



**Centrum voor Wiskunde en Informatica**  
**Annual Report 2004**



# Contents



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Centrum voor Wiskunde en Informatica (CWI) is the national research institute for mathematics and computer science. It is supported by the Netherlands Organisation for Scientific Research (NWO).

CWI is a founding member of ERCIM, the European Research Consortium for Informatics and Mathematics. The institute participates in Telematica Instituut and in the Amsterdam Science & Technology Centre (WTCW). It is a member of the World Wide Web Consortium (W3C) and it runs the W3C Office in the Benelux. CWI is located at Science Park Amsterdam.

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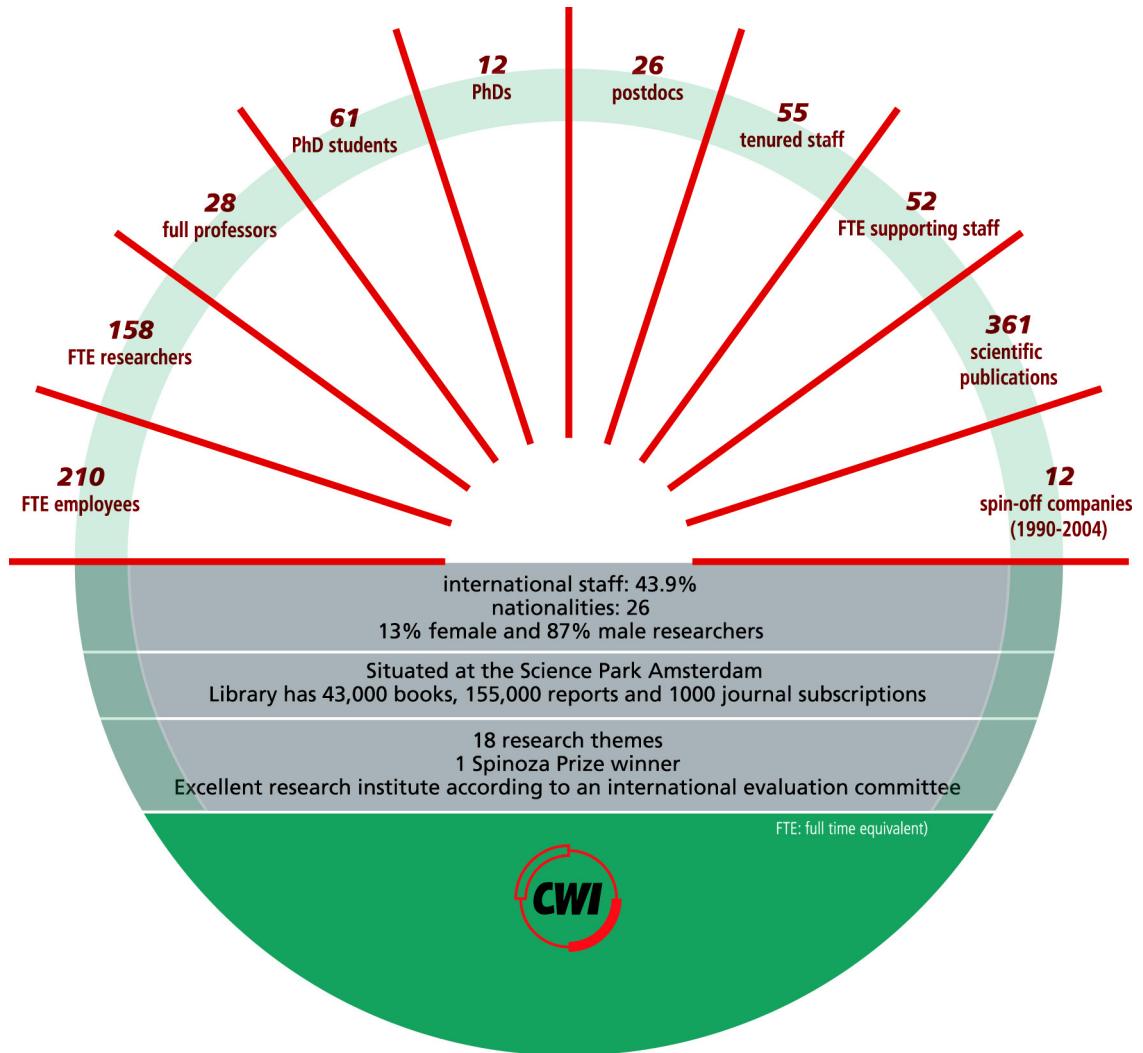
### The CWI annual report series consists of:

- Annual Report (English), a full colour document giving a general overview of CWI's activities
- Overview Research Activities (English), a comprehensive enumeration of CWI's research
- Jaarverslag (Dutch), a supplement containing the social and financial report and the works council report

Copies can be ordered at the Communications, Library and Information services department (CBI): [cbi@cw.nl](mailto:cbi@cw.nl)



## CWI at a glance







## Introduction

*With cautious optimism we ended the year 2004. Financially in safe waters and with challenging research programmes in its portfolio CWI is gradually growing.*

*The Bsik programmes BRICKS, MultimediaN and VL-e, so important for CWI, are well on their way now. They resulted already in interesting contacts, a growing research staff and new inspiration.*

*Two new pilot research themes were started and one outgrew its pilot status to continue as a full theme.*

*We participated in platforms and think tanks, preparing the setting of the national research agenda for mathematics and computer science. Whereas computer science has the full attention of politics, industry and financing organizations, the situation remains difficult for mathematics. The number of students continues to decrease, which leads to budget cuts at mathematics departments and to diminishing opportunities for CWI researchers to obtain academic positions. Fortunately, the Ministry of Economic Affairs and the Ministry of Education, Culture and Science – realizing how important mathematics is for society – joined forces with NWO to find new funding possibilities for mathematical research, which will be organized in clusters. CWI participates in two of the three clusters that have been selected for funding until now.*

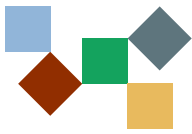
*In the last quarter of 2004 we prepared the six-yearly external evaluation of our institute by producing a self-evaluation. It is always a very useful exercise to collect all kinds of data, and to reflect on one's past activities and results. It also leads to identifying challenges for the coming years. CWI will focus on conducting advanced research, transferring knowledge, acting as a breeding ground and meeting place for young researchers and academic staff, fostering close contacts between academia and corporate and government parties, and playing a leading role in mathematics and computer science policy making.*

*As we are always aware of our mission – doing innovative fundamental research and transferring knowledge to society – and the goals derived from it, we structured this Annual Report accordingly.*

*Several research activities are highlighted. The complete research report is to be found in a separate volume and on our website. This is also the case with the social and financial annual report (in Dutch).*

**Jan Karel Lenstra**  
General Director





# Overview

## CWI Research Clusters

### **Probability, Networks and Algorithms (PNA)**

- 1 - Networks and Logic – Optimization and Programming
- 2 - Advanced Communication Networks
- 3 - Stochastics
- 4 - Signals and Images
- 5 - Cryptology and Information Security

### **Software Engineering (SEN)**

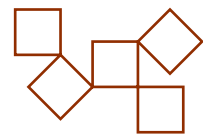
- 1 - Interactive Software Development and Renovation
- 2 - Specification and Analysis of Embedded Systems
- 3 - Coordination Languages
- 4 - Evolutionary Systems and Applied Algorithmics
- 5 - Convergent Media Infrastructures

### **Modelling, Analysis and Simulation (MAS)**

- 1 - Non-linear PDEs – Analysis and Scientific Computing
- 2 - Computing and Control
- 3 - Nonlinear Dynamics and Complex Systems

### **Information Systems (INS)**

- 0 - Standardization and Knowledge Transfer
- 1 - Database Architectures and Information Access
- 2 - Multimedia and Human/Computer Interaction
- 3 - Visualization and 3D Interfaces
- 4 - Quantum Computing and Advanced Systems Research



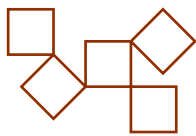
## CWI's mission and goals

*The Centrum voor Wiskunde en Informatica (CWI) is the national research centre for mathematics and computer science in the Netherlands. It was founded in 1946 as Mathematisch Centrum (Mathematical Centre) with the mission to perform frontier scientific research and to transfer the acquired knowledge to society.*

*Almost sixty years later much has changed. For example, computer science, still in its infancy in 1946, has obtained a more prominent position. But throughout these years, CWI's mission has to the present day lost nothing of its strength.*

**To achieve its mission CWI has formulated several goals:**

- 1 To conduct advanced research of societal and scientific relevance**
- 2 To act as a breeding ground for academic staff**
- 3 To train young researchers**
- 4 To transfer knowledge to society**
- 5 To play a leading role in the Dutch and European mathematics and computer scene**
- 6 To increase public interest in mathematics and computer science**



## 1 To conduct advanced research of societal and scientific relevance

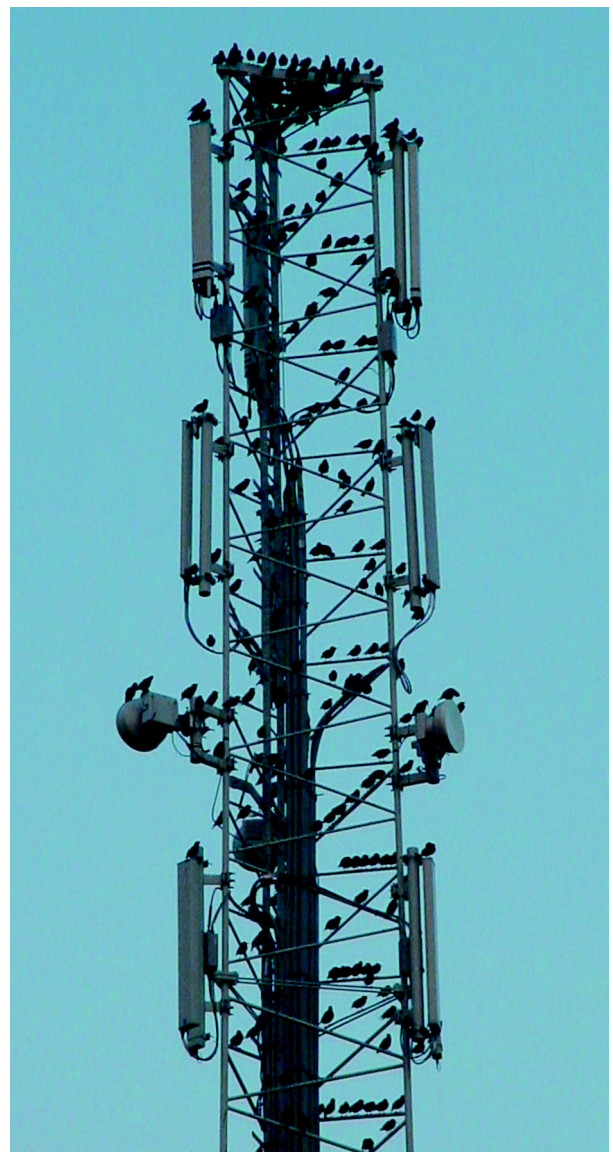
*CWI's research is organised in themes, interdisciplinary groups that study specific topics. New themes are created and old themes disbanded to respond to developments in the academic world, government, trade and industry. A large part of CWI's research is conducted in projects funded by various bodies like the European Union (EU), the Netherlands Organisation for Scientific Research (NWO), Telematica Instituut, the Technology Foundation (STW), the Dutch Ministry of Economic Affairs and parties from trade and industry.*

### New research themes

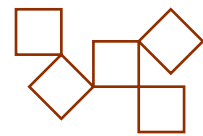
On January 1, the pilot theme Convergent Media Interfaces (SEN5) was launched. This group led by Dick Bulterman studies new methods to integrate audio, video, text and images into a multimedia presentation. Furthermore, they provide techniques to design, send and play the presentations over heterogeneous networks and devices, ranging from desktop computers to mobile phones.

The ever-growing importance of information and communication technology calls for advanced security technology. This area has many fundamental mathematical aspects. With the new Cryptology and Information Security pilot theme (PNA5) that started on June 1, CWI responds to these developments. One of the subjects studied by the theme, which is led by Ronald Cramer, is secure multiparty computation. This area deals with two or more parties who wish to securely achieve a joint task, even though they wish to keep sensitive, private information hidden from each other. Also part of the new theme is the Number Field Sieve project for factoring large integers, previously part of the Computing and Control theme (MAS2). One of the main applications of this research is the testing of public key security protocols.

The pilot theme Advanced Communication Networks (PNA2) proved to be viable over the last three years. As a result it acquired full theme status on January 1. The group, led by Michel Mandjes, develops mathematical models for communication network traffic. PNA2 contributed this expertise to projects from the EU and the Ministry of Economic Affairs. It also handled a large consultancy project for France Télécom.



*One of the areas of interest of the Advanced Communication Networks theme is the coordination of nearby base stations. This can avoid interference and divert traffic from heavily-loaded cells. Mathematical analysis shows that coordination strategies can increase network capacity.*



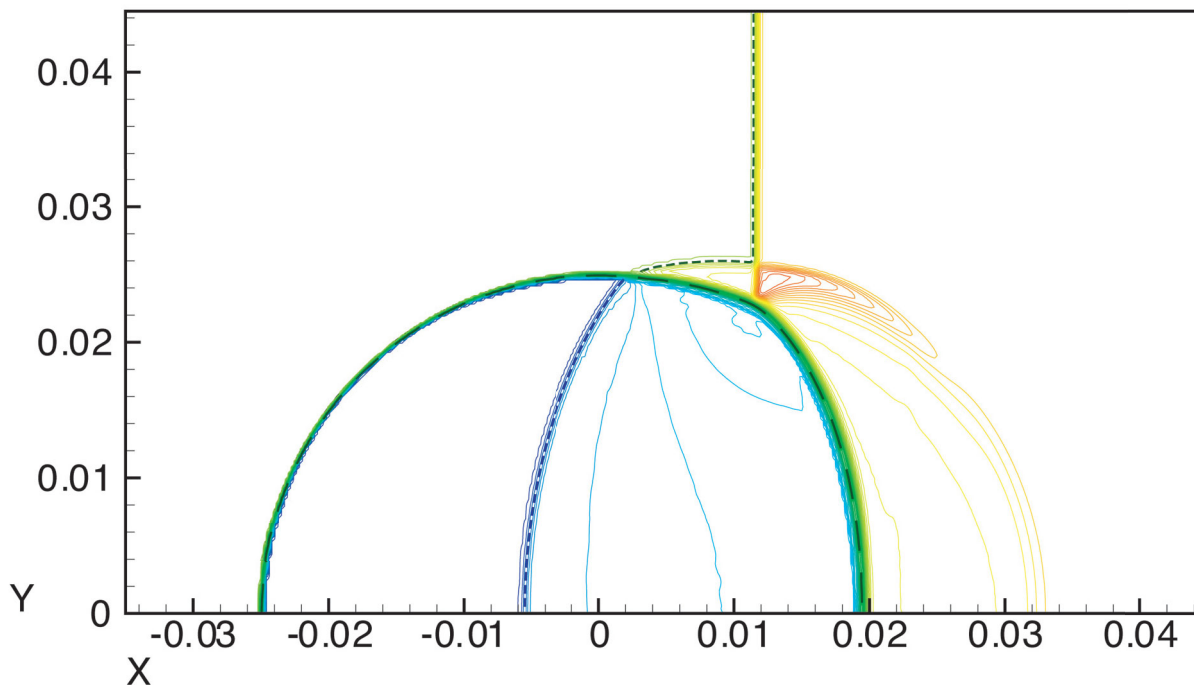
The pilot theme Nonlinear Dynamics and Complex Systems (MAS3), headed by Ute Ebert, became a full theme at the end of 2004. This theme investigates non-linear dynamics and pattern formation in spatially extended systems with applications to patterns in electric discharges.

## Projects

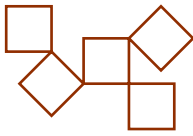
All CWI research themes are involved in one of the government-funded Besluit Subsidies Investerings in de Kennisinstructuur (Bsik) - projects to strengthen the Dutch knowledge-based economy. These Bsik projects are: BRICKS (fundamental ICT research), MultimediaN (multimedia) and Virtual Laboratory for e-Science (e-science). The Dutch government made the final decision on the Bsik project proposals in November 2003. During 2004 the various subprojects were initiated. In April, the CWI-coordinated BRICKS project was officially launched with a kick-off meeting at the NWO office in The Hague.

Apart from the Bsik projects, several other new projects were started in 2004. PNA2 updated their collaboration with France Télécom with a new version of

the FLORIN project on the performance of wireless communication networks. PNA5 started with a follow-up of the Ambulant project, funded by NLNet, to develop a new version of the SMIL multimedia language. The Dutch Ministry of Economic Affairs funded a project on stochastic techniques for electromagnetics. This project is carried out by the Computing and Control theme (MAS2). Among the NWO-funded projects started in 2004 were MIA (Medical Information Agents), which deals with agent technology for medical planning, and PHOTO-ID, a continuation of the EUROPHLUKES project on the automatic recognition of whales based on photos of their tails.



*The BRICKS subproject MSV-1 in which CWI is involved covers the numerical simulation of flows in two gases. The picture shows a helium bubble (thick dotted line) in air. The bubble is hit from the right by a shockwave (dotted thin line). The simulation shows how part of the wave's energy penetrates the bubble and another part is reflected (the orange lines on the right).*



### *MonetDB achieves high performance with complex queries*

It is a dream come through for everyone dealing with complex queries in large databases – MonetDB.

No more time consuming and yet insufficient processing, but high performances on complex queries even against extremely large databases comprising tables with hundreds of columns and multi-million rows.

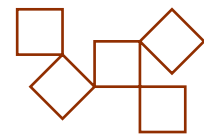
MonetDB is an open source high-performance database system developed by CWI scientists. Due to innovations on all levels of a DBMS it is much faster than traditional systems. This query processing at the speed of light can be realized by focusing on exploiting CPU caches. It is one of the first databases to do so. MonetDB also features automatic and self-tuning indexes, run-time query optimization and a modular software architecture.

The new database system has been applied in high-performance applications for data mining, OPLAP, GIS, XML Query, text- and multimedia retrieval. Data Distilleries – one of CWI's spin-offs – has successfully used MonetDB for eight years and also sold it to several financial organizations.

The development of MonetDB is an ongoing process. Worldwide twenty developers are busy with new versions and applications based on MonetDB. Twice a year a major release is prepared for tens of computer platforms, providing an easy means to tap into these scientific results.







## 2 To act as a breeding ground for academic staff

*CWI offers an ambitious research programme and excellent facilities. Furthermore, CWI academics do not have teaching responsibilities and they can devote all their time to research. Consequently, the institute offers researchers good opportunities to develop their talents. Many Dutch university professors in mathematics and computer science have worked or are working at CWI. National and international prizes and honorary degrees are another indication of the quality of CWI's staff.*

### Professorates

Three senior CWI staff members were appointed professor in 2004. On January 1, Arie van Deursen started as professor in software engineering at the Delft University of Technology. Van Deursen works at the Interactive Software Development and Renovation theme (SEN1). Farhad Arbab of the Coordination Languages theme (SEN3) became professor of Software Composition at Leiden University. Arbab, who is also assistant professor at the University of Waterloo (Canada) assumed his position on June 1. On the same day Ronald Cramer, leader of PNA5, was appointed professor of Cryptology at Leiden University. Finally, Robert van Liere, who heads CWI's Virtual Reality and 3D Interfaces theme, started as professor of Virtual Reality at the Technische Universiteit Eindhoven on September 1. Van Liere is the first chair of this scientific discipline in the Netherlands.

Additionally, on April 1, Rob van der Mei joined PNA2 for four days a week. The other day Van der Mei works as professor of Performance Analysis of Communication Networks at the Vrije Universiteit Amsterdam.

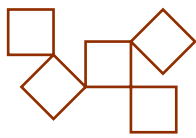


*Farhad Arbab of the Coordination Languages theme (SEN3) was appointed professor of Software Composition at the Leiden Institute for Advanced Computer Science*

### CWI full professors

University	UvA	UU	UL	RUG	EUR	TUD	TUE	VU	RU	WUR	UM	UT	UvT	Other	Total
CWI staff	10	1	2	0	0	1	8	6	0	0	0	0	0	0	28
Former CWI staff	4	8	4	1	3	2	11	6	4	1	1	3	1	24	73
<b>Total</b>	<b>14</b>	<b>9</b>	<b>6</b>	<b>1</b>	<b>3</b>	<b>3</b>	<b>19</b>	<b>12</b>	<b>4</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>1</b>	<b>24</b>	<b>101</b>





## Theme leaders

Theme leaders Wan Fokkink and Mark Peletier left CWI to work as full-time professors at the Vrije Universiteit and the Technische Universiteit Eindhoven. Jaco van de Pol succeeded Fokkink as head of the Specification and Analysis of Embedded Systems theme (SEN2) in September. Van de Pol already worked at CWI as a senior researcher. Peletier was succeeded by Arjen Doelman as leader of the theme Nonlinear PDEs: Analysis and Scientific Computing (MAS1). Doelman previously worked as a full-time professor of Applied Analysis and Dynamical Systems at the Universiteit van Amsterdam, a position he continues to hold for one day a week.

## Prizes

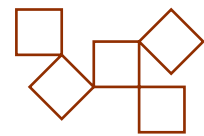
The Institute for Operations Research and the Management Sciences awarded the Frederick W. Lanchester Prize 2004 to Lex Schrijver. This prestigious prize is awarded annually for the best contribution to operations research and management sciences published in English. Schrijver, leader of CWI's Probability

Networks and Algorithms cluster, earned the prize for his book *Combinatorial Optimization – Polyhedra and Efficiency*, published in 2003 by Springer Verlag. It is the second time Schrijver wins the Lanchester Prize. In 1987 he received the award for his book *Theory of Linear and Integer Programming*.

The 2004 Minerva Prize went to CWI researcher Ute Ebert. The prize is awarded biannually by the Foundation for Fundamental Research on Matter (FOM) for the best scientific publication by a female author on a physics topic. Ebert is leader of the Nonlinear Dynamics and Complex Systems theme (MAS3). She received the award of 5000 euros for the paper *Spontaneous Branching of Anode-Directed Streamers Between Planar Electrodes* published in 2002 in the journal *Physical Review Letters*.



Alexander Schrijver during the Lanchester Prize Award ceremony at the INFORMS Annual Meeting in Denver, October 25. Schrijver received the award for his book *Combinatorial Optimization - Polyhedra and Efficiency*.



