Centrum voor Wiskunde en Informatica

Annual Report 2003

Centrum voor Wiskunde en Informatica

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

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

Colophon

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The CWI annual report series consists of:

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

They can be ordered at the Communication and Publication Department: cpd@cwi.nl

Introduction

Introduction

The year 2003 was not easy for CWI. It was a year of conclusion and parting. Several major national and European research projects were closed, whereas new subsidy programs were delayed. As a result of the prolonged unfavorable economic climate no new spin-offs were started. Moreover, Gerard van Oortmerssen resigned as general director to become director of TNO Telecom. In the twelve years he led the institute, van Oortmerssen had a large impact on CWI.

However, 2003 was also a year of new opportunities. The institute has shown great resilience during this difficult period. In November the government selected 38 proposals for the Bsik subsidy program to stimulate Dutch research. CWI's fundamental ICT research project BRICKS was appropriated 12 million euros. MultimediaN and Virtual Lab e-Science, projects in which CWI plays an important role, were also awarded Bsik funding. The European Sixth Framework Programme supports a number of newly established European research networks, called Networks of Excellence. CWI coordinates the MUSCLE Network of Excellence on multimedia understanding and participates in three others. Furthermore, several research proposals received funding from the Ministry of Economic Affairs. Because of these new activities and subsidies, CWI starts the new year with an extensive research portfolio and a growing staff.

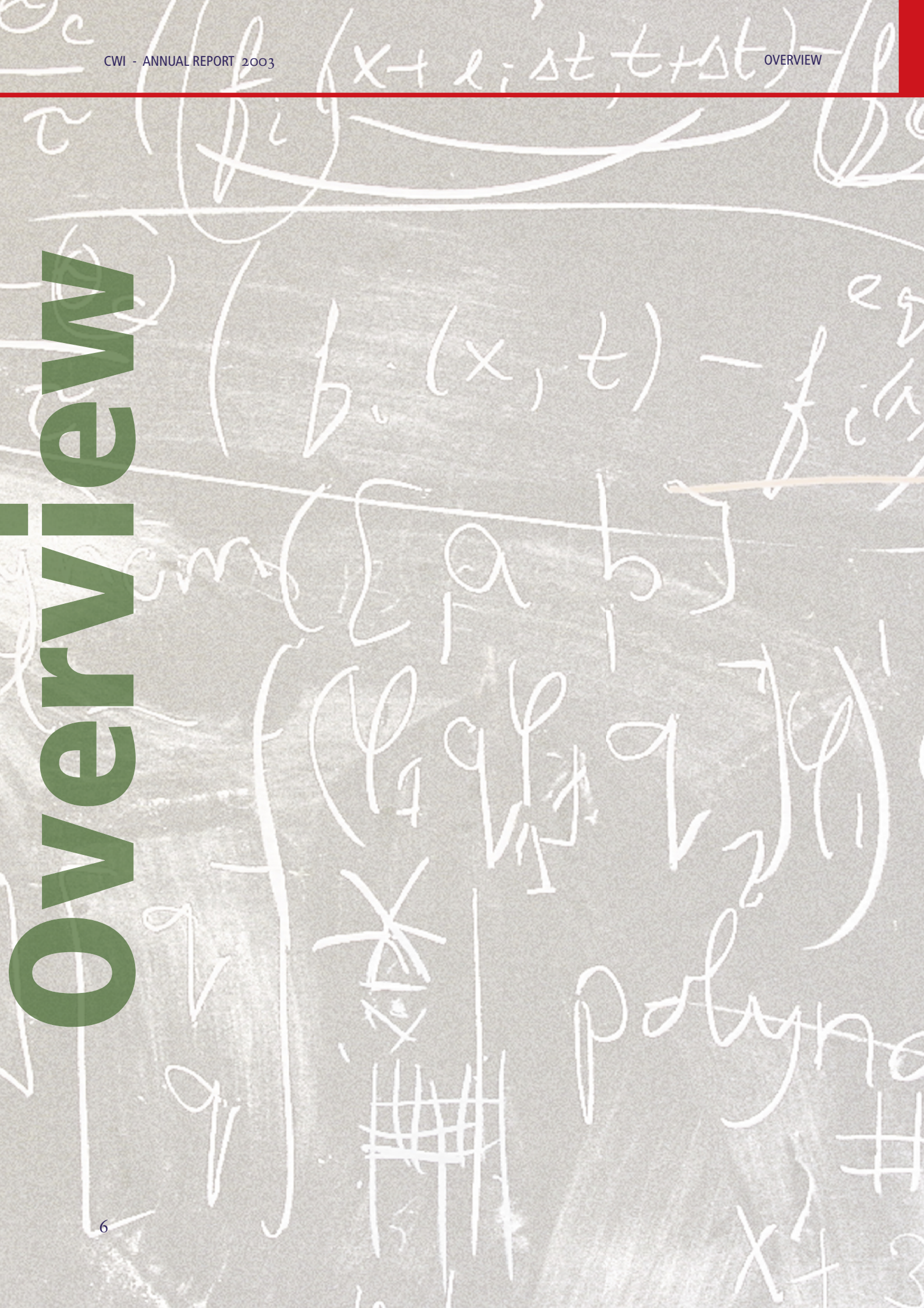
These successes can be attributed in the first place to the tireless efforts of CWI's staff. Many hours have gone into preparing and drafting proposals. The awarded subsidies are a testament to the quality of these efforts, as well as their value to science and society. Additional recognition of the staff can be found in the many prizes and personal grants awarded to CWI employees. In 2003, three researchers received large grants from NWO's Vernieuwingsimpuls subsidy program for talented researchers. Another staff member received the Peter Paul Peterich Prize for the best mathematical research proposal in NWO's Open Competition.

Fundamental research provides the foundation of innovation. Theoretic multimedia research at CWI in the late 1990s served as the basis for the SMIL language for designing streaming multimedia presentations. Nowadays, SMIL is integrated in most important media players. CWI performs fundamental research, while at the same time it keeps practical applications in mind. Our institute has years of experience in software engineering, visualization, multimedia, pattern recognition, optimization, and numerical simulation. These areas, which provide both scientific challenges and solutions to societal problems, are expected to be at the frontline of international research and development the coming years.

Innovation was an important item on 2003's political agenda. Many policymakers and opinion leaders stressed the importance of research and development. The government repeated its ambition to make the Netherlands one of the most important knowledge centers. With its extensive research portfolio and its capable staff, CWI plays an important role in these plans. After all, innovation has been on CWI's agenda for the past 58 years.

Jan Karel Lenstra
General Director

Overview



CWI in 2003

2003 saw the resignation of CWI's general director Gerard van Oortmerssen and his succession by Jan Karel Lenstra. Several new research projects were initiated, most notably BRICKS and two other large projects supported by the government's Bsik innovation program. Three CWI researchers received a large personal grant from the Netherlands Organization for Scientific Research (NWO) to reinforce their line of research. Several others received important prizes.

Research

CWI performs fundamental research in mathematics and computer science. Research topics are selected because of their scientific value and relevance to society. Numerous research projects were started in all major application areas of CWI like traffic, biosystems, and multimedia. The Dutch Ministry of Economic Affairs supported several research projects on software engineering. Among these proposals were TT-MEDAL (test development of software-intensive systems), GAME (documentation and maintenance of automatically generated software), CALCE (enabling software life cycles), IDEALS (improving integrating software in embedded systems), and CIM (software for incident management). The ministry also supports the BASIS project on the topical issue of biometrics, reinforcing CWI's strong position in the field of visual information. Theoretic research was not ignored either: CWI's successful quantum computing activities were continued with funding from the European Union and NWO.

Themes

CWI's research is organized in themes. The pilot theme Visualization and 3D Interfaces (INS3) received full theme status in 2003. Their research program includes the development of the Personal Space Station, a low-cost virtual reality environment. The pilot theme Advanced Communication Networks (PNA2) was upgraded to a full theme on January 1, 2004. PNA2 mainly develops mathematical models for communication network traffic.

The pilot theme Convergent Media Interfaces (SEN5) was officially launched on January 1, 2004. SEN5 is about new methods for designing, transporting, and rendering multiple multimedia objects like audio, video,

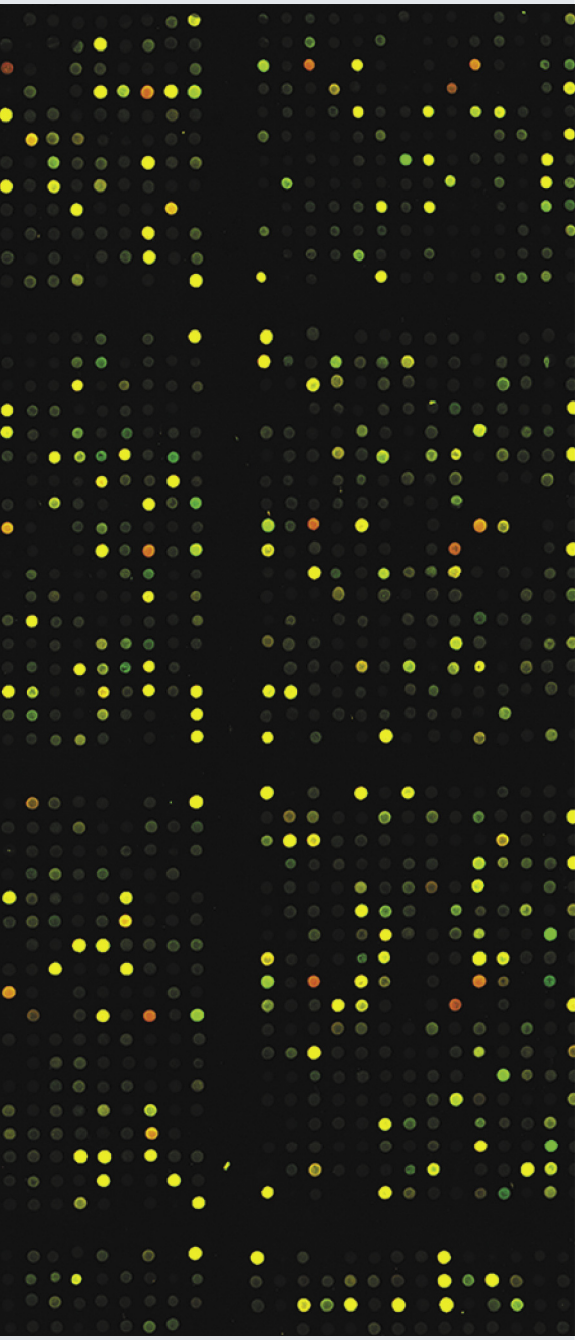
text, and images over heterogeneous networks and devices. Theme leader is Dick Bulterman.

Bsik

After a delay of almost a year, the Dutch government made a decision concerning the Bsik investment program in November. This program, also known as ICES/KIS-3, intends to stimulate the knowledge economy by supporting innovative projects for a total of 800 million euros. Of the 67 proposals 34 were selected for funding. Nine of them deal with ICT, including the BRICKS project coordinated by CWI. The institute also participates in two other selected proposals, MultimediaN and Virtual Lab e-Science. The government rejected two other projects coordinated by CWI, PRESTO and I-CARE. A description of BRICKS, MultimediaN, and Virtual Lab e-Science can be found below.

NWO

The Netherlands Organization for Scientific Research (NWO) covers seventy percent of CWI's budget with a basic subsidy. Furthermore, the institute receives funding from several NWO programs and grants. In 2003 the theme Nonlinear Partial Differential Equations (MAS1) did very well in the Computational Life Sciences program. Researchers from this theme participated in three of the projects selected for funding. Topics include the modeling and simulation of various biological processes like the functioning of living cells, genetic regulation systems, and the binding of carbon dioxide by algae.



Microarrays play an important role in genomics research. These slides carry thousands of gene bits (the image shows just a tiny detail of a single microarray). They are used in various experiments, for example to uncover gene function or genome structure. Micro-array experiments produce huge amounts of data. As a part of the BRICKS project, CWI researchers develop new methods of analysis.

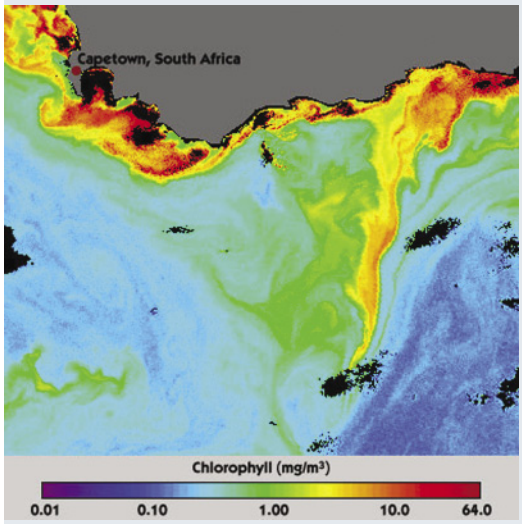
Image courtesy of Genomics Laboratory, UMC Utrecht.

Willem Hundsdorfer of the theme Nonlinear Dynamics and Complex Systems (MAS3) won the Peter Paul Peterich Prize for the best mathematics research proposal in the 2003 NWO Open Competition. The proposal was selected from a total of sixty submissions. Hundsdorfer will use the prize to fund his project *Multirate Time Stepping for Partial Differential Equations*. It focuses on the time step size in the computation of numerical solutions of certain problems, for example the electric discharge in lightning bolts. Varying the time step can drastically reduce computation time. More information on another project of Willem Hundsdorfer can be found in the Research Highlights section.

CWI researchers were also successful in the Vernieuwingsimpuls, NWO's grant program to help talented researchers expand their own line of research. Sander Bohte of the Evolutionary Systems and Applied Algorithmics theme (SEN4) won a Veni grant for his proposal on neural networks. Mark Peletier, leader of the theme Nonlinear Partial Differential Equations (MAS1), received a Vidi grant for his proposal on the coagulation of molecules in living cells. Harry Buhrman, leader of the Quantum Computing and Advanced Systems Research theme (INS4), won a Vici grant on the merit of his research proposal on quantum algorithms. The three awarded projects will be highlighted below.

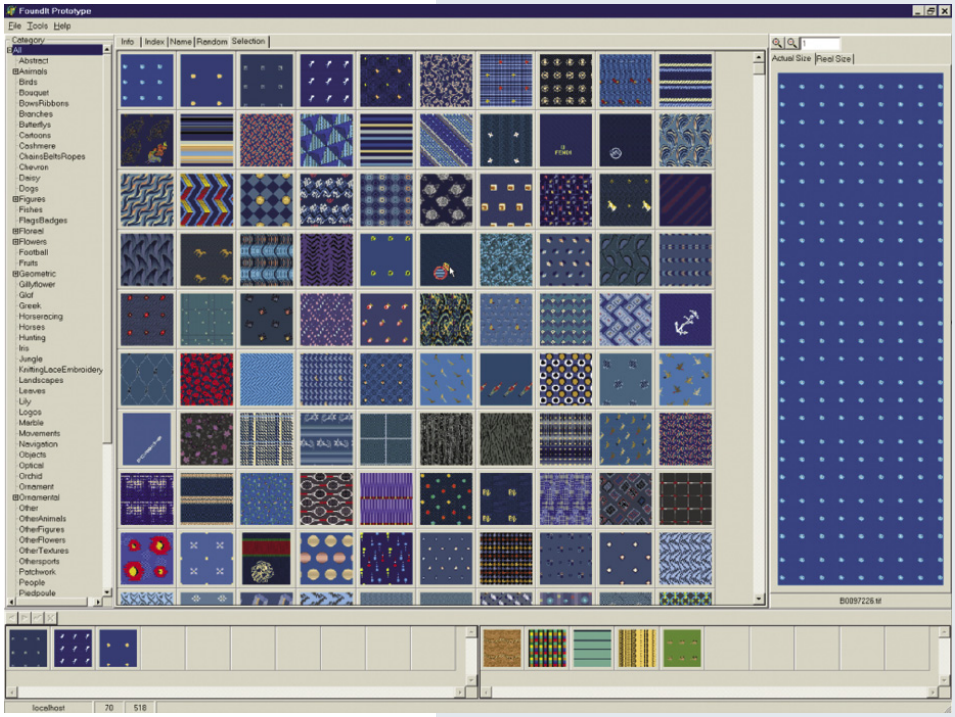
EU

In 2002 the European Union started the Sixth Framework Programme to fund and promote European research. CWI participates in many projects of this program. Examples are the Networks of Excellence, multi-partner research projects that aim to integrate European research activities in



Chlorophyll concentration around the South African coast. Chlorophyll is the molecule responsible for photosynthesis. In one of the projects supported by the NWO Computational Life Sciences program, CWI researchers study the binding of carbon dioxide from the air by ocean algae.

