	indefinite	INS4.2: NEUROCOLT II; INS4.3: BSI	E.4, F.1, F.2, H.3, I.2, I.5
Prof.dr.ir. P.M.B. Vitányi	0.8	theme leader, co-leader INS4.2, co-leader INS4.3	indefinite	INS4.1: QAIP; INS4.2: NEUROCOLT II; INS4.3; collaboration with several people	E.4, F.1, F.2, H.3, I.2, I.5
Dr. R.M. de Wolf	1.0	researcher, from August	2002-09-01 till 2006-09-01	INS4.1: QAIP, QUIP	E.4, F.1, F.2, H.3, I.2, I.5

Seconded

Name	Fte	Function(s)	Period	Subthemes + projects	Classification (MSC or CR)
Prof.dr. A.E. Brouwer (TUE)	0.2	researcher	till 2002-07-01		E.4, F.1, F.2, H.3, I.2, I.5
R.L.C. Cilibrasi, BSc (Caltech)	1.0	PhD student	2002-09-01 till 2006-09-01	INS4.2; INS4.3: ACAA	E.4, F.1, F.2, H.3, I.2, I.5
Prof.dr. F. Green (Clark Univ., USA)	1.0	researcher	2002-01-01 till 2002-06-01	INS4.1: QAIP	E.4, F.1, F.2, H.3, I.2, I.5

T.J. Lee, BSc (UvA)	1.0	PhD student	2002-01-01 till 2006-01-01	INS4.1; INS4.3: QAIP	E.4, F.1, F.2, H.3, I.2, I.5
Drs. T.T.R. Roos (Univ. Helsinki)	1.0	PhD student	2002-07-01 till 2002-12-31	INS4.2: NUFFIC, NEUROCOLT II	E.4, F.1, F.2, H.3, I.2, I.5

Scientific report

Highlights

- Start of European project RESQ.
- Proposal of a non-probabilistic statistics (algorithmic statistics) and proof of its 'rightness' by analysis of Kolmogorov's structure functions.
- Establishment of the relation between communication complexity and quantum mechanical non-locality. This allows great savings in classical communicated bits using entanglement as a resource.
- Development of a new tool: obtaining classical results in computational complexity by quantum mechanical proofs (this is reminiscent of complex (imaginary) numbers to obtain electrical engineering results or using complex analysis to evaluate integrals over real functions (as in Gauchy's residue theorem).
- Development of principled clustering and phylogeny algorithm based on the similarity metric (universal similarity measure based on Kolmogorov complexity).
- Completion of PhD thesis by W.K. van Dam.

PhD research

Title	PhD research of W.K. van Dam
Period	September 1996–October 2002
Leader	P.M.B. Vitányi
Funding	UvA

Progress report. The research of *Van Dam* is focused on quantum information theory and quantum computing (algorithmics) and quantum communication. He received his PhD from the UvA in October 2002 and now does a post-doc at UC Berkeley.

Title	PhD research of H.P. Röhrig
Period	November 1998–November 2003
Leaders	H.M. Buhrman, P.M.B. Vitányi
Funding	NWO

Progress report. The research of *Röhrig* is focused on the design and analysis of algorithms for quantum mechanical computers and communication. He will receive his PhD in the course of 2003.

Title	PhD research of M.G. de Graaf
Period	August 2001–August 2005
Leader	H.M. Buhrman
Funding	NWO

Progress report. The research of *De Graaf* is focused on the design and analysis of algorithms for quantum mechanical computers and communication.

Title	PhD research of T.J. Lee
Period	January 2002–January 2006
Leader	H.M. Buhrman
Funding	NWO

Progress report. The research of *Lee* is focused on the design and analysis of algorithms for quantum mechanical computers and communication, and on description complexity (Kolmogorov complexity) and its applications.

Title	PhD research of R.L.C. Cilibrasi
Period	September 2002–September 2006
Leader	P.M.B. Vitányi
Funding	NWO

Progress report. The research of *Cilibrasi* is focused on the design and analysis of algorithms for computational genomics and machine learning, and on description complexity (Kolmogorov complexity) and its applications.

INS4.1 – Quantum Computing

There is great progress and opportunities in nonclassical computational technologies and algorithmics by exploiting novel computational aspects of physical phenomena, using nonclassical algorithms, or using classical algorithmics in a nonclassical manner. Novel technologies comprise coherent quantum mechanical and reversible low-energy computing. Here, we focus on exploratory research dealing with quantum algorithmics, quantum communication complexity, quantum information theory, and quantum information retrieval algorithms. This work is part of a strong international effort aimed at solving the grand challenge of finding applications and limitations of quantum computing.

Title	QAIP – Quantum Algorithms and Information Processing
Period	1999–2002
Leader	H.M. Buhrman
Staff	M.G. de Graaf, R.S. Špalek, P.M.B. Vitányi, R.M. de Wolf
Funding	EU (Project IST-1999-11234)
Partners	CWI is coordinating partner (Buhrman); Paris, Bristol, Oxford, Berkeley and several sites in Israel, Canada

Progress report. De Wolf worked as a post-doc at UC Berkeley until August 2002, and at CWI after that. In 2002 he published a number of papers based mostly on earlier work on quantum query complexity and communication complexity. Together with I. Kerenidis (Berkeley), he established new lower bounds on classical locally decodable codes using, for the first time, a quantum proof technique, as well as new upper bounds for quantum private information retrieval. Together with *Buhrman* (CWI), he proved the surprising fact that efficient zero-error quantum algorithms cannot always be composed, in stark contrast to the (NEC research) situation in classical computing.

Buhrman and *Röhrig*, together with Fortnow (NEC research), Newman (Haifa Univ.), concluded their investigation of quantum property testing that was started the preceding year.

Title	QC – Quantum Computing
Period	1998–2005
Leader	P.M.B. Vitányi
Staff	H.P. Röhrig, post-doc vacancy
Funding	NWO (Grant 612.015.001)
Partners	none

Progress report. Buhrman, Röhrig and Massar (Brussels) worked throughout the year on improving physical experiments that demonstrate the nonlocality phenomenon of quantum mechanics. Using techniques from combinatorics, they found new bounds for closing the detection loophole ; further results (publication in preparation) with Høyer (Calgary) also address noise.

Buhrman, Röhrig and *Dodis* (New York Univ.) explored quantum algorithms for distributed-computing tasks.

Röhrig will receive his PhD in 2003 from the UvA.

Title	QIP – Quantum Information Processing
Period	1999–2005
Leader	H.M. Buhrman
Staff	H. Klauck, R.S. Špalek, R.M. de Wolf
Funding	NWO (Grant 612.055.001)
Partners	QAIP partners

Title	NoE QUIPROCONE IST-1999-29064 and ESF QiT Programme
Period	1999–2005
Leader	H.M. Buhrman P.M.B. Vitányi
Staff	H. Klauck, R.S. Špalek, R.M. de Wolf
Funding	EU and ESF
Partners	QAIP partners

Progress report. Klauck studied privacy and secure function evaluation in communication complexity. The focus is on quantum versions of the model and on protocols with only approximate privacy against honest players. He showed that the privacy loss (the minimum divulged information) in computing a function, can be decreased exponentially by using quantum protocols, while the class of privately computable functions (i.e., those with privacy loss 0) is not increased by quantum protocols.

Klauck investigated the complexity of sorting in the model of sequential quantum circuits. For all storage bounds S one can devise a quantum algorithm that sorts n numbers in time $T = O(n^{3/2}\log^{3/2} n/\sqrt{S})$. The following lower bound is shown: $TS = \Omega(n^{3/2})$. Hence for small values of S the upper bound is almost tight. Classically the time-space tradeoff for sorting is $TS = \Theta(n2)$.