*Ute Ebert receives the 2004 Minerva Prize*

The Royal Netherlands Academy of Arts and Sciences elected Ronald Cramer for the newly-founded De Jonge Akademie. This Junior Academy consists of 40 young, outstanding researchers from various academic backgrounds. De Jonge Akademie was founded to put the researchers in contact with other scientific disciplines and to encourage them to develop a view on their own field of research.

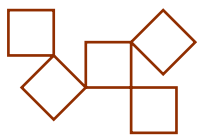


*Ronald Cramer*

The Royal Dutch Mathematical Society KWG appointed Cor Baayen as an honorary member. Baayen was scientific director of CWI from 1980 through 1994. In that function, Baayen gave a major boost to CWI's computer science research by convincing the Dutch government to include CWI in the national computer science subsidy programme INSP. He also was the first president of the European Research Consortium for Informatics and Mathematics ERCIM (1989–1993) and played an important role in its foundation.



*Cor Baayen was CWI's scientific director from 1980 through 1994*



### 3 To train young researchers

CWI considers it an important task to nurture young, starting researchers. The institute employs many PhD students and postdoc researchers. They form the basis of most projects and of the future senior staff of the institute.

#### PhDs

Twelve CWI researchers completed their PhD in 2004. Subjects of their work included agent technology, verification of embedded software, quantum computing, scheduling, numerical simulation and multimedia retrieval.

- ◆ Author
- ◆ Title
- ◆ University
- ◆ Thesis advisor(s) (for external advisors the university's name is added)

#### Research Cluster Probability, Networks and Algorithms

- ◆ **S. Brand**
- ◆ Rule-based Constraint Propagation: Theory and Applications
- ◆ Universiteit van Amsterdam
- ◆ K.R. Apt

#### Research Cluster Software Engineering

- ◆ **F. Alkemade**
- ◆ Evolutionary Agent-Based Economics
- ◆ Technische Universiteit van Eindhoven
- ◆ J.A. La Poutré, H.M. Amman (Technische Universiteit van Eindhoven)

- ◆ **F. Bartels**
- ◆ On Generalized Coinduction and Probabilistic Specification Formats
- ◆ Vrije Universiteit Amsterdam
- ◆ J.J.M.M. Rutten

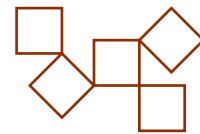
- ◆ **E.H. Gerding**
- ◆ Autonomous Agents in Bargaining Games
- ◆ Technische Universiteit van Eindhoven
- ◆ J.A. La Poutré

- ◆ **N. Ioustinova**
- ◆ Abstractions and Static Analysis for Verifying Reactive Systems
- ◆ Vrije Universiteit Amsterdam
- ◆ W.J. Fokkink

- ◆ **S.M. Orzan**
- ◆ On Distributed Verification and Verified Distribution
- ◆ Vrije Universiteit Amsterdam
- ◆ W.J. Fokkink

- ◆ **J. Pang**
- ◆ Formal Verification of Distributed Systems
- ◆ Vrije Universiteit Amsterdam
- ◆ W.J. Fokkink





### Research Cluster Modelling, Analysis and Simulation

◆ **M.R. Lewis**

◆ Numerical Methods for Water Flows with Free-Space Gravity Waves

◆ Delft University of Technology

◆ B. Koren

◆ **M.H. van Raalte**

◆ Multigrid Analysis and Embedded Boundary Conditions for Discontinuous Galerkin Methods

◆ Universiteit van Amsterdam

◆ P.W. Hemker

◆ **D. Sijacic**

◆ Spatio-temporal Pattern Formation in a Semiconductor-Gas-Discharge System

◆ Technische Universiteit van Eindhoven

◆ U. Ebert

### Research Cluster Information Systems

◆ **H.P. Röhrig**

◆ Quantum Query Complexity and Distributed Computing

◆ Universiteit van Amsterdam

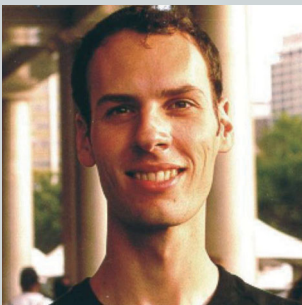
◆ H.M. Buhrman, P.M.B. Vitányi

◆ **T.H.W. Westerveld**

◆ Using Generative Probabilistic Models for Multimedia Retrieval

◆ University of Twente

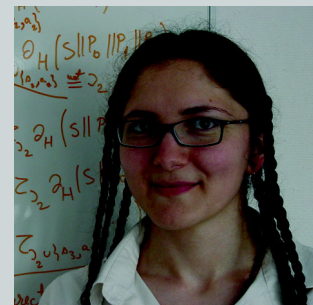
◆ F.M.G de Jong (University of Twente)



E.H. Gerding



N. Ioustinova



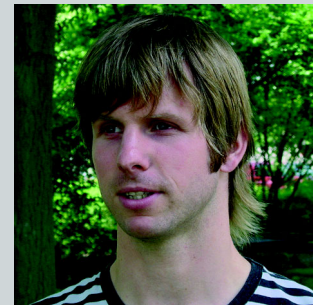
S.M. Orzan



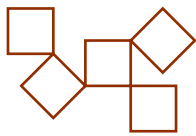
J. Pang



M.H. van Raalte



T.H.W. Westerveld



## Prizes and grants

In 2000 NWO established the ‘Vernieuwingsimpuls’ subsidy programme to enable young, excellent researchers to establish a personal line of research. There are three types of grants, Veni, Vidi and Vici, aimed at increasingly experienced researchers. In 2004 two CWI researchers received a Vidi grant, intended for experienced postdoc researchers. Pieter Collins from the Computing and Control theme (MAS2) and Peter Grünwald from the Quantum Computing and Advanced Systems Research theme (INS4) received 600,000 euros each over five years. Collins uses the funding to develop mathematical techniques to obtain guaranteed error margins for computations. This is especially important for safety critical applications. Grünwald will study statistical models. Often these models are too complex and as a result unreliable. Drawing from statistics, information theory and computer science, he develops methods to find the optimal balance between simplicity and complexity.

Harry van Zanten, Vrije Universiteit researcher and one day a week CWI researcher of the Stochastics theme (PNA3), earned a Veni grant for starting postdoc researchers. He receives up to 200,000 euros for a proposal on the modelling of statistical data, for example measurements of telecommunication networks.



On November 25, Stephanie Wehner received the ‘Bakkenist Jong Talent Prijs’. The award is given annually to the best computer science student at a Dutch university.

Postdoc researcher Jano van Hemert earned a TALENT grant from NWO for his proposal on evolutionary algorithms and optimization. Van Hemert, who works at CWI’s Evolutionary Systems and Advanced Algorithmics theme (SEN4), does not use the algorithms to find solutions but to generate problems that can be used to evaluate optimization methods. He uses the grant to visit the Center of Emergent Computing of the University of Edinburgh.

CWI PhD researcher Willem Jan van Hove won the best paper award during the tenth International Conference on Principles and Practice of Constraint Programming, held in Toronto. He earned the distinction for his paper A Hyper-Arc Consistency Algorithm for the Soft Alldifferent Constraint. Soft alldifferent constraints can be used to model and solve over-constrained combinatorial problems, such as personnel rostering. The paper describes an efficient algorithm to detect and remove infeasible combinations.

Another best paper award was won by CWI staff-members Thijs Westerveld and Arjen de Vries. Their article Multimedia Retrieval Using Multiple Examples was awarded during the International Conference on Image and Video Retrieval in Dublin. Westerveld and De Vries developed a method to find relevant multimedia files in a database using examples.

### Veni, Vidi and Vici grants at CWI

#### NWO Vernieuwingsimpuls grants

S.M. Bohte (Veni, 2002)

J.E. Frank (Veni, 2002)

M. Laurent (Vidi, 2002)

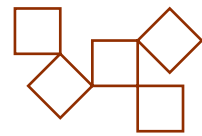
M.A. Peletier (Vidi, 2003)

H.M. Buhrman (Vici, 2003)

P.J. Collins (Vidi, 2004)

P.D. Grünwald (Vidi, 2004)

NWO awards Veni grants to young researchers (200,000 euro) to develop their ideas, Vidi grants (600,00 euro) to develop an innovative line of research and Vici grants (up to 1,250,000 euro) to strengthen the research groups of talented senior researchers.



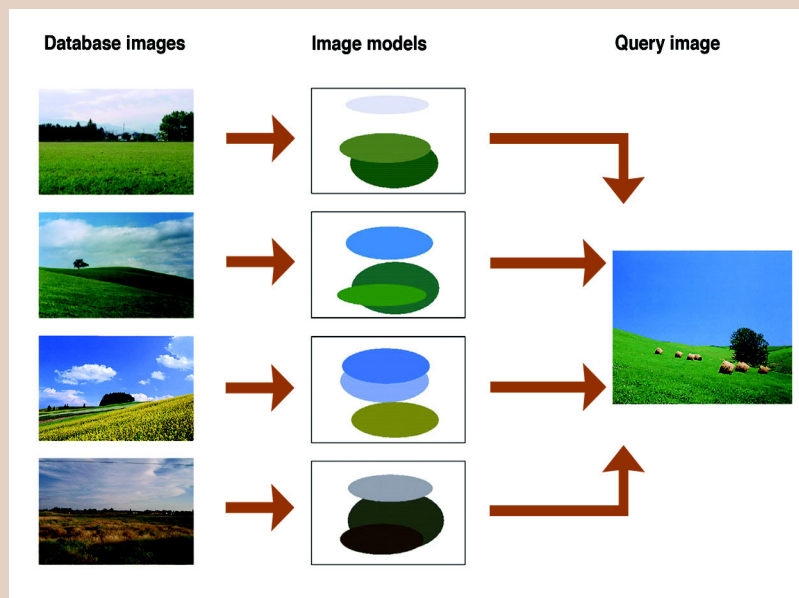
## Looking for images

Many image search engines are not really looking for images. Instead, they produce keywords attached to or located close to an image. For example, if a user is looking for a dog, the engine returns pictures that are named 'dog' or are found near the word dog in a document. Obviously this method is not always reliable. For instance, relevant images named *Alsatian.jpg* are overlooked. Moreover, it is not very effective if someone is looking for a brown dog. Many pictures of brown dogs are not accompanied by the word 'brown'.

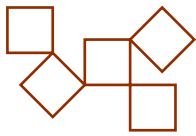
On November 25, CWI researcher Thijs Westerveld defended his PhD thesis on a different approach. In his search method queries do not consist of text but of a sample picture. Westerveld's technique generates a statistical model of the images in the database.

This model can be depicted as an arrangement of coloured areas representing typical elements of the images. The images can then be compared to each other using this model. Contrary to many other techniques that search for images, Westerveld does not make any assumptions about the type of image in the database.

Westerveld's method does have its limitations. That is why he combined image search with text-based techniques to further improve the results. Westerveld tested its performance on the evaluation database TRECVID. Despite the fact that this database consists of a heterogeneous collection of images, results of these tests are consistently above average.



CWI regularly hosts MSc students during their graduation research. One of them, Stephanie Wehner, won the 2004 Bakkenist Award for computer science. The annual prize of 15,000 euros and a certificate, is handed out to the best computer science graduate of a Dutch university. Wehner, a student at the Universiteit van Amsterdam, conducted her graduation research on quantum computing and security in collaboration with Harry Buhrman. After her graduation in June 2004 she continued to work at CWI as a PhD student.



## 4 To transfer knowledge to society

*Knowledge transfer to society cannot be done living in an ivory tower. CWI therefore has extensive connections with the government, trade and industry.*

### CWI in Bedrijf

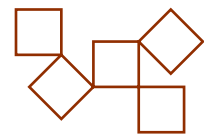
To maintain these ties CWI organizes the annual business day CWI in Bedrijf. On October 22, some 160 representatives from government, trade and industry

visited CWI for a programme around the theme ICT: Trends, troeven en twijfels (ICT: trends, trumps and doubts). Rob van der Mei (CWI) and Paul de Graaf

PARTNERS
IN
RESEARCH

<p style="text-align: center; font-weight: bold; margin: 0;">Companies</p> <ul style="list-style-type: none"> <li>Add-Controls</li> <li>Almende</li> <li>ASML</li> <li>BT</li> <li>Falck</li> <li>France Télécom</li> <li>Groeneveld Groep</li> <li>Hewlett Packard</li> <li>IBM</li> <li>KPN</li> <li>Logica CMG</li> <li>Lucent Technologies (Bell Labs)</li> <li>Microsoft Research</li> <li>NEC Research</li> <li>NOB</li> <li>Nokia</li> <li>NOS</li> <li>NS</li> <li>Nuon</li> <li>Ordina</li> <li>Phillips</li> <li>PinkRocade</li> <li>Satama</li> <li>Shell</li> <li>SPSS</li> <li>Thales</li> <li>UPC</li> <li>Vanenburg</li> <li>Vos Logistics</li> </ul> <p style="text-align: center; margin-top: 10px;">(45 companies)</p>	<p style="text-align: center; font-weight: bold; margin: 0;">Research Institutes</p> <table style="width: 100%; border: none;"> <tr> <td style="border: none;">AMOLF</td> <td style="border: none;">MARIN</td> </tr> <tr> <td style="border: none;">ESI</td> <td style="border: none;">NIH (KNAW)</td> </tr> <tr> <td style="border: none;">EURANDOM</td> <td style="border: none;">NLR</td> </tr> <tr> <td style="border: none;">FOM Rijnhuizen</td> <td style="border: none;">RIVM</td> </tr> <tr> <td style="border: none;">Fraunhofer ICT Group</td> <td style="border: none;">Telematica Instituut</td> </tr> <tr> <td style="border: none;">INRIA</td> <td style="border: none;">TNO</td> </tr> </table> <p style="text-align: center; margin-top: 5px;">(25 research institutes)</p>	AMOLF	MARIN	ESI	NIH (KNAW)	EURANDOM	NLR	FOM Rijnhuizen	RIVM	Fraunhofer ICT Group	Telematica Instituut	INRIA	TNO	<p style="text-align: center; font-weight: bold; margin: 0;">Universities</p> <ul style="list-style-type: none"> <li>Carnegie Mellon University</li> <li>Columbia University</li> <li>Cornell University</li> <li>Ecole Normale Supérieure Paris</li> <li>Erasmus Universiteit Rotterdam</li> <li>ETH Zürich</li> <li>Georgia Institute of Technology</li> <li>Helsinki University of Technology</li> <li>Imperial College London</li> <li>Indian Institute of Technology</li> <li>National University of Singapore</li> <li>New York University</li> <li>Princeton University</li> <li>Radboud Universiteit Nijmegen</li> <li>Rice University</li> <li>Rijksuniversiteit Groningen</li> <li>Stanford University</li> <li>Technische Universiteit Delft</li> <li>Technische Universiteit Eindhoven</li> <li>The Johns Hopkins University</li> <li>UC Berkeley</li> <li>Université catholique de Louvain</li> <li>Universiteit Leiden</li> <li>Universiteit Maastricht</li> <li>Universiteit Twente</li> <li>Universiteit Utrecht</li> <li>Universiteit van Amsterdam</li> <li>Universiteit van Tilburg</li> <li>University College London</li> <li>University of Aarhus</li> <li>University of Cambridge</li> <li>University of Heidelberg</li> <li>University of Waterloo</li> <li>Vrije Universiteit, Amsterdam</li> <li>Wageningen UR</li> </ul> <p style="text-align: center; margin-top: 5px;">(100 universities)</p>
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ESI	NIH (KNAW)													
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<p style="text-align: center; font-weight: bold; margin: 0;">CENTRUM VOOR WISKUNDE EN INFORMATICA</p>		<p style="text-align: center; font-weight: bold; margin: 0;">Miscellaneous</p> <ul style="list-style-type: none"> <li>NWO, STW, EU, Min. EZ</li> <li>Science Park Amsterdam</li> <li>Dutch research schools</li> <li>ERCIM: 18 members</li> <li>W3C: 350 members</li> <li>NLnet</li> <li>SARA</li> <li>SURFnet</li> <li>Rijksmuseum Amsterdam</li> <li>Rijkswaterstaat</li> </ul>												
<p style="text-align: center; font-weight: bold; margin: 0;">Financial institutions</p> <ul style="list-style-type: none"> <li>ABN AMRO</li> <li>ABP</li> <li>Belastingdienst</li> <li>ING</li> </ul>	<p style="font-size: 0.8em; margin: 0;">Based on the Overview Research Activities 2003 and the Institute Plan 2004</p>													





(employers' organization VNO-NCW) gave presentations on ICT developments. The talks were alternated with a panel discussion led by tv journalist Peter van Ingen and a spoken column by BSO (Origin) founder

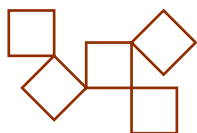
Eckart Wintzen. The latest results of CWI research were presented as demonstrations or poster presentations.



General director Jan Karel Lenstra and chair Peter van Ingen

The panel at CWI in Bedrijf: Kees van Hee (TU/e), Jan Kees de Jager (ISM BV and Innovatie Platform), Peter van Ingen (VPRO), Jacob Verschuur (Ernst & Young ICT Leadership) and Sylvia Roelofs (Nederland-ICT)





## Adviserships

Philips Research appointed Martin Kersten as an adviser on database technology for its ambient intelligence programme. Ambient intelligence covers a wide array of technologies for creating electronic environments adapting to their users. It ranges from hospital rooms containing various medical sensors monitoring a patient's health to home entertainment systems responding to their users' mood. This requires the development of sensors, advanced data processing algorithms, and flexible networks connecting the different devices and sensors. Kersten will advise Philips on the development of 'organic' databases that can store and manage data in these continuously changing networks.

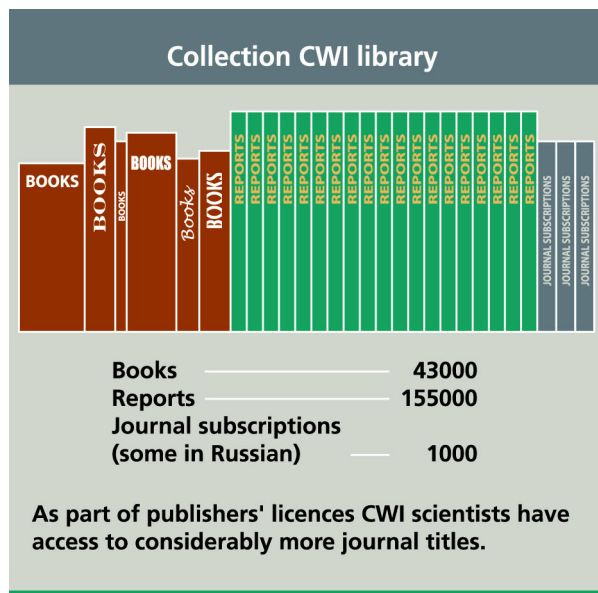


Ambient intelligence

As a part of its ambient intelligence programme Philips develops media servers that can store and manage pictures, movies and audio, and display or play them anywhere in the house. CWI advises Philips Research on database technology for ambient intelligence applications.

## Spin-offs

In July 2004 CWI's investment company CWI Incubator licensed the software package Argos to bio-start-up PodiCeps. PodiCeps currently investigates a method, developed by Roel van Driel of the Universiteit van Amsterdam, which chemically marks characteristic structures in tumour samples. Argos can subsequently be used to quantify relevant attributes of these structures like their size and shape. It can also present these attributes in a way to facilitate diagnosis. In exchange for the software licence, CWI Incubator received a minority share in PodiCeps



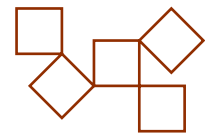
### Spin-offs CWI 1990-today

Year	Company	Business	Status
1990	DigiCash	Electronic payments	Ended, 1999
1994	General Design / Satama NLnet / UUnet	Web design ISP	Sold, 2000 Active
1995	CAN Diensten Data Distilleries	Mathematical software Data mining	Active Sold, 2003
1997	Unipay Technologies	Encryption, electronic authorization	Active
1998	Eidetica Oratrix Development	Search systems Multimedia authoring	Sold, 2002 Ended, 2002
2000	Software Improvement Group	Legacy software improvement	Active
2001	Epictoid	Animation tools	Ended, 2003
2002	Adaptive Planet	Component SW, tools	Active
2004	PodiCeps	Tumor screening	Active

### New employment for former CWI staff

Moved to	2001	2002	2003	2004	Total
University	6	5	6	7	24
Business	5	1	6	1	13
Spin off company	4	1	0	0	5
Own business	0	0	1	0	1
Abroad	7	6	8	8	29
Retired	2	3	1	5	11
Other	4	7	7	9	27





## 5 To play a leading role in the Dutch and European mathematics and computer science scene

*Not only does CWI exchange knowledge with its partners, it also actively invests in the mathematics and computer science community in the Netherlands and Europe. CWI researchers actively participate in the draft of the national research agenda for computer science (NOAG-i), the organization of Dutch graduate schools for mathematics (OOW) and its counterpart in computer science, IPN. CWI is also a member of the European Research Consortium for Informatics and Mathematics (ERCIM) and it hosts the Benelux Office of W3C.*

### IPN

The members of the Dutch Computer Science Research Platform (IPN) voted Paul Klint as their chairman. Klint, leader of CWI's Software Engineering cluster, will hold this position from February 1, 2004

to February 1, 2007. He also became chairman of the Advisory Board Computer Science of NWO. In both functions Klint succeeds Mark Overmars, professor of applied algorithms at Utrecht University and member of CWI's Governing Board.

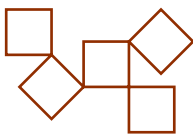


*Dedicated research in a beautiful scenery*

### *CWI stimulates top research in Schloss Dagstuhl*

CWI's director Jan Karel Lenstra was appointed member of the Scientific Advisory Board of the International Conference and Research Center for Computer Science (IBFI) in Schloss Dagstuhl in Germany, in December 2004. Following the tradition of the world-famous Mathematics Research Institute of Oberwolfach, IBFI regularly organizes specialized seminars for both established researchers and promising young scientists, who can only attend on invitation. The proposals for programmes and top researchers are selected by the scientific directorate, of which CWI's Paul Klint is a member.