Image courtesy of the Department of Theoretical Biology, Vrije Universiteit Amsterdam.



A search engine for textile patterns based on image content instead of added keywords. This was the result of the FoundIt project, finished in 2003. The user is asked to point out designs that resemble the desired pattern or are totally different from it. From this selection the engine extracts features and images to further refine the search results. FoundIt was developed at CWI's theme Signals and Images (PNA4) in cooperation with several European partners. The project was supported by the European Union.

Pieter Adriaans, chairman of CWI's Governing Board, opens the annual business day.

Visitors of the Sciencepark Amsterdam open day test their wits with CWI's mathematical puzzels.

Photo by Anne Marie Trovato

CWI network manager Piet Beertema played an important role in establishing the first European connection to internet in 1988.

specific fields. One of these networks that started in 2003 is PASCAL, which bundles research in the areas of pattern analysis, statistical modeling, and machine learning. CWI's theme Quantum Computing and Advanced Systems Research (INS4) is one of the participating groups. Other new networks in which CWI participates involve the next generation of internet (EURO-NGI) and image processing for multimedia applications (MUSCLE). The institute also acts as coordinator of this last network.

Knowledge transfer

The transfer of knowledge to society is an important part of CWI's mission. To this purpose the institute organizes conferences, meetings, and workshops. Among them were the W3C Semantic Tour in Brussels, the annual holiday course for mathematics teachers and the Dutch Belgium Information Retrieval Workshop. Stimulating the establishment of spin-off companies by CWI employees is also part of these activities.

Business day

The 2003 edition of CWI's annual business day *CWI in Bedrijf*, held in October, was devoted to games and entertainment. Entertainment has become an increasingly important application of computers. The design of realistic graphics and intelligent game play poses huge challenges to industry and science. In his presentation Mark Overmars from Utrecht University argued that game design should be taken seriously as a science. The other speakers, among whom internationally renowned computer chess expert Jaap van den Herik, talked about aspects of entertainment design. The next day CWI received several hundred visitors on the open day of the Sciencepark Amsterdam.

15 years of European internet

On Monday, November 17, CWI celebrated the fifteenth birthday of the European connection to internet. CWI was the first non-American organization in Europe to gain access to the American science network NSFnet, which was the equivalent of internet at the time. The connection was a result of extensive negotiations with the American internet administrators, mainly conducted by CWI's network manager Piet Beertema and his colleagues. Not much later other research organizations and companies were connected through CWI. For many years the institute remained the European internet gateway to the United States. The anniversary received much attention in the popular media.

Influenza survey

CWI contributed to the largest influenza survey ever conducted in the Netherlands and Flanders. The *Grote Griepmeting*, organized by science website Kennislink, the magazine Natuurwetenschap & Techniek and

several research centers, maps the spread of influenza and common cold from November 1, 2003 until April 1, 2004. The general public was invited to contribute to the survey by signing up on a website. On a regular basis they were asked to report any symptoms like fever, a sore throat or a runny nose. From this data an overview was created of the spread of influenza and cold-like diseases in the Netherlands and Flanders. The main objective of the Grote Griepmeting was to increase the public interest for science, but the results might also be used to improve mathematical models of the spread of epidemics or to plan vaccination campaigns.

Spin-off companies

The unfavorable investment climate for ICT companies continued throughout 2003. As a result, no new spin-off companies were launched. The successful customer relationship management and data-mining software developer DataDistilleries was acquired by the Nasdaq-listed provider of predictive analytic software and services SPSS. With the purchase of DataDistilleries the Chicago-based company strengthens its position in the market of business applications like fraud detection and targeting direct marketing campaigns.

National and international cooperation

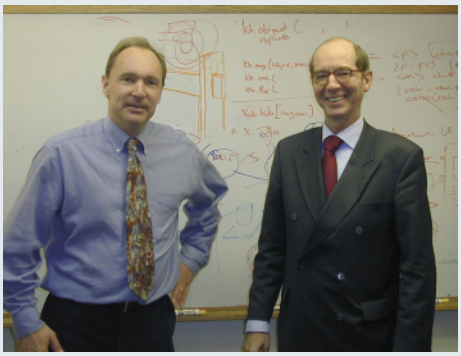
Research increasingly becomes a team effort. CWI is part of many national and international networks, most notably the European Research Consortium for Informatics and Mathematics (ERCIM). It participates in the International Conference and Research Center for Computer Science Dagstuhl in Germany. Since 1998 CWI hosts the Netherlands Office of the World Wide Web Consortium (W3C) and since 2002 the Benelux Office. Participation in the Institute for Mathematics and its Applications in Minneapolis was terminated. In the Netherlands, CWI is a member of the Telematics Institute. It also maintains close relations with the neighboring organizations on the Sciencepark Amsterdam as well as with Dutch universities and research schools.

ERCIM

The European Research Consortium for Informatics and Mathematics continued to grow. In 2003 two organizations joined. The Spanish Research Consortium for Informatics and Mathematics (SpaRCIM) became a member in July. The Fonds voor Wetenschappelijk Onderzoek - Fonds National de la Recherche Scientifique (FWO-FNRS) from Belgium joined in December.

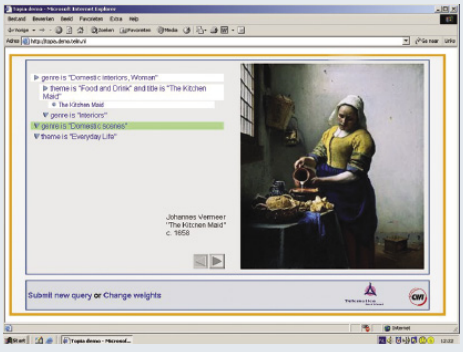
On December 1, 2003 ERCIM became the European Host of W3C (see below). It reinforces W3C's relations with European research centers and allows it to benefit from the expertise of ERCIM's member institutes. With 370 Member Organizations from all over the world W3C provides ERCIM with opportunities for global cooperation.

Currently, ERCIM has member organizations in eighteen European countries, employing more than 10,000 researchers in computer science and applied mathematics. The consortium has thirteen working groups, two of which are coordinated by CWI researchers. Working groups are networks of ERCIM researchers in a particular field. They organize workshops, promote mobility, and prepare common project proposals. The MUSCLE project on multimedia data mining and



ERCIM president Gerard van Oortmerssen and W3C director Tim Berners Lee (left).

In June PhD student Simona Orzan from CWI's theme Specification and Analysis of Embedded Systems (SEN2) received a best paper award at the annual workshop of the ERCIM working group Formal Methods for Industrial Critical Systems (FMICS). FMICS received ERCIM's Working Group Award 2003.



For the Topia project a demonstrator was designed that generates presentations based on a database of the collection of the Rijksmuseum Amsterdam.

machine learning is an example. It mainly consists of the Image and Video Understanding Group, which is coordinated by CWI researcher Eric Pauwels.

The ERCIM Office also coordinates projects. The DELOS Network for Digital Libraries again received the Network of Excellence status from the EU. CWI's Database Architectures and Information Access theme also participates in this network. The head of CWI's Personnel Department, José Koster, chairs ERCIM's HRM Board. This body is concerned with the stimulation of mobility, for example through the ERCIM Fellowship Programme, enabling young researchers to spend up to eighteen months in one or two ERCIM Institutes. In 2003 eight ERCIM researchers visited CWI through this program. The consortium publishes ERCIM News, a magazine that reports on European IT research.

W3C

In 2003 W3C released a new Recommendation for online forms called XForms 1.0. Web users can employ these forms to submit information to websites. CWI researcher Steven Pemberton presided the W3C Working Group that developed the worldwide standard. The Recommendation increases the potential of web forms and makes them easier to use. Experts expect XForms to have great potential in applications like e-commerce.

Telematics Institute

As a member of the Telematics Institute CWI contributes its expertise on queueing theory, multimedia, and software engineering to large ICT projects, working together with partners from trade, industry, and the academic world. Two projects in which CWI participated were finished in 2003. Autonomous Systems of Trade Agents (ASTA) applies intelligent software agent technology to e-commerce. It is described in more detail in the Research Highlights. Also concluded was Topia. In this project a system was developed that automatically generates multimedia presentations based on the results of a search query. In 2003 the M2C project on overprovisioning to ensure quality of service requirements for telecommunication networks started. It focuses on traffic measurement and efficient allocation of network resources based on these measurements.

WTCW / Sciencepark Amsterdam

CWI participates in the Amsterdam Science & Technology Centre (WTCW), a cooperative of knowledge institutes and companies at the Sciencepark Amsterdam in Watergraafsmeer. WTCW stimulates multi-disciplinary research, where possible in cooperation with trade and industry. It acts as coordinator for the Bsik project Virtual Lab e-Science in which CWI also participates. The Sciencepark Amsterdam has strong national and international ties with research centers, companies, and the government. In 2003 Maria van der Hoeven, Minister of Education, Culture, and

Science, and members of the think tank Nederland Kennisland visited the Watergraafsmeer. CWI was also visited by a delegation of members of parliament.

Personalia

CWI employs a total of 140 researchers. Many of them receive recognition from the scientific community for their achievements. Nine researchers completed their PhD thesis in 2003. Topics were in the area of software engineering, telecommunications, multimedia databases, neural networks, partial differential equations, system theory, and image processing. Two researchers continued to work at CWI.

Management

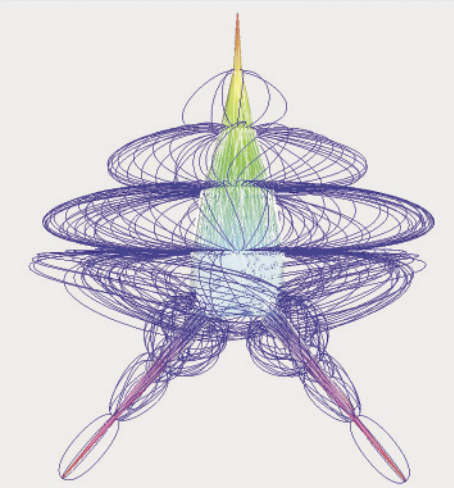
After twelve years of service, Gerard van Oortmerssen resigned as general director in May 2003 to take up the job of director of TNO Telecom. Van Oortmerssen joined CWI in 1991 as managing director. In 1994 he became general director. From 1998 to 2003 he also acted as president of ERCIM. A tribute to Gerard van Oortmerssen can be found below.

In October Jan Karel Lenstra succeeded van Oortmerssen. Lenstra is no stranger to CWI. He worked at the institute from 1969 to 1989. The last six years of this period, he led the Department of Operations Research, Statistics and System Theory. He was appointed full professor of Combinatorial Optimization at Eindhoven University of Technology in 1989. From 1999 to 2002 he was dean of the Department of Mathematics and Computer Science. He left Eindhoven in 2002 to join the Georgia Institute of Technology. From May to October Wim Hutter acted as interim director. Hutter is a former director of NWO. Paul Klint, leader of the Software Engineering cluster, was deputy director in this transition period.

Appointments

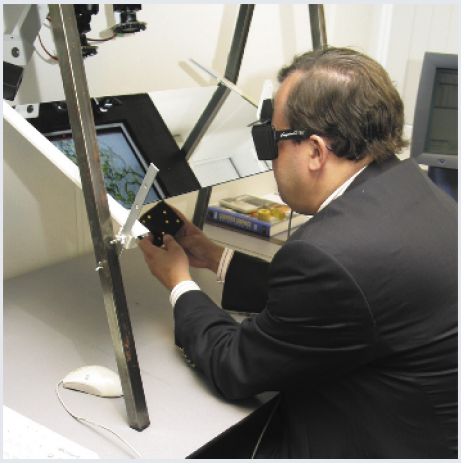
In 2003 Rob van den Berg was appointed professor of spatial stochastics at the Faculty of Sciences of the Vrije Universiteit Amsterdam. Van den Berg leads CWI's Stochastics theme (PNA3). Among his research interests are telecommunication networks and percolation, a branch of stochastics studying transitions in connectivity in random systems. See also the Research Highlights section.

As of January 1, 2004 Arie van Deursen is appointed professor of software engineering at the Faculty of Electrical Engineering, Mathematics and Computer Science of the Delft University of Technology. Van Deursen is a member of the theme Interactive Software Development and Renovation (SEN1) where he works on software renovation. In Delft he set up the



Visualization of a state space graph. Together with the French sister institute INRIA, researchers from SEN2 have set up the first VLTS Benchmark Suite. This online database contains several very large transition systems (VLTS), systematic descriptions of complex processes like railway safety systems. These descriptions, also referred to as state space graphs, include all possible states of the system and the way these states are related to each other. The benchmarks can be used to evaluate algorithms operating on state space graphs, like model checkers and visualization tools.

Image courtesy of Frank van Ham, Eindhoven University of Technology.



Member of Parliament Mat Herben using the Personal Space Station, CWI's virtual reality system that allows manipulation of the objects on screen.

Miranda van Uitert was one of the CWI researchers to defend her PhD thesis. She identified a number of causes of congestion in Generalized Processor Sharing (GPS) communication networks. GPS is a technique to schedule incoming network traffic at switches. Bandwidth is assigned to different types of traffic according to pre-defined weights. It allows the network operator to prioritize traffic types that require small delays like voice data over less demanding types like e-mail. Her results contribute to the research of queueing problems in communication networks. In future this can lead to a more economic use of bandwidth.

On May 14 CWI bid farewell to its general director Gerard van Oortmerssen (right).

Paul Vitányi was appointed CWI Fellow.

Software Evolution Research Laboratory that will work closely together with CWI on this topic.

On August 1, 2003 Mark van den Brand from SEN1 became lecturer at the Hogeschool van Amsterdam (HvA). Van den Brand's appointment reinforces the HvA's computer science curriculum, in particular on the subject of software quality.

Vitányi CWI Fellow

On January 1 Paul Vitányi was appointed CWI Fellow for his research accomplishments and leadership. Under his supervision the Quantum Computing and Advanced Systems theme became one of the world's prominent groups in quantum computing, distributed algorithms, algorithmic information theory, learning and inference methods, and reversible adiabatic computing. Together with Ming Li he pioneered the use of Kolmogorov complexity, an alternative information theory. Their book *An Introduction to Kolmogorov Complexity and Its Applications* is considered a classic. On January 1 Vitányi stepped down as theme leader. He was succeeded by Harry Buhrman.

Klop member KNAW and CWI Fellow

Jan Willem Klop was elected member of the Royal Netherlands Academy of Science (KNAW). He was also appointed CWI Fellow. Klop works in the Specification and Analysis of Embedded Systems theme (SEN2). He is part-time professor at the Vrije Universiteit Amsterdam and the University of Nijmegen. Together with Jan Bergstra and Jos Baeten, Klop worked on the development of process algebra (ACP).

Dantzig Prize for Schrijver

Lex Schrijver received the George B. Dantzig Prize for his complete work in optimization. This prize, awarded every three years by the Mathematical Programming Society (MPS) and the Society for Industrial and Applied Mathematics (SIAM), is the most prestigious award in mathematical optimization. Schrijver received the prize for his 'deep and fundamental research contributions to discrete optimization'. Schrijver currently leads the Probability, Networks and Algorithms cluster at CWI.

2003 Also saw the publication of Schrijver's magnum opus Combinatorial Optimization, Polyhedra and Efficiency. This three-volume book published by Springer-Verlag gives an in-depth survey of this field.

Fulkerson Prize for Gerards and Schrijver

Bert Gerards received the Delbert Ray Fulkerson Prize, as did Lex Schrijver. It is awarded by the MPS and the American Mathematical Society (AMS) for outstanding papers in the area of discrete mathematics. He received the award for an article with Geelen and Kapoor in the Journal of Combinatorial Theory. Gerards leads CWI's Networks and Logic – Optimization and Programming theme (PNA1). Schrijver's prize-winning article appeared in the same journal. It is the second time Schrijver wins this triennial award.

De Wolf wins Cor Baayen Award

ERCIM's 2003 Cor Baayen Award was won by CWI researcher Ronald de Wolf for his work on quantum computing. De Wolf works at the Quantum Computing and Advanced Systems Research theme INS4. He designed several quantum algorithms that surpass classical equivalents. Furthermore, he proved various limitations of quantum computers and showed how quantum algorithm theory can be used to prove classical theorems. De Wolf is the first Dutch scientist to win the Cor Baayen Award. This prize for the most promising European researcher in computer science or applied mathematics was introduced in 1995. It is named after former CWI director and first ERCIM president Cor Baayen.