Buhrman and *Klauck* investigated a quantum version of Maurer's bounded storage model in cryptography.

Špalek wrote his Master's thesis about quantum circuits, and a joint paper with P. Høyer on the same topic. The main result is that the quantum equivalent of the classical fan-out gate allows for constant depth circuits for many important and useful primitives like multiplication, sorting, addition, etc. These primitives need logarithmic depth in the classical setting.

INS4.2 – MDL Learning and Algorithmic Statistics

Applications and implementations of MDL include automatic grammar generation from large

text corpora, pattern recognition (learning optimal model granularity) and comparative evaluation of predictive accuracy of MDL and new forms of stochastic complexity. Furthermore, basic research in 'algorithmic' sufficient statistic, individual statistic that summarize all relevant information in the individual data. We also apply our methods to resolve and elucidate problems in cognitive psychology.

Title	NEUROCOLT II – Neural networks and computational learning theory
Period	April 1999–2002
Leaders	P.D. Grünwald, P.M.B. Vitányi
Staff	R.L.C. Cilibrasi, J.T. Tromp
Funding	EU (Working Group Nr. 8556)
Partners	Royal Holloway College Univ. London, and 10 more sites

Title	UL – Universal Learning
Period	2002–2006
Leader	P.M.B. Vitányi
Staff	P.D. Grünwald and vacancy PhD student
Funding	NWO (project 612.052.004)
Partners	HIIT Helsinki, Univ. College Univ. London, Royal Holloway College Univ. London

Progress report. Grünwald worked intensively on the Maximum Entropy (ME) Principle. He finalized his joint work with professor A.P. Dawid (Univ. College London). The resulting 60-page paper has been tentatively accepted by the *Annals of Statistics*. The most important new result is probably the one characterizing the so-called *Pythagorean Property* of the Maximum Entropy (Minimum Relative Entropy) Principle.

Grünwald also collaborated with J.Y. Halpern from Cornell Univ. Ithaca, NY, USA. It was studied how probability distributions should be updated with information that is not necessarily in the form of an event. Several new results on CAR (Coarsening at Random) were derived, most importantly a randomized algorithm that generates all and only CAR distributions.

Grünwald continued his work on 'entropification', a concept developed in his thesis in the context of the MDL Principle. In joint work with H. Tirri's group of the Helsinki Institute of Information Technology, it was now applied as a tool to extend the Bayesian posterior to a 'supervised' or 'conditional' case. This work was presented at the Seventh Valencia Meeting on Bayesian Statistics, held in Tenerife, Spain.

Vitányi together with Vereshchagin (Moscow State Univ.) validated Kolmogorov's 1974 proposal to found statistical theory on finite combinatorial principles independent of probabilistic assumptions, as the relation between the individual data and its explanation (model), expressed by Kolmogorov's structure function. They succeeded in improving previous results by L.A. Levin, A.K. Shen, V.V. Vyugin, P. Gács, T. Cover.

Vitányi together with Ming Li, Xin Chen, Xin Li (Univ. Waterloo), Bin Ma (Univ. Waterloo) proposed a new class of metrics appropriate for measuring effective similarity relations between sequences, say one type of similarity per metric. Vitányi et al. give two distinctive applications in widely divergent areas (the experiments by necessity use just computable approximations to the target notions).

Tromp and *Vitányi* together with Li (Univ. Waterloo) provided a new representation-independent formulation of Occam's razor theorem in Computational Machine Learning (saying basically, if you can significantly compress the data into a much shorter theory, then this has good generalization and prediction properties), based on Kolmogorov complexity. This new formulation allows us to: (i) Obtain better sample complexity than both length-based and VC-based versions of Occam's razor theorem, in many applications; and (ii) Achieve a sharper reverse of Occam's razor theorem than before. Specifically, we weaken the assumptions made before by Board et al. and extend the reverse to superpolynomial running times.

Vitányi together with N. Chater (Warwick Univ.) continued working in cognitive psychology based on algorithmic information theory. They 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* and *Trends in Cognitive 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, RUG), D.M. Barends (RIVM), investigated time-dependent nonlinearity of nebulizer drug output. They an-

alyze a simple compartment model to obtain an analytic expression of this function. They also present an analytic expression for the remainder volume of solvent at the end of the nebulizing time.

INS4.3 – Advanced Algorithms, Systems, and Genomics

The project develops principles and algorithms for distributed and parallel systems. Moreover, it identifies limitations and possibilities of future systems by exploiting fundamental mathematical techniques of complexity theory. A major item is the descriptional complexity, leading to both the 'incompressibility method' and 'learning by compression.'

Title	ACAA – Average-Case Analysis of Algorithms
Period	2000–2006
Leader	P.M.B. Vitányi
Staff	R.L.C. Cilibrasi, R. Manniesing
Funding	NWO (project 612.55.002)
Partners	Univ. Waterloo, BSI

Progress report. They developed a new and much faster algorithm for phylogeny tree construction using quartet cleaning, based on randomization, hill-climbing, and parallel processing. These results improve existing genomics software.

Title	Distributed algorithmics
Period	2000–2004
Leader	P.M.B. Vitányi
Staff	J.T. Tromp, P.M.B. Vitányi
Funding	CWI (basic funding)
Partner	Lucent (Bell Labs)

Progress report. Tromp, Vitányi presented the first explicit, and currently simplest, randomized algorithm for two-process wait-free test-and-set. It is implemented with two 4-valued single writer single reader atomic variables. A test-and-set takes at most 11 expected elementary steps, while a reset takes exactly 1 elementary step. Based on a finite-state analysis, the proofs of correctness and expected length are compressed into one table.

Vitányi together with Haldar (Lucent, Bell Labs) resolved an intricate question in interprocess communication: 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 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.

Vitányi resolved another intricate question in interprocess communication: Multireader shared registers are basic objects used as communication medium in asynchronous concurrent computation. He proposed a surprisingly simple and natural scheme to obtain several wait-free constructions of bounded 1-writer multireader registers from atomic 1-writer 1-reader registers, that is easier to prove correct than any previous construction. Our main construction is the first symmetric pure timestamp one that is optimal with respect to the worst-case local use of control bits; the other one is optimal with respect to global use of control bits; both are optimal in time.

Title	Kolmogorov complexity and its applications
Period	1999–2003
Leader	P.M.B. Vitányi
Staff	H.M. Buhrman, R.L.C. Cilibrasi, T.J. Lee, J.T. Tromp, P.M.B. Vitányi
Funding	CWI (basic funding)
Partners	M. Li (Univ. Waterloo, Canada), T. Jiang (UC Riverside, USA)

Progress report. Vitányi together with Li and Jiang resolved a question in combinatorial geometry using Kolmogorov complexity as a new tool in that area: From among $\binom{n}{3}$ triangles with vertices chosen from n points in the unit square, let T be the one with the smallest area, and let A be the area of T. Heilbronn's triangle problem asks for the maximum value assumed by A over all choices of n points. We consider the average-case: If the n points are chosen independently and at random (with a uniform distribution), then there exist positive constants c and C such that $c/n^3 < \mu_n < C/n^3$ for all large enough values of n, where μ_n is the expectation of A. Moreover, $c/n^3 < A < C/n^3$, with probability close to one. The proof uses the incompressibility method based on Kolmogorov complexity; it actually determines the area of the smallest triangle for an arrangement in 'general position'.