IBFI is located in an isolated castle, which used to be a home for elderly Franciscan nuns and the residence of several noble families. Due to its seclusion, visitors can, for one week, completely focus on a computer science topic. This can be an established research field or an area overlapping various disciplines. The informal agenda, the inspiring atmosphere, the outstanding research library and leisure activities to promote interaction, make the seminars highly productive. The Scientific Advisory Board emphasizes the importance of increasing the participation of women and improving the quality of the seminars.



## ERCIM

ERCIM consists of 18 research institutes and university consortia on applied mathematics and computer science, creating a network of 12,000 researchers. Its activities include joint projects and working groups on topics ranging from image understanding to environmental modelling. ERCIM members advise the EU on research policy issues. The consortium also stimulates mobility by its fellowship programme. During 2004, several researchers spent time at CWI through this scheme.

ERCIM's president Stelios Orphanoudakis resigned in October 2004. He had been in office since January 2004. As his successor the ERCIM board of directors elected Keith Jeffery, director IT of the British Council for the Central Laboratory of the Research Councils (CCLRC).



Keith Jeffery, director IT of CCLRC (UK), succeeded Stelios Orphanoudakis as president of ERCIM

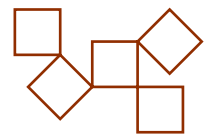
At the request of the European Commission, ERCIM's Board of Directors wrote a strategic document on the major ICT trends for the near future. The text will also act as a guideline for ERCIM's own strategic decision making.

## W3C

CWI hosts the W3C Benelux Office. This organization, consisting of more than 350 members from research, trade and industry, develops and recommends common standards for the internet. Among the protocols set up by W3C are the wide-spread HTML, XHTML and XML languages for the design of web-pages and the SMIL multimedia language.

On June 11 the W3C Benelux Office and the Internet Society Belgium (ISOC Belgium) signed a Memorandum of Understanding to spread open standards to the internet communities of Belgium and Luxembourg. W3C Benelux and ISOC Belgium intend to organize joint activities to increase the knowledge on possibilities and complications of standards among internet professionals, decision makers, scientists, and other parties. An evaluation after six months will show whether the collaboration will be continued or possibly even expanded.



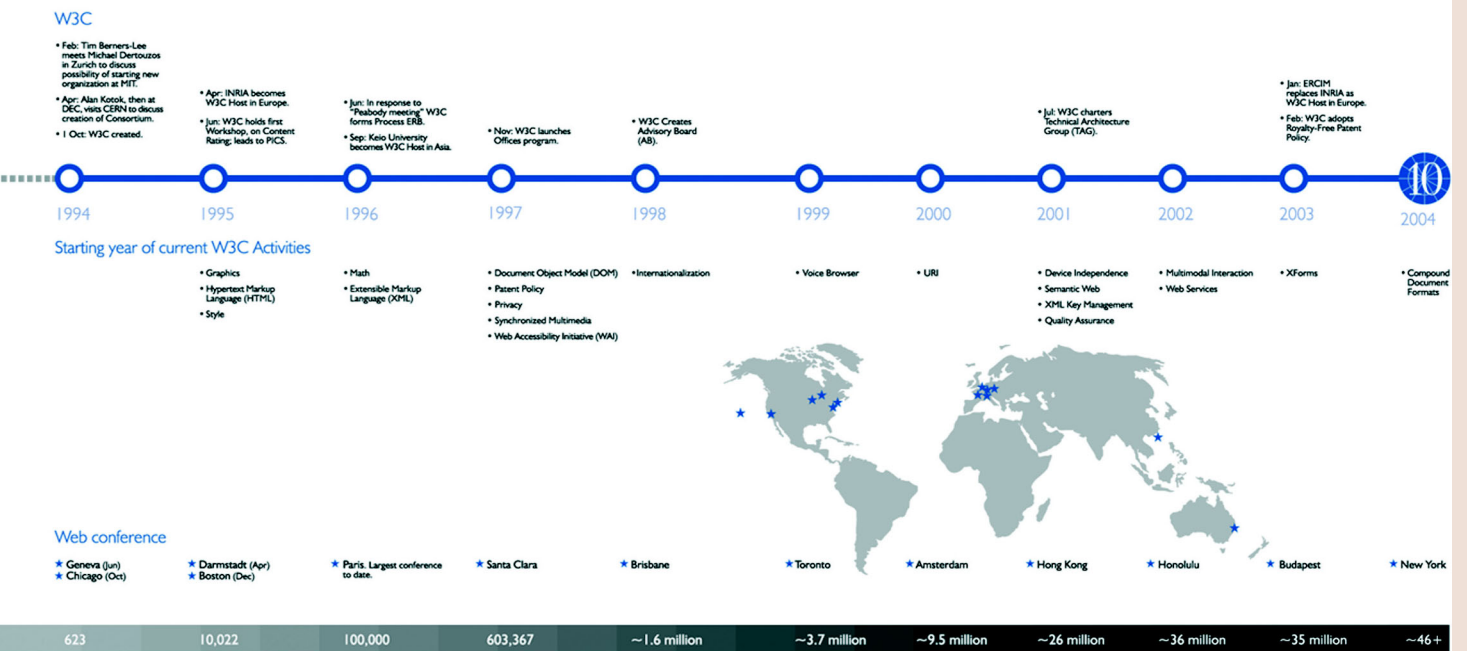


## W3C celebrates decade of web technology

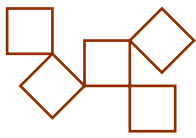
December 2004, several CWI researchers attended the tenth anniversary celebration of the World Wide Web Consortium (W3C) in Boston. Director Tim Berners-Lee invented the World Wide Web in 1989 while working at CERN in Switzerland. In October 1994, he founded W3C at MIT in Boston, in collaboration with CERN and with support from DARPA and the European Commission. Now, over 350 organizations— companies, governments and research institutes – collaborate to create global web standards. In its first ten years, W3C produced more than eighty such W3C Recommendations. Thanks to this worldwide effort, societies can profit from broadly shared agreements on web technology.

As the starting point of the European Internet, CWI has also been very active in both W3C research and organization. CWI research constitutes the base of several international W3C Recommendations, such as SMIL, XHTML and XForms. CWI researcher Steven Pemberton is the international chair of both the XHTML and XForms Working Groups. Since 1998, CWI hosts the W3C Office in the Netherlands to promote national involvement in web development. This was expanded to the W3C Benelux Office in 2002. It organizes tutorials for web developers and policymakers, in cooperation with ISOC in the Netherlands and Belgium. CWI researcher Ivan Herman is Head of Offices worldwide.

W3C10 Time Line Graphic







*HPOPT 2004, the 8th International Workshop on High Performance Optimization Techniques: Optimization and Polynomials, took place at CWI from June 23-25*

### **Retirement .nl Piet Beertema**

On the occasion of his retirement, September 16, 2004, CWI honoured its systems manager and network manager Piet Beertema with a symposium on the history and future of the Internet. This gave Beertema the opportunity to reunite with co-pioneer Rick Adams. Sixteen years earlier they created the very first transatlantic internet connection, thus firmly putting Amsterdam on the worldwide map. Luckily, already in 1986, Beertema had the foresight, to register *cwi.nl*, thereby creating the *.nl* domain. His networking efforts made him the founding father of the Internet domain-registration system in the Netherlands.



*Piet Beertema (r) and Rick Adams, internet pioneers*

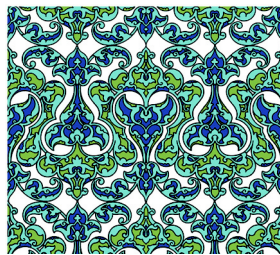
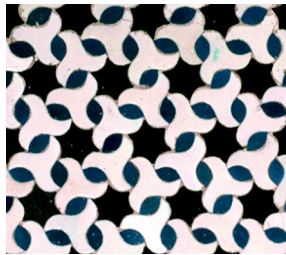
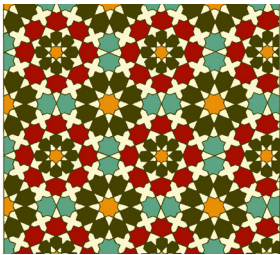
For years Beertema handled all Dutch registrations, not only technically but also by developing and refining regulations and procedures, which he diligently upheld and forced others to uphold. In 1996 this laborious task was taken over by the Stichting Internet Domeinregistratie Nederland. Beertema first became a Board member there and actively participated in organizing EU.net, later he was appointed special advisor. His insight and hard work yielded him a royal honour 'Ridder in de Orde van de Nederlandse Leeuw' in 1999.

## 6 To increase public interest in mathematics and computer science

*The popularity of computer science and especially mathematics has decreased over the last years. Universities are facing declining enrolments at the mathematics and computer science faculties, although there is some improvement. This will undoubtedly have great consequences for the pool of potential CWI academics. CWI therefore not only spreads its results in the scientific community, but it also communicates about mathematics and computer science with the general public.*

### Teacher course

In collaboration with the Netherlands Association of Mathematics Teachers CWI organizes an annual summer course for mathematics teachers from the Netherlands and Flanders (Belgium). In 2004 the subject was *Structuur in schoonheid* (Structure in beauty).



Turkish Rozet Patterns

### Bessensap

At the NWO event Bessensap, which aims at improving the popularization of science, a CWI researcher - Paul Klint - won a prize for the best popular presentation in a masterclass.

### Working Group Mathematics and Industry

For the Dutch Study Group Mathematics and Industry CWI publishes its proceedings. It also popularizes the scientific reports.

### CWI in the media

As the media play an important role as intermediary between scientists and the general public CWI produced more press releases and increased contacts with science journalists.

### Open day

On October 23, CWI was open for a general audience during the annual National Science Week. Hundreds of visitors enjoyed themselves exploring science.

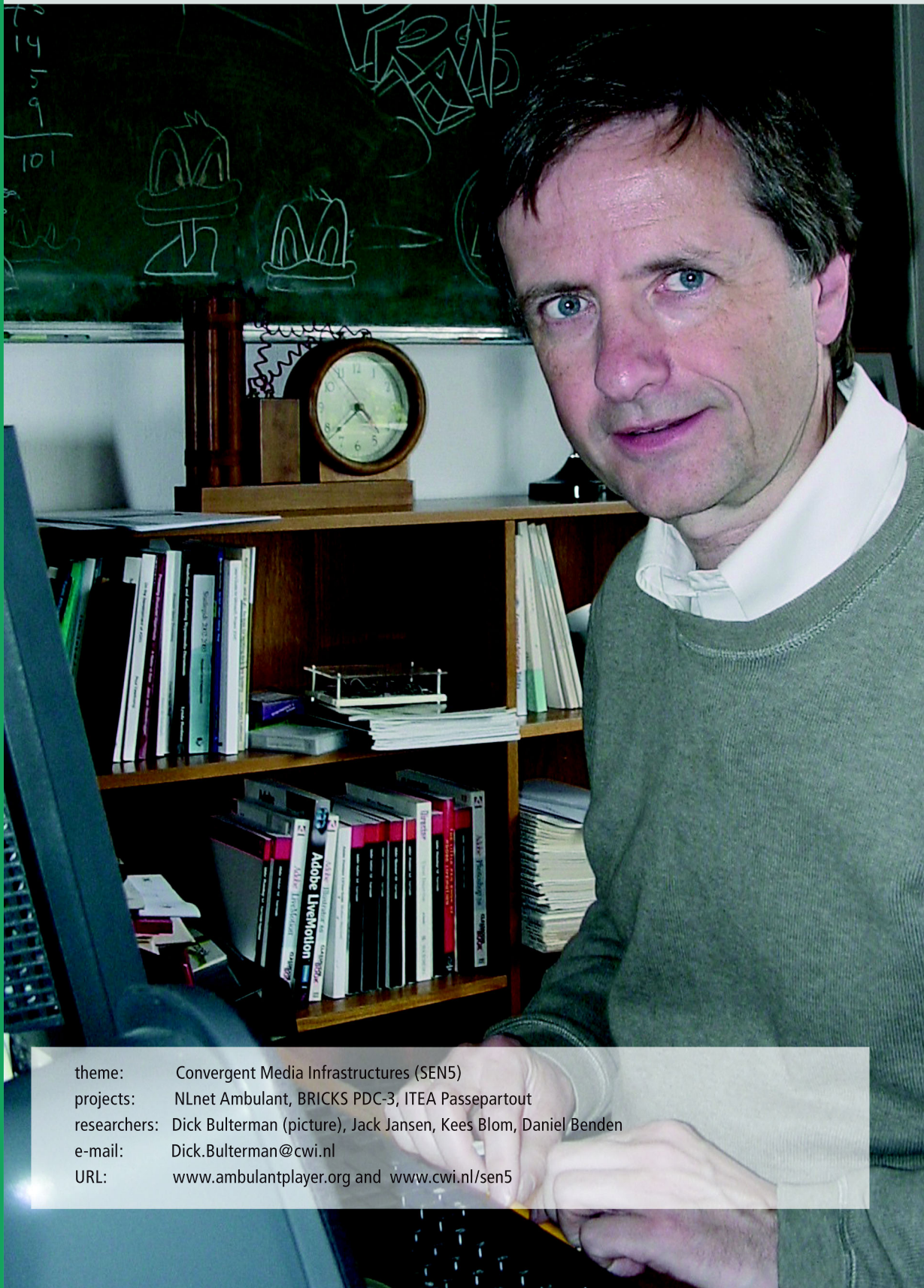


Open day, children exploring InternetLab

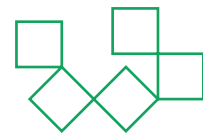




# Research Highlights



theme: Convergent Media Infrastructures (SEN5)  
projects: NLnet Ambulant, BRICKS PDC-3, ITEA Passepartout  
researchers: Dick Bulterman (picture), Jack Jansen, Kees Blom, Daniel Benden  
e-mail: Dick.Bulterman@cwi.nl  
URL: [www.ambulantplayer.org](http://www.ambulantplayer.org) and [www.cwi.nl/sen5](http://www.cwi.nl/sen5)

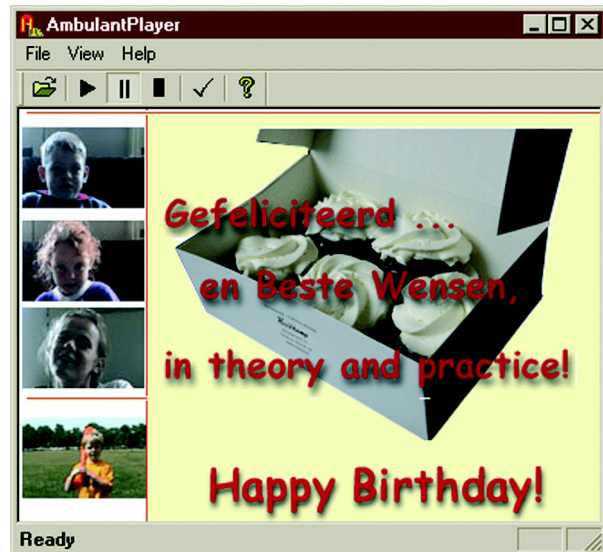


## Mobile SMIL brings multimedia together

A single mobile multimedia presentation actually consists of multiple streams of visual, audio and text information. Storing and handling these streams separately can make multimedia much more attractive for consumers and producers because each of the information sets can be customized to the needs of the user. The SMIL multimedia language, which originated at CWI, is an excellent tool for coordinating multi-stream multimedia. CWI researchers are heavily involved in the development of Mobile SMIL 2.1 and are developing the necessary software infrastructure and authoring tools to support mobile presentations.

People usually treat mobile multimedia presentations, such as movies or slide shows, much in the same way as 'old-fashioned' reels of film. Image, sound and text are all collected on the same distribution site and set out together. If you want to see a minute of moving images, it is always accompanied by a minute of audio and a minute of subtitles.

However, multi-server multimedia enables an alternative perspective. A movie can also be seen as composed of multiple streams of images, audio and subtitles. Separating these streams has several advantages for both producers and consumers of multimedia presentations. Movie DVDs provide an excellent example of the potential of this idea. Unlike on videotapes, subtitles are stored separately on DVDs. This allows studios to serve a worldwide audience with a single disc, instead of having to press separate editions for different countries. Unlike the DVD example, separate streams can also be stored on different physical locations like multiple media servers.



*This application demonstrates the use of DVD-like menu selection in a streaming media presentation. There are many open issues for authoring and verifying these types of applications.*

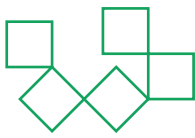
### Mobile availability

The advent of handheld multimedia devices like PDAs and mobile phones provides another application area. As these devices have limited graphical capabilities and low bandwidth connections, they cannot play a high-bandwidth news item suitable for notebooks and desktop computers. But if the high bandwidth presentation consists of separate streams, it is possible to reuse some of them in a presentation tailor-made for handheld devices. The low-bandwidth version of the item could for example show a slide show of screen shots instead of moving images, but it could retain the audio stream



*These two illustrations show different versions of a single newscast, both of which are encoded in a single presentation. In the left image, the space on the desktop is used to create interactive menus and support large video displays with optional captions. In the right illustration, the same presentation – now formatted for a mobile device – is shown. Here, individual menus are replaced with area menus and inter- and intra-menu navigation.*





of the high-quality version. In this way multimedia producers can efficiently make their content available to a wide range of platforms.

Another development that can benefit from the separate multimedia streams is content enrichment. Consumer electronics manufacturers expect that people will want to personalize their multimedia collections, for example by making personal selections and adding annotations. But since not everybody in the family is interested in the other's comments on the snapshots from last year's holiday, it is much more efficient to store the original content and the added annotations in separate locations.

## SMIL

Although these technological developments are stimulating the separation of multimedia streams, the idea is not new. CWI has more than ten years of experience in research on the composition of presentations from separate multimedia items. Research on the CWI Multimedia Interchange Format (CMIF) formed the basis for the Synchronized Multimedia Integration Language (SMIL, pronounced as 'smile'). SMIL is the W3C standard for composing multimedia presentations. First released in 1997, it has been included in all important media players, such as Apple's QuickTime, the RealNetworks' Realplayer and MMS players on mobile phones. The newest mobile version of SMIL will be released in the fall of 2005.

Much in the same way as HTML allows content providers to design a layout for a website, SMIL allows them to format a presentation. But where HTML cannot handle timing issues like the synchronization of audio and video signals or creating a montage of different media items, SMIL is specifically designed for these tasks. The language captures the framework of a presentation, which contains information on what multimedia item must be shown when and where. It also contains pointers to the location where the items are stored.

## Software infrastructure

With these attributes SMIL is very well suited to form the basis of content enrichment and platform-dependent multimedia. But a presentation framework alone is not sufficient. Relevant, easy-to-use authoring systems are required to set up presentations as well as a software infrastructure to deliver and coordinate the separate streams. To address these problems, CWI

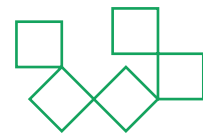


*This presentation is a prototype electronic patient record. The patient in this case is a race horse, who has undergone an operation on one of its legs. Using gestures and digital ink, a medical expert (or even the owner) can take fragments of the presentation and add domain-specific comments interactively. These can then be shared in a protected manner among different classes of users of the information.*

established the pilot theme Convergent Media Infrastructures (SEN5).

Authoring systems are crucial for the spread of SMIL-based content enrichment. Without relevant applications and accessible user interfaces, SMIL will remain the domain of experienced developers. Digital medical files are one of the possible applications where content enrichment possesses added value. Researchers from SEN5 are working on the Ambulant Annotator tool to compile multimedia patient files with a tablet PC. Physicians can enrich a file with new text, images and movies. They can also add spoken or written annotations or highlight specific areas of interest in the multimedia items. These features make it possible to easily share patient data and ask colleagues for their opinion without having to refer the patient.

Recently SEN5 started another project on content enrichment. In cooperation with Philips and other partners in the Passepartout consortium, the theme is working on so-called transparent authoring systems for home entertainment applications. This allows users to make and annotate compilations of multimedia items on their home server without giving them the idea that they are actually programming a SMIL presentation.



## Ambulant player

These applications will also play an important role in SEN5's second line of research. They serve as test cases for the study of the software infrastructure necessary for managing and delivering multimedia over a network. The streams must be synchronized, buffered to ensure continuous playback and sufficient bandwidth must be assigned on the network. Furthermore, specific applications can make additional demands. For example, video streams are often transmitted by first sending the first frame and subsequently the difference between that frame and the next to save bandwidth. However, this scheme gives a problem if you want to offer a rewind function, for example when a user wants to play a movie from a home media server.

The first result of the pilot theme's research is the Ambulant Player. Ambulant is the first open source

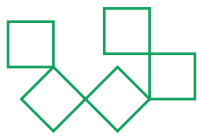
player offering full support of the latest Mobile SMIL version. It runs on a wide range of operating systems and platforms including PDAs and tablet PCs. Since its first release in September 2003, the Ambulant Player has been downloaded by more than 10,000 users. Several universities have already adopted it. The Japanese Society for Rehabilitation of Persons with Disabilities plans to include the player in a project studying earthquake and flood warning systems for the deaf and blind.

The overall goal of SEN5 research is to study the content creation, distribution and consumption patterns for both professional and home users in a convergent environment. The language and authoring applications described in this section provide an overview of the initial results of the pilot project.



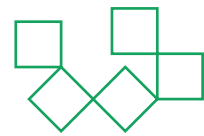
*In a worldwide web of users, information is rarely constant. Often, individual content streams need to be adapted to the needs of various communities. In this example, we see how a user's guide for a flashlight – which is called a 'torch' in the UK – can be tailored from within a SMIL presentation. Delivering the 'right' content requires sophisticated infrastructure models and flexible authoring tools; these areas are among the principal research thrusts of this theme.*





theme: Signals and Images (PNA4)  
projects: EUROPHLUKES, PHOTO-ID  
researchers: Mark Huiskes (left), Eric Pauwels (right, coordinator), Elena Ranguelova (middle) and  
Adri Steenbeek (not in this picture)  
e-mail: Eric.Pauwels@cwi.nl  
URL: <http://homepages.cwi.nl/~ely/projects.htm>





## Computer recognizes whale tails

How many whales are there in the ocean and how do they migrate? To answer these questions it is important to identify individual animals. Until now, biologists tried to search by hand through vast amounts of photographs. In the European EUROPHLUKES project that ended in 2004, CWI researchers developed a method for semi-automatic pattern recognition of whale tails and dorsal fins. This is a first step towards automatic photo-identification of individual animals.