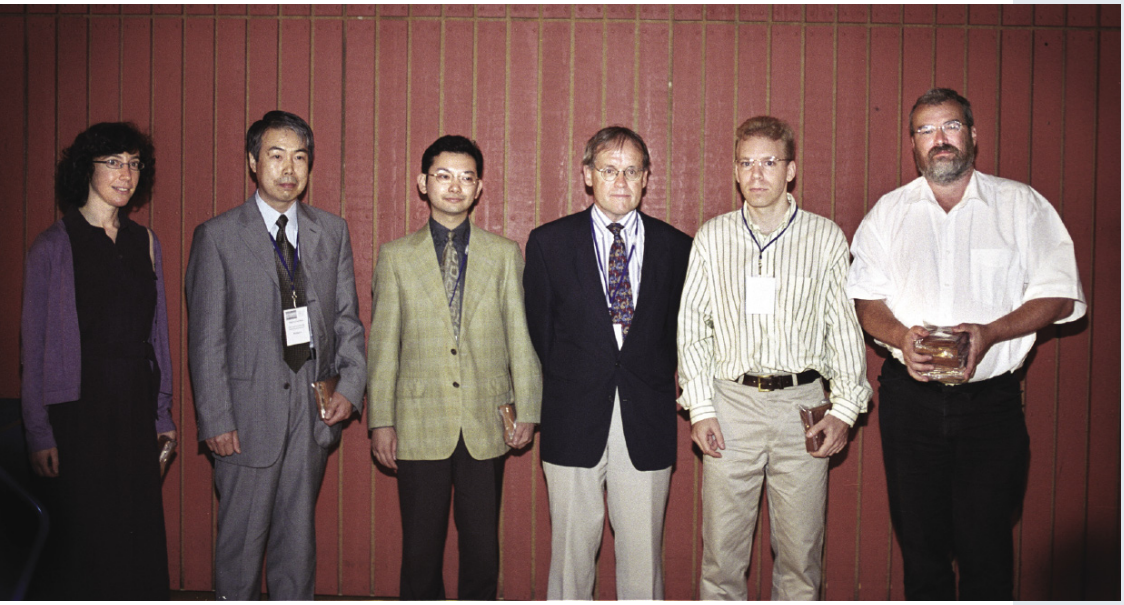
Jeroen Wackers best graduate Delft University of Technology

The Faculty of Aerospace Engineering of the Delft University of Technology elected Jeroen Wackers as the best graduate student of the year 2002–2003. Wackers completed his graduation work in cooperation with CWI's Computing and Control theme MAS2. His grade average exceeded nine (on a scale of one to ten). With his thesis on the solution of 2D unsteady Euler equations he graduated with honor. Wackers continues to work at CWI as a PhD student.

Ronald de Wolf receives the ERCIM Cor Baayen Award for the most promising European researcher in mathematics and computer science.

Jeroen Wackers at the award ceremony of best graduates of the Delft University of Technology.

Photo courtesy of MMS, Delft University of Technology.



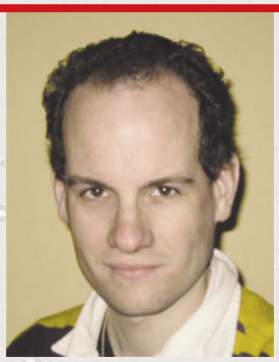
Bert Gerards (first person on the right) and Lex Schrijver (third person on the right) at the award ceremony for the Fulkerson Prize during the International Symposium on Mathematical Programming in Copenhagen.

Photo courtesy of ISMP 2003.

Veni, Vidi, Vici

CWI's researchers came, saw and conquered. Sander Bohte, Mark Peletier and Harry Buhrman were given a Veni, Vidi and Vici grant in 2003. For the first time CWI hosts winners of all three components of NWO's Vernieuwingsimpuls subsidy program for talented researchers. Three names to watch in mathematics and computer science.

NWO's Vernieuwingsimpuls intends to stimulate innovative research. Outstanding researchers are given individual grants to pursue their own research ideas. The program consists of three parts. The Veni grant, amounting up to 200,000 euros for three years, allows PhD graduates to develop their own ideas. Vidi, up to 600,000 euros for five years, aims at innovative researchers with several years of experience. It allows them to set up their own line of research. The Vici grant, up to 1,250,000 euros for five years, is intended for senior researchers and can be used to set up or expand their own research group.



Sander Bohte

Researcher at the Evolutionary Systems and Applied Algorithmics theme (SEN4)

Research interests

Artificial neural networks. A neural network is a simplified computer model of the human brain. It consists of a web of interconnected artificial neurons. The neurons perform 'computations' by transforming and passing on signals they receive from other neurons. The network can improve its performance by adjusting the magnitude of the signals based on the processed data. Due to their special structure, neural networks are very suitable for speech and image recognition.

In particular Bohte studies so-called artificial spiking neural networks. Classical neural networks use signals that represent the rate at which biological neurons emit signals. However, brain research indicates that the timing of these spike-shaped signals also contains significant information. These insights led to the development of the more realistic spiking neural networks, which use precisely timed spikes to pass on information.

Veni project

The main objective of Bohte's grant-winning research is to increase the size of artificial spiking neural networks. This expands a network's ability to handle complex tasks. Bohte proposes to use small spiking neural networks as agents, intelligent software components that can autonomously perform certain tasks. It has been shown that systems of multiple agents are able to perform difficult tasks (for some examples see the Research Highlights section). Moreover, these systems can easily be expanded.

To realize this, Bohte will investigate reinforced learning in spiking neural networks. This common strategy in agent technology involves introducing rewards or punishments for neurons that react to the environment in certain ways. By carefully choosing the reward it is possible to influence the behavior of the system as a whole. For this part of the project, Bohte builds on the extensive knowledge of rewarding methods in agent systems that exists in SEN4. The research will also give new insights in the way the human brain functions.

Mark Peletier

Leader of the theme Nonlinear PDEs: Analysis and Scientific Computing (MAS1)

Research interests

Partial differential equations. Models of this type describe many natural phenomena, ranging from electromagnetic fields to fluid flows. As a result, applying and solving partial differential equations has always been an important part of modern mathematics.

One of the main applications studied by Peletier is biology. In particular, he participates in the Silicon Cell initiative of CWI, the University of Amsterdam and the Vrije Universiteit in Amsterdam. The goal is to achieve an integrated model of all processes in living cells. Partial differential equations play an important role in the project, for instance in descriptions of chemical reactions in the cytosol, the fluid inside cells, and in the mechanics of cell membranes.

Vidi project

Peletier's Vidi project is connected to his Silicon Cell research. It deals with so-called partially localized structures, solutions of reaction-diffusion equations that are concentrated in one direction, but extended over the other directions. Nature shows a prime example of partially localized structures. Lipid molecules typically aggregate into two-dimensional structures (cellular membranes) that are essential to cellular function. Currently, not many mathematical models exist that explain the existence and stability of partially localized structures. Peletier attempts to fill this gap by constructing models by analogy with existing descriptions of polymer melts. The first steps in this direction are promising.

The focus will be on two central questions. First, it is unclear which type of models, systems of differential equations, admits stable structures of this type. Understanding the stability in terms of the structure of the equations is an essential step. Secondly, an important challenge is to make a connection between high and low-level models. Peletier conjectures that existing high-level descriptions of membranes, based on the so-called Helfrich energy, arise as upscaled limits of smaller-scale models considered in this project. Making this connection rigorous, and developing the necessary theory is an important challenge with many possible consequences outside this field.

Harry Buhrman

Leader of the theme Quantum Computing and Advanced Systems Research (INS4)

Research interests

Quantum computing. Classical computers operate by manipulating bits, memory units that can be either zero or one. Quantum computers alter this fundamental principle. Quantum bits, or qubits can be zero and one at the same time. This is called superposition. Computing with a qubit is therefore comparable to computing two numbers in parallel. Furthermore, the amount of numbers that can be manipulated in one stroke increases quickly with the amount of qubits. An operation on thirty qubits for example, equals an operation on more than a billion numbers.

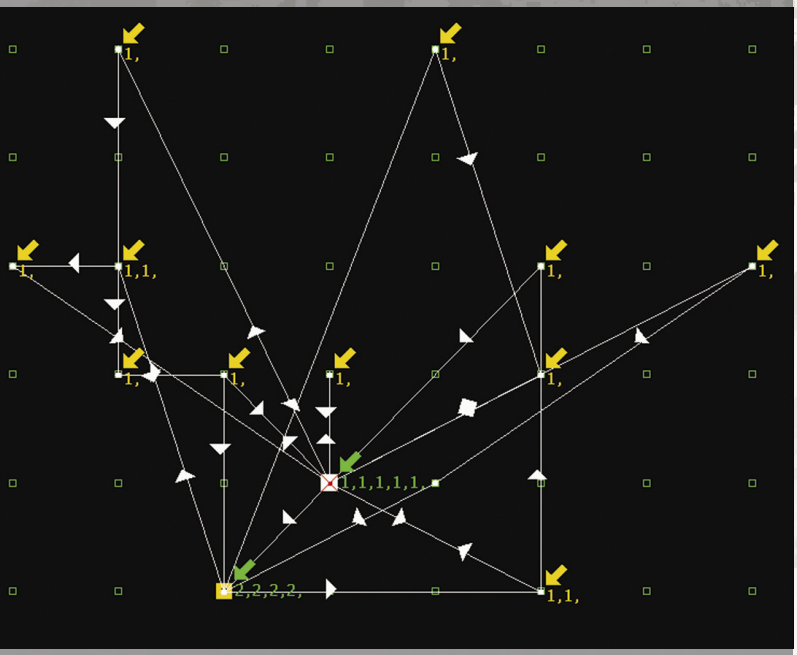
One of the problems with quantum computing is that these numbers are hidden in the qubits. However, it is possible to access them by exploiting another characteristic of quantum bits. The hidden numbers can amplify or cancel each other. This is referred to as interference. By carefully designing the computation process, the wrong answers get extinguished but the correct outcome remains. Because they process many numbers at the same time, quantum computers are much faster than their classical counterparts. But since it is not always possible to obtain useful interference, they can unfortunately only be used for a limited number of tasks like factoring large numbers,

Vici project

Although several experimental physics groups worldwide are currently working on it, a large-scale quantum computer has not yet been built. Buhrman's Vici project covers theoretic research on quantum algorithms. It includes the design of novel quantum algorithms, as well as the study of a quantum computer's limitations. One of the main problems with actual quantum computers is the vulnerability of qubits to disturbances. As part of the project, Buhrman works on error correcting codes, which protect the data by spreading it among multiple qubits.

Bsik

Strengthening the knowledge society is an important objective of the Dutch government. In 2003 it made a decision on the 800 million euro Bsik subsidy program to stimulate research in a number of strategic fields including ICT. As the national research institute for computer science and mathematics, CWI is well equipped to contribute to Bsik. It participates in three projects: BRICKS deals with fundamental ICT research, MultimediaN with multimedia, and Virtual Laboratories e-Science provides a national e-science environment.



The BRICKS project includes the development of decision support systems for logistics. CWI already has considerable expertise in this area. The DEAL project for example, uses intelligent agents to distribute freight jobs over trucks. The figure shows a route planned by one truck. A green number indicates a load picked up by the truck. A yellow number marks a delivery.

BRICKS

Participants

CWI (coordinator), Delft University of Technology, Eindhoven University of Technology, Twente University, Utrecht University, and NWO

ICT is one of the pillars of today's society. It has pervaded every corner, from agriculture to high-tech industry and from health care to defense. For its part, ICT builds on research in computer science and applied mathematics. Not only does research in these disciplines solve fundamental and practical problems in ICT, it also generates new ideas and educates personnel for the sector. Furthermore, other fields like life sciences, logistics and physics also benefit from progress in computer science and applied mathematics. No wonder that government, industry, and the academic world have repeatedly stressed the importance of informatics and mathematics research.

The BRICKS (Basic Research in Informatics for Creating the Knowledge Society) consortium answers this call. It builds on the existing high quality of the partners' existing research activities. Participating groups have a proven track record in one or more of the project's themes. With the BRICKS funding additional personnel can be hired to strengthen and expand their research portfolio. A subsidy program to support promising groups and individual researchers outside the BRICKS consortium is also included.

The project strengthens ICT research in the areas of parallel and distributed computing, modeling, simulation and visualization, intelligent systems, and algorithms and formal methods. These themes offer both fundamental scientific challenges and solutions for practical problems. NWO lists them among the research areas in which major breakthroughs are foreseen in the near future. Projects include the development of new test methods for cryptosystems to secure network traffic, intelligent decision support systems for logistic problems, simulations of fluid flows, and algorithms and machine learning techniques for bioinformatics.

MultimediaN

Participants

University of Amsterdam (coordinator), CWI , Delft University of Technology, TNO, Twente University, Telematics Institute, Philips, and IBM. Supplemented with 28 high-tech companies and institutes

The future of communication is multimedia. Whether for business or pleasure, multimedia is a very natural way of sharing information. Both industry and science recognize the extension of the possibilities of multimedia storage, management, retrieval, and communication as a major priority.

This brings along several challenges that will require much research. Currently, a lot of multimedia is fragmented and separated in different formats. Advanced applications will integrate language, image and sound. Content is often inaccessible to multimedia systems. CD players can reproduce a piece of music, but they do not know what is playing. The supply of multimedia can be intimidating and confusing. New methods of filtering and personalizing multimedia must be introduced to guide the user. Furthermore, multimedia is often poorly organized in different systems.

The MultimediaN consortium is set up to meet these challenges. Its proposal consists of ten major projects covering all aspects of multimedia. One example is Multimedia Ambient Databases, which aims at developing a database management system for an expandable network of devices for personalized multimedia delivery. The Semantic Access project deals with the accessibility problem using automatic feature extraction and user feedback. Another part covers the development of a digital time machine, a service that gives access to cultural heritage information.

Additionally, technology transfer plays an important role in MultimediaN. Potentially relevant scientific results often reach the industry and application developers late. Research has become very specialized and new developments are generally only published in scientific journals. On top of this, adoption of new multimedia technology requires know-how and large investments. To stimulate knowledge transfer between science and industry, MultimediaN acts as a multimedia research community.

Virtual Laboratory e-Science

Participants

19 organizations from trade, industry, and research including WTCW (coordinator), CWI, University of Amsterdam, NIKHEF, AMOLF, SARA, Unilever, and Philips

ICT developments like e-mail and internet have stimulated national and international scientific cooperation. However, increased contact between scientists is just the beginning of the potential of ICT for research projects. Increased network bandwidth, the sharing of computer power, storage and other resources (also known as the Grid) and visualization allow far-reaching forms of cooperation, usually referred to as enhanced science or e-science.

An e-science environment allows scientists to remotely access the results from large-scale, expensive experiments like the Large Hadron Collider, currently built at the European particle physics center CERN in Switzerland. Alternatively, it enables them to use the combined processor power of computers all over the world. A glimpse of the potential of this strategy could be seen in 1999 when an international team of scientists, coordinated by CWI, combined their computer resources to factorize the RSA-155 code for internet data security. An e-science environment also offers visualization and data-mining facilities to access large amounts of information.

The Virtual Laboratory for e-Science (VL-E) project stimulates Dutch e-science by researching relevant technologies including the development of a large-scale distributed system based on high-performance networking and Grid technology. Furthermore, an e-science environment is created for applications like genomics, food research, and high energy physics.

The Sciencepark Amsterdam plays an important role in VL-E. The project is managed by WTCW, the organization that coordinates joint research activities of the Sciencepark's residents. The presence of one the world's largest internet exchanges AMS-IX, a high capacity network and SARA's supercomputer and visualization facilities make the area a logical focus for VL-E. CWI's main contribution is in the field of visualization and user interfaces. The Visualization and 3D Interfaces theme INS3 will develop a virtual environment for user cooperation.

12 Years

Gerard van Oortmerssen

A cautious captain. It is a popular metaphor for Gerard van Oortmerssen. This is obviously prompted by his background as a maritime engineer. But it equally refers to the way he sailed CWI into calmer waters. A portrait of the man who led CWI for twelve years.