Lee did research in resource bounded Kolmogorov complexity, especially in relation to the

language compression problem, and considering weak versions of time-bounded symmetry of information.

Tromp studied the complexity of rush hour type sliding block puzzles. In cooperation with *Cilibrasi*, he set out to determine the hardness of unit rush hour, in which all pieces are of size 1x1. A program was written to completely search all puzzles of size $m \times n \leq 36$, suggesting an exponential increase in solution length of hardest puzzles. A paper is being written combining these results with earlier results on size 2 rush hour puzzles.

Tromp also continued work on the mathematics behind the PatternHunter genomic search tool and on algorithms for bounds consistency of the alldifferent constraint.

Title	Computational complexity
Period	2000–2004
Leader	H.M. Buhrman
Staff	H.M. Buhrman, P.M.B. Vitányi, R.M. de Wolf
Funding	CWI (basic funding)
Partners	NEC Research (Rutgers Univ., UC Berkeley)

Progress report. *Buhrman*, with Fortnow (NEC), and Pavan (Iowa State) studied average case complexity. They studied the question whether all NP complete sets are easy on average. They show that if this is the case then every randomized polynomial time algorithm can be derandomized (BPP=P). The paper 'Some results on derandomization' is accepted at STACS'03.

Buhrman, together with Fortnow (NEC) and Chang (Univ. Maryland) studied NP computation in a non-uniform setting. They showed that co-NP is NP computable; computable with 1 bit of advice per length is equivalent to PH collapsing to $\hat{\text{DP}}$. This shows the deep relation between nonuniform computation and the polynomial time hierarchy. The paper 'One bit of advice' was accepted for STACS'03.

Buhrman studied with *Green* and *De Graaf* the relation between several notions of randomized selfreducibilities. They show that random selfreductions can be very powerful even if just one query is asked. A paper is forthcoming.

Buhrman together with Allender, Koucky, Runnenburger (Rutgers Univ.) and Van Melkebeek (Wisconsin Univ.) continued the study to the polynomial time bounded versions of Kolmogorov random strings and showed the surprising result that the set of random strings is hard for complexity classes under non-uniform reductions. They also show that PSPACE is polynomial time reducible to the set of resource unbounded Kolmogorov random strings. The paper 'Power from Random Strings' was accepted at FOCS'02.

Buhrman, Ambainis (Berkeley), Høyer (Calgary) and Karpinski (Bonn) studied the quantum complexity of matrix multiplication and related problems. They show that the problem of verifying the matrix product can be done more efficiently than classically. Classically this can be done in $O(n^2)$ operations. They show that a quantum computer only needs-sub-quadratic-$O(n^{7/4})$ operations. A paper is forthcoming.

Title	Computational genomics
Period	1999–2003
Leader	P.M.B. Vitányi
Staff	R.L.C. Cilibrasi, J.T. Tromp, P.M.B. Vitányi
Funding	CWI (basic funding)
Partners	M. Li (Univ. Waterloo, Canada) T. Jiang (UC Riverside, USA)

Progress report. The last decade has witnessed an explosion in the amount and complexity of genomic data. Much of this data is publicly available for academic and commercial use by biological, medical and pharmaceutical researchers. In order for novel biological discovery to occur, computational tools must be developed to store, manipulate, visualize and analyze the genomic data. The Bioinformatics Research Group designs, develops and assesses computational tools for the exploration of genomic data. Topics include:

- Genome analysis including statistical methods for gene prediction and the detection of horizontally transferred genes.
- Genome compression.
- Sequence alignment, sequence consensus, and motif discovery.
- Algorithms for inferring evolutionary trees.
- Tools for modelling sequence evolution and for conducting simulation studies.

Their research plan includes both the theoretical analysis of algorithms and development of and experimentation with practical computational tools. They have successfully cooperated (*Tromp*) in designing a software package (PatternHunter) that gives faster and more sensitive homology search, and improves on popular packages like MegaBlast and BL2SEQ

(http://www.bioinformaticssolutions.com/products/ph.php), and in designing (*Vitányi*) a general theory of 'Similarity Metric' leading to a computational method to obtain a first completely automatic computed whole mitochondrial phylogeny tree, and, in a completely different area, automatic derivation of the language tree of 52 Euro-Asian languages based solely on text corpora and no other knowledge.

Societal aspects and knowledge transfer

Projects with partners in public and private sector

- QIP; see page 160.
- NoE QUIPROCONE IST-1999-29064 and ESF QiT Programme; see page 160.
- NEUROCOLT II; see page 161.
- UL; see page 161.
- ACAA; see page 162.

Teaching activities

- Course Quantum Computing, UvA, January–April: H.M. Buhrman, M.G. de Graaf (teaching asistent).
- Intensive Course Kolmogorov Complexity and Learning, Univ. of Helsinki, April: P.M.B. Vitányi.

Other external contacts

- Coordination of EU-Project QAIP: Quantum Algorithmics and Information Processing: H.M. Buhrman.
- Work-Area manager of EU-Working Group NeuroCOLT II: P.M.B. Vitányi.
- Leave of Absence as senior programming executive at Bioinformatics Solutions Inc. (BSI), Waterloo, Canada: J.T. Tromp.

Organization of conferences, workshops, courses, meetings

- Quantum Computing Seminar (bi-weekly): H.P. Röhrig. Speakers from outside CWI: F. Green, Y. Dodis, S. Aaronson, I. Kerenidis, I. Newman, M. Szegedy, S. Massar.

Lectures, conferences, courses, project meetings, working visits

Visits to conferences, workshops, symposia

- QIP 2002 - The Fifth Workshop on Quantum Information Processing, IBM T.J. Watson Research Center, Yorktown Heights, New York, January 14–17: H.M. Buhrman. M.G. de Graaf, H.P. Röhrig (Talk: *Quantum Property Testing*).
- TUD, Delft, January 23: P.D. Grünwald (Talk: *Universal Modelling: introduction to modern MDL*).
- Dagstuhl Seminar 02081 on Algorithmic Combinatorial Game Theory, Dagstuhl, Germany, February 4–9: J.T. Tromp.
- Symp. Theor. Aspects Comput. Science, STACS'2002, Juan-Les-Pins/Antibes, France, March 14–16: H. Klauck (Talk: *On Quantum and Approximate Privacy*), M.G. de Graaf (Talk: *The quantum Yao Principle*).
- Schloss Dagstuhl, Complexity of Boolean Functions seminar, March 16–22: H.M. Buhrman (Talk: *Quantum Fingerprinting*), H. Klauck (Talk: *Lower Bounds for Quantum Communication Complexity*).
- AI and Cognitive Sciences Symp., UU, April 15: P.M.B. Vitányi (Talk: *The Quantum Computing Challenge*).
- EUROCRYPT, Amsterdam, April 28–30: H.P. Röhrig.
- NEUROCOLT Workshop on Generalization bounds smaller than 1, Windsor, UK, April 29–May 2: P.D. Grünwald (Talk: *MDL, Bayes, SRM and the $\sqrt{n}$ in classification*).
- Gatsby Computational Neuroscience Unit, London, UK, Hosted by Professor P. Dayan, May 3: P.D. Grünwald (Invited talk: *Universal Modelling: introduction to modern MDL*).
- Seventh Valencia Meeting on Bayesian Statistics, Tenerife, Spain, June 1–7: P.D. Grünwald (Contributed talk: *Supervised Posterior Distributions*).
- Philips NatLab Seminar, Eindhoven, June 5: H.M. Buhrman (Talk: *Quantum Computing and Communication Complexity*).
- 9th International Colloquium on Structural Information and Communication Complexity (SIROCCO '02), Andros, Greece, June 10–14: P.M.B. Vitányi (Talk: *A Protocol for Randomized Anonymous Two-Process Wait-Free Test-and-Set with Finite-State Verification*).
- Int. Coll. Cognition, Meaning, and Complexity Self-Orgazing Systems, Rome, Italy, June 14–15: P.M.B. Vitányi (Invited Talk: *Meaningful Information*).