### Stock management

Governments and organizations such as the International Whaling Commission want to know more about the whale population in order to protect biodiversity and to make informed choices about possible hunting within certain limits. Using parameters such as the number and age of female animals, scientists can estimate mathematically how the population will evolve. Identification is an important tool to collect these data for stock management. One of the most convenient ways is photo-identification. It is less intrusive than harpooning whales for a sample of DNA and it is more extensive because of potentially large collections of photographs from biologists, sailors and tourists.



In 2001 the EUROPHLUKES project started, a European network to develop a PHOTO-ID system and database for cetaceans – whales, dolphins and porpoises. The objective is to know if a cetacean was already photographed, and if so, where and when. The network comprises more than forty partners and participants, mostly marine biologists. It is coordinated by Leiden University and is funded by the Fifth Framework of the European Union. To deal with specific computer vision problems, researchers of CWI's Signals and Images group were invited to the team.

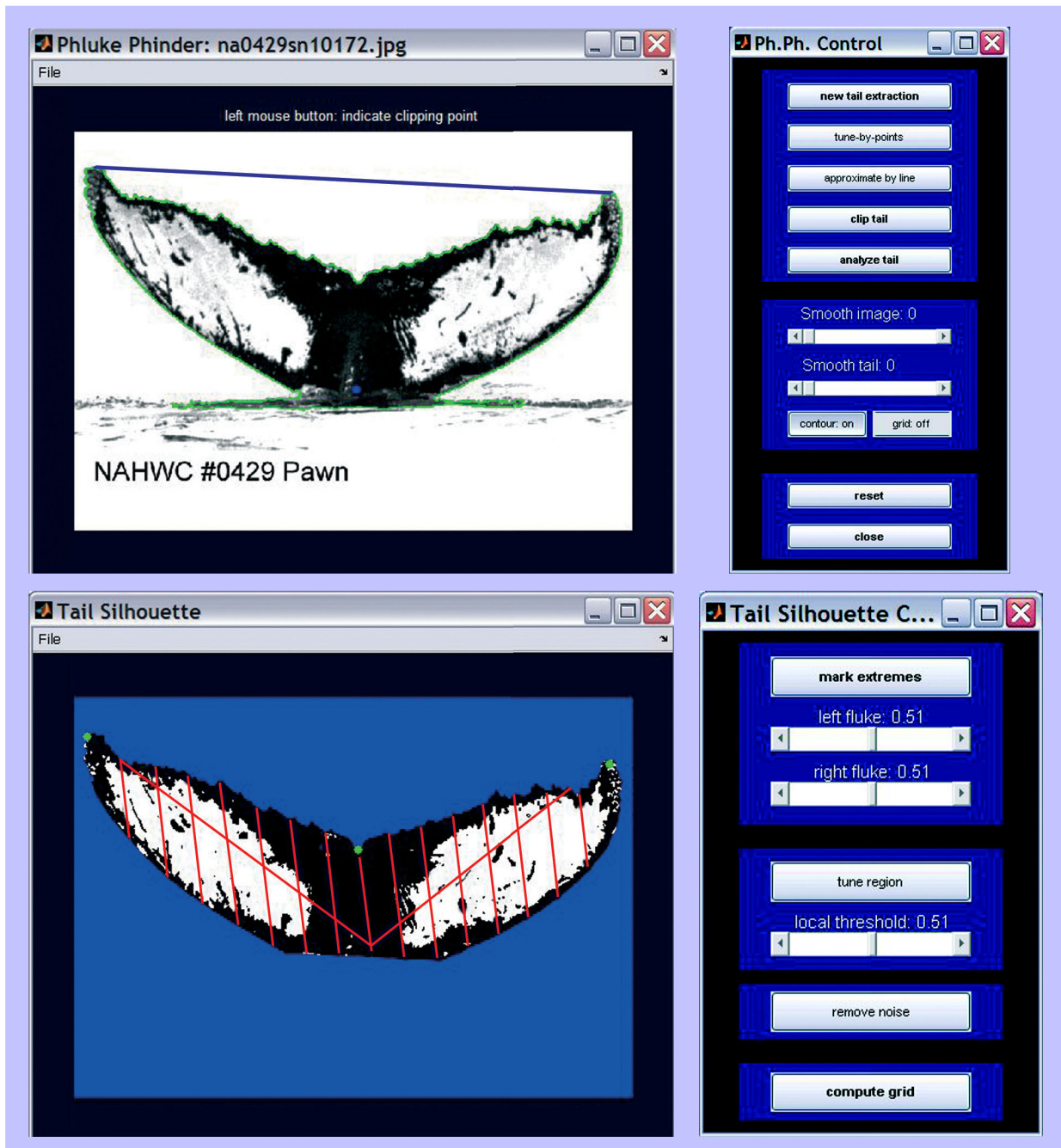
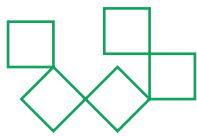
### Watershed method

Human beings can easily identify individual whales, due to the unique spots and scars on the animals' skin and the shape and indentations of their tails or dorsal fins. However, they can only compare a few pictures at a time, whereas photographic collections are growing rapidly. A computer on the other hand, can quickly compare thousands of pictures in databases but it has great difficulties in spotting similarities. For instance, a tail can look different when it is turned, waves can occlude specific marks and the picture quality can vary enormously. In a black and white picture it is not always easy to distinguish between tail and water and on top of that, a computer is not intelligent so it cannot immediately recognize the most important marks – it has to compare all features, big and small.

To recognize individual characteristics semi-automatically, CWI researchers combined and applied several mathematical techniques: image segmentation, contour and feature extraction and finally, comparison of these data with an image database. First, the grey-level of the image is represented as a three-dimensional picture: white is high, darker is lower. At the edge between sea and tail the difference in grey-scale will be large, or in other words, the gradient will be high. The picture of this gradient can be viewed as a 'topological surface': It has mountains, plains and valleys. In the so-called watershed method, virtual water floods this surface. When the water is so high that two lakes in valleys are about to merge, a virtual watershed is placed. This procedure has been programmed in MATLAB, a technical computing language, allowing the computer to robustly identify regions of similar grey scales and thus extract the contours of the tail or dorsal fin.

### Spots and scars

To compare spots and scars on a tail photographed from nearby with one that is photographed from a larger distance or a different viewpoint, the researchers attach a virtual grid to the tail that is always the same, or in other words 'invariant under affine transformations'. This grid is used as a coordinate system. To define it, the user specifies three anatomical points in the tail: the middle notch of the fluke and its both tips. Assuming that the tail is not too flexible, parallelism and relative distances can be used to divide the

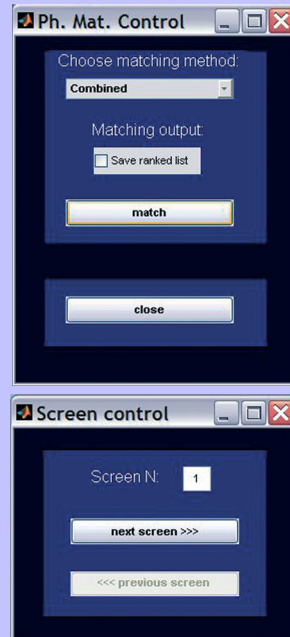
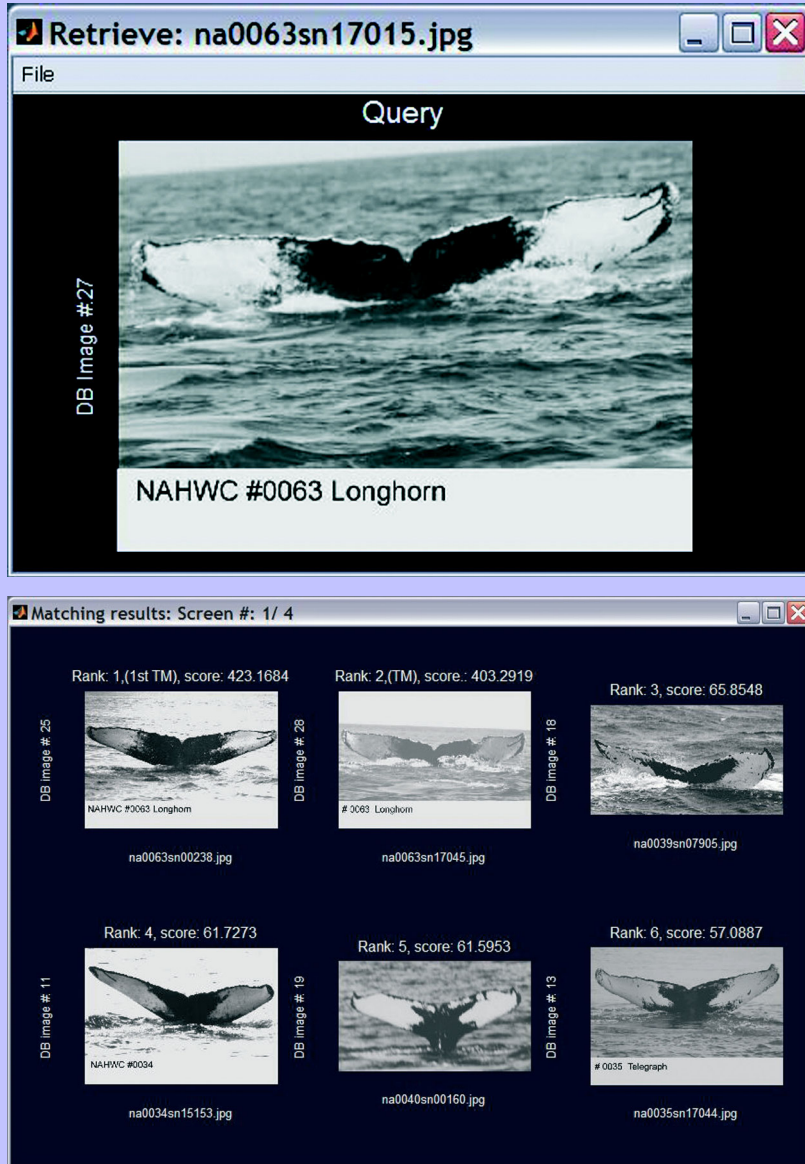
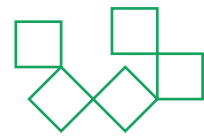


tail into a large number of small regions, for example thirty. The proportion of spots to background in each of these regions can then be represented in a 30-dimensional vector, which can be compared with other vectors in the database of identified animals.

The performance can be improved by combining the above feature vector with a more detailed mathematical description of specific, salient spots and scars on the animal. With morphological processing these marks can be found – both their centre of gravity with respect to the grid and a computed approximating el-

lipse. Using these data, the computer gives a top list of potential matches with pictures from the database. The user can then pick the actual match from this shortlist or confirm that there is no matching animal in the database. At the moment, the system has been tested on 340 images of 150 individual humpback whales. For 97% of the images the correct match was found within the top-50 and for 60% the correct match was found at the very first position. This method makes it possible to compare pictures with larger cetacean databases.





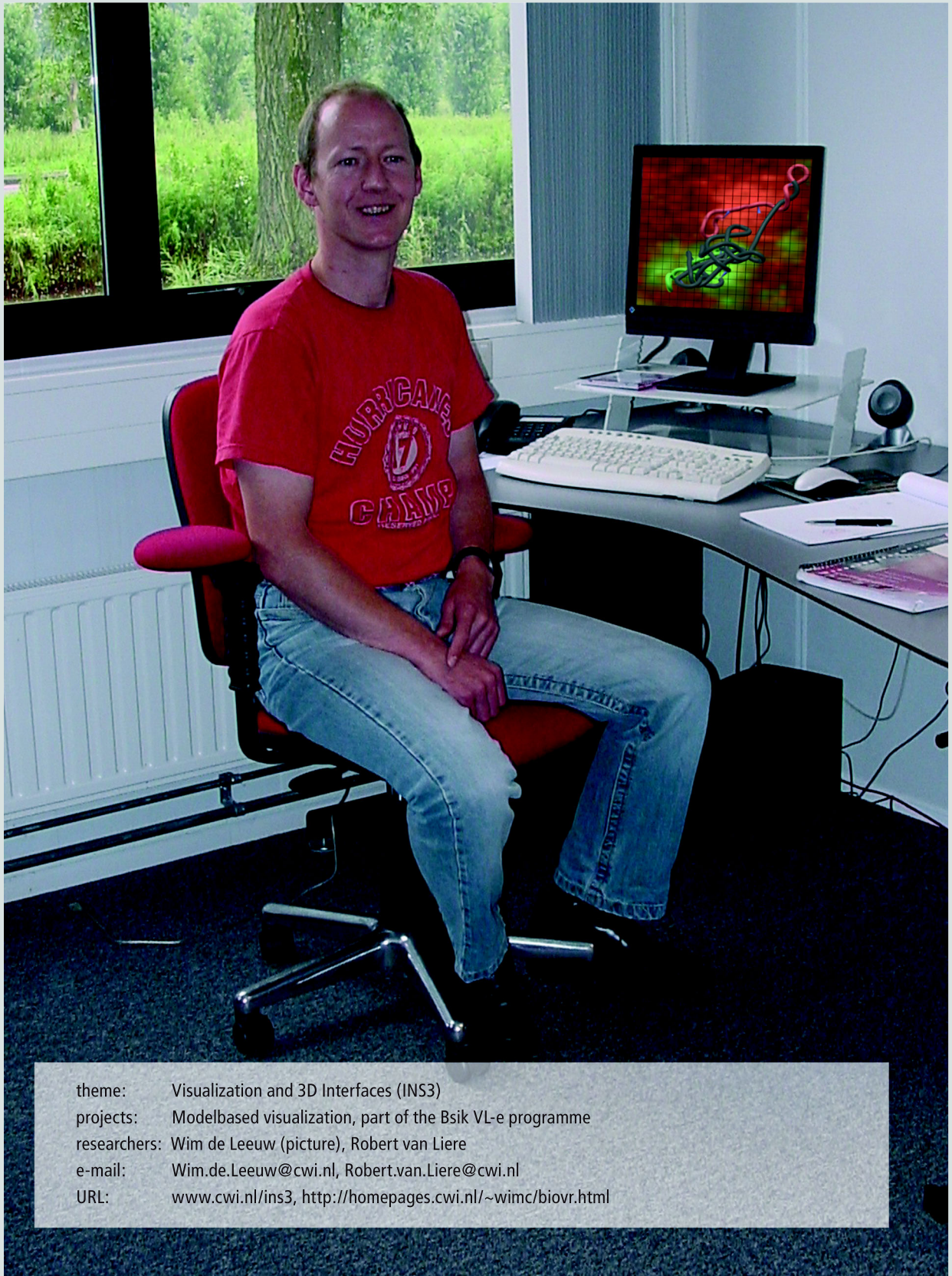
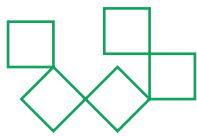
Left page: Individual whales can be identified by their markings. CWI's software system Phluke Phinder detects the shape of the tail and the location of its various spots.

*This page: Given the query image as input, the system automatically determines the most similar images and displays them for inspection by marine biologists.*

## Biometry

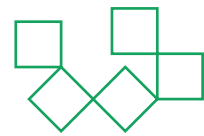
In the future, the group will combine the method to find spots on humpback whales with the method to recognize the tail shape of sperm whales. It hopes to extend the method to semi-automatic recognition of other animals, such as elephant recognition from the shape of their ears. The researchers will also try to recognize whales on satellite images, where the animals could easily be mistaken for an iceberg or a ship. This way, the group hopes to make additional contributions

to the important problem of photo-identification in biodiversity studies. Related activity within the group focuses on biometric technologies for human beings, such as face and iris recognition, fingerprints and hand geometry, especially for use in intelligent home environments.



theme: Visualization and 3D Interfaces (INS3)  
projects: Modelbased visualization, part of the Bsik VL-e programme  
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URL: www.cwi.nl/ins3, <http://homepages.cwi.nl/~wimc/biovr.html>





## Better algorithms for innovative life sciences

“Look”, computer scientist Wim de Leeuw points at his screen, “in this situation you want to know what actually has happened.” He shows beautifully colored 3D images of cellular structures while using the Argos System for interpretation of data. In this system, developed by CWI researchers De Leeuw and Robert van Liere in collaboration with the Swammerdam Institute of Life Sciences (Universiteit van Amsterdam), quantitative analysis and visualization techniques are combined. One of the applications is automated tumour detection in tissue samples, which now can be done faster and more reliable. Other applications can be found in biology. “My role”, De Leeuw says, “is to improve the visualization and analysis techniques by making the algorithms better. Then it will be easier for biologists to recognize what happened.”

With laser scanning confocal microscopy (LSCM) biologists scan fluorescently labelled specimen in three dimensions. The Argos system aims at the analysis of three dimensional volume data such as produced by LSCM microscopy. The system integrates quantitative analysis and visualization. Visualization is used to present extracted data as well as intermediate results. This enables close monitoring of the process. The analysis is based on the extraction of biologically relevant features from the data, using image processing techniques and attributes of these features such as size and roundness.

### Interactive inspection

The analysis of biological data poses specific demands on automatic processing. Noise due to the imaging process and biological variation necessitates the analysis of collections of data sets and the ability to closely track the process. The software allows the inspection of intermediate results. Interactive feedback allows the user to trace the results back to the raw data, for example to spot problems in the used feature filters or an anomaly in a particular nucleus.

“I am learning to observe as a biologist,” says De Leeuw, “at first we – mathematician and biologist – were sitting side by side behind the computer screen. Now I know where to focus on and how to present numbers. The biologists, on the other hand, want to know more and more: Why this structure, what happened, is there a relation, why is this part round and that part not, what is its size, – questions generate more questions.” A new development is, that the biologists can inspect the data in 3 dimensions using

stereo. With a head tracker and shutter glasses they can easily inspect an object from all sides, which is helpful in obtaining insight into complex spatial structures. For typical experiments tens of gigabytes of raw data are produced. During processing, relevant information with regard to the performed operations is stored for interactive inspection later on. Argos offers image processing, feature detection and quantitative information extraction tools for the analysis of large volume data collections integrated with visualization. Novel insights into the data can be gained.

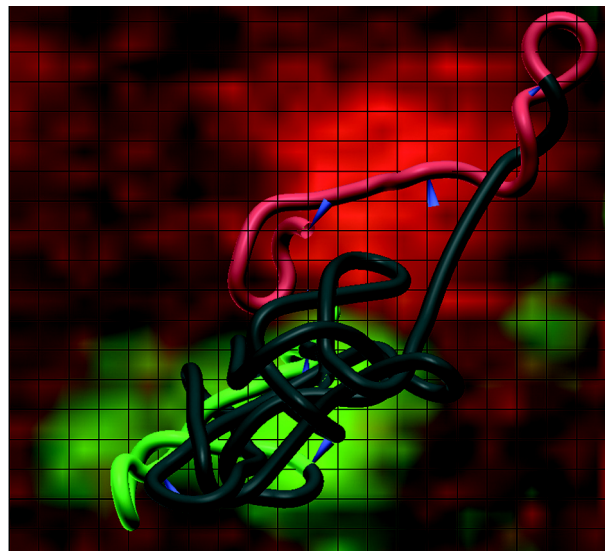
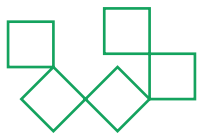


Fig.1 Visualization of a flexible fiber model satisfying position constraints of probe location superimposed on an image of LSCM data.

### Tumour detection

One of the applications of the system is the automated tumour detection in tissue samples. Yearly pathologists check several hundreds of thousands of tissue samples for tumours. Currently, the examination of these tissue samples is done manually, which is very difficult and complicated. The nuclei of malignant tumours can differ in various ways from the nuclei of benign tumours. “The structure of the nucleus, for instance, can be more or less granular and those grains have different dimensions and densities,” explains Wim de Leeuw. “Argos uses image-processing techniques to quantify these characteristics based on images of the nuclei from tissue samples. Pathologists can make much cheaper and more accurate diagnoses with these quantified characteristics than with images alone. Noise in images and natural differences between nuclei make a



correct diagnosis difficult. But the visualization possibilities of Argos make it possible to present various features of the investigated nuclei and to discriminate between healthy and sick cells.”

The Dutch company Podiceps will use the Argos technology for developing a new tumour detection method. Investment organization CWI Incubator participates in this spin-off. In July they signed an Agreement of Collaboration.

### Cellular structures

Another application in which the system is used is the quantitative analysis of scientific experiments to determine structural properties of spatial cellular structures such as chromatin. Subtle differences in structure can only be deduced by the study of a collection of microscopic images. Such experiments involve a large number of steps: filtering out the relevant features, detection of the features, calculation of attributes and

statistical analysis of these attributes. Combining these steps in a single system allows close control over the entire process and tracking of the effects the various steps have on the final result.

### Next step

The next step will be the building of geometric models of cellular structures, expects Wim de Leeuw. The concept is illustrated in figure 1. The use of models can serve the purpose of more effective visualization of the underlying data, the process can also be used the other way around. Fitting and visualization can be used to facilitate the testing of hypotheses with respect to the model. Comparing the model to the experimental data provides clues to adapt and improve the model.