"When van Oortmerssen succeeded Jan Nuis as managing director in 1991, CWI found itself in an alarmingly bad financial situation", tells Gerke Nieuwland, at that time chairman of CWI's Governing Board, the Curatorium. CWI was forced to contract a loan from NWO to cover deficits. Moreover, compulsory redundancies were necessary. Van Oortmerssen, previously head of research and development at the Maritime Research Institute (MARIN), managed to improve the situation by careful financial management. He appointed a controller and built up spare funds. "His achievements were impressive", says Nieuwland.

In 1994 scientific director Cor Baayen retired and van Oortmerssen assumed the newly created position of general director. In this capacity he initiated a new structure. The former departments, organized according to discipline, were substituted by strategic research themes, combined in four clusters. The themes became responsible for their own budget. To stimulate the circulation within the organization, all executive functions became temporary. "To a sceptic observer, this reorganization might look like just another reshuffle, but in practice the operation turned out to be very drastic", tells Jaco de Bakker, former leader of the Software Engineering cluster. "Transparency increased, it became possible to compare the performance of the themes and in the careful hands of van Oortmerssen large shocks were avoided. The desired circulation was clearly achieved."

De Bakker is not the only one to mention van Oortmerssen's caution. Ad van Tok, controller from 1994 to 1998, recalls the way van Oortmerssen steered CWI's portfolio to more applied research. "He was capable of finding a balance between the part of the institute that wanted to perform purely fundamental research and the part that wanted to bring a number of changes. Van Oortmerssen was incredibly patient and took one step at a time." According to CWI Fellow and former theme leader Paul Vitányi, cautious, delayed management was van Oortmerssen's main characteristic. "Decisions were not taken lightly, but long deliberated, discussed and being advised upon."

Many people who worked with van Oortmerssen also remember his tireless efforts to promote CWI. Van Oortmerssen set up the annual business day *CWI in Bedrijf* to tighten the bonds with trade and industry.

He also stimulated the creation of spin-off companies. This resulted in successful businesses like the web design company General Design, acquired by Satama International in 2000. CWI researcher Marcel Holsheimer founded customer relation management and data-mining software company DataDistilleries. "Personally, I am very grateful to Gerard van Oortmerssen for his role in the creation of DataDistilleries. His conviction that CWI should actively support spin-offs has been crucial for DataDistilleries' success."

Van Oortmerssen also served two terms as president of ERCIM, from 1998 to 2003. During his presidency the consortium grew from eleven to eighteen members. He strengthened ties with the European Union, the European Science Foundation and the US National Science Foundation. Van Oortmerssen also adopted the proposal to make ERCIM the European Host for W3C in 2003.

During his twelve years as manager, van Oortmerssen left his mark on CWI. The institute has a healthy financial basis. The organizational structure he introduced is still intact. CWI's reputation as a high-class research organization has been reinforced. Lex Schrijver, leader of the Probability, Networks and Algorithms cluster summarizes van Oortmerssen's importance to the institute as follows: "Gerard made CWI aware of society and society aware of CWI."

Research Highlights

Theme:	Database Architectures and Information Access (INS1)
Project:	Feature Grammar Systems
Researchers:	Menzo Windhouwer (photo), Martin Kersten (project leader)
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Grammar enables effective multimedia search queries

Retrieving files from a multimedia database is like finding a book in a library: Without a catalogue of keywords you will be searching for ages. But generating and updating such a catalogue is almost as difficult. CWI introduces so-called feature grammar systems to facilitate these tasks.

Multimedia is everywhere. Libraries and museums digitize their collections and make them available to interested parties. Many people store large amounts of digital pictures, documents and MP3s on their computers. Effectively, the World Wide Web is a huge multimedia library. Cheap disk space brought the storage of large amounts of multimedia within reach for everyone. At the same time it complicated the retrieval of objects. Not only have databases become larger, they also contain more types of media. Most people are able to find a text containing certain keywords. But anyone who has ever used Google Image Search to look for a specific picture knows that finding what you need can be far from easy. The majority of search engines can only interpret textual data. They cannot 'see' what is depicted in an image or 'hear' what is on an MP3.

Annotation

A way to deal with this problem is to annotate media objects in advance. Annotations describe particular features of the stored media objects and can be used to guide semantic search queries. When for example MP3s are annotated for genre and background information of the performing artist, search queries like 'find me all blues songs played by guitarists from Mississippi' can give meaningful results.

Annotation can be done manually, but for large multimedia collections this quickly becomes impossible. Therefore, it is necessary to turn to automatic annotation using extraction algorithms. Extraction algorithms are computer programs designed to obtain features from media objects. This can be very easy, like finding the length of an MP3, or complicated like detecting human faces in images. Designing clever extraction algorithms is a necessary condition for an automatic annotation system.

Context dependency

But high-quality extraction algorithms alone are not enough. Just as important is a system to coordinate the extraction of annotations. The main problem is that annotations depend on context. In practice this means annotations depend on each other. This has consequences for the way extraction algorithms should be used. For example, feeding charts or logos to a face extractor would be a waste of system resources and time. The annotation system makes sure the extractor is only applied to images with a high chance of containing faces, like photos or drawings.

The lack of context also complicates incremental maintenance. Without knowledge of the context and interdependencies the entire annotation process should be rerun every time some extraction algorithm is added or replaced. The annotation system finds dependencies and determines exactly which annotations should be updated and which can be reused.

Context dependency of annotations can also cause extraction algorithms to give ambiguous answers, especially when dealing with complex features. This can result in outputs like 'this image either contains a human or a pig'. The annotation system should be able to handle these ambiguities.

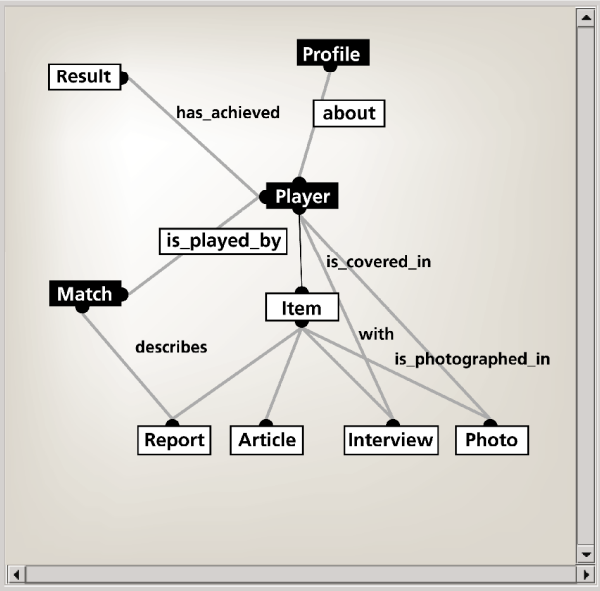
Valid sentences

CWI solves these difficulties by combining database technology with ideas from formal language theory in the Acoi annotation management system. Its basis is formed by the theory of feature grammar systems. Such a system not only describes the annotations themselves, but also their dependencies and contexts. Feature grammar can be compared to grammar in natural language. Grammar determines which word classes can be combined in what order to form a valid sentence. A feature grammar system does the same for annotations and extraction algorithms. The system determines what extraction algorithms must be called to form a valid annotation 'sentence'.

Since the feature grammar system also stores the annotations' place in the network of interdependencies, incremental maintenance is possible. When updating the database the sentences can be reinterpreted to determine which extractions must be redone. Furthermore, techniques from formal language theory could be modified and used in the annotation system. Resolving ambiguities for example, is a classic problem in this branch of computer science.

Case studies

Acoi was tested in a number of case studies. Together with a number of basic extraction algorithms it was used to create an annotation index for a collection of webpages. Adding new extraction algorithms proved the system can indeed easily be extended. The case study also

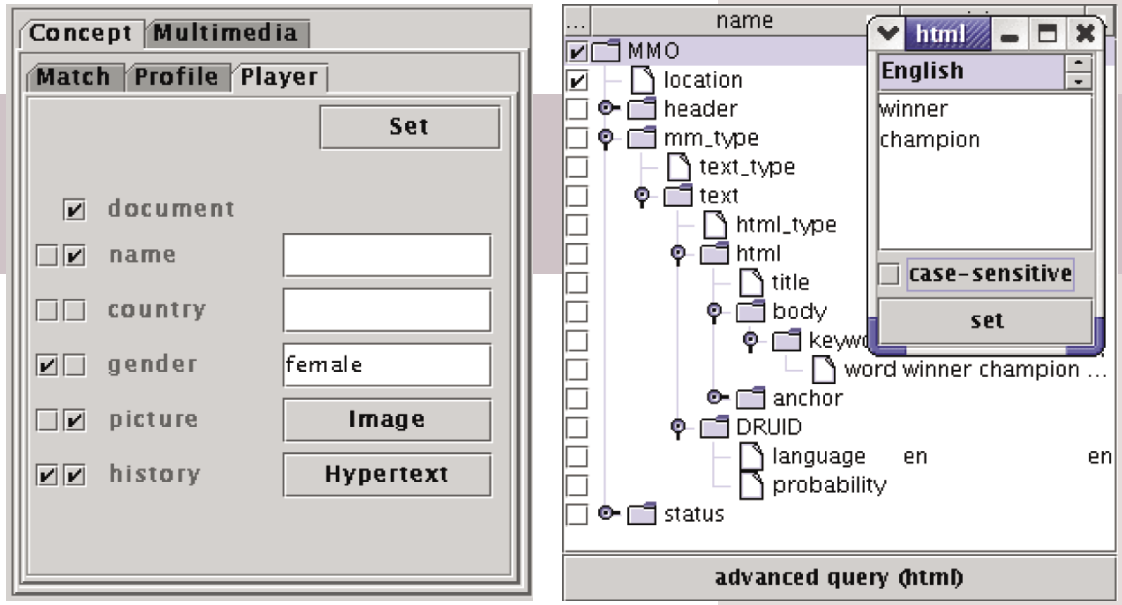


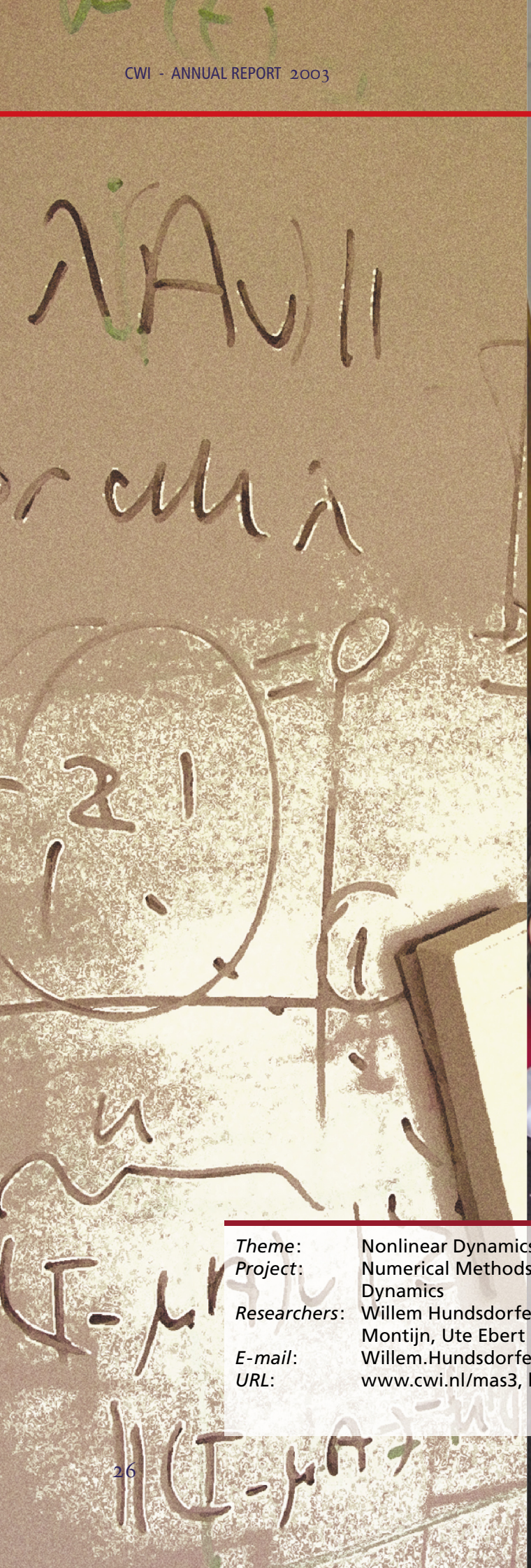
The annotations extracted by Acoi can be used to formulate detailed search queries. These examples of a query formulation are taken from the Australian Open search engine, one of the Acoi case studies.

showed another advantage of the annotation system. Traditional search engines build their indexes from scratch with each web crawl. Acoi's index on the other hand, is updated incrementally.

The annotation management system was also used in combination with a presentation generator to unlock the digitized collection of the Rijksmuseum Amsterdam to the public. The generator, also developed at CWI, uses the annotations to automatically compose a semantically structured multimedia presentation on a user-defined subject. Since the extraction algorithms used to detect the style of paintings often give rise to uncertainties, the case study demonstrated Acoi's ability to handle ambiguities. It was also shown that the feature grammar system enabled efficient reuse of extraction algorithms in different contexts.

CWI's feature grammar system is unique. Other annotation systems have been developed, but they all lack the explicit storage of the annotations' context. As a result Acoi is the only system that elegantly handles ambiguities and allows for incremental maintenance. In the near future, Acoi will be used in the Bsik project MultimediaN.





Theme: Nonlinear Dynamics and Complex Systems (MAS3)
Project: Numerical Methods for Leading Edge Dominated Dynamics
Researchers: Willem Hundsdorfer (project leader), Carolynne Montijn, Ute Ebert (from top to bottom)
E-mail: Willem.Hundsdorfer@cwi.nl
URL: www.cwi.nl/mas3, homepages.cwi.nl/~willem

Studying sparks with pen and computer

Complex natural phenomena are sometimes governed by simple laws. CWI researchers showed that three equations are enough to describe the propagation and branching of sparks. The discovery was the result of numerical simulations and careful physical and mathematical interpretation. At CWI, applied and numerical mathematicians work closely together with physicists and electrical engineers to study the behavior of sparks.

How do sparks propagate? Gases are normally electrically insolating. Still, lightning bolts can travel through air as if it were a conducting medium. The key is the formation of streamers, conducting channels of electrons and ions that are created by high electric fields. The creation and propagation of a streamer are determined by three mechanisms. In high electric fields free electrons can gain sufficient energy to create additional electron-ion pairs through collisions with neutral particles. The free ions and electrons move in the direction of the local electric field or in the opposite way, depending on the sign of their electric charge. This movement leads to the build-up of space charge densities that modify the electric field. These mechanisms can be cast into three differential equations.