- Summer School Quantum Computing, Organized by G. Brassard, Montréal, Canada, July 15–19: H.M. Buhrman (Invited lectures: *Polynomial Method* and *Quantum Computing*).
- Workshop on Quantum Computing, Calgary, Canada, July 21–28: H.M. Buhrman (Invited Talk: *Combinatorics and Quantum Non Locality*).
- Eighth Annual International Computing and Combinatorics Conference, Singapore; August 15–17: P.M.B. Vitányi (also Program Committee) (Talk: *Sharpening Occam's Razor*).
- MSRI workshop on quantum computing, Berkeley, CA, August 30: R.M. de Wolf (Talk: *Quantum communication complexity*).
- Fall School in Logic, Prague, Czech Republic, September 16–22: T.J. Lee (Talk: *Arithmetical Definability over Finite Structures*).
- Spatial Stochastic Seminar, CWI, September 19: P.D. Grünwald (Talk: *Universal Modelling: introduction to modern MDL*).
- 6th International Colloquium on Grammatical Inference, Amsterdam, September 23–25: Opening Keynote Talk (invited): *Algorithmic Statistics*.
- Quantum algorithms and complexity workshop, Banff, Canada, September 26: R.M. de Wolf (Talk: *Quantum computing and locally decodable codes*).
- Dagstuhl Seminar 02421 – Algebraic Methods in Quantum and Classical Models of Computation, Schloss Dagstuhl, Wadern, Germany, October 13–18: Organizer: H.M. Buhrman, Participant: M.G. de Graaf, H.P. Röhrig, H. Klauck (Talk: *Algebraic Methods in Quantum and Classical Models of Computation*), R.S. Špalek (Talk: *Quantum Fan-out is powerful*), P.M.B. Vitányi (Talk: *Quantum Kolmogorov Complexity*).
- Laboratoire d'Algorithmique, Complexité, et Logique, Péris, October 21: T.J. Lee (Talk: *Arithmetical Definability over Finite Structures*).
- Information Theory Workshop (ITW) 2002, Bangalore, India, October 20–25: P.D. Grünwald (Invited talk: *Game Theory, Maximum Generalized Entropy, Minimum Discrepancy, Robust Bayes and Pythagoras*).
- 16th International Symposium on DIStributed Computing (DISC 2002) October 28–30: P.M.B. Vitányi (Talk: *Simple Wait-Free Multireader Registers*).
- 43rd Annual IEEE Symposium on Foundations of Computer Science, Vancouver, Canada November 16–19: P.M.B. Vitányi (Talk: *Kolmogorov's Structure Functions with an Application to the Foundations of Model Selection*).
- CAG Seminar, Computer Science Department, Univ. Victoria, Victoria, BC, Canada, November 20–22: P.M.B. Vitányi (Invited talk: *The Similarity Metric*).
- 13th Annual International Symposium on Algorithms and Computation Vancouver, Canada, November 20–23: P.M.B. Vitányi (Talk: *Meaningful Information*).
- Neural Information Processing Systems 2002 (NIPS*2002), Vancouver-Whistler, BC, Canada, Universal Learning Algorithms and Optimal Search Workshop; December 10–14: P.M.B. Vitányi (Invited lecture: *The Similarity Metric*).
- Quantum Information Processing (QIP 03), MSRI, Berkeley, December 17: R.M. de Wolf (Talk: *Quantum Computing, Locally Decodable Codes, and Private Informaton Retrieval*).

Working visits

- Computer Science Dept. (Dodis), New York Univ., January 17–18: H.P. Röhrig.
- Univ. Helsinki, and Helsinki Institute of Technology, Helsinki, Finland, April 8–13. Intensive Course: Kolmogorov Complexity and Its Applications: P.M.B. Vitányi.
- Univ. Geneva (Gissin); Pre-RESQ Workshop, May 2–5: H.M. Buhrman (Talk: *Overview computer science, quantum fingerprinting*), H.P. Röhrig (Talk: *Closing the Detection Loophole by Combinatorics*).
- ACM Symp. Theory of Computing; IEEE Computational Complexity Theory Conference (CCC), Univ. Montréal (Brassard); PC-meeting and Steering Committee meeting CCC, May 19–24: H.M. Buhrman.
- Bonn Univ. (Karpinski), Bonn, Germany, June 12–14: H.M. Buhrman.
- Free Univ. (Massar), Brussels, June 26–27: H.P. Röhrig.
- 29-th International Colloquium on Automata, Languages and Programming, Malaga, Spain; July 8–13: P.M.B. Vitányi.
- School of Information Systems Colloquium, Univ. East Anglia, Norwwich, UK, September 29–30: P.M.B. Vitányi (Invited Talk: *Introduction to Kolmogorov Complexity and Its Applications*).

- Working visit and Examiner, Learning Machinery Lab, Royal Holloway College, Univ. London, Egham, UK, September 27–October 3: P.M.B. Vitányi (Invited Talk: *Algorithmic Statistics*), P.M.B. Vitányi (Invited Talk: *The Similarity Metric*).
- Univ. Calgary, Calgary, Canada, October 3: R.M. de Wolf (Talk: *Quantum Communication Complexity and Razborov's Lower Bound*).
- Free Univ. (Massar), Brussels, November 7–8: H.M. Buhrman, H.P. Röhrig.
- Computer Science Department, Iowa State Univ., Ames, Iowa, USA, December 6–11: P.M.B. Vitányi (Distinguished lecture: *The Similarity Metric*), P.M.B. Vitányi (Invited lecture: *Algorithmic Statistics*).

Project meetings
- EU QUIPROCONE PC meeting, Brussels, January 8: H.P. Röhrig.
- EU Project Meeting, RESQ, January 24: H.M. Buhrman.
- EU Project QAIP Review Meeting, Paris, France, February 26–March 3: H.M. Buhrman.
- EU Project RESQ Meeting, Brussels, June 7: H.M. Buhrman.

Memberships of committees and other professional activities

H.M. Buhrman
- Professor of Computer Science, UvA.
- Member editorial board Theory of Computing Systems–TOCS (Springer-Verlag).
- Member steering committee IEEE Computational Complexity Theory Conference series.
- Member of Programme Committee STACS 2002, Antibes, France.
- Member program committee IEEE Computational Complexity Theory Conference 2002.
- Member program committee of the Symposium on Theoretical Aspects of Computer Science (STACS'02).
- Chair program committee IEEE Computational Complexity Theory Conference 2003.
- Member reading and promotion committee W.K. van Dam, Univ. Amsterdam, 'On Quantum Computation Theory'.
- Coordinator EU Project 'Quantum Algorithms and Information Processing' (QAIP), IST-1999-11234. (1999–2002) involving 13 sites.
- Co-coordinator EU Project RESQ IST-2001-37559 (Quantum Computing) (2002–2005) (Follow-up of QAIP).
- Coordinator of the NWO project 'Extending Feasible Computation: Quantum Computing'.
- Member of Steering Committee for Anual Conference on Quantum Information Processing (QIP).
- Co-organizer (together with Fortnow and Thierauf) of Dagstuhl Seminar 02421 – Algebraic Methods in Quantum and Classical Models of Computation Schloss Dagstuhl.
- Thesis advisor of M.G. de Graaf, H.P. Röhrig, and T.J. Lee.