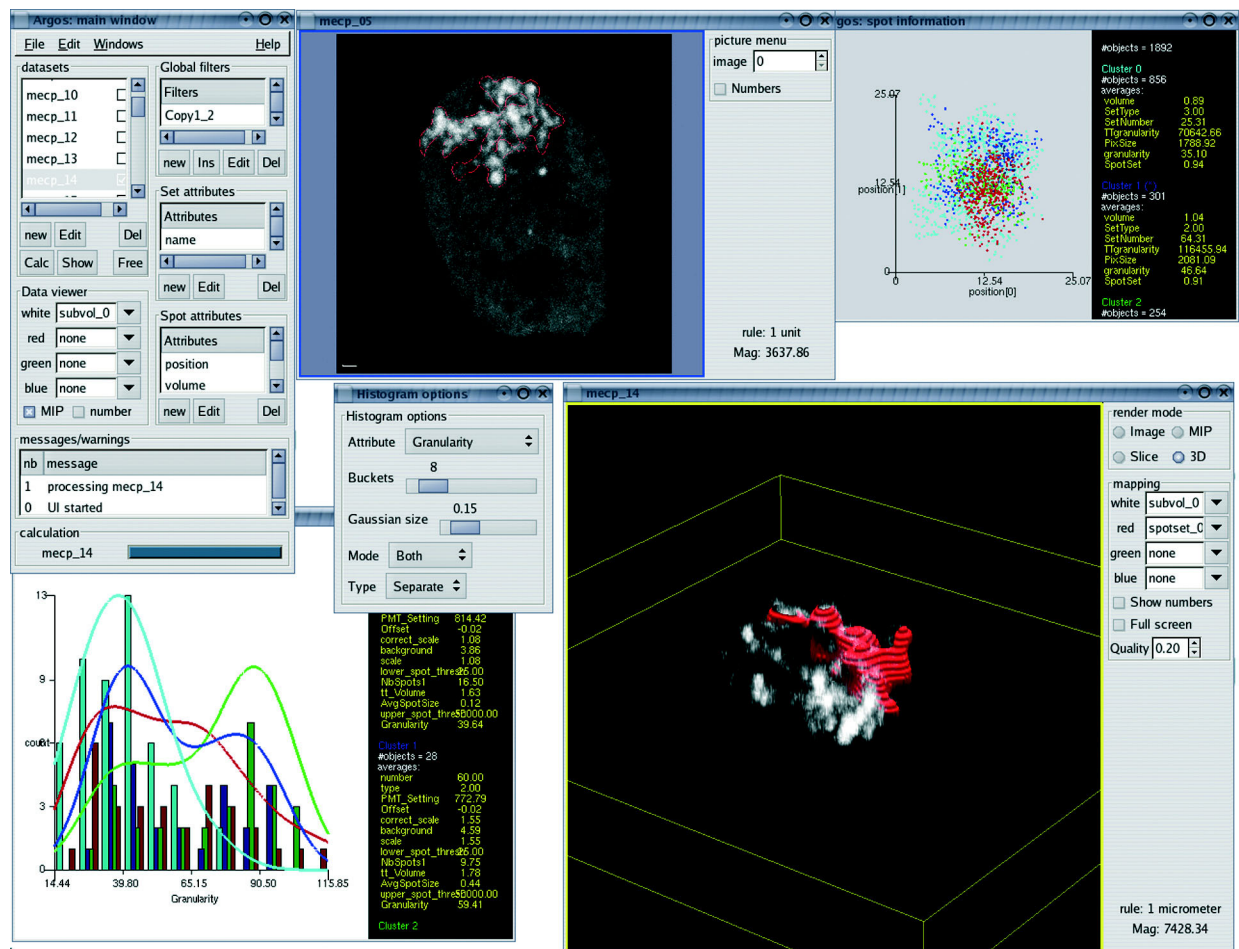


Fig.2 Screen shot of Argos illustrating various visualization possibilities in the analysis process. In the top middle window and the bottom right window two data sets are shown using projection and direct volume rendering. The scatter plot and histogram show attributes of features of the data set.



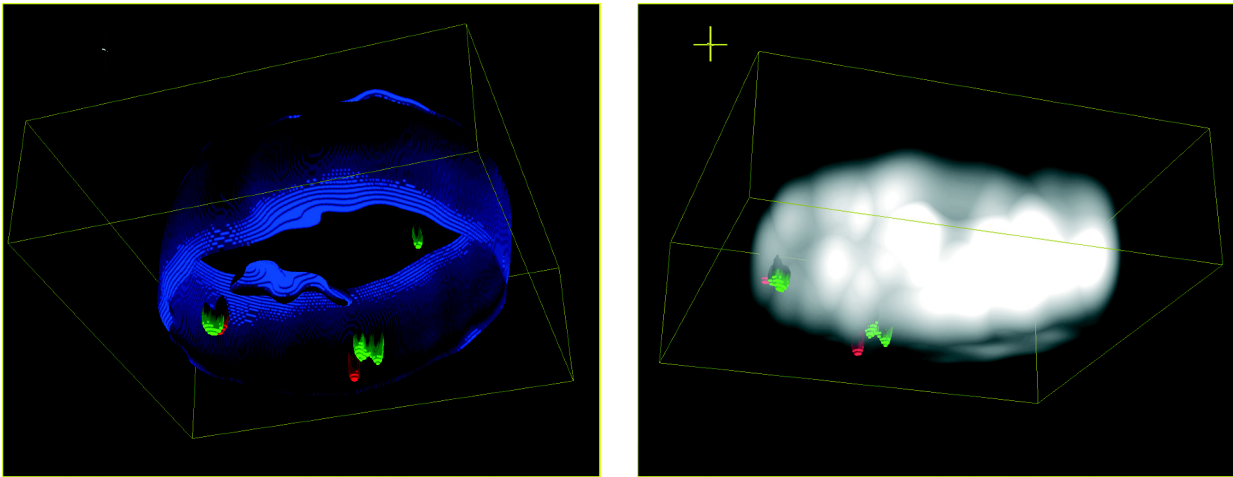
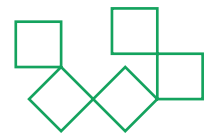


Fig.3 Three dimensional visualization techniques are used to show spatial information. Left: the features found in the data are shown using iso surfaces. Right: the features are combined with direct volume rendering to show volume data.

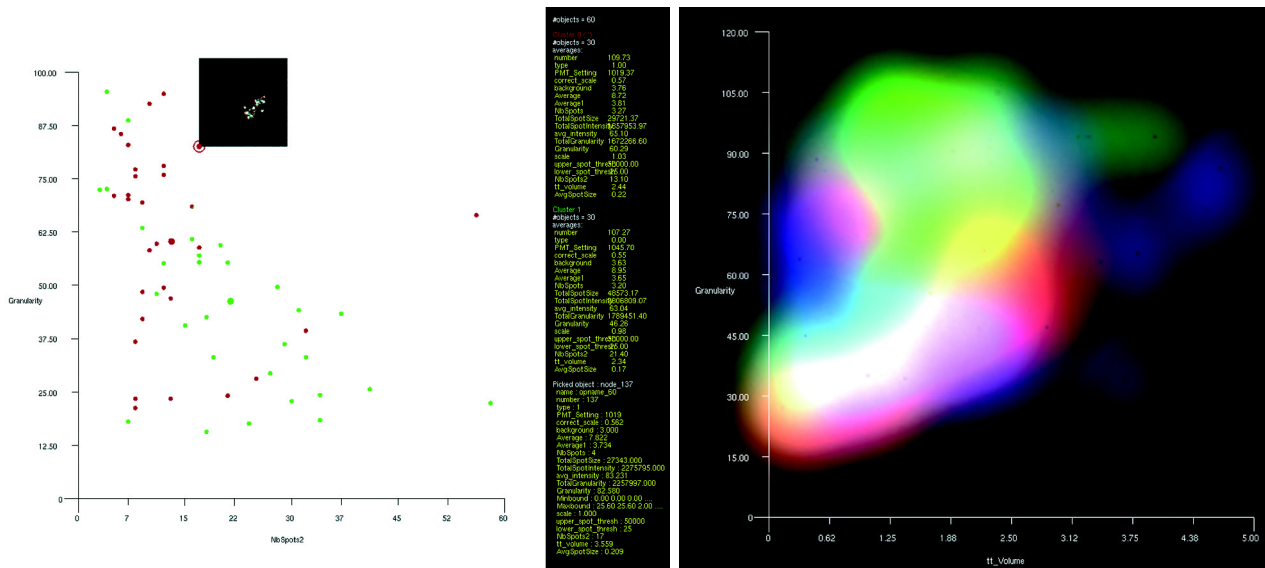
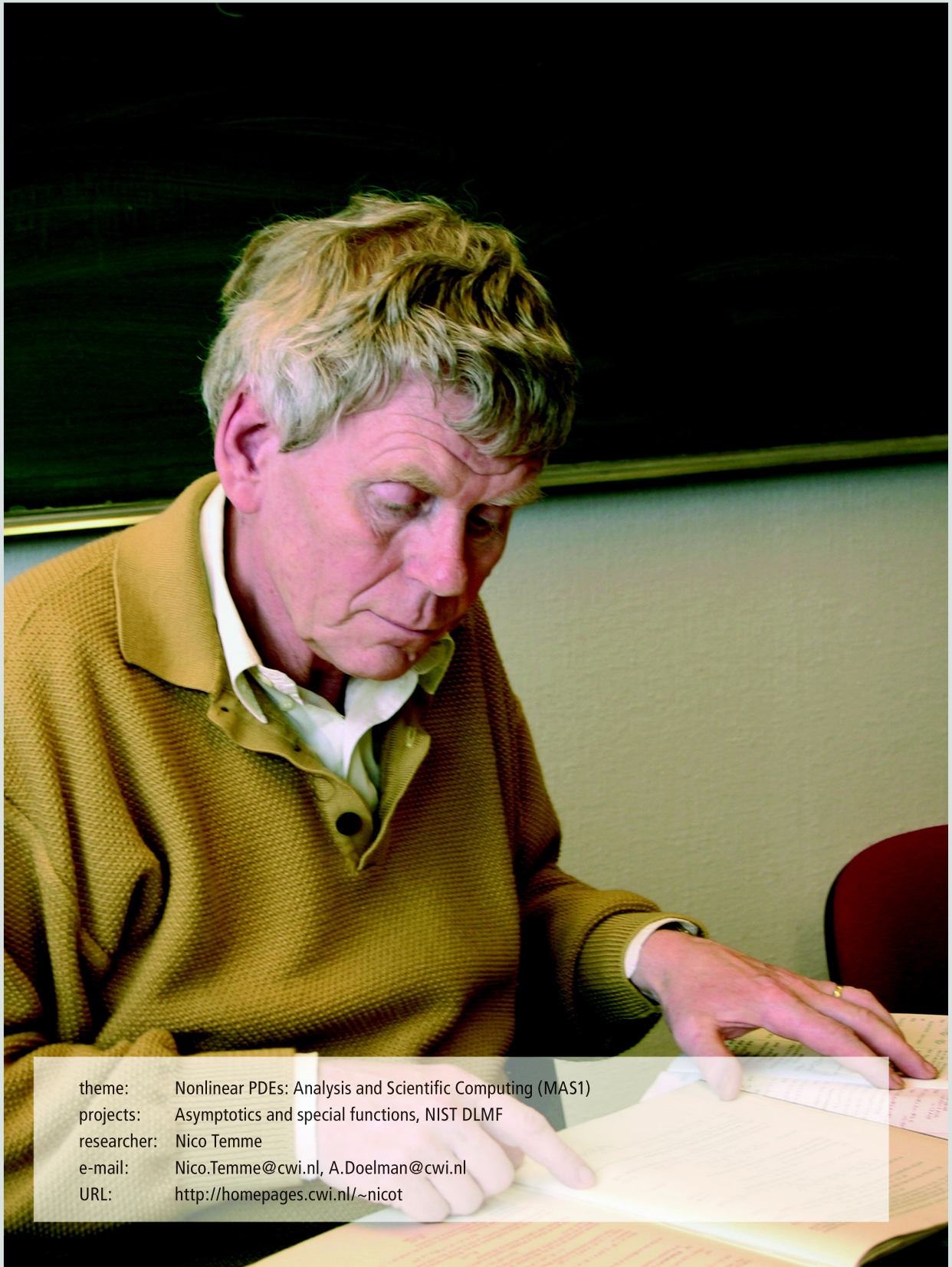
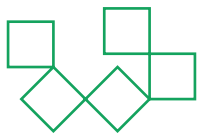
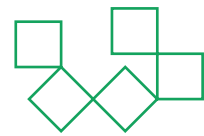


Fig.4 The right image shows a scatter plot of set attributes, colour shows the type of cell: control green or manipulated red. A thumbnail of an image indicates the selected data set. On the left splat maps are used to emphasize the distribution of attribute values for the different cell types.



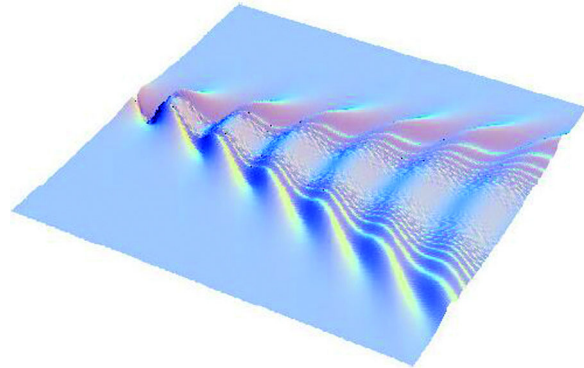
theme: Nonlinear PDEs: Analysis and Scientific Computing (MAS1)  
projects: Asymptotics and special functions, NIST DLMF  
researcher: Nico Temme  
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URL: <http://homepages.cwi.nl/~nicot>



## Complete face lift for popular mathematical handbook

The revision of one of the most cited mathematical handbooks – named after its editors of 1964 ‘Abramowitz & Stegun’ – is in full progress. CWI researcher and member of the editorial board Nico Temme marvels at the new approach which will result not only in an up to date handbook of mathematical functions, but first and for all in a digital database and a public website with many possibilities.

Every one and a half hour *The Handbook of Mathematical Functions* by Milton Abramowitz and Irene Stegun, is being cited in the Science Citation Index. Since its publishing in 1964 by the National Bureau of Standards (now National Institute of Standards and Technology - NIST) A&S, as it usually is called, is a best seller. More than 150,000 copies of the original edition and more than 500,000 of the cheaper commercial editions were sold. Mathematicians and scientists, using mathematics, use it as a standard reference book for complex formulas as it contains a large number of identities for special functions. From the very moment it appeared on the market, however, it was already out of date, because it covered mathematical functions as they were known until 1960. “But”, says Nico Temme, “developments around computer science started from 1960, and as we all know, since



*Kelvin's ship-wave pattern, an application of the Airy function*

1960 there have been numerous advances in the basic theory of mathematical functions and in domains of applications.” Temme should know: since the 1980s he is a high-ranking expert in Asymptotics and Special Functions. After his PhD thesis *Some aspects of applied analysis: asymptotics, special functions and their numerical computation* (1978) he continued his research in this area resulting in many papers and in the monographs *The calculation of special functions* (1984, with co-author Kees van der Laan), *Speciale functies in de mathematische*

### *Scientific context in 1964*

### *and in 2004*

- Only paper publications

- Publications on Web, CD-ROM, PDF, and paper

- Scientific computing in its infancy, unknown to most mathematicians

- Numerical libraries in C and Fortran making tables obsolete

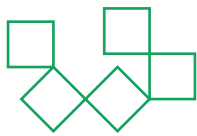
- Numerical tables of function values (e.g., logarithms) useful

- New branches of applied mathematics like wavelets, fractals, splines

- Figures drawn by primitive plotters or mechanical tools

- Mathematics presentation with TeX, MathML, Maple, Mathematica
- Visualization tools like VRML, SVG





*physica* (1990), *Special Functions, An Introduction to the Classical Functions of Mathematical Physics* (1996).

## Digital Library

About ten years ago NIST decided it was time to develop a successor of A&S. And from the beginning it was clear that NIST did not want the same structure – that of a static reference book. Temme: “One recognized the information needs of modern users, that simply ask for a computerized environment. So the new A&S should be designed in the form of a knowledge base – the Digital Library of Mathematical Functions (DLMF).”

An Editorial Board was installed, consisting of four members: Dan Lozier (general), Frank Olver (mathematics), Charles Clark (physics), and Ron Boisvert



The Editorial Board with Nico Temme (standing, second from left) and Richard Askey (standing, fourth from left)

(computer science), assisted by nine Associate Editors, amongst them Nico Temme and Richard Askey to cover Special Functions.

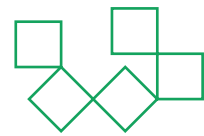
“We decided,” recalls Nico Temme, “to continue the general contents of the Handbook, but to skip the vast collection of tables, and to add new subjects and new chapters, for example on methodology. The website should contain the complete Handbook in which we provide verified mathematical formulas, examples for applications and methods for computations. Per chapter we deal with functions. New chapters on methodology are about *Asymptotic Approximations*, *Computer Algebra*, and *Integrals with Coalescing Saddles*. As new subjects we added amongst others *Generalized and  $q$ -Hypergeometric Functions*, *Hill’s Equation* and *Painlevé Transcendents*.”

Nico Temme has written three of the forty chapters of the revised Handbook. It will be produced by NIST in paper, illustrated with colour graphics and sold for

a reasonable price by a commercial publisher. The website will not only provide the handbook text, but also software references and downloading possibilities, a search engine, dynamic and interactive graphics, and downloadable formulas. The project will be finished in 2005/2006.

The users are expected to be experienced scientific professionals, mainly physicists, mathematicians and other scientists, but also engineers, and teachers. For them it is important that they can be sure, that all mathematics has been validated. The users have free access to the website and to all the documents, which can be produced either on paper or as CDs or DVDs. NIST will maintain the website.

As Nico Temme will retire in 2005, working at the Digital Library of Mathematical Functions is one of his last scientific productions – one of his crown jewels.



## The Handbook of Mathematical Functions: old and new

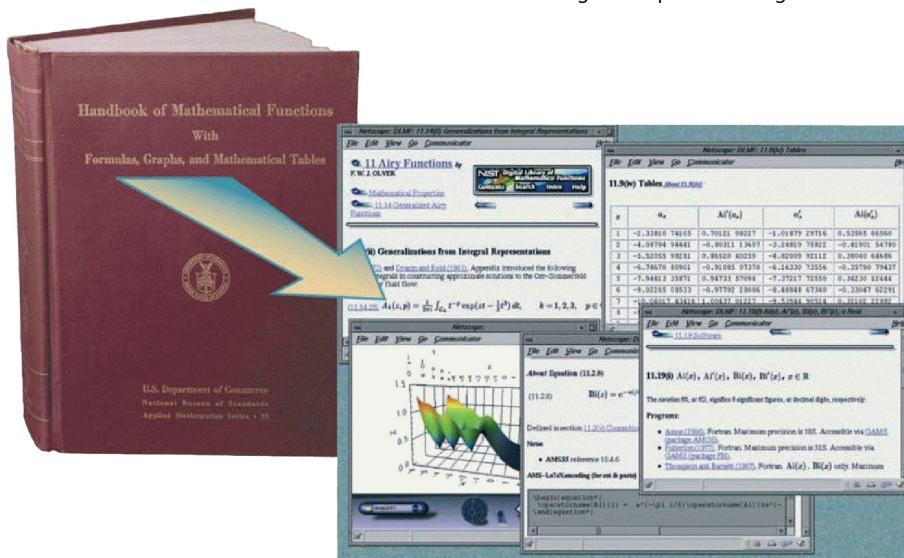
1964 2004

Handbook of Mathematical Functions

- ◆ Hardbound and paperback of 1045 pages
- ◆ Plethora of formulas
- ◆ Numerical tables of function values, constants like  $e$  and  $\pi$ , prime numbers, occupy about 50% of the pages

Digital Library of Mathematical Functions and Handbook

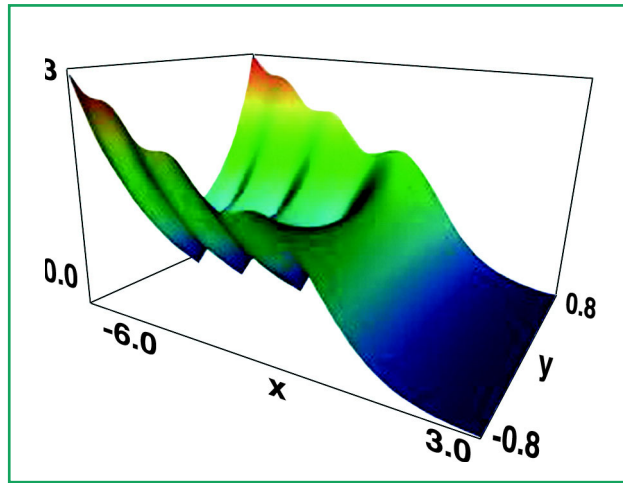
- ◆ Verified and validated formulas, sometimes references to proofs
- ◆ Applications
- ◆ References to algorithms and software without validation
- ◆ Methodology chapters
- ◆ References, web indices
- ◆ 3D animating colour pictures using VRML



1964  
Presentation of the Airy functions  
Formulas (page 446, 10.4.2-10.4.4)

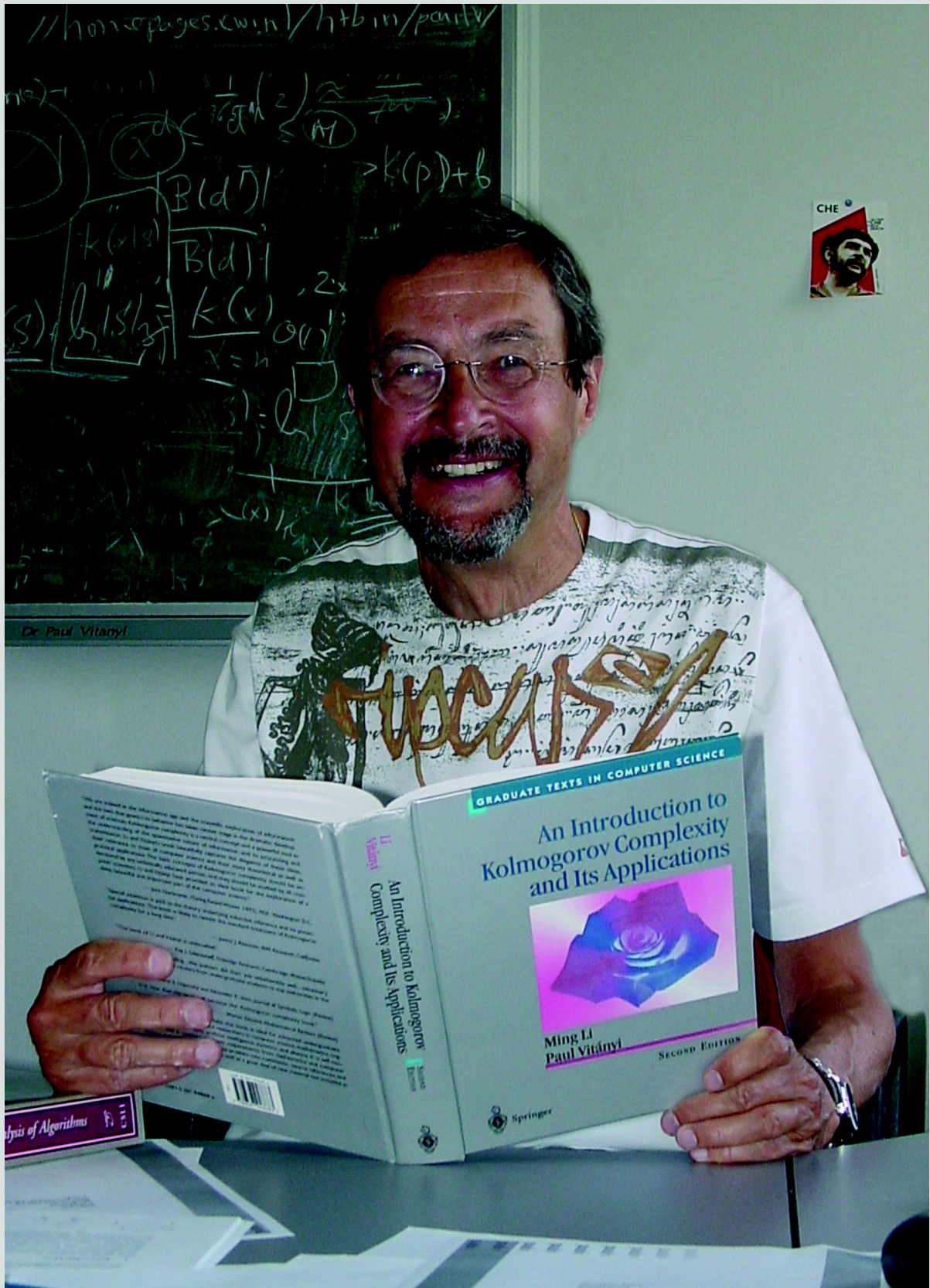
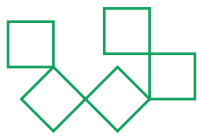
Now  
Formulas as left and 3D pictures

$$\begin{aligned}
 Ai(z) &= c_1 f(z) - c_2 g(z), \\
 Bi(z) &= \sqrt{3}[c_1 f(z) + c_2 g(z)], \\
 f(z) &= \sum_{k=0}^{\infty} 3^k \left(\frac{1}{3}\right)_k \frac{z^{3k}}{(3k)!} \\
 g(z) &= \sum_{k=0}^{\infty} 3^k \left(\frac{2}{3}\right)_k \frac{z^{3k+1}}{(3k+1)!} \\
 c_1 &= 3^{-2/3} / \Gamma(1/3), \\
 c_2 &= 3^{-1/3} / \Gamma(1/3)
 \end{aligned}$$

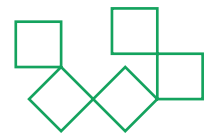


The absolute value of the Airy function in the complex plane









## CWI Fellow Paul Vitányi – forever curious

Some researchers continuously head for new directions. Other researchers sink their teeth into a subject and never let go. And then there are a few who do both. Paul Vitányi (1944), CWI Fellow and professor of theoretic computer science at the Universiteit van Amsterdam, falls into the last category.