Branches

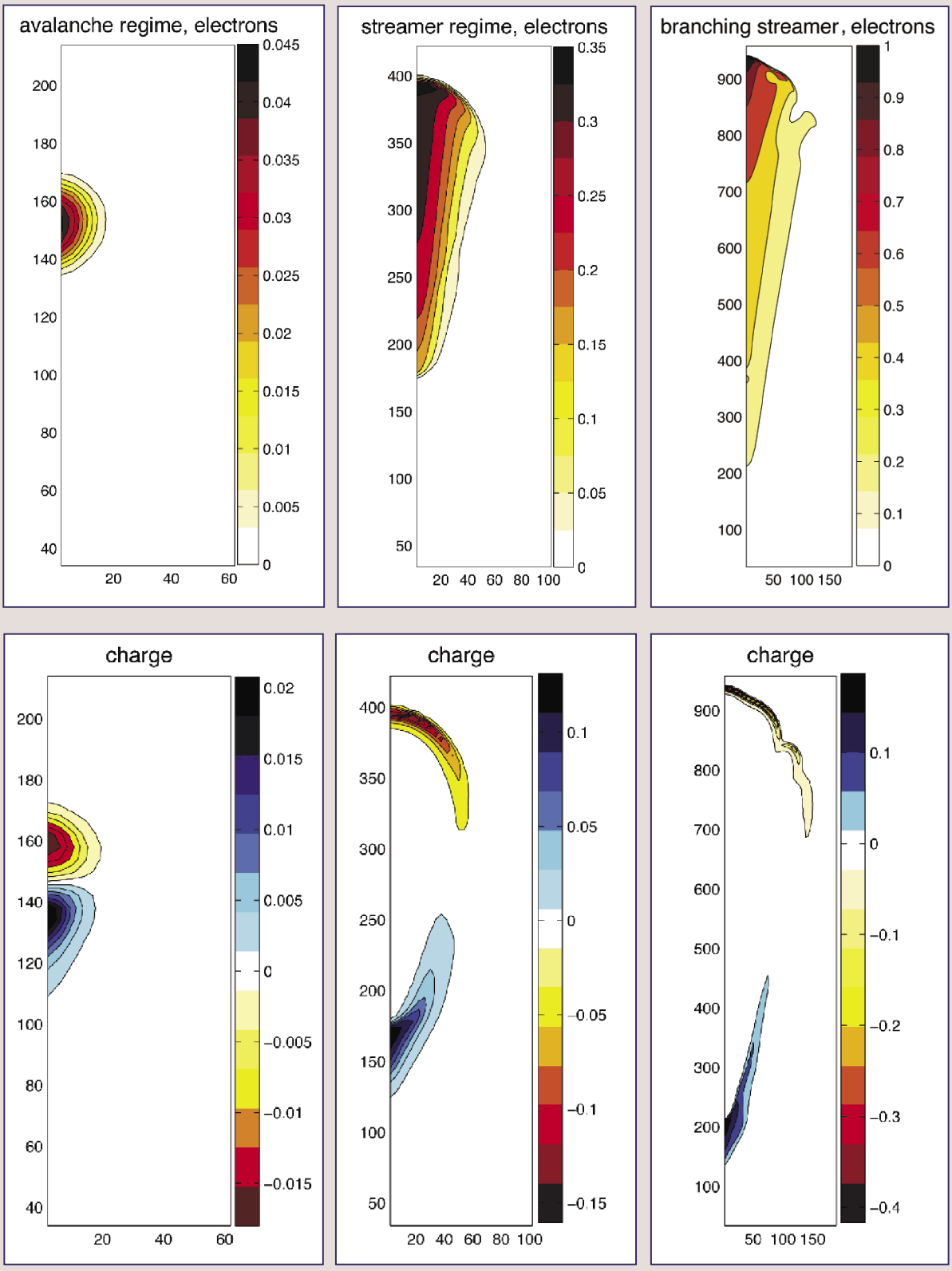
However, not only do sparks propagate, they also grow new branches. It was generally believed that the propagation model had to be extended with additional physical processes to describe this behavior. But simulation and analysis by CWI's Nonlinear Dynamics and Complex Systems theme (MAS3) showed that, under the proper conditions, these three equations are sufficient to understand not only the propagation, but also the branching of streamer channels.

The processes modeled by the equations are deeply nonlinear and far from an equilibrium. The interior of the streamer tip is electrically screened. The exterior is surrounded by a thin space charge layer. If this layer is sufficiently sharply curved, it creates a strong enhancement of the electric field ahead of the tip. In this zone, creation and motion of charged particles is very rapid. When the space charge layer becomes sufficiently thin in comparison to the channel radius, the structure becomes unstable and the streamer channel splits.

Simulations

Simulation is an indispensable tool for the study of gas discharges. It allows researchers to monitor the development of the physical quantities step by step. But even in simple models, simulation is far from trivial. Generally, simulations impose a grid on the event space. The model is then evaluated at every grid point. This is repeated at regular points in time. The size of the grid cells is one of the most important considerations when designing a simulation. It needs to be fine enough to resolve small details. On the other hand, a fine grid means more points to evaluate and therefore a larger computational burden.

Propagating and branching sparks contain structures with widely different scales. The thickness of the space charge layer around the tip is very small compared to the radius of the streamer, which is small compared to the streamer's length. In turn, the entire streamer fills only a small part of the total simulated volume. The space charge layer calls for a very fine grid, whereas other parts of the streamer do not have these stringent requirements. Using a uniform fine grid would



The electron and charge densities at different phases of streamer formation. In the avalanche phase the free electrons in the gas are accelerated by the electric field and start to ionize gas molecules. In the streamer phase a conducting channel of electrons and ions is formed. The branching streamer pictures show the onset of branches at the thin, curved space charge layer. The tip of the streamer is negatively charged. The electrons are much lighter than the positive ions and therefore faster. The bulk of the streamer contains both ions and electrons. Since their charges cancel each other out, a large part of the streamer is of neutral charge.

therefore be unnecessary and unworkable. Even if only a two-dimensional space is considered, the computations would take much too long.

Grid refinement

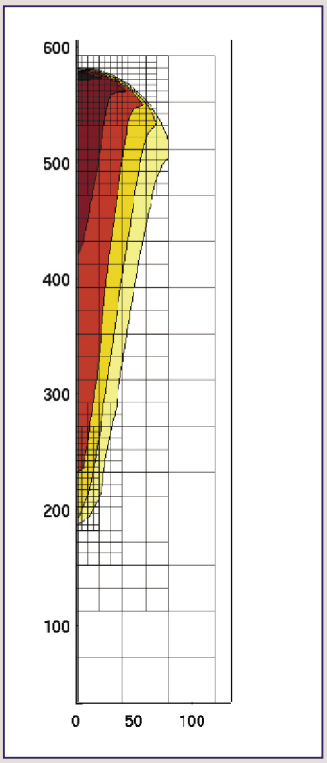
Numerical mathematicians often deal with such problems by using local grid refinements. At locations where detailed events are expected, a small grid is chosen. A coarse grid is used at locations where few things happen, like in the gas outside the streamer. Unfortunately, when implemented in a straightforward fashion for gas discharges, this method turns out to lead to unrealistic results. Analysis showed that streamers have so-called pulled fronts. The driving force of the propagation is not only located in the space charge layer, but also just in front of it. As a result the entire area around the tip of the streamer is very sensitive. Not only does it amplify small physical events, it can also blow up small calculation errors in the simulation domain causing non-physical solutions. The CWI researchers solved this problem by also applying a fine grid to the area in front of the tip.

Simulation was further improved by using separate grid refinements for the different physical processes. For example, charge densities are negligible far away from the streamer. The electric field, however, is greater than zero in those parts of the simulation domain. Evaluating the equations describing the electric field would be essential there, whereas the equations describing the charge densities would not yield any relevant information. Using the same grid for both parts of the model would therefore involve unnecessary computations.

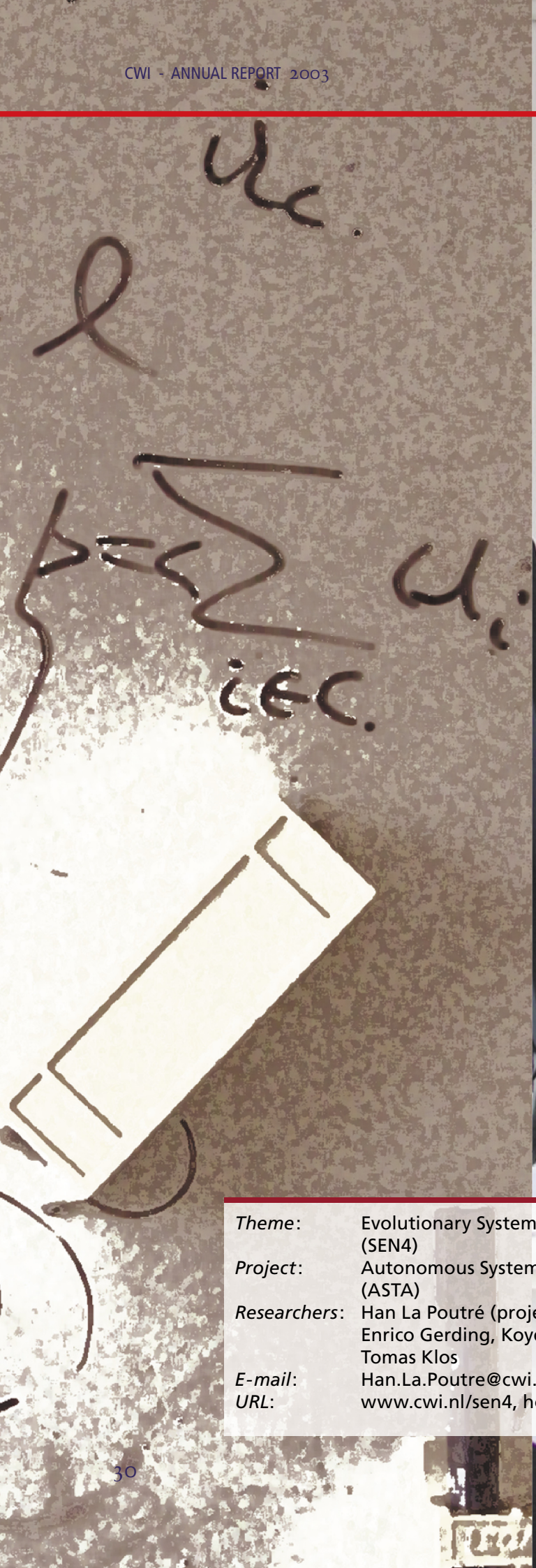
Before these adjustments could be implemented, several difficulties had to be overcome. Most notably, the introduction of multiple grids is complicated by the mutual influence of the different parts of the model. But the improvements lead to a significant gain of time and memory. Simulations that took a month to run five years ago can now be completed within hours.

Three dimensions

Currently, CWI's simulations of gas discharges are effectively two-dimensional. One of the goals of future research is to extend them to three dimensions. Furthermore, to comprehend sparking in different types of gases it is necessary to include the effect of indirect ionization mechanisms through photons. Simulation continues to answer questions and inspire theoreticians to develop new models, which in turn offer new challenges to numerical mathematicians. Together theory and simulation push the boundaries of knowledge on the complex phenomena of sparks and lightning.



Grid sizes used in the streamer simulations. The grid is refined at places where much happens, like at the tip of the streamer. Outside the streamer where not much changes occur, a coarse grid suffices.



Theme:	Evolutionary Systems and Applied Algorithmics (SEN4)
Project:	Autonomous Systems of Trade Agents in E-commerce (ASTA)
Researchers:	Han La Poutré (project leader, photo), Enrico Gerding, Koye Somefun, Sander Bohte, Tomas Klos
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Virtual markets solve complex problems

The market can be a powerful, invisible organizing mechanism. With intelligent software agent systems CWI researchers can replicate this well-known economic principle in a computer. These virtual marketplaces provide solutions to problems in areas ranging from e-commerce to logistics.

What determines the price of a CD player? Most people do not have the knowledge and equipment to build one themselves. Still, electronics manufacturers do not ask excessive prices. The competition between the different companies keeps them in check. Apparently, from this interplay of opposing forces an order can emerge.

Independent

The organizing potential of markets can be mimicked on computers through agent technology. Agents are software components capable of independently performing specific tasks. They are often capable of learning from previous experiences or from other agents. Agents can be programmed to cooperate, for example when retrieving information from large databases. To create a market place, agents should be programmed to compete. For example, someone could order an agent to buy the cheapest digital camera at an auction site. At the same time, someone looking to sell his camera could instruct his agent to sell it to the highest bidder. The interaction between the competing agents leads to an acceptable outcome.

However, such outcomes are not always desirable. The increase of accidents after the privatization of the British railways is just one example of the dangers of the market. Rules and constraints are therefore crucial to prevent unwanted consequences. By carefully programming the environment, tasks and strategies of the agents, a designer can influence the behavior of the system as a whole. This is one of the main research topics of CWI's theme Evolutionary Systems and Applied Algorithmics (SEN4).

Negotiating and bidding

E-commerce is one of the possible applications of agents studied at CWI. Although the dotcom bubble has burst, companies like Amazon and easyJet show that online retail indeed has a future. However, e-commerce is still limited to simple transactions that are closed manually. In the ASTA project (Autonomous System of Trade Agents in E-Commerce), funded by the Telematics Institute, researchers from SEN4 and TNO developed agent systems that can automatically perform more advanced interactions like negotiating and bidding. The autonomy of agents makes them well suited for these exchanges, which require many biddings and price comparisons.

Strategies

Since the agents perform autonomous transactions for their users, reliability of the system is critical. A fundamental study on the influence of trading scenarios and agent strategies on the system's behavior was a major part of the project. The considered scenarios ranged from a single 'take it or leave it' offer to complex negotiations with multiple rounds and multiple partners. Agents were programmed to show more complex behavior, like trying alternative strategies and rejecting unfair offers, even if this would mean that they would return to their users empty-handed.

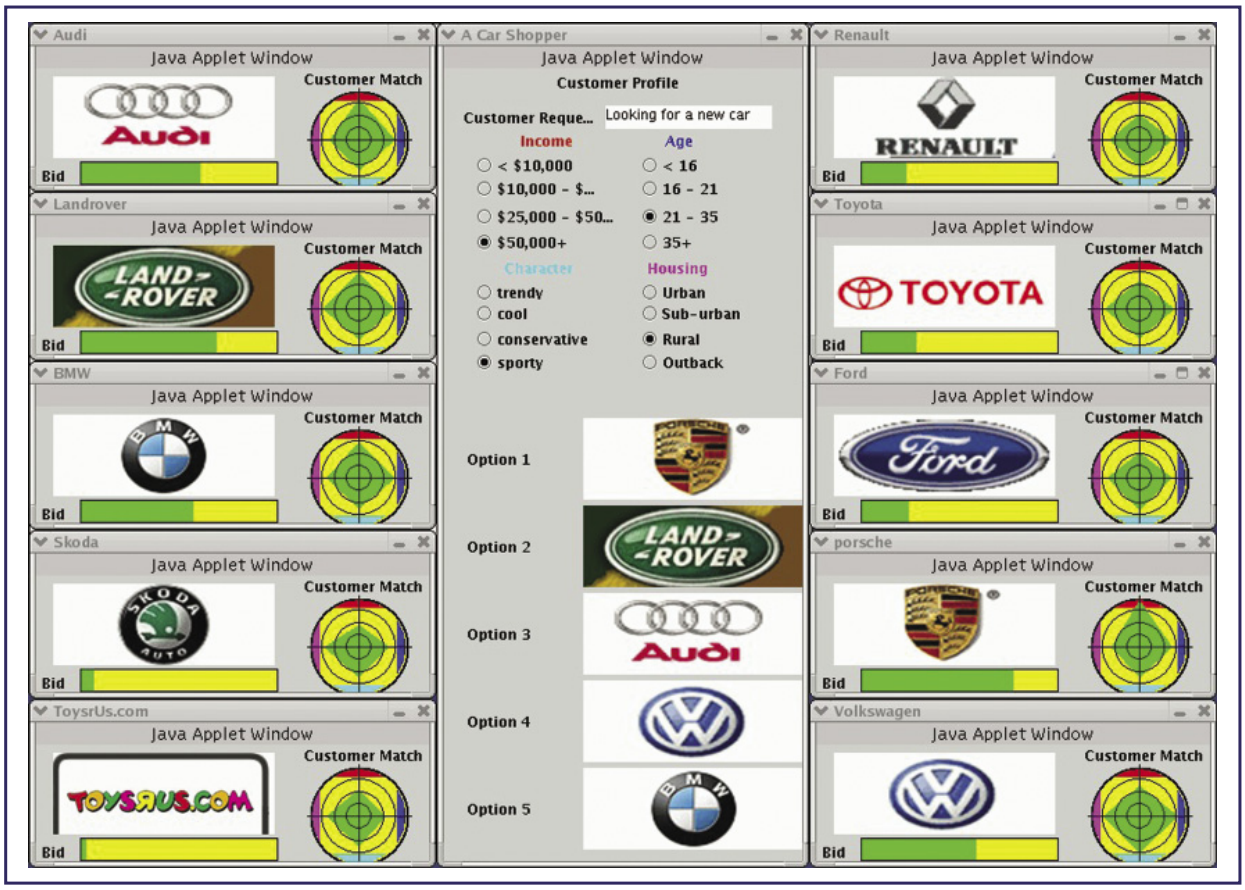
To evaluate the impact of these scenarios on the agents' strategies, a simulation environment was developed. The simulator shows how the agents adapt their strategies based on their previous experiences. It also gives a good impression of the behavior of the agent system as a whole. In this way unwanted consequences can be avoided.

News broker

ASTA included two business cases. For banking and insurance company ING, a news broker was developed. Many ING departments use information from financial press agencies. Currently, the costs for these services are divided equally over these users. The agent system developed by CWI charges for the actual use of news items. It consists of a broker agent selling individual news items. An employee interested in telecommunication companies, tells her own client agent to look out for that subject. If such an item is in high demand, the broker agent can ask a high price to the client agents. But if he makes it too high, none of the client agents will buy it, and the broker has to rethink its strategy. This way the broker and client agents determine a fair price together. Another part of the ING case dealt with the negotiation of subscription prices.