P.D. Grünwald
- 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, UvA.
- 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, 14th European Conference on Machine Learning (ECML-2003), Dubrovnik, Croatia, September 22–26, 2003.

- Program Committee, 14th Annual International Symposium on Algorithms and Computation (ISAAC'03), Kyoto, December 15–17, 2003.
- Program Committee, 13th European Conference on Machine Learning (ECML'02), which was 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.
- Organizing/Program Committee 'Workshop on Complexity and Inference' for the 'Computational Information Theory and Coding Year' (2002–2003) at DIMACS at Rutgers Univ.
- Member of EU fifth framework project QAIP, IST-1999-11234 (1999–2002).
- Member of EU Project RESQ IST-2001-37559 (Quantum Computing) (2002–2005).
- Coordinator Project Universal Learning, (2002–2006) NWO (project 612.052.004).
- Coordinator Project Quantum Computing (1998–2005) NWO (Grant 612.015.001).
- Coordinator Project Average-Case Analysis of Algorithms, (2000–2006) NWO (project 612.55.002).
- Member of the NoE QUIPROCONE IST-1999-29064.
- Member of the ESF QiT Programme.
- 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.
- Publicity Committee Dutch Mathematical Society, since 1989.
- Advisor Monash Key Centre for Computational Data Analysis, Monash Univ., 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'.
- Member committee of the Society for Theoretical Computer Science in The Netherlands.
- Member of the board Dutch Institute for Logic, Language, and Computation (ILLC).
- Member of the committee Dutch Institute for Programming and Algorithmics (IPA).
- Member of the committee Onderzoeksschool Logica (OzL).
- PhD Supervisor in 2002 of W.K. van Dam, H.P. Röhrig, R. Manniesing, R.L.C. Cilibrasi, M. Hutter, UvA.
- Examiner PhD viva of Yura Kalnichka at Computer Science Department, Royal Holloway College, Univ. London, 'Predictive Complexity' (PhD advisor V. Vovk).

Visitors

- N.K. Vereshchagin (Moscow State Univ. Russia, January 8–February 6. Host: P.M.B. Vitányi.
- F. Green (Clark Univ., USA), February 1–June 1. Host: H.M. Buhrman.
- R.L.C. Cilibrasi (Caltech), March 20–April 5. Host: P.M.B. Vitányi.
- M. Hutter (IDSIA Lugano), April 2–7. Host: P.M.B. Vitányi.
- L.F.C. Antunes (Univ. Porto, Portugal), April 9–July 30. Host: P.M.B. Vitányi.
- Y. Dodis (New York Univ., USA), May 2–30. Host: H.M. Buhrman.
- J. Garay (Lucent, USA), May 3–5. Host: P.M.B. Vitányi.
- R.M. de Wolf (UC Berkeley, USA), March 25–30. Host: H.M. Buhrman.
- C. Smith (Univ. Maryland, USA), June 21–23. Host: P.M.B. Vitányi.
- T. Lozano-Perez (MIT, USA), June 2–30. Host H.M. Buhrman.
- S. Aaronson (UC Berkeley, USA), June 15– August 19. Host: H.M. Buhrman.
- I. Kerenides (UC Berkeley, USA), July 1–21. Host: H.M. Buhrman.

- I. Newman (Haifa Univ., Israel), August 5–30. Host: H.M. Buhrman.
- M. Szegedy (Rutgers Univ., USA), August 15–30. Host: H.M. Buhrman.
- T.T.R. Roos (Univ. Helsinki, Finland), August 1–December 20. Host: P.D. Grünwald.
- L. Lamport (Microsoft Research), November 8–9. Host: P.M.B. Vitányi.
- S. Massar and J. Barrett (ULB), December 10–15. Host: H.P. Röhrig.

Publications

Books and book chapters

P.D. Grünwald (2002). Taking the Sting out of Subjective Probability. D. Barker-Plummer, D. Beaver, J. van Benthem, P. Scotto Di Luzio, (eds.). *Words, Proofs, and Diagrams*, CSLI Publications 2002, 75–94, ISBN 1-57586-406-1.

P.M.B. Vitányi, M. Li (Univ. Waterloo) (2002). Simplicity, Information, Kolmogorov Complexity, and Prediction. A. Zellner, H.A. Keuzenkamp, M. McAleer (eds.). *Simplicity, Inference and Medelling*, Cambridge Univ. Press, Cambridge, UK, 135–155, ISBN 0521803616.

M. Li (Univ. Waterloo), P.M.B. Vitányi (2002). Algorithmic Complexity. N.J. Smelser, P.B. Baltes (eds.). *International Encyclopedia of the Social & Behavioral Sciences*, Pergamon, Oxford, 376–382, ISBN 0-08-043076-7.

Papers in refereed journals and proceedings

E. Allender (Rutgers Univ.), H.M. Buhrman, M. Kouck (Rutgers Univ.), D. van Melkebeek (Univ. Wiscousin), D. Ronneburger (Rutgers Univ.)(2002). Power from Random Strings. *Proceedings of the 43rd Annual IEEE Symposium on Foundations of Computer Science*, 669–678.

H.M. Buhrman, P.B. Miltersen (Aarhus Univ.), J. Radhakrishnan (De Paul Univ. Chicago) (2002). Are bitvectors optimal? *SIAM J. Computing* **31**(6), 1723–1744.

H.M. Buhrman, R.M. de Wolf (2002). Complexity measures and decision tree complexity: a survey. *Theor. Comput. Sci.* **288**(1), 21–43.

H.M. Buhrman, L. Longpre (NE Univ. Boston) (2002). Compressibility and resource bounded measure. *SIAM J. Computing* **31**(3), 8760–886.

X. Chen, M. Li (Univ. Waterloo), B. Ma (Univ. W. Ontario), J.T. Tromp (2002). DNA-Compress: fast and effective DNA sequence compression. *Bioinformatics* **18**(12), 1696–1698.

P. Gács (Boston Univ.) J.T. Tromp, P.M.B. Vitányi (2002). Correction to: 'Algorithmic Statistics'. *IEEE Trans. Inform. Theory* **48**(8), 2427.

M.G. de Graaf, R.M. de Wolf (2002). On quantum versions of the Yao principle. *Proceedings of 19th Annual Symposium on Theoretical Aspects of Computer Science (STACS'2002)* LNCS **2285**, Springer, 347–358.

P.D. Grünwald, J.Y. Halpern (Cornell Univ.) (2002). Updating Probabilities. *Proceedings of the Eighteenth Conference on Uncertainty in Artificial Intelligence (UAI 2002)*, Edmonton, Canada, 187–196.

P.D. Grünwald, A.P. Dawid (Univ. College London) (2002). Game theory, maximum generalized entropy, minimum discrepancy, Robust Bayes and Pythagoras. *Proceedings ITW 2002*, Bangalore, India, October, 94–97.

S. Haldar (Lucent), P.M.B. Vitányi (2002). Bounded concurrent timestamp systems using vector clocks. *J. Assoc. Comp. Mach.* **49**(1), 101–126.

P. Høyer (Univ. Calgary), R.M. de Wolf (2002). Improved quantum communication complexity bounds for disjointness and equality. *Proceedings of 19th Annual Symposium on Theoretical Aspects of Computer Science (STACS'2002)* LNCS **2285**, Springer, 299–310.