“Paul always draws from the source and reverts to the originators.” That is how Jan van Leeuwen, professor of computer science at Utrecht University, describes the methods of his colleague. “He is someone who really studies a subject in depth. But he also has a very broad outlook and is always interested in how that subject is applied in other contexts.” Van Leeuwen’s characterization is supported by the wide range of subjects on Vitányi’s publication list. When he joined CWI in 1971, to work on his PhD research, after turning down a position at Berkeley because of his then girlfriend, Vitányi was studying Lindenmayer systems, models of organic growth studied with formal language theory. But soon his work diverged to many other aspects of theoretical computer science: algorithms and complexity theory, distributed computing, physics of computation, machine learning and Kolmogorov complexity.

### Kolmogorov complexity

Together with Ming Li from Waterloo University in Canada Vitányi published the best-selling book *An Introduction to Kolmogorov Complexity and Its Applications* in 1993. Until then all information on Kolmogorov complexity and its uses were scattered over various publications, including some in Russian. Li and Vitányi were the first to collect this knowledge and present it as a unified whole. It is the field of science Vitányi is best known for. “Their book made the field known to a wide audience”, says Peter Gács, professor of computer science at Boston University and a renowned Kolmogorov complexity expert. “It presented a rather balanced view of its creation and applications, a welcome and strong counterweight to the one-sided view before it, via books by self-promoters.”

For Ray Solomonoff, one of the original developers of Kolmogorov complexity, the book also meant acknowledgement for his achievements. “Though I had published the basic idea of program length com-

plexity five years before Kolmogorov, this was not recognized by the scientific community until Li and Vitányi described the history of the discovery in their book.”

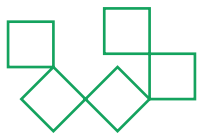
### New applications

Vitányi, however, is more than an anthologist. Gács: “Paul used Kolmogorov complexity to prove very difficult theoretical problems. He is also coming up with new ideas for applications of Kolmogorov complexity.” A recent example is the work he did together with CWI researchers Rudi Cilibrasi and Ronald de Wolf on a universal similarity measure. The method can be used to find relations in data, like similarities between composers, languages or DNA, without any a priori knowledge of the type of data investigated.

According to Gács, Vitányi serves as a central figure at the intersection of several communities working on Kolmogorov complexity. Jorma Rissanen, former researcher of IBM and professor emeritus at the Tampere University of Technology is a prominent member of one of those communities. In 1978 he introduced Minimum Description Length (MDL), a method to select a good statistical model to fit data, inspired by Kolmogorov complexity. “Paul’s research on algorithmic information theory has had a direct impact on my own work on MDL. His recent work with Vereshchagin on the Kolmogorov structure function (a further refinement of Kolmogorov complexity) has inspired me to develop my application of the structure function to probabilistic models. In fact, without it, I would never be able to do it.”

### Internationally prominent

Vitányi was no stranger to the theoretical informatics community before the publication of *Kolmogorov Complexity and Its Applications*. Together with a small group of researchers including Jan van Leeuwen and Peter van Emde Boas (now professor at the Universiteit van Amsterdam) Vitányi stood at the basis of Dutch algorithm and complexity research, an area covering the design and analysis of algorithms, in particular concerned with the difficulty in computation. Van Leeuwen recalls: “When I met Paul around 1970 Dutch computer science was focused on the semantics of programming languages and formal languages.



We were both part of a group of eager young researchers around Aristid Lindenmayer and Grzegorz Rosenberg studying Lindenmayer systems and other cellular automata. In the beginning we were working with techniques from formal languages, but we slowly moved to algorithms and complexity. It was a stimulating time, we all had the feeling we were doing something exciting.”

Van Leeuwen regards Vitányi as one of the leading complexity researchers in the Netherlands and a prominent figure internationally. “Paul has exceptional competence in this area. He solved quite a few fundamental problems that had remained open for years.”

### Ming Li

Inextricably linked with Vitányi is Ming Li. Not only did they write *Kolmogorov Complexity and Its Applications*, they worked together on more than 60 publications covering many areas. “I met Paul for the first time at the 1984 Symposium on the Theory of Computing in Chicago”, Li recalls. “We both had been working on the same theoretical problem and decided to meet at the conference. It turned out that we shared common interests and both believed that Kolmogorov complexity would be a major field of research and a source of a lot of applications in computer science. Since then we have been collaborating.”

### Quantum computing

Li also regards his colleague as a scientific leader. “Paul leads research directions and recognizes important directions to pursue.” According to Harry Buhrman, who succeeded Vitányi as leader of CWI’s Quantum Computing and Advanced Systems Research research group, it was Vitányi who saw the potential of quantum computing in an early stage. “In 1995 Paul invited quantum computing researcher André Berthiaume from the University of Montreal and later on Richard Cleve from the University of Calgary. Their visits sparked my interest in quantum computing.”

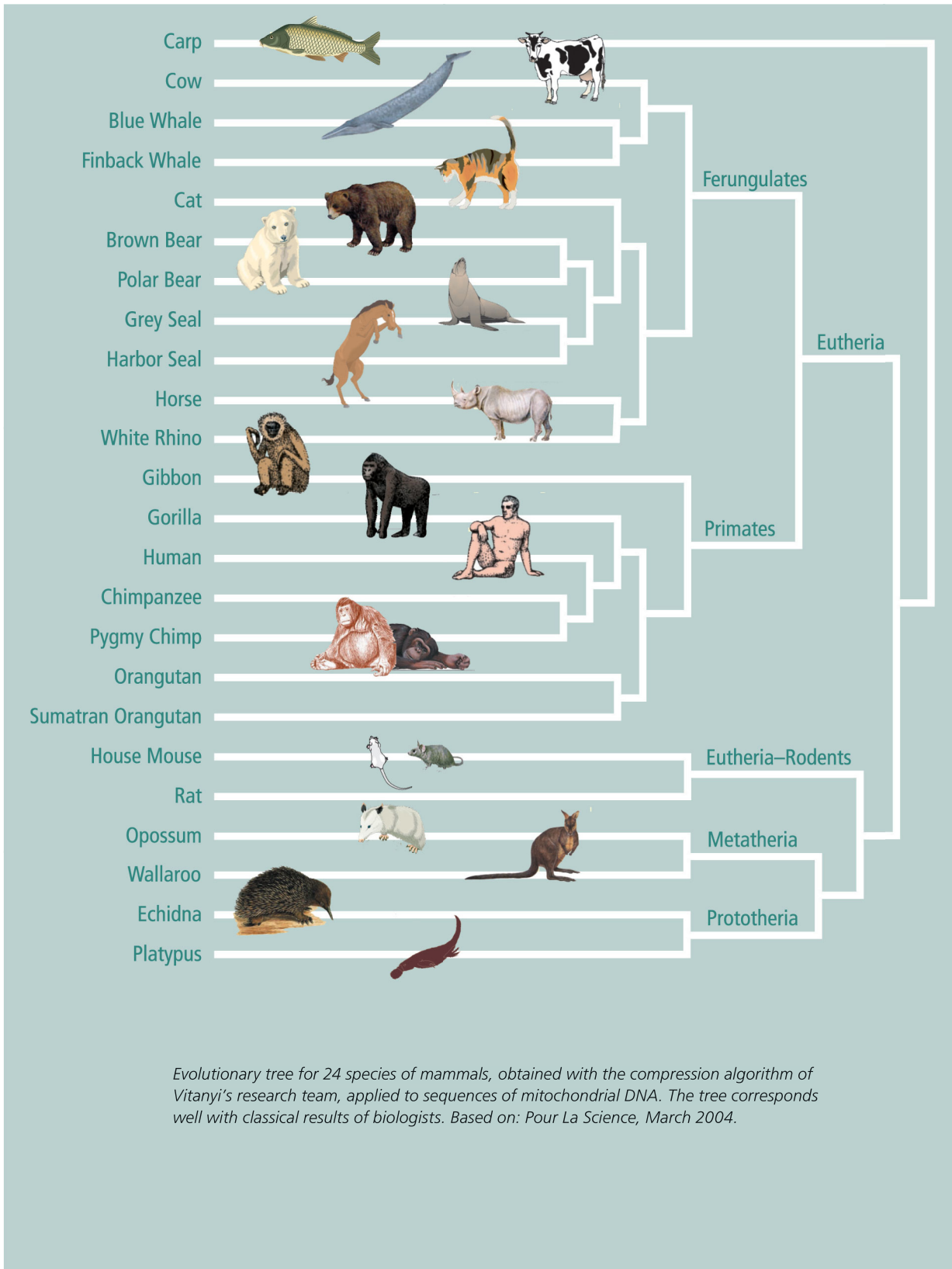
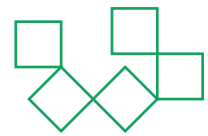
Throughout his career Vitányi has remained a researcher first and foremost. According to Van Leeuwen, who is currently dean of the faculty mathematics and computer science of Utrecht University, Vitányi is “not a person to waste his time in committees.” Even as a theme leader he did not fall out of this role. Buhrman: “Paul is interested in your work, but he keeps a distance. He gave me room to pursue my interest in quantum computing and build my own line

of research around it. For me this freedom worked out really well, but not everybody likes it.”

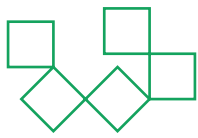
Vitányi’s colleagues and co-workers all speak highly of his wide, profound knowledge in other areas than theoretic computer science. Solomonoff: “I have been impressed with Paul’s curiosity and erudition in a great variety of fields like mathematics, the sciences and the arts.” Readers of *Kolmogorov Complexity and its Applications* can attest to that: scattered in the text are quotes from Newton, Archimedes, and the eighteenth century writer Samuel Johnson. Discussions with Vitányi on any topic are not easily won. As Li puts it: “Paul has a strong opinion on everything, and for good reasons.”

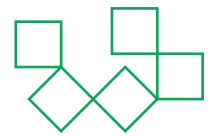
### *Kolmogorov complexity*

Kolmogorov complexity is a computer’s perspective of randomness. The Kolmogorov complexity of a data sequence is defined as the length of the shortest algorithm that can print that string. If the algorithm is much shorter than the sequence it produces, the data is not very complex. For example a sequence of ten thousand 1’s can be compressed with an algorithm like ‘print a 1 ten thousand times’. A random sequence of 1’s and 0’s on the other hand, cannot be printed in any other way than with a print command followed by the sequence itself. That string is of the same size as the algorithm that produces it and is therefore complex. This idea, developed by Ray Solomonoff, Andrei Kolmogorov and Gregory Chaitin (independently from each other) in the 1960s turned out to be very powerful. It can for example be used to solve fundamental problems in logic and statistics and it provides the basis of several machine-learning techniques.









## Young mathematician between animals and curling ropes

Young researcher Bob Planqué (1977) can be best characterized by his broad interests: from mathematics to biology, and from doing fundamental research to engaging the public in experiments. He just finished his PhD research on the mathematical description of rods on cylinders at CWI and started as a postdoc researcher on the description of the behaviour of ants in Bristol. CWI stimulated the young doctor's career in mathematics.

From his youth, Bob has always been fascinated by animals, especially birds. Yet after high school he started to study mathematics at Leiden University. "I had to choose between mathematics and biology. Mathematics was the harder subject, so I decided that, to learn it well, I had to study it properly," Bob says. In his last year he went to Bath as an Erasmus student, a programme subsidized by the European Union.

There he became fascinated by the mathematics of the behaviour of host birds against cuckoos, and in particular in the ways they might defend themselves from being exploited. Defence strategies are for example the removal of big eggs from their nest or the removal of any single young bird. Bob found mathematically that the costs of combining these strategies are higher than the benefits. He finished this research as a PhD student at CWI, with Mark Peletier - now working at the Technische Universiteit Eindhoven - as his supervisor.

Due to his broad interests, Planqué's next project was about ropes. "You can turn and twist them and they get all sorts of strange forms, almost stable situations. Look, if I twist this rope until it's heavily curled and when I move this funny configuration the form stills stays the same. But it's not the optimal one. Can we predict where the rope's contact points with itself will be and where the forces are transferred? These questions intrigued Mark and me."

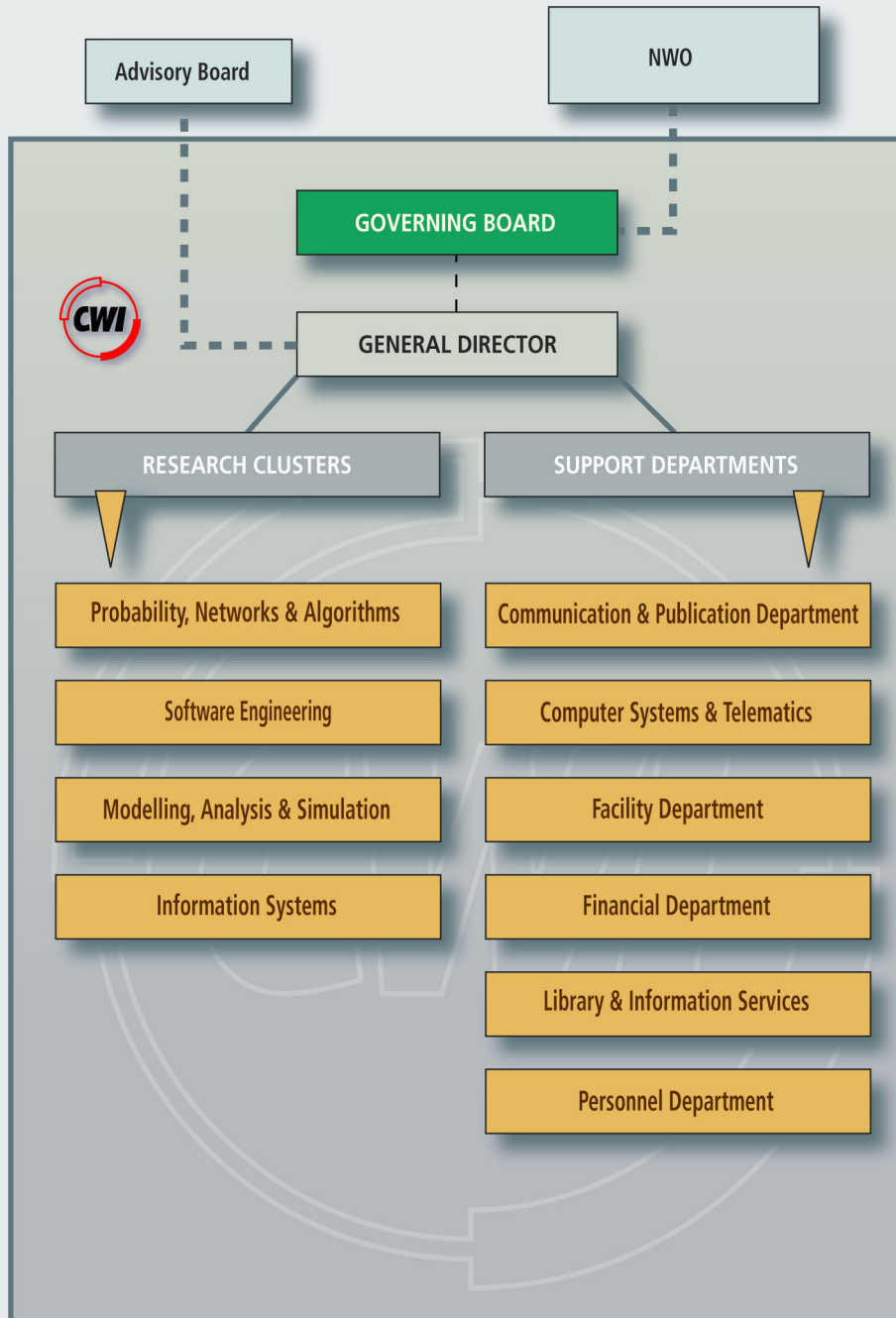
Analytically the curled rope with open ends is a very complex situation. Therefore, the researchers studied a special example of a curled rope: a rod on a cylinder. After much analysis at CWI it appeared that, although the rope lies next to itself along a long interval, the forces are only transferred in some special points. These and other results from Bob Planqué's PhD thesis might eventually be used for mathematical study of more complex situations, like the supercoiling of DNA.

CWI also accommodated one of Bob's other interests: to attract the public's attention to science. "I really love telling people how mathematics works and making them enthusiastic, mostly by letting them explore things themselves". It started with the Euro Diffusion project in 2002, in which people tried to monitor the spread of euro coins across Europe. Mathematical modelling on this problem was done at the Dutch Study Group Mathematics and Industry, an annual event that is amongst Planqué's favourite pastimes. He and Mark Peletier also organized public games like building strong paper packages on Science Days.



*Bob Planqué mathematically studied defence strategies against cuckoos*

However, animals kept drawing Planqué's attention. His next mathematical research project in Bristol is about ants. These animals solve many problems using collective behaviour. Although each ant has only limited information of its surroundings, as a whole the colony manages to efficiently use this to great effect. "It's just another one of those marvellous phenomena. The more and better I look, the more I find. That's what's keeping me in this business for some time to come," the young doctor in mathematics says.