Customer relation management

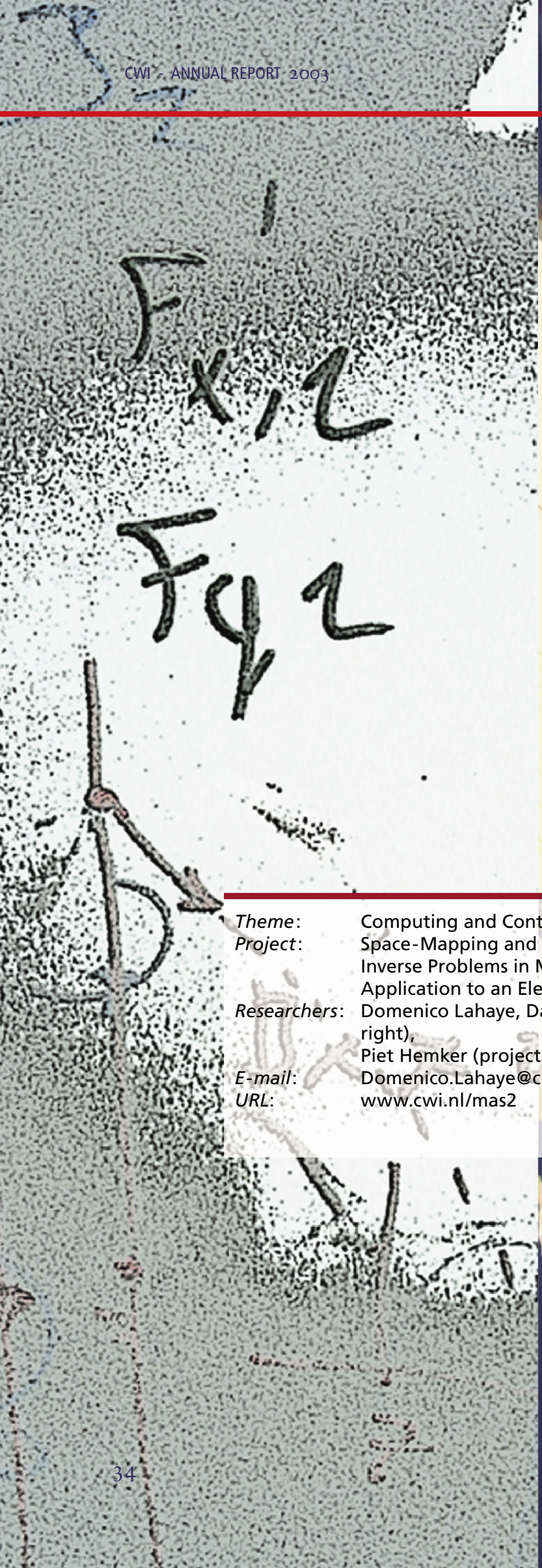
The second case shows the agents' potential for customer relation management. It consists of a system that shows personalized advertisements to known visitors of a large online shopping mall. Based on the visitor's profile, shops can have their agents bid for advertisement space. The highest bidders have their advertisements displayed to this particular visitor. Take for example a 25-year-old woman visiting the mall. The agent of a clothing store aiming at women in their early twenties will offer more for an advertisement on the mall's homepage than the agent of a shop catering for an older clientele. If the woman does not visit the store despite this advertisement, the store agent uses this information to update his strategy.

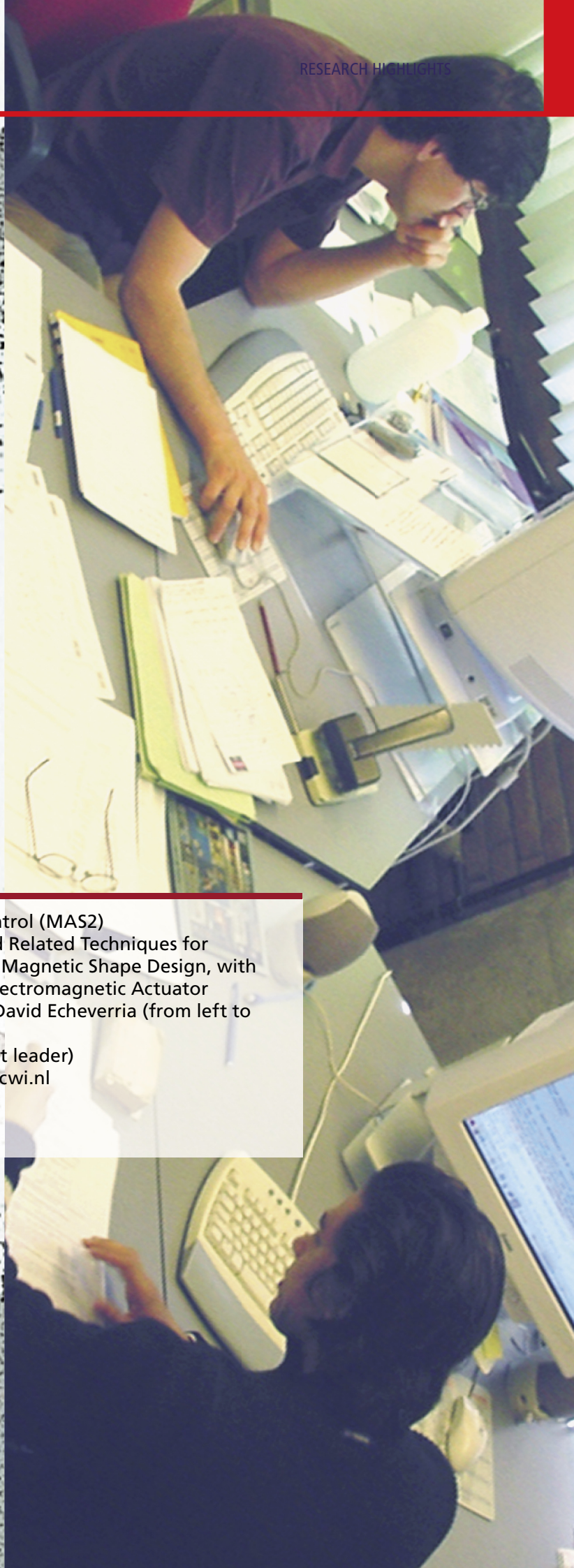


Logistics

Although ASTA was completed by the end of 2003, agent technology is a continuing focus of SEN4 in various other projects. For instance, the Medical Information Agent project employs agents for health care planning. Another example is Distributed Engine for Advanced Logistics (DEAL), dealing with road transport. The capacity of trucks is often not fully utilized. DEAL improves the efficiency of a transport company by representing every truck by an agent. The agents bid for new freight jobs. If a job can easily be fitted into a driver's schedule, his agent will increase its offer. This system ensures the loads are distributed over the trucks as efficiently as possible.

Agents can be employed for customer relationship management in an on-line shopping mall. The website builds a profile of every visitor using a questionnaire. The agents representing the shops compare the visitor's profile with that of their average customer. A large green surface in the left and right panels indicates a good match (this is normally invisible to the visitor). Based on this data, the agent makes an offer for advertisement space aimed at this particular visitor. The highest bidder gets the most prominent position in the middle panel, which is shown to the visitor.





Theme:	Computing and Control (MAS2)
Project:	Space-Mapping and Related Techniques for Inverse Problems in Magnetic Shape Design, with Application to an Electromagnetic Actuator
Researchers:	Domenico Lahaye, David Echeverria (from left to right), Piet Hemker (project leader)
E-mail:	Domenico.Lahaye@cwi.nl
URL:	www.cwi.nl/mas2

Combining fine and coarse models in electromagnetics

The accuracy of advanced computer simulations combined with the speed of simple analytical models: CWI researchers develop methods for designing electromagnetic devices that capture the best of both worlds. These space-mapping techniques work with detailed and coarse models at the same time. By drawing parallels to similar methods, which have been studied at CWI for twenty years, it is possible to further improve space-mapping.

Numerous electronic devices depend on magnetic fields for their operation. Deflection coils produce a magnetic field to direct the electron beams in television tubes. MRI scanners use superconducting magnets to create images. For many of these appliances the exact shape of the field is very important. Engineers have to choose the magnet's design parameters in such a way it produces the best possible approximation of the desired field.

Trial and error

Unfortunately, there is no direct way to derive the design parameters from a given field. However, calculating the field from given design parameters can be done. Engineers therefore usually deal with the inverse problem by setting the parameters to certain values, calculate the resulting magnetic field and compare it to the desired field. The design parameters are then modified based on this difference. This process of trial and error is repeated until an acceptable field is obtained.

An important step in this process is the selection of the model to describe the magnetic field. Engineers can choose from simple analytical models to complex numerical simulations. Simple analytical models are fast and intuitive but often very inaccurate. The alternative is to use numerical simulations. More and more simulation methods and packages are developed that can perform electromagnetic computations with great accuracy. However, these techniques are generally time-consuming and expensive.

Combining fine and coarse models

Researchers of CWI's theme Computing and Control (MAS2) combine these two approaches. In a project funded by the Ministry of Economic Affairs, they work on so-called space-mapping methods. Space-mapping was originally developed in the 1990s by microwave engineers. It optimizes the design using the fast, coarse model, but the process is regularly adjusted using information from the accurate, fine model. This can be achieved by finding a mathematical link ('mapping') between both models. Computing this link is less time-consuming than optimizing the fine model. If the mapping is used together with an adequate coarse model, the process results in an accurate solution in much less computer time.

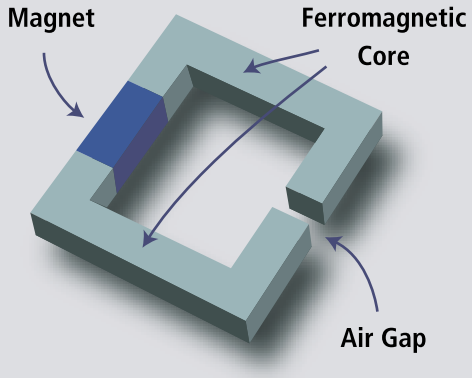
This can be compared to shooting with a hunting rifle that has a deviation. The equivalent of a coarse model would be to ignore the defect and aim with the bead on the barrel. But due

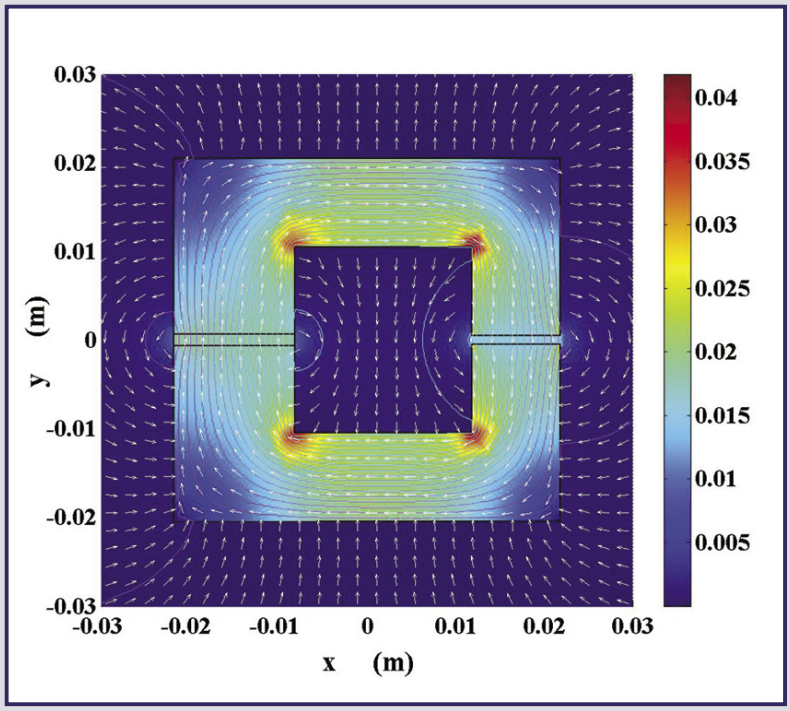
to the rifle's deviation, the hunter would miss his quarry. Space-mapping is comparable to calibrating the gun. The hunter would first shoot at a target as if the rifle is perfectly straight. By precisely measuring the bullet's deviation from the center, the hunter can compensate for it during his next shot. After a few shots and subsequent measurements, he knows where to aim to shoot exactly on target. The next time he uses the rifle for hunting, he can still use the coarse model (aiming quickly with the bead), but he improves his accuracy with information from the fine model (measuring the deviation on the target).

Theoretical framework

First CWI's space-mapping technique has been applied to simple systems with a few parameters, like a permanent magnet. It found the optimal design more than ten times faster than an off-the-shelf numerical simulation package. Currently, the method is applied to more complicated configurations. Eventually, space-mapping will be used to optimize the design of an actuator for a high accuracy position system. The actuator will be realized in cooperation with the Electromagnetics and Power Electronics research group of the Eindhoven University of Technology (TUE), which has much experience in modeling and designing electromagnetic devices.

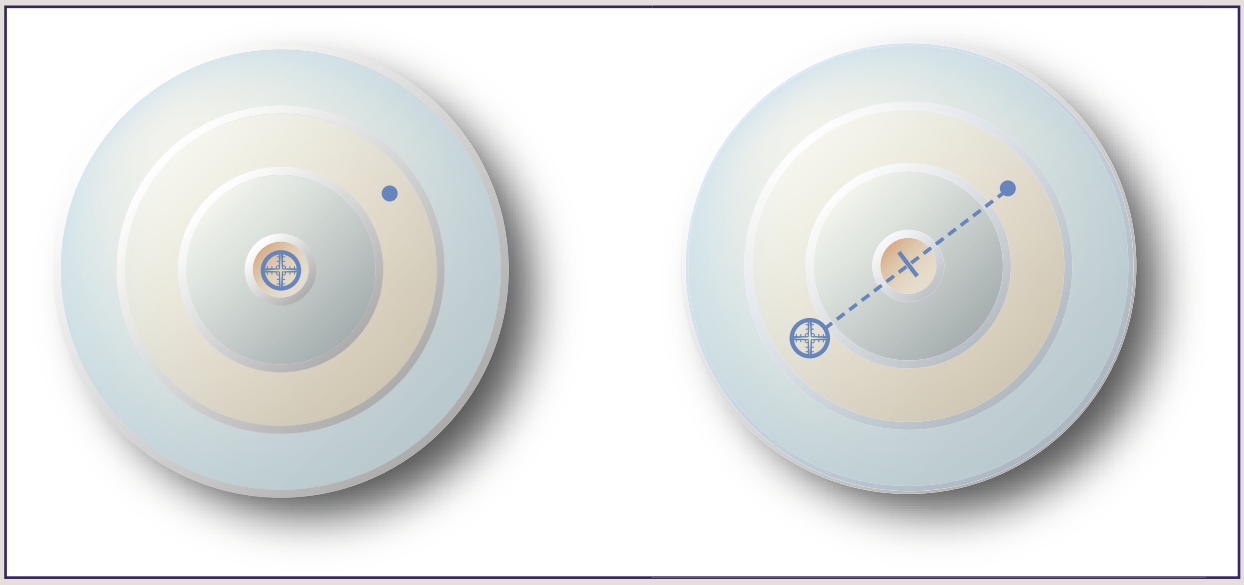
CWI's space-mapping algorithm was used to optimize the design of a permanent magnet (left). It chooses the width of the air gap in such a way that the magnet produces the best approximation of a desired magnetic field. This optimal magnetic field is shown in the figure on the right. The arrows point in the direction of the field and the colors indicate its magnitude.





The second objective of the project is to provide a solid theoretical framework for space-mapping. This will give insight in how fast the optimization reaches an adequate solution. It can serve as a basis to improve the technique. Fundamental analysis might also reveal which coarse models yield better results when used for space-mapping. The theoretic foundation is based on the theory of defect correction techniques, which can be used to efficiently solve partial differential equations. These techniques show a striking resemblance to space-mapping. CWI's Computing and Control theme has years of experience in working with defect correction, mainly for the simulation of flows. If a link can be established between the two techniques, this vast body of knowledge and experience also becomes available for space-mapping.

It is this theoretical approach that makes the space-mapping research at CWI and TUE stand out. A few other research groups from research organizations like the McMaster University in Canada and the Technical University of Denmark are also working on space-mapping. But their approach is more practical. The Computing and Control theme is the first to exploit the relation with defect correction.



Space-mapping can be compared to calibrating a crooked gun. For the first shot it is best to aim at the center of the target (indicated by the crosshairs) and measure the deviation (indicated by the hole). The best strategy for the second shot would be to 'mirror the error'.