T. Jiang (UC Riverside), M. Li (Univ. Waterloo), P.M.B. Vitányi (2002). The average-case area of Heilbronn-type triangles. *Random Structures and Algorithms* **20**(2), 206–219.

H. Klauck (2002). On Quantum and Approximate Privacy. *Proceedings 19th International Symposium on Theoretical Aspects of Computer Science (STACS 2002)*, LNCS **2285**, Springer-Verlag, 335–346.

M. Li (Univ. Waterloo), J.T. Tromp, P.M.B. Vitányi (2002). Sharpening Occam's razor. *Proceedings 8th Intn'l Computing and Combinatorics Conference (COCOON)* LNCS **2387**, Springer-Verlag, Berlin, 411–419.

B. Ma (Univ. W. Ontario), J.T. Tromp, M. Li (Univ. Waterloo) (2002). PatternHunter: faster and more sensitive homology search. *Bioinformatics* **18**(3), 440–445.

J.T. Tromp, P.M.B. Vitányi (2002). A Protocol for Randomized Anonymous Two-

Process Wait-Free Test-and-Set with Finite-State Verification. *Proceedings 9th International Colloquium on Structural Information and Communication Complexity (SIROCCO 2002)*, Carleton Univ. Press, 275–292.

J.T. Tromp, P.M.B. Vitányi (2002). Randomized wait-free two-process test-and-set. *Distributed Computing* **15**, 127–135.

N.K. Vereshchagin (Moscow State Univ.), P.M.B. Vitányi (2002). Kolmogorov's structure functions and an application to the foundations of model selection. *Proceedings 47th IEEE Symp. Found. Comput. Sci.*, 751–760.

P.M.B. Vitányi (2002). Meaningful information. *Proceedings 13th International Symposium on Algorithms and Computation (ISAAC)* LNCS **2518**, Springer-Verlag, Berlin. 588–599.

P.M.B. Vitányi (2002). Simple wait-free multireader register. *Proceedings 16th Intn'l Symp. Distributed Computing (DISC'02)* LNCS **2508**, Springer-Verlag, Berlin, 118–132.

P.M.B. Vitányi (2002). Correction to: 'Quantum Kolmogorov complexity based on classical descriptions'. *IEEE Trans. Inform. Theory* **48**(4), 1000.

CWI reports

INS-R0207

See page 173 for complete titles.

Other publications

E. Allender (Rutgers Univ.), H.M. Buhrman, M. Kouck, D. Ronneburger (Rutgers Univ.), D. van Melkebeek (Univ. Wisconsin) (2002). Power from Random Strings. *Electronic Colloquium on Computational Complexity (ECCC)(028).*

H. Buhrman, L. Fortnow (Univ. Chicago), I. Newman (Univ. Haifa), H. Röhrig (2002). *Quantum Property Testing.* quant-ph/0201117.

H. Buhrman, S. Massar (Free Univ. Brussels) H. Röhrig (2002). *Combinatorics and Quantum Nonlocality.* quant-ph/0209052.

M.G. de Graaf, P. Valiant (Stanford Univ.) (2002). *Comparing EQP and $MOD_{p^k}P$ using Polynomial Degree Lower Bounds,* quant-ph.

H. Klauck (2002). *Quantum Time-Space Tradeoffs for Sorting.* quant-ph/02011174.

R.M. de Wolf (2002). Fingerprints from quantum mechanics. *Nieuwsbrief van de Nederlandse Vereniging voor Theoretische Informatica.* Invited paper.

PhD thesis

W.K. van Dam (2002). *On Quantum Computation Theory*, UvA, October 9. Thesis advisor: Prof.dr.ir. P.M.B. Vitányi.

Technical reports published elsewhere

P.D. Grünwald, A.P. Dawid (Univ. College, London) (2002). *Game Theory, Maximum Entropy, Minimum Discrepancy, and Robust Bayesian Decision Theory.* Technical Report 223, Univ. College London, February.

Software developed

- *PatternHunter:* DNA database and protein-to-protein search capability. Over 100 times faster than BLAST on a single PC. J.T. Tromp et al. at Bioinformatics Solutions Inc., Waterloo, Canada.
- *DNACompress:* fast and effective DNA sequence compression. J.T. Tromp et al. at Bioinformatics Solutions Inc., Waterloo, Canada.

APPENDICES

A CWI reports

A.1 Downloads of CWI reports 1997–2002

Year	# of reports downloaded	Total # of hits
2002	1065	486002
2001	967	279008
2000	853	149416
1999	740	64607
1998	623	38623
1997	536	28332

A.2 PNA reports

PNA-R0201. R. Núñez Queija. *Queues with equally heavy sojourn time and service requirement distributions.*

PNA-R0202. S.C. Borst, O.J. Boxma, M.J.G. van Uitert. *The asymptotic workload behavior of two coupled queues.*

PNA-R0203. P.J. Oonincx. *Empirical mode decomposition: a new tool for S-wave detection.*

PNA-R0204. K.G. Dębicki. *Some properties of generalized Pickands constants.*

PNA-R0205. M.R.H. Mandjes, D. Mitra (Bell Labs/Lucent Tech., USA), W.R.W. Scheinhardt. *Models of network access using feedback fluid queues.*

PNA-R0206. N.K. Boots (VU), M.R.H. Mandjes. *Fast simulation of a queue fed by a superposition of many (heavy-tailed) sources.*

PNA-R0207. K. Kumaran (Bell Labs/Lucent Tech., USA), M.R.H. Mandjes, A. Stolyar (Bell Labs/Lucent Tech., USA). *Convexity properties of loss and overflow functions.*

PNA-R0208. P.J. Oonincx, P.M. de Zeeuw. *An image retrieval system based on adaptive wavelet lifting.*

PNA-R0209. K.G. Dębicki, M.R.H. Mandjes. *Exact overflow asymptotics for queues with many Gaussian inputs.*

PNA-R0210. M. Laurent, F. Rendl (Univ. Klagenfurt, Austria). *Semidefinite programming and integer programming.*

PNA-R0211. G. Piella. *A general framework for multiresolution image fusion: from pixels to regions.*

PNA-R0212. H.J.A.M. Heijmans, B. Pesquet-Popescu (Ecole Nat. Sup. Télécom., France), G. Piella. *Building nonredundant adaptive wavelets by update lifting.*

PNA-R0213. K.O. Dzhaparidze, J.H. van Zanten (Free Univ. Amsterdam). *A series expansion of fractional Brownian motion with Hurst index exceeding 1/2.*

PNA-R0214. N. Gribkova (Univ. St. Petersburg State Trans., Russia), R. Helmers. *The empirical Edgeworth expansion for a studentized trimmed mean.*

PNA-R0215. S.C. Borst, R. Núñez Queija, M.J.G. van Uitert. *User-level performance of elastic traffic in a differentiated-services environment.*

PNA-R0216. K.O. Dzhaparidze, J.H. van Zanten (Free Univ. Amsterdam). *A series expansion of fractional Brownian motion.*

PNA-R0217. E. Capobianco. *On multiscaling in volatility processes.*

PNA-R0218. K.G. Dębicki, A.P. Zwart, S.C. Borst. *The supremum of a Gaussian process over a random interval.*

PNA-R0219. R. Helmers, B-Y. Jing (Univ. Sci. Tech., Hong Kong), G. Qin (Univ. Georgia, USA), W. Zhou (Univ. Sci. Tech. Hong Kong). *Saddlepoint approximations to the trimmed mean.*

PNA-R0220. K.G. Dębicki, M.R.H. Mandjes. *Traffic with an FBM limit: convergence of the workload process.*