## Organization

### Research

Cluster Theme	Cluster leader Theme leader
<b>Probability, Networks and Algorithms</b> Networks and Logic – Optimization and Programming Advanced Communication Networks Stochastics Signals and Images Cryptology and Information Security (pilot)	<b>A. Schrijver</b> A.M.H. Gerards M.R.H. Mandjes J. van den Berg H.J.A.M. Heijmans / E.J.E.M. Pauwels R.J.F. Cramer
<b>Software Engineering</b> Interactive Software Development and Renovation Specification and Analysis of Embedded Systems Coordination Languages Evolutionary Systems and Applied Algorithmics Convergent Media Infrastructures (pilot)	<b>P. Klint</b> P. Klint J.C. van de Pol J.J.M.M. Rutten J.A. La Poutré D.C.A. Bulterman
<b>Modelling, Analysis and Simulation</b> Nonlinear PDEs: Analysis and Scientific Computing Computing and Control Nonlinear Dynamics and Complex Systems	<b>J.G. Verwer</b> A. Doelman B. Koren U. Ebert
<b>Information Systems</b> Standardization and Knowledge Transfer Database Architectures and Information Access Multimedia and Human-Computer Interaction Visualization and 3D Interfaces Quantum Computing and Advanced Systems Research	<b>M.L. Kersten</b> M.L. Kersten M.L. Kersten L. Hardman R. van Liere H.M. Buhrman

### Management

#### Management Team

J.K. Lenstra (general director)  
 M.L. Kersten, P. Klint, A. Schrijver, J.G. Verwer (cluster leaders)  
 D.G.C. Broekhuis (controller)

#### Governing Board

P.W. Adriaans (University of Amsterdam), chairman  
 C.J. van Duijn (Technische Universiteit Eindhoven)  
 F.A. van der Duyn Schouten (Tilburg University)  
 M.H. Overmars (Utrecht University)  
 S.J.M. Roelofs (Nederland~ICT)

### Support

#### Communication & Publication Department

G.M.T. Nieuwendijk

#### Computer Systems & Telematics

I.L. Dijkstra

#### Facility Department

F.J.G. Goudsbloem

#### Financial Department

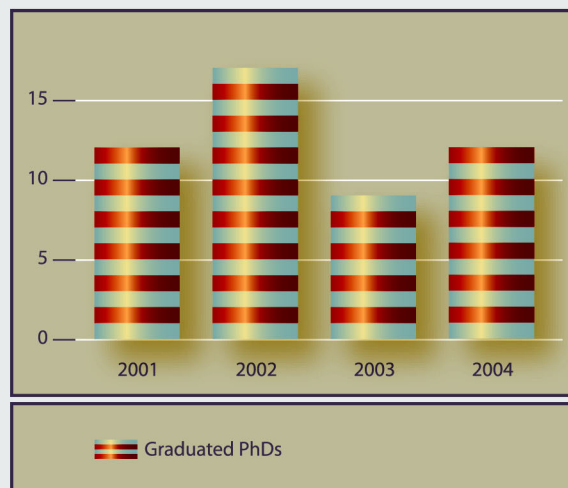
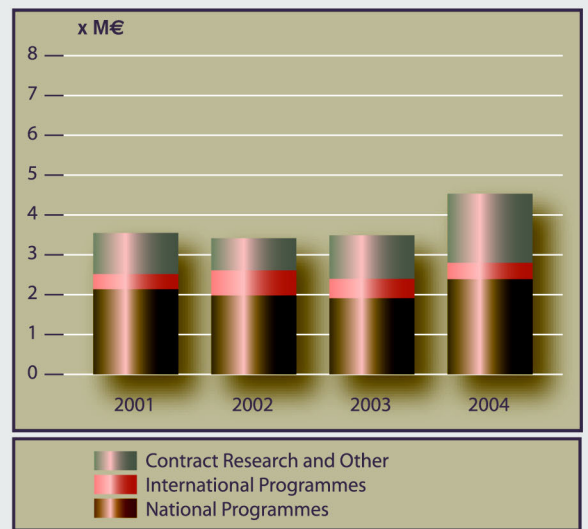
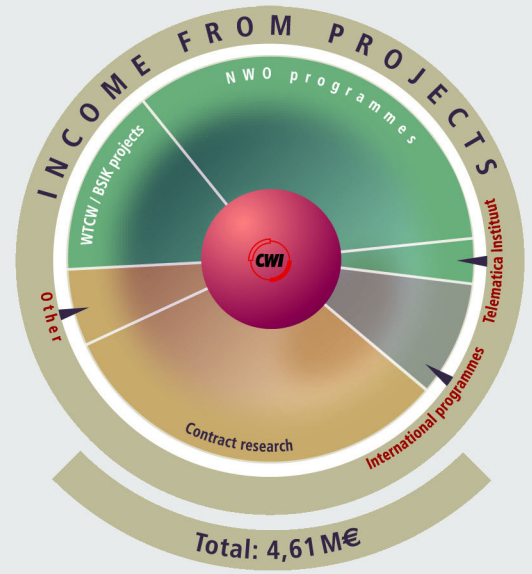
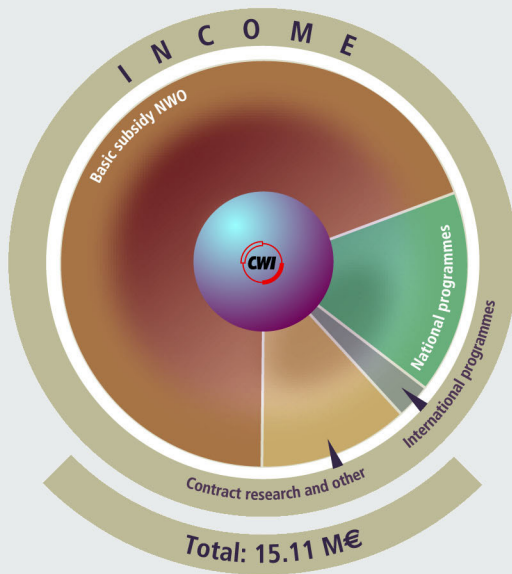
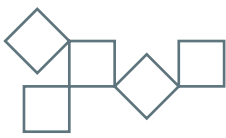
E. de Boer

#### Library & Information Services

A.L. Ong

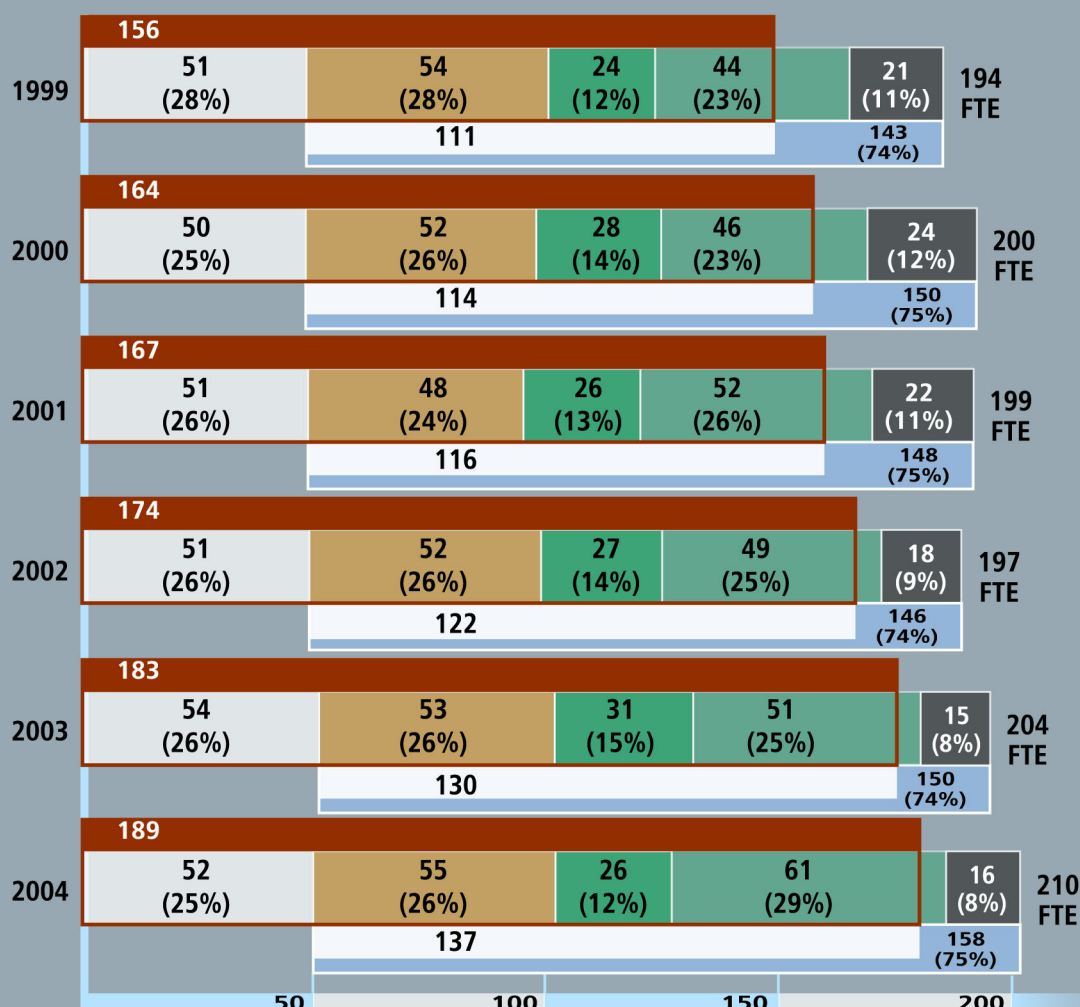
#### Personnel Department

J. Koster





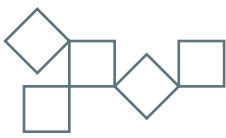
### CWI staff 1999-2004



### Statistics of CWI output 2001-2004

	CWI				PNA				SEN				MAS				INS			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
Refereed journals or proceedings	265	260	316	308	85	60	105	62	64	79	89	131	49	58	54	74	67	63	68	41
Other journals or proceedings	21	28	27	22	7	10	7	8	11	10	14	5	0	2	1	2	3	6	5	7
Monographs	6	9	6	5	3	1	2	2	3	4	0	3	0	1	1	0	0	3	3	1
Book chapters	14	12	10	14	0	4	3	9	9	4	3	2	1	0	0	1	4	4	4	2
PhD Theses	12	17	9	12	4	2	2	1	2	7	3	6	1	4	3	3	5	4	1	2
Professional products and other output	101	116	138	94	45	33	51	31	24	32	39	38	6	9	9	12	26	42	39	13
<b>Total</b>	<b>419</b>	<b>442</b>	<b>506</b>	<b>455</b>	<b>144</b>	<b>110</b>	<b>170</b>	<b>113</b>	<b>113</b>	<b>136</b>	<b>148</b>	<b>185</b>	<b>57</b>	<b>74</b>	<b>68</b>	<b>92</b>	<b>105</b>	<b>122</b>	<b>120</b>	<b>66</b>





### CWI 2004 staff numbers

#### Male/female staff in FTE at the end of 2004 (CWI payroll)

	Research	Support
Male	123.0	31.4
Female	17.8	19.5

#### Master students in numbers

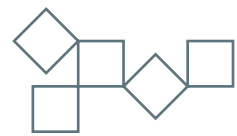
2001	2002	2003	2004
9	13	16	21

### International staff in 2004 in FTE/year

European country	FTE	%	European country	FTE	%
Austria	1.0	2%	Italy	2.1	4%
Belgium	2.8	5%	Poland	3.6	7%
Bulgaria	7.0	13%	Portugal	1.0	2%
Czech Republic	1.0	2%	Rumania	4.0	7%
Finland	1.0	2%	Russia	4.0	7%
France	0.8	1%	Serbia	2.0	4%
Germany	12.6	23%	Spain	4.5	8%
Great Britain	3.0	5%	Sweden	1.0	2%
Hungary	3.0	5%	Ukraine	1.0	2%
			Europe	55.4	80%
			Americas	7.2	10%
			Asia	6.0	9%
			Australia	1.0	1%
			Africa	0.0	0%
Total non-Dutch in FTE		69.6	43.9%		
Total CWI research staff in FTE		158.4	100%		

### International staff at CWI in numbers 2001-2004

Year	# Persons	# Nationalities	# European nationalities
2001	68	24	19
2002	63	25	17
2003	76	25	16
2004	75	26	18



## CWI clusters and themes



### Probability, Networks and Algorithms

Cluster leader: A. Schrijver

#### Networks and Logic – Optimization and Programming

Theme leader: *A.M.H. Gerards*

##### Networks and Optimization

The design, analysis and implementation of optimization and approximation algorithms for combinatorial problems with the help of methods from graph theory, topology, discrete mathematics, geometry, and integer, linear, and semi-definite programming with special attention to network problems (flows, routing and VLSI-design) and scheduling and time-tabling.

##### Constraint and Integer Programming

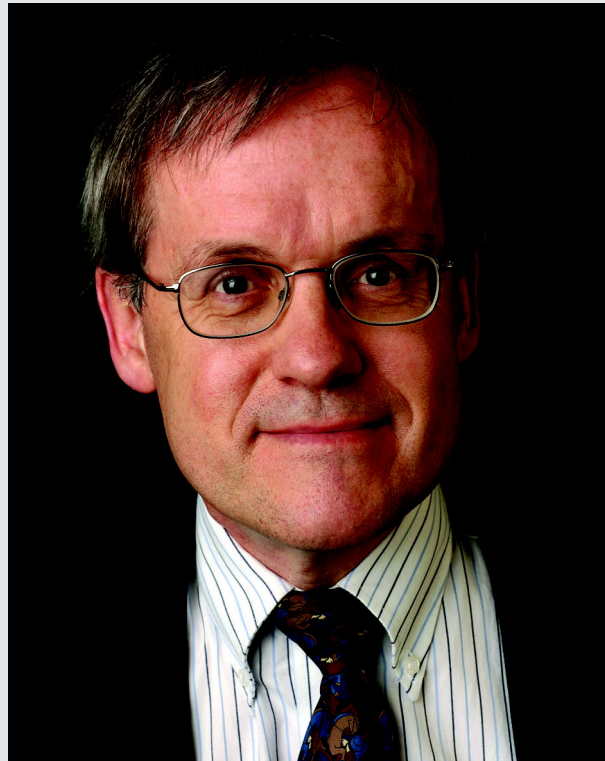
Foundations and the applications of integer and constraint programming, including their cross-fertilization.



*A.M.H. Gerards*

##### Algorithmic and Combinatorial Methods for Molecular Biology

The mathematical analysis of molecular structures in biology and the design, analysis and implementation of algorithms for computational molecular biology. The methods come from combinatorics (graph theory and combinatorial optimization), computer science (constraint programming and computational complexity) and mathematical programming (linear, integer, and semi-definite programming).



*A. Schrijver*

### Advanced Communication Networks

Theme leader: *M.R.H. Mandjes*

##### Traffic Modelling, Analysis, and Performance

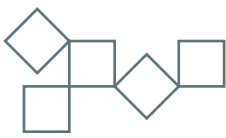
Development of queueing-theoretic models, methods, and algorithms for studying congestion phenomena in communication networks. Focus is on issues related to service integration and quality differentiation in communication networks. Furthermore, feedback-based flow-control protocols like TCP are studied. The role of long-tailed phenomena and the impact on network performance remains a subject of research.

##### Wireless Networks

Development of queueing-theoretic models and algorithms for dimensioning, engineering, and operating integrated-services wireless networks.

##### Service Differentiation

Studying mechanisms that allocate the available network resources (bandwidth, buffer space) to the population of heterogeneous users in an economically sound way. In particular, charging network users based on their contribution to congestion by packet

*M.R.H. Mandjes*

marketing, allocation of bandwidth through auctions, and models that allocate cost among network users in conjunction with network measurements.

#### Performance of Distributed ICT Systems

Development of quantitative models for the end-to-end QoS over multiple domains. Developing models for the provisioning of bandwidth and cache space in access networks.

#### Stochastics

*Theme leader: J. van den Berg*

##### Probability

Fundamental and applied research on mathematical models of biological and physical processes with self-organized critical behaviour, dynamic percolation phenomena near criticality, reinforced random walks on finite graphs, and random spatial processes.

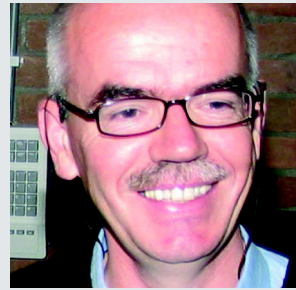
*J. van den Berg*

##### Stochastic Analysis

Fundamental and applied research, in particular on statistical methods for dynamical stochastic models and statistical inference for stochastic processes related to financial data.

## Signals and Images

*Theme leaders: H.J.A.M. Heijmans / E. Pauwels*

*H.J.A.M. Heijmans**E.J.E.M. Pauwels*

#### Image Understanding, Retrieval, and Indexing

Research on storage, indexing, and retrieval of visual information. In particular, it is directed towards the development of mathematical methodologies that enable the generation of a content-based description of images.

#### Image Representation and Analysis

Research on various multi-resolution techniques in signal and image processing, such as wavelet analysis, mathematical morphology, and image scale-spaces, as well as with specific applications such as seismology, data fusion, and image filtering.

#### Stochastic Geometry

Modelling and analysis of random geometric structures using techniques from spatial statistics, and stochastic and integral geometry.

## Cryptology and Information Security

*Theme leader: R.J.F. Cramer*

*R.J.F. Cramer*

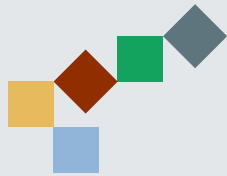
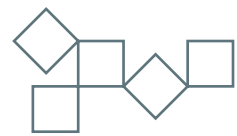
#### Cryptology

Public key cryptography, quantum cryptography, formal security analysis, applied information security, secure computation, information theoretic security, mathematics of cryptology.

#### Computational Number Theory and Discrete Tomography

Factoring large integers, cryptanalysis, discrete tomography.





## Software Engineering

Cluster leader: P. Klint

### Interactive Software Development and Renovation

Theme leader: P. Klint

#### Software Evolution

Development of methods, tools, and techniques that help to make and keep software systems sufficiently flexible.

#### Software Transformation

Improvement of run-time efficiency (optimization), improvement of static structure (refactoring), and systematic modification (computer-aided maintenance) of software systems.

#### Generic Language Technology

Increased applicability of the ASF+SDF and ASF+SDF Meta-Environment is achieved by the introduction of more structure on the lexical level and improved pretty printing functionality. Parallel to these developments the relation calculator is further improved, it can be used to extract facts from source code regarding, for instance, data and control flow. Various applications were tackled in the area of reverse engineering analysis of C code with respect to consistency of comments and source-to-source transformations of COBOL code.

#### Concept-Based Reasoning and Knowledge Engineering

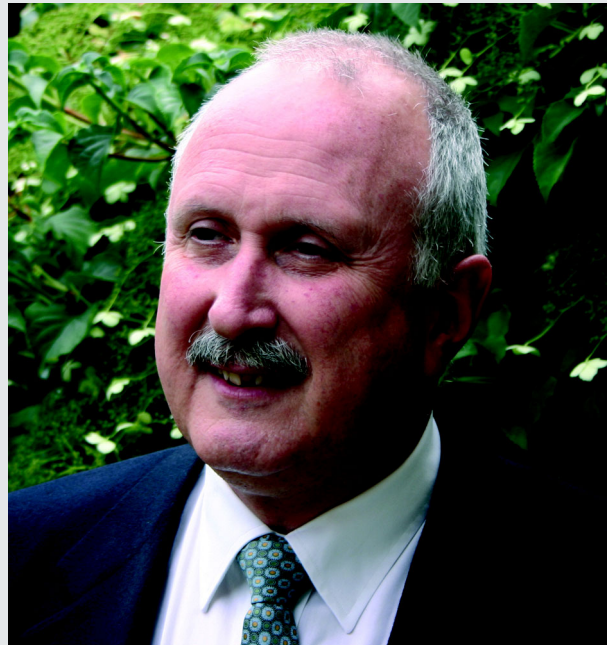
Applied logic research covering a broad spectrum of aspects, like dynamic logic, tableau reasoning, construction of electronic textbooks for logic, and interactive information engineering.

### Specification and Analysis of Embedded Systems

Theme leader: J.C. van de Pol



J.C. van de Pol



P. Klint

#### Distributed Systems

Study of specification, analysis and testing techniques for computer controlled systems, which allow more efficient design and construction with fewer embedded faults. This is achieved by developing and implementing algorithms for the analysis and verification of distributed systems for the  $\mu$ CRL toolset. Techniques and algorithms are assessed and improved via case studies in various application domains (communication protocols, embedded systems, hybrid systems).

#### Process Theory and Verification

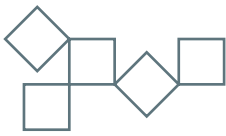
Fundamental study of verification techniques. Furthermore, the program deals with the development of methods for proof checking as a means to improve the quality of mathematical proofs. The purpose is to develop methods for establishing the correctness of programmed systems 'beyond a reasonable doubt'. Central issues are process theory, binary decision diagrams, automated deduction, and term rewriting.

### Coordination Languages

Theme leader: J.J.M.M. Rutten

#### Coordination and Component-Based Architectures

Development of formal models for components and component-based software that capture the relevant semantics of the behaviour of a component in its interface, enable construction of systems by composition of exogenously coordinated components, allow com-

*J.J.M.M. Rutten*

positional derivation of the properties of a system from those of its constituent components, and support notions of distribution and mobility. The developed models and formalisms will be used as the foundation for the implementation of practical component-based software engineering tools and support environments.

#### Formal Methods for Coordination Languages

Development and application of formal methods for coordination languages. Work in Omega is continued, involving tool-development for the verification of UML models and the formalization of the semantics of UML models in XML. Computer-aided verification methods are applied to the correctness of distributed implementations of mobile channels. Furthermore, work on tool-development for description logics is also continued.

#### Coalgebraic Models of Computation

Development of coalgebra as a unifying mathematical framework for (transition, dynamical, probabilistic) systems and various (object-oriented and component-based) programming paradigms. This includes the application of coinductive techniques to Reo, the calculus for the construction of component connectors developed by this theme as well as theory and tool development for Reo. Furthermore, coinduction is applied to bitstreams, in order to arrive at an algebraic calculus of digital circuits.

#### Evolutionary Systems and Applied Algorithmics

*Theme leader: J.A. La Poutré*

*J.A. La Poutré*

The research group focuses on the combination of (distributed) adaptive computation with application-oriented fields of economics, management, and e-societies (like for e-commerce). Typical application topics concern markets and market mechanisms, negotiation, auctions, and social aspects, for instance game theory.

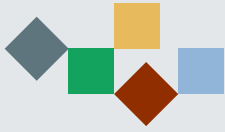
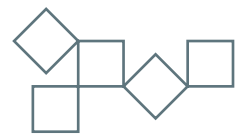
The concept of agents in both computer science as well as in economics and social sciences yield important areas of research. In both cases, adaptive behaviour of agents, based on their own point of view ('bounded rationality') in a dynamic environment is essential. To allow learning in distributed systems of interacting agents, machine learning techniques like evolutionary systems, neural networks and adaptive algorithms are investigated. These algorithms then form the 'heart' of learning agents in e-business applications and simulated markets. Gained insights apply to both agent technology (how to build a truly learning agent) and economics (how to simulate adapting agents).

#### Convergent Media Infrastructures

*Pilot leader: D.C.A. Bulterman*

*D.C.A. Bulterman*

Studying methods for the specification, scheduling, and verification of composite presentations so that they can be distributed across a heterogeneous collection of underlying devices and networks, while appearing to run on an abstracted homogeneous environment. The research capitalizes the knowledge gained in the past by building the Ambulant Player.



## Modelling, Analysis and Simulation

Cluster leader: J.G. Verwer

### Nonlinear PDEs: Analysis and Scientific Computing

Theme leaders: M.A. Peletier (until September),

A. Doelman (as of September)



M.A. Peletier



A. Doelman

#### Scientific Computing in the Life Sciences

Mathematical modelling, mathematical and numerical analysis, and numerical simulation for life sciences, in particular biology and medicine. Cooperation has been established with researchers working in cell, neuro, and microbiology.

#### Nonlinear Dynamics of Natural Systems

Mathematical analysis of finite and indefinite dynamical systems in interaction with the earth and life sciences. Embedded in the national 'cluster' Nonlinear Dynamics of Natural Systems.

#### Geometric Integration of Wave Phenomena

Numerical analysis and simulation of partial differential equations, in particular structure-preserving numerical methods with applications to conservative continua like geophysical fluids, and a Runge-Kutta-Chebyshev method for advection-diffusion-reaction equations.



J.G. Verwer

#### Asymptotics and Special Functions

Research on uniform asymptotic expansions and numerical and algebraic algorithms for special functions. Contributions to the handbook of Mathematical Functions by Abramowitz and Stegun.