Theme: Stochastics (PNA3)
Project: Study Group Stochastic Löwner Evolution
Researchers: Rob van den Berg (project leader, photo), Antal Járai
E-mail: J.van.den.Berg@cwi.nl
URL: www.cwi.nl/pna3

Using the Löwner equation to understand percolation

An eighty-year-old equation from pure mathematics caused a small revolution in spatial stochastics. The Löwner equation can be used to great effect in the theory of percolation. The discovery triggered a series of exciting new results continuing up to today. CWI was the host for a group of Dutch mathematicians and physicists that met regularly to study and discuss these developments.

Until the late Nineties, most scientists working on percolation were unfamiliar with the Löwner equation. This differential equation was primarily used in pure mathematics, for instance, in the proof of the Bieberbach conjecture. In 1999 the Löwner equation made a sudden entrance in spatial stochastics when the mathematician Oded Schramm linked it to percolation and related fields.

Path

Percolation studies the characteristics of clusters in random grids like the one shown in figure 1. Every cell has the same probability of being grey. If this probability equals ½, the system is on the brink of creating a cluster of infinite size. These systems are referred to as critical systems.

Percolation typically deals with questions like what is the probability of a path from the upper side to the lower side, or how to estimate the probability that a particular grid cell is part of a cluster with radius n when n is large. Schramm considered a step-by-step exploration of the grid, shown in figure 2, and proposed a description in terms of the Löwner equation. This proved to be a crucial step to the solution of a number of these questions.

Growing hull

The Löwner equation can be used to describe a curve that grows locally and continuously from a point on the boundary of a half-plane (see figure 3) without crossing itself. The Riemann mapping theorem states that it is possible to locally stretch, shrink and rotate the complement of the hull enclosed by the curve in such a way that it is transformed into the half-plane. Such an operation is called a conformal map (see figure 4). Note that at every point in time the hull is different, and therefore so is the conformal map. These maps change the two-dimensional trajectory of the tip of the curve into a one-dimensional movement along the boundary of the half-plane. Using the Löwner equation it is possible to derive the growing hull from this one-dimensional movement.

Brownian motion

Schramm investigated the behavior of the growing hull for the case where the one-dimensional movement is a Brownian motion. The future displacement of a point that performs a Brownian motion is independent of its past movements and has the same stochastic behavior. Schramm observed that these properties are reflected in the corresponding two-dimensional growth process of the hull. This can be seen in figure 5.

Based on general principles predicted by physicists, Schramm believed that if the size of the grid cells becomes infinitely small, the exploration process in critical percolation would also show this behavior. This became even more plausible after further work by Schramm, Lawler and

Werner. Finally, it was Smirnov who managed to complete the proof of this conjecture in 2001.

These discoveries made the Löwner equation the natural candidate to describe two-dimensional critical percolation. It clarifies the overall picture of the percolation process. Furthermore, the equation 'rephrases' the process in terms of the Brownian motion and conformal mapping, bringing the percolation problems within reach of the many tools that exist in those areas.

Accomplishments

One of the first accomplishments of the Löwner equation was the confirmation of an old conjecture about the cluster size of a critical percolation system. Physicists had predicted that the probability that the radius of a cluster is larger than n, behaves like $n^{-5/48}$ for large clusters. Using the Löwner equation, this prediction could be formally proved. In the following years the equation also played an important part in the proof of several other conjectures.

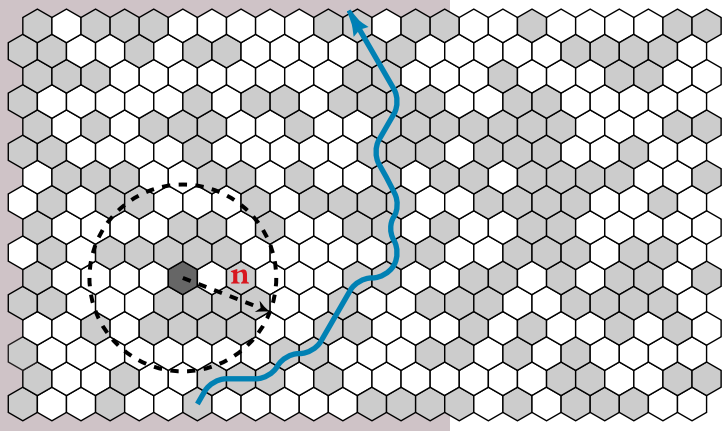


Figure 1: **P**ercolation clusters on a hexagonal grid. Its cells have a probability p of being grey, and $(1 - p)$ of being white. The blue line indicates an occupied path that connects the upper and lower side of the domain. The marked cell is part of a cluster with a radius of three cells. Percolation tries to compute or approximate these probabilities for very large clusters and domains.

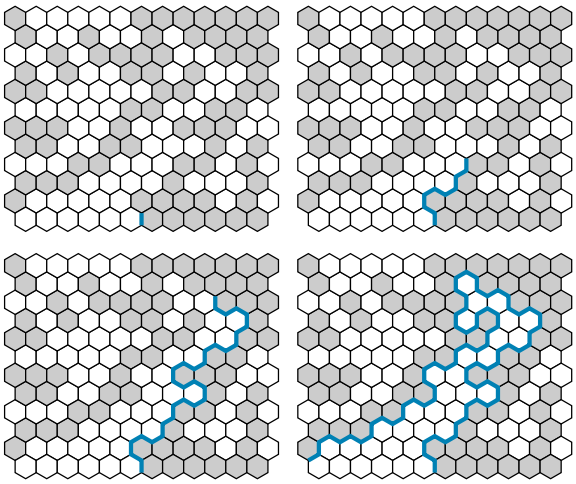


Figure 2: **T**he step-by-step exploration of a percolation system. The blue curve indicates the growing boundary of the cluster. It starts on the border between a grey and a white strip on the side of the grid. At every step it encounters at most one new cell. Since the curve represents the boundary of a cluster, it always keeps a grey cell on the right and a white cell on the left. Based on the color of the new cell the curve will take a right or left turn.

These exciting developments motivated researchers from CWI's Stochastics theme (PNA3) to start a study group on what is now called the Schramm–Löwner equation. Throughout 2003, mathematicians and theoretical physicists from CWI and universities in Amsterdam, Delft, Leiden, and Eindhoven frequently met at CWI to discuss these new methods and results. One of the main goals of the group was to make these new ideas and techniques better known in the Netherlands. Furthermore, it is believed that these methods can be important for the theme's research on self-organized critical forest fires.

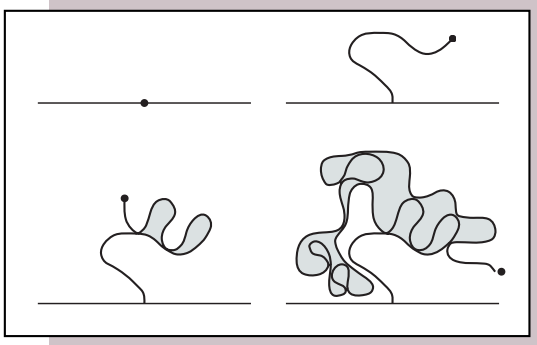


Figure 3: **A**n example of the type of growing hulls described by the Löwner equation. It starts in a point on the edge of the half-plane and grows continuously from the tip. Every time the curve touches itself, the enclosed area becomes part of the hull. Notice the similarity between this process and the exploration of a percolation system.

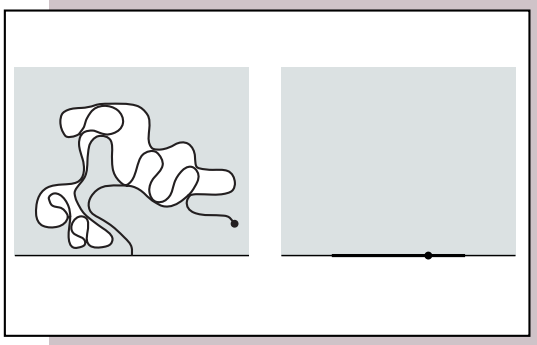


Figure 4: **T**he shaded part of the left figure represents the complement of the surface from figure 3. A conformal map can transform this complement to the half-plane by stretching the part cut out by the surface along the boundary of the half-plane. This map transforms the growth of the original curve to a movement along the boundary of the half-plane.

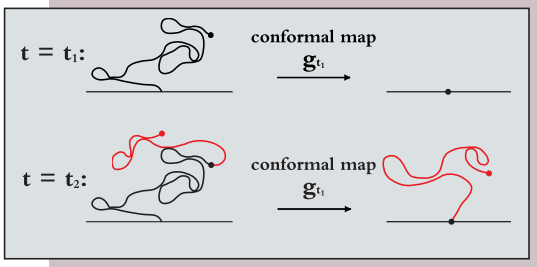


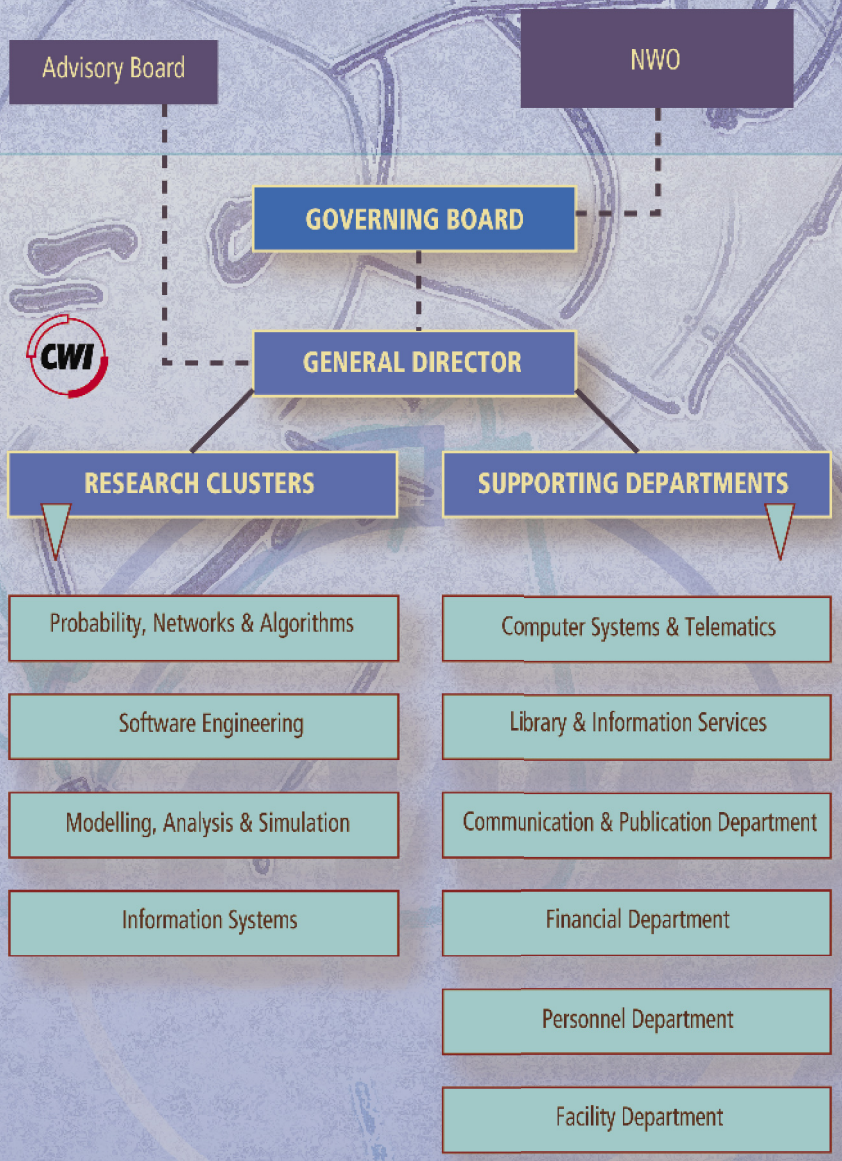
Figure 5: **A** conformal map g_{t_1} at time t_1 changes the area outside the curve to the shape of the half-plane. If the same transformation is then applied at a later time t_2, it 'pastes' the part of the curve already present at t_1 to the boundary. The part that grew from t_1 to t_2 appears as a new curve growing from the boundary. This new curve has exactly the same stochastic behavior as the original one.

Löwner Equation

$$\frac{d}{dt} g_t(z) = \frac{2}{g_t(z) - \xi(t)}; \; g_0(z) = z, \; z \in \mathbb{H}$$

z — location on the half-plane
t — time
ξ — location of the tip of the growing curve
g_t — the conformal map that transforms the complement of the growing hull to the half-plane at time t

Appendices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Organization

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

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

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I.L. Dijkstra

Library & Information Services
A.L. Ong

Communication & Publication Department
E.M. Stokhof / J.K. Lenstra (ad interim)

Financial Department
E. de Boer

Personnel Department
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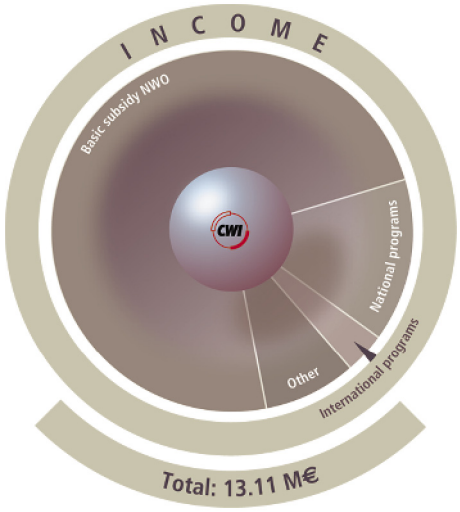
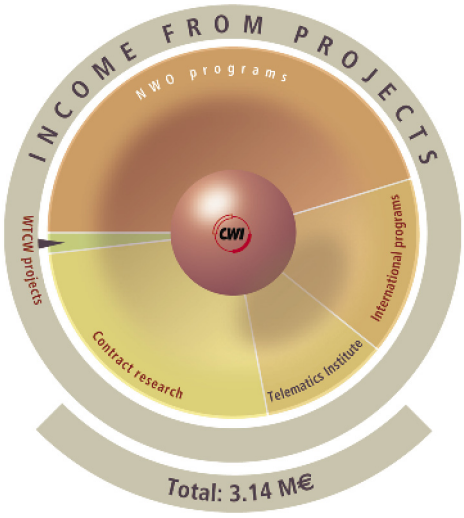
CWI at a glance

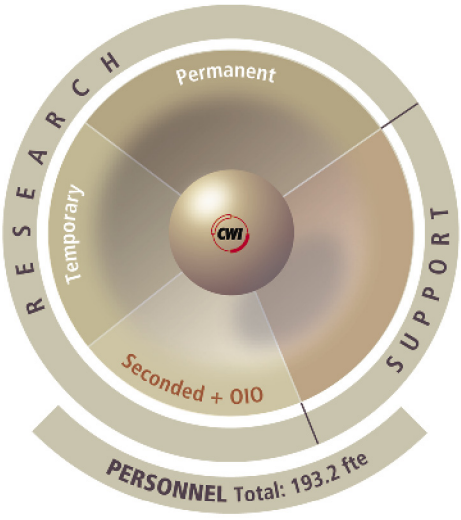
Income



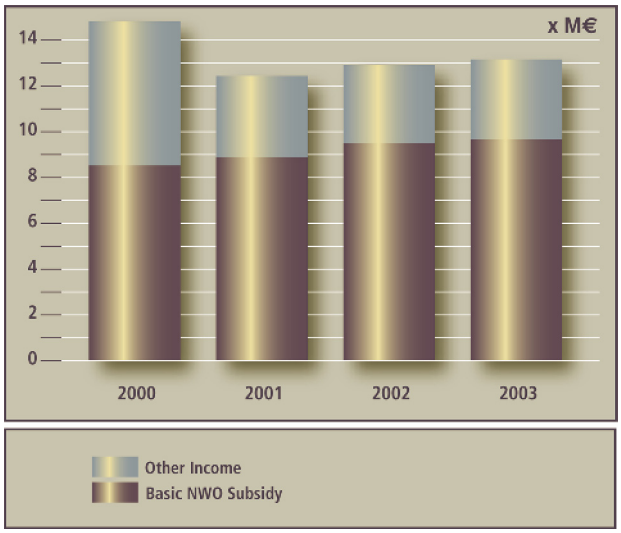
Breakdown of Income from National and International Projects



Personnel

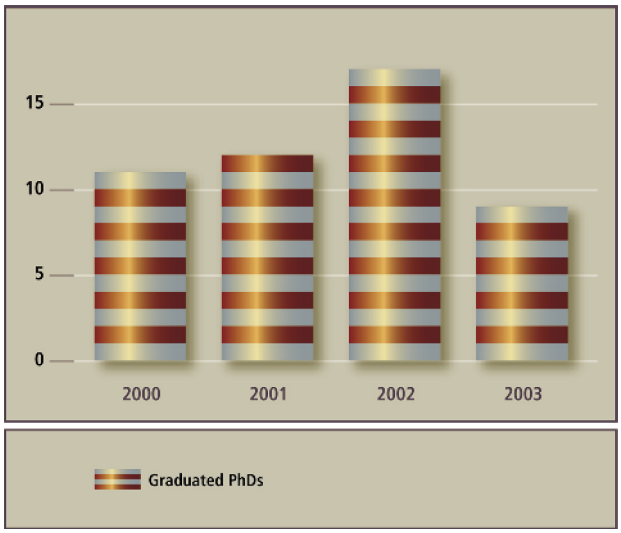


CWI Income



Breakdown non-NWO Income

Graduated PhDs



CWI PhD theses

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

S.M. Bohte
Spiking Neural Networks
Leiden University
J.N. Kok (Leiden University) and J.A. La Poutré

C.M. Cuesta
Pseudo-Parabolic Equations with Driving Convection Term
Vrije Universiteit Amsterdam
J. Hulshof (Vrije Universiteit Amsterdam)

I.A. Guerra Benavente
Stabilization and Blow-up for Some Multidimensional Nonlinear PDEs
Eindhoven University of Technology
C.J. van Duijn (Eindhoven University of Technology) and J. Hulshof (Vrije Universiteit Amsterdam)

D. Jibetean
Algebraic Optimization with Applications to System Theory
Vrije Universiteit Amsterdam
J.H. van Schuppen

M. de Jonge
To Reuse or to Be Reused: Techniques for Component Composition and Construction
University of Amsterdam
P. Klint

G. Piella Fenoy
Adaptive Wavelets and their Application to Image Fusion and Compression
University of Amsterdam
P.W. Hemker

M.J.G. van Uitert
Generalized Processor Sharing Queues
Eindhoven University of Technology
S.C. Borst and O.J. Boxma

J.M.W. Visser
Generic Traversal over Typed Source Code Representations
University of Amsterdam
P. Klint

M.A. Windhouwer
Feature Grammar Systems: Incremental Maintenance of Indexes to Digital Media Warehouses
University of Amsterdam
M.L. Kersten

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 mathematical optimization.

