



**Centrum Wiskunde & Informatica
Annual Report 2007**



Contents



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

CWI is a founding member of ERCIM, the European Research Consortium for Informatics and Mathematics. The institute is a member of the World Wide Web Consortium (W3C) and it manages the W3C Office in the Benelux. CWI is located at Science Park Amsterdam.

CONTENTS

Introduction

Overview	6
1. To conduct advanced research of societal and scientific relevance	8
2. To act as a breeding ground for academic staff and young researchers	12
3. To transfer knowledge to society and increase public interest in mathematics and computer science	18
4. To play a leading role in the Dutch and European mathematics and computer science scene	24

Research highlights	32
Milk cartons and traffic-jams	34
The web: a work of art	38
Going once, going twice...	42
Fishing for bugs	46

Appendices	48
Organization	49
Facts and figures	50
CWI clusters and groups	53
International and national research programmes	60

The CWI annual report series consists of:

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

Copies can be ordered at the Communication and Information Department: info@cw.nl

Introduction

It has been a busy and exciting year with many highlights. To name but a few we are not only expanding our research efforts, we are also expanding our accommodation. We started the construction of our new wing. This year CWI launched its strategy plan up to 2012, *A fundamental difference*. Our research will focus on four strategic research themes: earth and life sciences, societal logistics, the data explosion, and software as service.

The evolution of CWI's field of research is making its potential impact on science and society bigger than ever before. Algorithmics has pervaded many branches of mathematics, and advanced information processing is turning areas like physics, biology, sociology, cognitive science, economics, and linguistics into computational sciences. As the new century develops, more and more empirical sciences will absorb insights from mathematics and computer science, creating rich sources of inspiration and opportunities. CWI sees it as a challenge to play a vital role in the development of the national and international research landscape from this perspective.

CWI concentrates on fundamental questions that are inspired by practical problems, giving us a well-defined place in the landscape of European research. Our strength is the discovery and development of new ideas, and the transfer of knowledge to academia and to Dutch and European industry. The results of our work are of continued importance for our economy, from payment systems and cryptography to telecommunication and the stock market, from public transport and the internet to water management and meteorology. It is CWI's policy to maintain a strong presence within the national and European research community by focusing on excellence in its staff and by directing its resources to solving new and societally relevant problems. We are encouraged by the positive reviews received in the past. For the upcoming years CWI received a welcome bonus from NWO for its excellent evaluation. The money will be spent on research in computational biology, on improving our external communication, and on a programme for sabbaticals and visitors. As part of this, we will set up an internship programme to enable top-notch PhD students from abroad to do part of their research at CWI. This way new and lasting research contacts will be established.

In the past decades research in mathematics and computer science has focused on rapid exploitation of scientific results. In Europe, this has led to the disruption of long-term research, which is an unfortunate development. Fundamental, curiosity-driven research is the source of all innovation. Institutes like CWI, with their worldwide reputation in long-term research, are catalysts for global economic growth. Institutes such as ours are essential for further innovation.

There is a lot of work in progress. CWI is in full swing. Starting up the process of developing a new corporate logo and everything that comes with it is another important feature of this year. In 2008 we will introduce this new logo and our fully improved website, with detailed information about our research. We will be happy to have you as our guests.



Jan Karel Lenstra
General Director



Overview

CWI Research Clusters

Probability, Networks and Algorithms (PNA)

Algorithms, Combinatorics and Optimization
Probability and Stochastic Networks
Signals and Images
Cryptology and Information Security

Software Engineering (SEN)

Interactive Software Development and Renovation
Specification and Analysis of Embedded Systems
Coordination Languages
Computational Intelligence and Multi-agent Games
Distributed Multimedia Languages and Infrastructures

Modelling, Analysis and Simulation (MAS)

Dynamical Systems and Numerical Analysis
Scientific Computing and Control Theory
Multiscale Modelling and Nonlinear Dynamics

Information Systems (INS)

Standardization and Knowledge Transfer
Database Architectures and Information Access
Semantic Media Interfaces
Visualization and 3D Interfaces
Quantum Computing and Advanced Systems Research



CWI

Founded in 1946, Centrum Wiskunde & Informatica (CWI) is the Netherlands' national research institute for mathematics and computer science.