PNA-R0221. M.R.H. Mandjes, M.J.G. van Uitert. *Sample-path large deviations for tandem and priority queues with Gaussian inputs.*

PNA-R0222. J. van den Berg, A.A. Járai. *The lowest crossing in 2D critical percolation.*

PNA-R0223. S.C.Borst. *User-level performance of channel-Aware scheduling algorithms in wireless data networks.*

PNA-R0224. P.M. de Zeeuw. *A toolbox for the lifting scheme on quincunx grids (LISQ).*

A.3 SEN reports

SEN-R0201. J. Pang. *Analysis of a security protocol in μCRL.*

SEN-R0202. J.K. Hoogland, C.D.D. Neumann, M.H. Vellekoop (UT). *Symmetries in jump-diffusion models with applications in option pricing and credit risk.*

SEN-R0203. F. Arbab. *A channel-based coordination model for component composition.*

SEN-R0204. M. de Jonge. *Source tree composition.*

SEN-R0205. M. de Jonge. *The Linux kernel as flexible product-line architecture.*

SEN-R0206. R. Banach (Univ. Manchester), F. Arbab, G.A. Papadopoulos (Univ. Cyprus), J.R.W. Glauert (Univ. East Anglia). *A multiply fibred automaton semantics for IWIM.*

SEN-R0207. A. Ponse, M.B. van der Zwaag. *The logic of ACP.*

SEN-R0208. D.D.B. van Bragt, J.A. La Poutré. *Why agents for automated negotiations should be adaptive.*

SEN-R0209. Y.S. Usenko. *Linearization of μCRL specifications.*

SEN-R0210. A. van Deursen, J.M.W. Visser. *Building program understanding tools using visitor combinators.*

SEN-R0211. R. van Stee (Univ. Albert-Ludwigs), J.A. La Poutré. *Minimizing the total completion time on-line on a single machine, using restarts.*

SEN-R0212. H.A. de Jong, P.A. Olivier. *Generation of abstract programming interfaces from syntax definitions.*

SEN-R0213. D.D.B. van Bragt, D.J.A. Somefun, E. Kutschinski, J.A. La Poutré. *An algorithm for on-line price discrimination.*

SEN-R0214. M. de Jonge. *Pretty-printing for software reengineering.*

SEN-R0215. A. van Deursen, M. de Jonge, T. Kuipers (Software Improvement Group, Amsterdam). *Feature-based product line instantiation using source-level packages.*

SEN-R0216. F. Arbab, J.J.M.M. Rutten. *A coinductive calculus of component connectors.*

SEN-R0217. P.J. 't Hoen, S.M. Bohte, E.H. Gerding, J.A. La Poutré. *An extensible agent architecture for a competitive market-based allocation of consumer attention space.*

SEN-R0218. D.D.B. van Bragt, J.A. La Poutré. *Co-evolving automata negotiate with a variety of opponents.*

SEN-R0219. C.D.D. Neumann. *On the structure of Gaussian pricing models and Gaussian Markov functional models.*

SEN-R0220. P.J. 't Hoen, D.D.B. van Bragt, J.A. La Poutré. *Bidding with decommitment in a multi-agent transportation model.*

SEN-R0221. F. Bartels. *GSOS for probabilistic transition systems.*

SEN-R0222. A. Kurz, D. Pattinson (LMU München). *Coalgebraic modal logic of finite rank.*

SEN-R0223. M. Bidoit (LSV, France), R. Hennicker (LMU München), A. Kurz. *Observational logic, constructor-based logic, and their duality.*

SEN-R0224. J.J.M.M. Rutten. *Coinductive counting with weighted automata.*

SEN-R0225. S.C.C. Blom. *Lifting infinite normal form definitions from term rewriting to term graph rewriting.*

SEN-R0226. A. Palmigiano (Univ. Barcelona). *A new coalgebraic semantics for positive modal logic.*

SEN-R0227. N. Ioustinova, N. Sidorova (TUE), M. Steffen (Chr.-Albr.-Univ. Kiel). *Closing open SDL-systems for model checking with DTSpin.*

SEN-R0228. N. Ioustinova, N. Sidorova (TUE), M. Steffen (Chr.-Albr.-Univ. Kiel). *Abstraction and flow analysis for model checking open asynchronous systems.*

SEN-R0229. W.J. Fokkink, J. Pang. *Cones and foci for protocol verification revisited.*

SEN-R0230. P. Zoeteweij. *A coordination-based framework for distributed constraint solving.*

SEN-R0231. B. Badban, J.C. van de Pol. *Two solutions to incorporate zero, successor and equality in binary decision diagrams.*

A.4 MAS reports

MAS-R0201. J. Huisman (UvA), B.P. Sommeijer. *Simulation techniques for the population dynamics of sinking phytoplankton in light-limited environments.*

MAS-R0202. L. Schäfer (Univ. Essen, Germany), U.M. Ebert, A. Baumgärtner (Forschungszentrum Jülich, Germany). *The coherent scattering function in the reptation model: analysis beyond asymptotic limits.*

MAS-R0203. B. Lastdrager. *Numerical solution of mixed gradient-diffusion equations modelling axon growth.*

MAS-R0204. J. Huisman (UvA), B.P. Sommeijer. *Population dynamics of sinking phytoplankton in stratified waters.*

MAS-R0205. A. Gil (Univ. Autónoma Madrid, Spain), J. Segura (Univ. Carlos III Madrid, Spain), N.M. Temme. *Computation of the modified bessel function of the third kind of imaginary orders: uniform Airy-type asymptotic*

expansion.

MAS-R0206. P.W. Hemker, W. Hoffmann (UvA), M.H. van Raalte. *Two-level Fourier analysis of a multigrid approach for discontinuous Galerkin discretisation.*

MAS-R0207. P.W. Hemker, G.I. Shishkin (Acad. Ural Branch, Russia), L.P. Shishkina (Acad. Ural Branch, Russia). *High-order time-accurate schemes for singularly perturbed parabolic convection-diffusion problems with Robin boundary conditions.*

MAS-R0208. J. Wensch (Univ. Martin-Luther Halle-Wittenberg, Germany), B.P. Sommeijer. *Parallel simulation of axon growth in the nervous system.*

MAS-R0209. N.M. Temme. *Large parameter cases of the Gauss hypergeometric function.*

MAS-R0210. W.H. Hundsdorfer, S.J. Ruuth (Univ. Simon Fraser, Burnaby, Canada) R.J. Spiteri (Univ. Dalhousie, Halifax, Canada). *Monotonicity-preserving linear multistep methods.*

MAS-R0211. J.L. López (Univ. Pública Navarra, Spain), N.M. Temme. *Two-point Taylor expansions of analytic functions.*

MAS-R0212. D.E.A. van Odyck. *Review of numerical special relativistic hydrodynamics.*

MAS-R0213. A. Gil (Univ. Autónoma Madrid, Spain), J. Segura (Univ. Carlos III Madrid, Spain), N.M. Temme. *AIZ, BIZ: two Fortran 77 routines for the computation of complex airy functions.*

MAS-R0214. P. Moree (UvA), H.J.J. te Riele. *The hexagonal versus the square lattice.*

MAS-R0215. H.C. Williams (Univ. Calgary, Canada), H.J.J. te Riele. *New computations concerning the Cohen-Lenstra heuristics.*

MAS-R0216. G.W. Hunt (Univ. Bath, UK), G.J. Lord (Univ. Heriot-Watt, UK), M.A. Peletier. *Cylindrical shell buckling: a characterization of localization and periodicity.*