Constraint and Integer Programming

Foundations and applications of constraint programming. The foundational work concentrates on the design and implementation of an adequate programming environment for constraint programming. The application part concentrates on the use of constraint programming for various optimization problems drawing on integer programming techniques.

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.

Advanced Communication Networks
Theme leader: M.R.H. Mandjes

Wireline Networks, TCP/IP

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, UMTS

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

Network Economics

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

Stochastics
Theme leader: J. van den Berg

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

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 leader: H.J.A.M. Heijmans

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

Software Engineering
Cluster leader: P. Klint

Interactive Software Development and Renovation
Theme leader: P. Klint

Software Renovation
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 flexibility and generality of the ASF+SDF Meta-Environment is achieved by further simplifying connections with other systems and by localizing specific dependencies on ASF+SDF. Various applications were developed: an environment for Action Semantics, a LaTeX to MathML convertor, various source-to-source transformations, and a relation calculator to handle queries about facts extracted from source code regarding, for instance, data and control flow.
Dynamic Logic
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: W.J. Fokkink

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

Evolutionary Systems
Research on evolutionary systems and agent systems in economics, e-business, and management.

Neural Networks and Discrete Algorithms
The activities concentrate on classification and learning by neural networks, and on algorithms applicable to on-line design and management environments.

Convergent Media Interfaces
Pilot leader: 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 leader: M.A. Peletier

PDEs in the Life Sciences
Mathematical modeling and numerical simulation for life sciences, in particular biology and medicine. Cooperation has been established with researchers working in cell, neuro, and microbiology.

PDEs at CWI
Generating research activity in the analysis of PDEs by creating a 'hot spot' of PDE-analysis at CWI.

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

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

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.

Computational Number Theory and Data Security
The development of new mathematical and computational techniques for the solution of number-theoretic problems with applications in cryptography, crystallography, and medicine. Algorithms are studied for factorization and primality testing, for computing discrete logarithms, and for the solution of large sparse systems of linear equations over finite fields. Another activity is the study of algorithms in discrete tomography for the recovery of binary images from their projections. The computational techniques used in factoring large numbers can be used here with profit.

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
Pilot leader: U.M. Ebert

Analytical and numerical modeling 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.

Database Architectures and Information Access
Theme leader: M.L. Kersten

Multimedia Databases
Development of an efficient storage and retrieval system of multimedia data.

AmbientDB
Development of the next generation database technology to support Ambient applications.

Query Optimizers
Development of a multi-layer query optimizer infrastructure to support multimedia information access.

MonetDB
Promoting the development and use of the database experimentation platform MonetDB.

Multimedia and Human-Computer Interaction
Theme leader: H.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. Current research focuses on modeling of domain-dependent and domain-independent discourse to steer the presentation generation process, investigation of dependencies of the user and domain models in the generation process, investigation of characteristics of media types for presenting information to the user, and investigation to what extent graphic design knowledge can be included in the generation process.

Visualization and 3D Interfaces
Theme leader: 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

Quantum Computing
Research on quantum information and communication technology, quantum computer architectures, quantum algorithms, quantum communication complexity, quantum complexity classes, quantum information retrieval, and quantum information theory.

MDL Learning and Algorithmic Statistics
Design, implementation, and comparative analysis of a series of practical applications of machine learning techniques. This includes investigating the relation between data compression and generalization properties and prediction in the sense of the 'minimum description length' paradigm, basically a formal version of Occam's Razor.

Algorithms, Complexity, and Genomics
Design and analysis of algorithms for distributed and parallel systems. Applications of Kolmogorov complexity in algorithmics and computational complexity. Design, analysis, and implementation of bioinformatics algorithms.

International and national research programs

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:

KUN	University of Nijmegen
RUG	University of Groningen
TUD	Delft University of Technology
TUE	Eindhoven University of Technology
UL	Leiden University
UM	Maastricht University
UT	Twente University
UU	Utrecht University
UvA	University of Amsterdam
UvT	Tilburg University
VU	Vrije Universiteit Amsterdam

European programs

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

FOUNDIT: Feedback-operated User Interface for Design and Image Retrieval
2001-2003
Univ. Gent, Sophis Systems N.V., Pianezza Paolo SNC, Clama Mattress Ticking N.V., Chantemur
E.J.E.M. Pauwels

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

Biofilms: Natural Biofilms as High-Tech Conditioners for Drinking Water
2000-2003
Univ. Barcelona, Wasserforschung Mainz GmbH, Czech Acad. Science, Forschungszentrum Karlsruhe, UvA
B.P. Sommeijer

CC: Computation and Control
2002-2005
Verimag, Parades, ETH Zürich, Lund Univ. of Technology, EDF, ABB
J.H. van Schuppen

TRIAL SOLUTION
2000-2003
Univ. Koblenz-Landau, Heidelberger Akad. Wissenschaften, Trinity College Dublin, Univ. de Nice, FIZ Karlsruhe, Open Univ. (UK), Univ. of Chemnitz, Univ. Köln, Springer-Verlag, Harri Deutsch, Shang IT
M. Hazewinkel

QUESTION-HOW
2001-2003
INRIA, SICS, Fraunhofer Gesellschaft, CNR, CLRC, Hebrew Univ. Jerusalem, ICS-FORTH
I. Herman

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

DONET: Discrete Optimization Network
1999-2003
Univ. Cath. Louvain, RFW Univ., Univ. Pierre et Marie Curie, IASI, Univ. Lisbon, Ecole Polytechnique Fédérale de Lausanne, London School of Economics and Political Sciences, TUE, UM, UvA, Univ. Padova, Univ. Köln, Univ. Grenoble
A.M.H. Gerards

DYNSTOCH: Statistical Methods for Dynamical Stochastic Models
2000-2004
HU Berlin, UPCT, ALU-FB, UHEL, UCL, LADSEB-CNR, UPMC
K.O. Dzhaparidze

MASCOT: Metadata for Advanced Scalable Video Coding Tools
2001-2003
Free University, Laboratoires d'Electronique Philips Paris, Ecole Nationale Supérieure des Télécommunications, Centre de Morphologie Mathématique, Heinrich-Hertz-Institut, Polytechnic Univ. of Catalonia, Poznan Univ. of Technology
H.J.A.M. Heijmans

BIOVISION
2002-2003
British Telecommunications PLC, Teletrust Deutschland, NPL Management Limited, CNR, Daon ltd, Government Communications Headquarters, Nationwide Building Society
B.A.M. Schouten

NAME: Network for Agile Methodologies Experience
2002-2003
Libera Univ. di Bolzano, Datasiel Sistemi E Tecnologie di Informatica S.P.A., Univ. Politécnica de Valencia, Technische Univ. München, Univ. degli Studi di Cagliari, Univ. of Sheffield
L.M.F. Moonen

MKMnet: Mathematical Knowledge Management Network
2002-2003
Univ. of Bath, Numerical Algorithms Group, Univ. College London, Heriot-Watt Univ., Univ. of Birmingham, Univ. Pierre et Marie, German Research Center for Artificial Intelligence, Saarland Univ.
M. Hazewinkel

ONTOWEB
2001-2004
VU, UPM, DFKI, UNIKARL-AIFB, UoM, OU, VUB, LADSEB-CNR, INRIA, UvA, FT R&D, INTERPRICE, CNR ITBM, Ontoprise, BIOVISTA, QMW, UNIABDN, IW CONSULT, FORTH, PWC
H.L. Hardman

QUIPROCONE: Quantum Information Processing & Communications
2000-2003
Many. Hewlett Packard is main contractor
P.M.B. Vitányi

PASCAL: Pattern Analysis, Statistical Modeling and Computational Learning
2003-2007
Univ. London, and 50 more sites
P.D. Grünwald

National programs

NWO

SPCO: Semidefinite Programming and Combinatorial Optimization
2002-2007
-
M. Laurent

Dutch-Hungarian Cooperation Project: Combinatorial and Algebraic Structures and Algorithms
2001-2003
TUE, Eötvös Loránd Univ.
A.M.H. Gerards

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

EQUIP: Enabling Quality of Service in IP-based Communication Networks
2002-2006
UT
M.R.H. Mandjes

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

WA: Wavelets and Their Applications
1999-2003
RUG, TUE, UT
H.J.A.M. Heijmans

Inference for Random Sets
2001-2003
UU, Univ. of Berkeley, EURANDOM
M.N.M. van Lieshout

Biography Aad van Wijngaarden
2000-2004
-
G. Alberts

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

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

PROMACS: Probabilistic Methods for the Analysis of Continuous Systems
1999-2003
TUE
J.J.M.M. Rutten

COCON: Coalgebra and Control
2001-2003
MAS2
J.J.M.M. Rutten

CoMoLo: Coalgebra Modal Logic
2002-2005
UvA, KUN
J.J.M.M. Rutten

EESEM: Evolutionary Exploration Systems for Electronic Markets
1999-2004
TUE
J.A. La Poutré

ScaNN: Scalable Reinforcement Learning in Asychronous Spiking Neural Networks
2003-2007
-
S.M. Bohte

Quality of Service for Multimedia Systems
1999-2005
Philips Research
J.A. La Poutré

Microbial Ecology, Phytoplankton Models
2001-2005
UvA
B.P. Sommeijer

Neurobiology, Modeling of Axon Growth
2001-2005
-
J.G. Verwer

Mathematical Analysis of Partially Localized Structures
2003-2007
-
M.A. Peletier

Geometric Numerical Methods for Continuum Mechanics
2002-2005
-
J.E. Frank

Computational Magnetohydrodynamics in Special Relativity
2001-2003
FOM Rijnhuizen, UU, Univ. Michigan
B. Koren

hp-Adaptive Methods for 3D Convection Dominated Flows
2002- 2003
UvA
P.W. Hemker

Numerical Singular Perturbation Problems
2000-2003
UT, KUN, TCD, RAS-UB
P.W. Hemker

Factoring Large Numbers as Validation of RSA
1997-2006
UL, Univ. Bonn, Microsoft Research
H.J.J. te Riele

Mathematical Aspects of Discrete Tomography
2002-2006
UL, Univ. of Debrecen
H.J.J. te Riele

SICA: System Identification with Computer Algebra
1999-2003
UM
J.H. van Schuppen

NUMLED: Numerical Methods for Leading Edge Dominated Dynamics
2002-2006
-
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
H.L. Hardman

CHIME: Cultural Heritage in an Interactive Multimedia Environment
2002-2004
-
H.L. Hardman

I²RP: Intelligent Information Retrieval and Presentation in Public Historical Multimedia Databases
2002-2005
Rijksmuseum Amsterdam, RUG, UM, UL
H.L. Hardman

QC: Extending Feasible Computation: Quantum Computing
1998-2005
-
P.M.B. Vitányi

Universal Learning
2002-2006
HIIT Helsinki, Univ. London
P.M.B. Vitányi

ACAA: Average-Case Analysis of Algorithms
2000-2006
Univ. Waterloo, BSI
P.M.B. Vitányi

STW

MIAS: Multiresolution Image Analysis and Synthesis
1999-2003
The Johns Hopkins Univ., TNO, Akzo Organon, Thales
H.J.A.M. Heijmans

Improving the Quality of Embedded Systems Using Formal Design Techniques and Systematic Testing
2000-2004
-
W.J. Fokkink

Formal Design, Tooling, and Prototype Implementation of a Real-time Distributed Shared Dataspace
2000-2005
KUN
J.C. van de Pol

Development of a State-of-the-art Navier-Stokes Solver for Water Flows around Moving Ships
1999-2003
MARIN
B. Koren

Senter

EQUANET
2003-2004
Lucent Technologies, UT, TNO Telecom, TUE
M.R.H. Mandjes

IDEALS: Idiom Design for Embedded Applications on a Large Scale
2003-2006
ASML, TUE, UT, ESI
A. van Deursen

GAME: Generic Application Maintenance Environment
2003-2007
First Result, IBM
P. Klint

CIM III: Cybernetic Incident Management
2003-2005
SEN4, TUD, VU, Almende, CMotions, Falck
F. Arbab

DEAL: Distributed Engine for Advanced Logistics
2002-2005
Almende, ERBS, VU, Groeneveld Groep, Post-Kogeko Transport Groep, Vos Logistics
J.A. La Poutré

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

Waterland
1998-2004
TI, UT, TNO-TPD, NOB, NOS
A.P. de Vries

ICES/KIS-2 projects

MIA: Multimedia Information and Analysis
1999-2003
UvA
M.L. Kersten

Virtual Lab
2001-2003
UvA
R. van Liere

Contract research

Stagesporen
1995-indefinite
VU, UM
A.M.H. Gerards

Railway Optimization
1994-indefinite
NS Reizigers
A.M.H. Gerards

FLORIN: Flow-level Performance of Integrated 3G CDMA Networks
2003
France Télécom
M.R.H. Mandjes

DocGen: Documentation Generation
1999-indefinite
Software Improvement Group BV
A. van Deursen

Ambulant Mobile SMIL for PDAs
2003
NL.net
D.C.A Bulterman

Simulation of the Population Development of the Toxic Cyanobacterium Microcystis in Lake Nieuwe Meer
2003
Nuon, UvA
B.P. Sommeijer

ASF: Asymptotics and Special Functions
1999-2005
Univ. Madrid, Univ. Pamplona, UvA, Abramowitz-Stegun group
N.M. Temme

Telematics Institute projects

M2C-QoS: Measuring, Modeling and Cost Allocation for Quality of Service
2003
UT
M.R.H. Mandjes

ArchiMate: Enterprise Architecture Animation
2002-2004
Ordina Institute, KUN, UL, ABP, ABN AMRO, Belastingdienst
F. Arbab

ASTA: Autonomous Systems of Trade Agents in E-commerce
1999-2003
ING, TNO
J.A. La Poutré

Topia: Topic-based Interaction with Archives
2003
IBM, TUE
H.L. Hardman

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

BARRIER
2000-2004
Univ. Münster, FOM, ERCIM
U.M. Ebert

STREAMERS-EXP: Streamer Discharges in Gases: Experiments
2002-2007
TUE, FOM
U.M. Ebert