#### Computing and Control

Theme leader: B. Koren



B. Koren

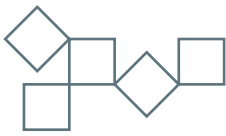
#### Computational Fluid Dynamics and Computational Electromagnetics

Current research focuses on the development of numerical methods for the computation of free-surface flows in spacecraft aerodynamics (rocket-engine jets) and ship hydrodynamics (free-surface water waves), space-mapping and finite-element techniques for shape optimization of electromagnetic devices, multigrid and hp-adaptive techniques for discontinuous Galerkin methods for convection-diffusion problems.

#### Control and System Theory

Research on fundamental problems of control and





system theory for various dynamic systems motivated by control problems of engineering and by cell biology. Current research is directed at control of hybrid systems with applications to control of car engines, dynamic system properties of hybrid systems, realization theory for subclasses of hybrid systems, supervisory control of decentralized and modular discrete-event systems, and realization of rational positive systems with applications to biological models.

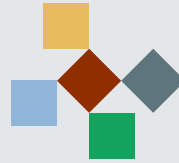
### Nonlinear Dynamics and Complex Systems

*Theme leader: U. Ebert*



*U. Ebert*

Analytical and numerical modelling of spatio-temporal patterns, in particular, in electric discharges. Application-directed as well as basic research on analysis and numerics of nonlinear PDEs. Additional research concerns numerical methods for convection-diffusion equations, with emphasis on monotone numerical schemes and grid refinements in space and time.



### Information Systems

Cluster leader: M.L. Kersten

#### Standardization and Knowledge Transfer

*Theme leader: M.L. Kersten*

Knowledge transfer on evolving standards, primarily within the context of the World Wide Web Consortium (W3C). This includes general management of all the W3C offices worldwide, leadership of the W3C HTML Working Group, co-leadership on the W3C XForms activities, and participation in the work of the Document Format domain of W3C.



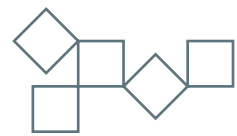
*M.L. Kersten*

#### Database Architectures and Information Access

*Theme leader: M.L. Kersten*

##### Multimedia Databases

Development of an efficient storage and retrieval system of multimedia data. The research line on multimedia information retrieval aims at developing a multimedia database system, which can offer a high level of abstraction to both developers of end-user applications and researchers working on content analysis techniques.



### Database Architectures

Development of the next generation database technology to support Ambient Intelligence applications. Ambient Intelligence refers to digital environments in which multimedia services are sensitive to people's needs, personalized to their requirements, anticipatory of their behaviour and responsive to their presence.

### Query Languages & Optimization

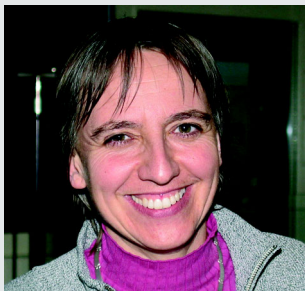
Development of a multi-layer query optimizer infrastructure to support multimedia information access. At the core of such a system we envision a sound and flexible probabilistic model to steer the retrieval process, integrated with query optimizers and kernel functionality.

### MonetDB Dissemination

Promoting the development and use of the database experimentation platform MonetDB. MonetDB is an open source high-performance database system developed at CWI, designed to provide high performance on complex queries against large databases, e.g., combining tables with hundreds of columns and multi-million rows.

### Multimedia and Human-Computer Interaction

Theme leader: *L. Hardman*



*L. Hardman*

Investigation of the boundaries between multimedia and the Semantic Web and development of models and tools for automatic generation of high-quality hypermedia presentations, taking into account design knowledge, user characteristics, and platform-specific requirements.

This includes the modelling of argument structures for the generation of meaningful video sequences; domain-independent structuring of a semantically annotated media repository for presentation to end-users, dependencies of the user and domain models in the

generation process, characteristics of media types for presenting information to the user, and to what extent graphic design knowledge can be included in the generation process.

### Visualization and 3D Interfaces

Theme leader: *R. van Liere*



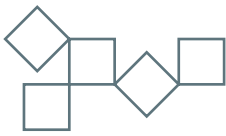
*R. van Liere*

### Data Visualization

Projects in the application area of the Dutch Living Cell initiative. Key research focus is the interactive visualization of time dependent data sets and the exploration of multidimensional information spaces. Furthermore, the problems of classification and visualization of multidimensional parameter spaces are addressed.

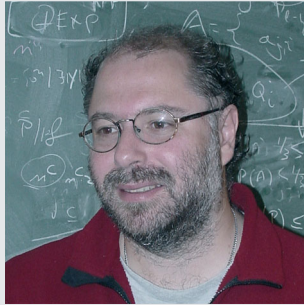
### 3D User Interfaces

Projects concerned with applying virtual reality technology to cost effective and ergonomic desktop virtual environments. Two-handed interaction with tangible devices is the key research focus. This research is combined with the engineering of prototype desktop solutions together with several affiliated research groups.



## Quantum Computing and Advanced Systems Research

Theme leader: *H.M. Buhrman*



*H.M. Buhrman*

### Quantum Computing

Research on quantum information and communication technology and processing, quantum algorithms, quantum communication complexity, quantum complexity classes, quantum cryptography, quantum information theory, and applications of quantum information theory to classical computing and physics.

### MDL Learning and Algorithmic Statistics

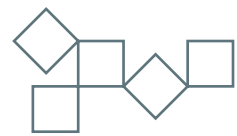
Information theoretic methods for learning from data, Minimum Description Length (MDL), maximum entropy, pattern recognition, learning when all models are wrong, practical individual rate distortion theory, and applications and refinement of parameter free clustering and classification

### Advanced Algorithms, Systems and Genomics

Kolmogorov complexity, computational complexity, distributed computing, and bio-informatics. In particular: new non relativizing separations in line with P vs NP problem, time limited Kolmogorov complexity, universal distributions, characterization of random strings, and symmetry of information. General lower bound techniques. Design and analysis of algorithms for distributed and parallel systems.







## International and national research programmes

*CWI participates in many national and international research projects. This overview lists all major projects with their duration, partners, and CWI project leader(s).*

The following abbreviations for Dutch universities are used throughout the list:

RU	Radboud University Nijmegen, formerly KUN (Catholic University of Nijmegen)
RUG	University of Groningen
TUD	Delft University of Technology
TUE	Technische Universiteit Eindhoven
UL	Leiden University
UM	Maastricht University
UT	University of Twente
UU	Utrecht University
UvA	Universiteit van Amsterdam
UvT	Universiteit Tilburg
VU	Vrije Universiteit Amsterdam

## European programmes

### European Union

#### **EUROPHLUKES**

2001-2004

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 Delfin, Whale Watch Azores  
H.J.A.M. Heijmans

**OMEGA:** Correct Development of Real-time embedded in UML

2002-2005

Verimag, CAU, KUN, Weizmann Institute, OFFIS, EADS Launch Vehicles, France Télécom, Israeli Aircraft Industries, NLR  
F.S. de Boer

**CC:** Computation and Control

2002-2005

Verimag, Parades, ETH Zürich, Lund Univ. of Technology, EDF, ABB  
J.H. van Schuppen

**RESQ:** Resources for Quantum Computing

2003-2006

Univ. Libre de Bruxelles, Univ. Paris-Sud, Univ. of Bristol, Max-Planck Gesellschaft zur Forderung der Wissenschaften, UU, SZTAKI, Univ. de Genève, Univ. of Cambridge, Univ. of Gdansk  
H.M. Buhrman



## EU networks

**AMORE:** Algorithmic Methods for Optimizing the Railways in Europe

2000-2004

Univ. Konstanz, ETH Zürich, Technical Univ. Denmark, CTI

Patras, DIS-DIE Rome, l'Aquila, EUR, NS Reizigers

A.M.H. Gerards

**ADONET:** Algorithmic Optimization Discretization

2004-2007

Various partners: CWI is coordinator of the Dutch Consortium

M. Laurent

**EuroNGI:** Design and Engineering of the Next Generation Internet, Towards convergent multi-service networks

2003-2006

58 partners from different countries

M.R.H. Mandjes

**DYNSTOCH:** Statistical Methods for Dynamical Stochastic Models

2000-2004

HU Berlin, UPCT, ALU-FB, UHEL, UCL, LADSEB-CNR, UPMC

K.O. Dzhaparidze

**BIOSECURE:** Biometric for Secure Authentication

2004-2007

48 partners from different countries

B.A.M. Schouten

**MUSCLE:** Multimedia Understanding through Semantics, Computation and Learning

2004-2008

38 partners from different countries

E.J.E.M. Pauwels (scientific coordinator)

**DELOS:** Digital Libraries

2004-2008

60 partners from different countries

M.L. Kersten

**PASCAL:** Pattern Analysis, Statistical Modelling and Computational Learning

2003-2007

Univ. London, and 50 more sites

P.D. Grünwald



## National programmes

### NWO

**SPCO:** Semidefinite Programming and Combinatorial Optimization

2002-2007

LAAS-CNRS, Univ. Klagenfurt, Univ. Rennes, TUD

M. Laurent

**CIP:** Constraint and Integer Programming Techniques

2002-2007

ERCIM, Univ. Victoria (Canada), Univ. Singapore, Brooklyn College

K.R. Apt

**FDP:** Foundations of Declarative Programming

2002-2007

UvA, VU

K.R. Apt

**LT:** Performance Analysis of Communication Networks;

Emphasis on Long-tailed Traffic Phenomena

1996-2004

Columbia Univ., TUE, Lucent Technologies

M.R.H. Mandjes

**Van Gogh Grant**

2002-2004

INRIA

R. Núñez Queija

**FAST:** Large-deviations Asymptotics and Fast Simulation

2001-2005

Lucent Technologies, UT, VU

M.R.H. Mandjes

**RAPS:** Rare-event Analysis of Processor-Sharing systems

2004-2007

Lucent Technologies, TUE

S.C. Borst

**SOC:** Mathematical Models of Biological and Physical Processes with Self-organized Critical Behaviour

2001-2005

VU, Wesleyan

J. van den Berg

**DPP:** Dynamic Percolation Phenomena near Criticality

2002-2004

UvA, UU, VU

J. van den Berg

**Dutch-Hungarian Cooperation**

2002-2004

Univ. Budapest, EURANDOM

J. van den Berg

**AGP:** Spectral Analysis of Processes with Stationary Increments

2003-2007

VU

K.O. Dzhaparidze

**Mathematical Aspects of Discrete Tomography**

2002-2006

UL, FEI Eindhoven, Lawrence Berkeley National Laboratory

H.J.J. te Riele

**Algorithmic Validation of Widely Used Cryptosystems**

2004-2007

Microsoft, TUE, UL,

H.J.J. te Riele

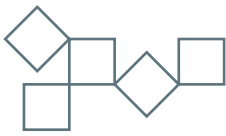
**Biography Aad van Wijngaarden**

2000-2004

-

G. Alberts





**Deliver:** Intelligent Software Management and Delivery

2003-2006

Exact BV, Planon BV, ChipSoft BV, VU

P. Klint

**LPPR:** Language-Parametric Program Restructuring

2004-2006

VU

J. Heering

**IT-VDS:** Integrating Techniques for the Verification of Distributed Systems

2002-2005

TUE

J.C. van de Pol

**TIPSY:** Tools and Techniques for Integrating Performance

Analysis and System Verification

2004-2007

TUE

W.J. Fokkink

**Account:** Accountability in Electronic Commerce Protocols

2004-2007

VU, UT

W.J. Fokkink

**CBCS:** Coordination-based Parallel Constraint Solving

2000-2003

PNA1, Univ. Nantes

F. Arbab

**MOBI-J:** Assertional Methods for Mobile Asynchronous

Channels in Java

2001-2004

UL, Christian-Albrechts-Univ. Kiel

F.S. de Boer

**CoMoLo:** Coalgebra Modal Logic

2002-2005

UvA, KUN

J.J.M.M. Rutten

**C-Quattro:** Compositional Construction of Component

Connectors

2004-2008

VU

F. Arbab, J.J.M.M. Rutten

**EESem:** Evolutionary Exploration Systems for Electronic

Markets

1999-2004

TUE

J.A. La Poutré

**MIA:** Medical Information Agent

2004-2008

AMC, UM, TUE

J.A. la Poutré

**ScanN:** Scalable Reinforcement Learning in Asynchronous Spiking Neural Networks

2003-2007

-

S.M. Bohte

**Quality of Service for Multimedia Systems**

1999-2004

Philips Research

J.A. La Poutré

**Three-dimensional Simulation of Phytoplankton Dynamics**

2001-2005

UvA

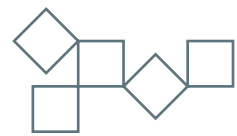
B.P. Sommeijer

**Numerical Modelling of the Formation of Neuronal Connections of the Nervous System**

2001-2005

Netherlands Institute for Brain Research (NIH)

J.G. Verwer



**Mesoscale simulation paradigms in the Silicon Cell**

2004-2008

UvA

J.G. Blom

**3D-RegNet:** Simulation of Developmental Regulatory Networks

2004-2008

UvA

J.G. Blom

**Mathematics and Computation for the System Biology of Cells**

2004-2008

UvA, TUE, VU, MAS2 (Van Schuppen)

J.G. Blom

**Modelling of Developmental Regulatory Networks**

2004-2008

UvA

J.G. Blom

**CellMath:** Mathematics and Computation for the System Biology of Cells

2004-2008

VU, UvA, TUE, MAS2 (van Schuppen)

J.G. Blom

**Geometric Numerical Methods for Continuum Mechanics**

2002-2005

-

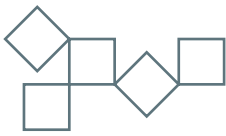
J.E. Frank

**hp-Adaptive Methods for 3D Convection Dominated Flows**

2001-2005

UT, TCD, RAS-UB

P.W. Hemker



**Robust:** Numerical Methods and Computational Technologies for Singularly Perturbed Multiscale Problems

2004-2006

TUE, MSU Moscow, RAS UB

P.W. Hemker

**NUMLED:** Numerical Methods for Leading Edge Dominated Dynamics

2002-2006

-

W.H. Hundsdorfer

**MRPDE:** Multirate Time Stepping for PDEs

2004-2007

-

W.H. Hundsdorfer

**CIRQUID:** Complex Information Retrieval Queries in a DBMS

2003-2007

UT

A.P. de Vries

**NASH:** Networked Adaptive Structured Hypermedia

2002-2004

TUE

L. Hardman

**CHIME:** Cultural Heritage in an Interactive Multimedia

Environment

2002-2004

-

L. Hardman

**I<sup>2</sup>RP:** Intelligent Information Retrieval and Presentation in Public Historical Multimedia Databases

2002-2005

Rijksmuseum Amsterdam, RUG, UM, UL

L. Hardman

**QC:** Extending Feasible Computation: Quantum Computing

2000-2005

-

P.M.B. Vitányi

**Universal Learning**

2002-2005

HIIT Helsinki, Univ. London

P.M.B. Vitányi

**ACAA:** Average-Case Analysis of Algorithms

2000-2004

Univ. Waterloo, BSI

P.M.B. Vitányi

**Quantum Information Processing**

Vici project

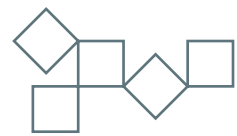
2004-2009

-

H.M. Buhrman







## STW

### **PHOTO-ID:** Photo-ID for Cetaceans Using Shape Matching

Methods

2004-2006

CML Leiden, Netherlands National Herbarium, UU

E.J.E.M. Pauwels, E.B. Ranguelova

### **SEQ:** Sequential Point Processes

2004-2006

Centrum voor Milieukunde Leiden, Fom-AMOLF, ITC, Kapteyn

Instituut, Philips Research

M.N.M. van Lieshout

## SenterNovem (including IOP)

### **EQUANET**

2003-2005

Lucent Technologies, UT, TNO-ICT, TUE

M.R.H. Mandjes

### **BASIS:** Biometric Authentication Supporting Invisible Security

2004-2008

UT, TUE

B.A.M. Schouten

### **IDEALS:** Idiom Design for Embedded Applications on

a Large Scale

2003-2006

ASML, TUE, UT, ESI

A. van Deursen

### **TT-Medal:** Testing Methodologies with Advanced Languages

2004-2005

LogicaCMG, ProRail, Improve QS, Fokus, DaimlerChrysler,

Nokia, VTT, Conformiq, Nethawk

J.C. van de Pol

### **CIM III:** Cybernetic Incident Management

2003-2006

SEN4, TUD, VU, Almende, CMotions, Falck

F. Arbab, J.A. La Poutré

### **DEAL:** Distributed Engine for Advanced Logistics

2002-2006

Almende, ERBS, VU, Groeneveld Groep, Post-Kogeko Transport

Groep, Vos Logistics

J.A. La Poutré

### **Calce:** Computer-aided Life Cycle Enabling

2003-2006

PinkRocade Public BV, Software Improvement Group, VU

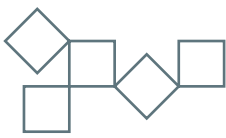
J. Heering

### **IOP-EMVT:** Space-mapping and Related Techniques for Inverse Problems in Magnetic Shape Design, with Application to an Electromagnetic Actuator

2003-2007

TUE

P.W. Hemker



## Bsik projects

**IOP-EMVT:** Stochastic Methods for Field Computations in EMC Problems  
2004-2007  
TUE  
P.W. Hemker

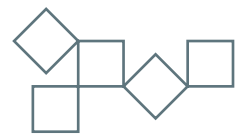
**Waterland**  
2001-2005  
TI, UT, TNO-TPD, NOB, NOS  
A.P. de Vries

**BRICKS:** Basic Research in Informatics for Creating the Knowledge Society  
2004-2009  
TUD, TUE, UT, UU, NWO  
J.K. Lenstra, J.G. Verwer

**MultimediaN:** Multimed 12 Netherlands  
2004-2008  
CTIT IBM, LogicaCMG, TI, TNO, TUD, UU, UvA, VU, V2-Waag Society  
M.L. Kersten

**VL-e:** Virtual Laboratory for e-Science  
2004-2009  
see [www.vl-e.nl](http://www.vl-e.nl) about VL-e consortium partners  
R. van Liere





## Contract research

### Stagesporen

1995-indefinite

VU, UM, UL

A.M.H. Gerards

### Railway Optimization

1994-indefinite

NS Reizigers

A.M.H. Gerards

### FLORIN: Flow-level Performance of Integrated 3G CDMA

Networks

2003-2006 (verlengd)

France Télécom

M.R.H. Mandjes

### DocGen: Documentation Generation

1999-indefinite

Software Improvement Group BV

A. van Deursen

### Ambulant Mobile SMIL for PDAs

2003-2004

NL.net

D.C.A. Bulterman

### Ambulant NxG

2004-2006

NL.net

D.C.A. Bulterman

### ASF: Asymptotics and Special Functions

1999-2005

Univ. Madrid, Univ. Pamplona, UvA, Abramowitz-Stegun group

N.M. Temme

## Telematica Instituut projects

### M2C-QoS: Measuring, Modelling and Cost Allocation for Quality of Service

2003-2004

UT

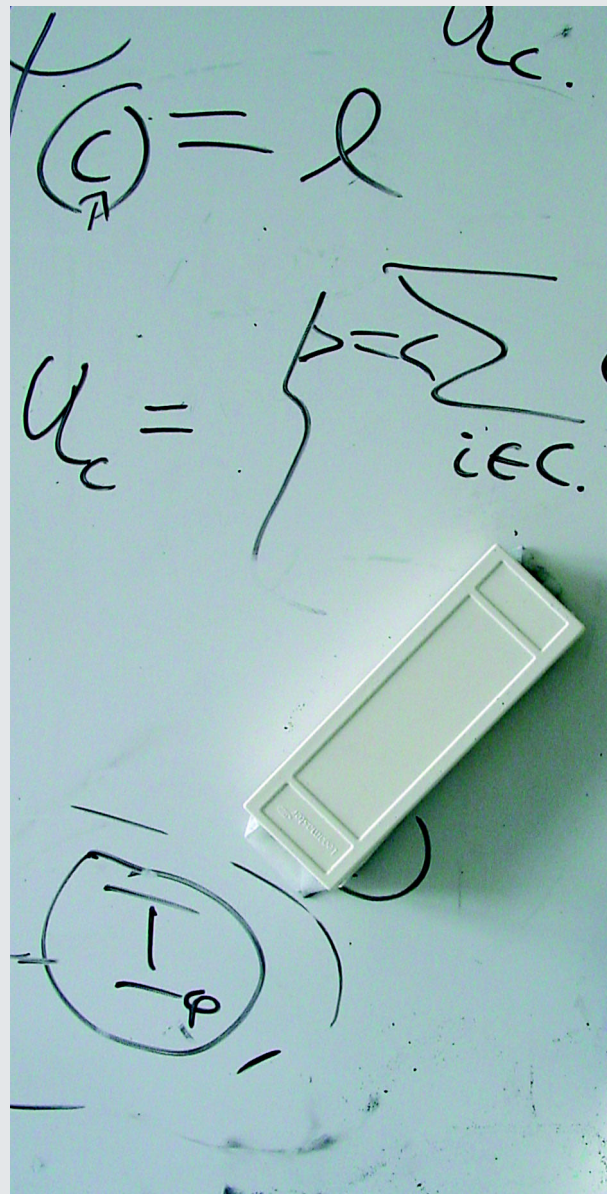
M.R.H. Mandjes

### ArchiMate: Enterprise Architecture Animation

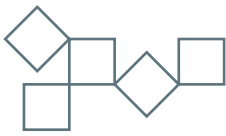
2002-2004

Ordina Institute, KUN, UL, ABP, ABN AMRO, Belastingdienst

F. Arbab







## Miscellaneous

**SMCS:** Statistical Methods for Compound Sums, with Applications in Finance  
2000-2004  
ITB, Bandung, KNAW  
R. Helmers

### **Discontinuous Galerkin Methods and Singularly Perturbed Problems**

2000-2004  
UvA  
P.W. Hemker

### **Multigrid for hp-Adaptive Discontinuous Galerkin Discretizations of Convection-Diffusion Equations**

2003-2004  
ERCIM  
P.W. Hemker

**STREAMERS-Moscow:** streamer discharges: experiments, theory, applications  
2004-2007  
NWO-RFBR programme (Russisch Nederlandse Samenwerking)  
TUE, MIPT (Moscow), IVTAN (Moscow)  
U.M. Ebert

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