MAS-R0217. P.W. Hemker, W. Hoffmann (UvA), M.H. van Raalte. *Fourier two-level analysis for discontinuous Galerkin discretization with linear elements.*

MAS-R0218. C. Francke (UvA/VU), P.W. Postma (UvA), H.V. Westerhoff (VU), J.G. Blom, M.A. Peletier. *Why the phosphotransferase system of Escherichia coli escapes the diffusion limitation of signal transduction, transport and metabolism that confronts mammalian cells.*

MAS-R0219. S. Cavallar (TUE). *Three-large-primes variant of the number field sieve.*

MAS-R0220. J.K. Krottje. *On the dynamics of a mixed parabolic-gradient system.*

MAS-R0221. E.H. van Brummelen (TUD), B. Koren. *A pressure-invariant conservative Godunov-type method for barotropic two-fluid flows.*

MAS-R0222. A. Gil (Univ. Autónoma Madrid, Spain), J. Segura (Univ. Carlos III Madrid, Spain), N.M. Temme. *On the zeros of the Scorer functions.*

MAS-R0223. A. Gil (Univ. Autónoma Madrid, Spain), J. Segura (Univ. Carlos III Madrid, Spain), N.M. Temme. *GIZ, HIZ: two Fortran 77 routines for the computation of complex Scorer functions.*

MAS-R0224. R. Planqué, N.F. Britton (Univ. Bath, UK), N.R. Franks (Univ. Bristol , UK), M.A. Peletier. *The adaptiveness of defence strategies against cuckoo parasitism.*

MAS-R0225. R. Vidunas (Univ. Antwerpen, Belgium), N.M. Temme. *Parabolic cylinder functions: examples of error bounds for asymptotic expansions.*

MAS-R0226. M.A. Peletier, H.V. Westerhoff (VU), B.N. Kholodenko (Univ. Thomas Jefferson, Phil., USA). *Control of spatially heterogeneous and time-varying cellular reaction networks: a new summation law.*

MAS-R0227. P.W. Hemker, M.H. van Raalte. *Fourier two-level analysis for higher dimensional discontinuous Galerkin discretisation.*

MAS-R0228. J.G. Blom, M.A. Peletier. *The importance of being cigar-shaped.*

MAS-R0229. J.G. Blom, M.A. Peletier. *A continuum model of lipid bilayers.*

MAS-R0230. A. Gil (Univ. Autónoma Madrid, Spain), J. Segura (Univ. Carlos III Madrid, Spain), N.M. Temme. *Computing special functions by using quadrature rules.*

MAS-R0231. R. Planqué, N.F. Britton (Univ. Bath, UK), N.R. Franks (Univ. Bristol, UK). *Rare enemies and rare friends: adaptations that make other adaptations maladaptive.*

MAS-R0232. M. Lewis, B. Koren. *Efficient computation of steady, 3D water-wave patterns, application to hovercraft-type flows.*

MAS-N0201. L. Voort. *Een discontinue Galerkin methode toegepast op een eendimensionaal diffusieprobleem.*

MAS-N0202. G.F. Duivesteijn. *Improved capturing of contact discontinuities for two-fluid flows.*

A.5 INS reports

INS-R0201. J.R. van Ossenbruggen, H.L. Hardman. *Smart style on the semantic web.*

INS-R0202. F.-M. Nack, H.L. Hardman. *Denotative and connotative semantics in hypermedia: proposal for a semiotic-aware architecture.*

INS-R0203. S. Manegold, P.A. Boncz, M.L. Kersten. *Generic database cost models for hierarchical memory systems.*

INS-R0204. F.-M. Nack, H.L. Hardman. *Towards a syntax for multimedia semantics.*

INS-R0205. O. Rosell Martinez. *Design dependencies within the automatic generation of hypermedia presentations.*

INS-R0206. Z.R. Struzik, W.J. van Wijngaarden (AMC, Amsterdam), R. Castelo (UU). *Reasoning from non-stationarity.*

INS-R0207. P.D. Grünwald, J.Y. Halpern (Cornell Univ., Ithaca, USA). *Updating probabilities.*

INS-R0208. Z.R. Struzik. *Taming surprises.*

B Publications outside the research clusters

W. Mettrop, P. Nieuwenhuysen (2001) Internet search engines – Fluctuations in document accessibility. *Journal of Documentation* **57**(5), 623–651

C Survey of ERCIM Fellows and Indian Institute of Technology summer internships

C.1 ERCIM Fellows

Name	Research theme	Period
Dr. G.C.K. Abhayaratne	PNA4	2002-06-01–2003-03-01
Dr. E. Capobianco	PNA3	2001-04-01–2002-10-01
Dr. R. Gennari	PNA1	2002-07-16–2003-08-31

C.2 Indian Institute of Technology summer internships

From May 1 till August 1, the following people from IIT were seconded to CWI as summer intern:

Name	Research theme
N. Gupta	PNA4
G. Kandoi	MAS2
G. Katariya	INS2
S. Nain	SEN2
P. Singh	SEN3
M. Srivastava	INS1
I. Vaishnavi	SEN4

D Acronyms of universities in the Netherlands

Acronym	Name of university	Acronym	Name of university
EUR	Erasmus University Rotterdam	UT	University Twente
KUN	Catholic University Nijmagen	UU	University Utrecht
RUG	University Groningen	UvA	University of Amsterdam
TUD	Delft University of Technology	UvT	University of Tilburg
TUE	Eindhoven University of Technology	VU	Free University Amsterdam
UL	University Leiden	WUR	Wageningen University and Research Centre
UM	University Maastricht		

E PhD theses

AUTHOR
Date, University
Title
Thesis advisor(s)

E.H. VAN BRUMMELEN
February 8, UvA
Numerical Methods for Steady Viscous Free-Surface Flows
P.W. Hemker

T. KUIPERS
February 26, UvA
Techniques for Understanding Legacy Software Systems
P. Klint

D. LANSER
March 7, UvA
Numerical Methods for Atmospheric Flow and Circulation Problems
J.G. Verwer

S.W.W. ROLLES
March 20, UvA
Random Walks in Stochastic Surroundings
M.S. Keane

S.P. LUTTIK
April 3, UvA
Choice Quantification in Process Algebra
J.A. Bergstra, J.F. Groote

R. VAN STEE
May 8, UL
On-line Scheduling and Bin Packing
J.N. Kok

P.A. BONCZ
May 31, UvA
Monet: A Next-Generation DBMS Kernel For Query-Intensive Applications
M.L. Kersten

S.H. CAVALLAR
June 5, UL
On the Number Field Sieve Integer Factorisation Algorithm
R. Tijdeman

B. LASTDRAGER
September 18, UvA
Sparse Grids and Numerical Time Integration
J.G. Verwer

W.K. VAN DAM
October 9, UvA
On Quantum Computation Theory
P.M.B. Vitányi

M.B. VAN DER ZWAAG
October 11, UvA
Models and Logics for Process Algebra
J.A. Bergstra

J.I. DEN HARTOG
October 17, VU
Probabilistic Extensions of Semantical Models
J.W.de Bakker

A.R. SCHMIDT
November 7, UvA
Processing XML in Database Systems
M.L. Kersten

R. GENNARI
December 2, UvA
Mapping Inferences
K.R. Apt

Y.S. USENKO
December 2, TUE
Linearization in μCRL
J.F. Groote, W.J. Fokkink

L.M.F. MOONEN
December 5, UvA
Exploring Software Systems
P. Klint

S. MANEGOLD
December 17, UvA
Understanding, Modeling, and Improving Main-Memory Database Performance
M.L. Kersten