CWI conducts pioneering research in mathematics and computer science, generating new knowledge in these fields and conveying it to broader society, and to trade and industry in particular. CWI's research is dedicated to four strategic research themes. CWI obtains around 60% of its funding from the Netherlands Organisation for Scientific Research (NWO). The remaining 40% is obtained through national and international programmes and contract research commissioned by industry.

To achieve its mission, CWI has formulated the following goals:



To conduct advanced research of societal and scientific relevance



To act as a breeding ground for academic staff and young researchers



To transfer knowledge to society and increase public interest in mathematics and computer science



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



To conduct advanced research of societal and scientific relevance

Long-term research is a catalyst for continued economic growth. Institutes like CWI are breeding grounds for human capital, innovation, and education. CWI initiates new research and introduces new areas of expertise in the Netherlands. It addresses research problems of great societal relevance. This section highlights a number of major contributions of the institute and its researchers.

A fundamental difference

On 4 July CWI proudly presented its strategy for the years 2007-2012 to the Governing Board of NWO. The publication is titled *A fundamental difference* and that is exactly what we aim to make. At CWI researchers concentrate on fundamental questions that are inspired by practical problems. Our strength is the discovery and development of new ideas, and the transfer of knowledge within academia and to Dutch and European industry. In 2005 an international committee reviewed our research institute as excellent and to further strengthen this position the next five years CWI focuses on four strategic research themes: earth and life sciences, societal logistics, the data explosion and software as service.

These four themes will be individually introduced in the section Research Highlights, pages 32-47.

Copies of CWI's strategy can be ordered through info@cwi.nl, or can be downloaded at www.cwi.nl/about/strategy.

Grants

Microsoft Research 'Beyond Search Award' for CWI research in sponsored search auctions

On 6 December, Microsoft Research awarded \$50,000 to CWI researchers Sander Bohte, Nicole Immorlica, Vangelis Markakis and Han La Poutré for research on socially structured user behaviour and externalities in sponsored search auctions. Based on the vast data collected by Microsoft Live Search and Microsoft AdCenter, the research aims to develop new insights on how and when users click on the advertisements shown along search engine results.

The group will study two issues related to optimizing the allocation of sponsored search ads for a specific querying user: first, they will attempt to exploit the fact that a user is likely to behave like other users they know. The challenge is to derive the relevant 'social structure' from the Microsoft search logs. And second, they wish to refine the ad allocation model to account for the fact that the advertisement a user is likely to click on, is influenced by the content of other, surrounding advertisements, so-called 'externalities'. The researchers will have access to Microsoft data which refers to a 100 million entries in the adCenter query logs and 15 million entries in Live Search query logs that contain data on what exactly users were searching for.

The research will be carried out starting early 2008. The group expects to have publishable results by the end of November 2008.



From left to right: Peter Nijkamp (NWO), Jan Karel Lenstra (CWI), Arjen Doelman (CWI), Cees de Visser (NWO), Ron Dekker (NWO).

Security important theme in Veni grants

Out of 530 project proposals CWI researchers Dennis Hofheinz and Milad Niqui have each been awarded a Veni grant for their research in computer security. In total 89 Veni grants were to be divided in December. The talented young scientists receive 208,000 euros for their innovative and original research.

Awards

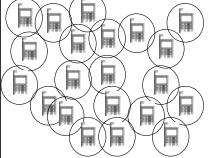
Young researcher wins BRICKS 2007 Dissemination Award

Promoting your research in just one minute and capturing the attention of an audience of 100 people is quite a challenge. On the BRICKS Midterm Symposium on 13 March in Amsterdam, Erik Jan van Leeuwen (CWI) succeeded in winning the BRICKS 2007 Dissemination Award (an iPod nano 8G). Out of 48 entries he obtained the majority of votes from the public jury for his research poster *Algorithms for Wireless Networks*.



BRICKS
Basic Research in Informatics
www.bsic-bricks.nl

Algorithms for wireless networks
Erik Jan van Leeuwen – CWI, Amsterdam - E.J.van.Leeuwen@cwi.nl

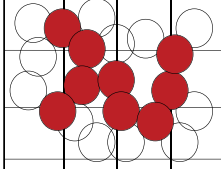


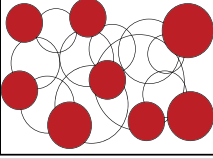
Model for wireless networks

- Devices are points in the plane
- Together with radio range defines disks
- Induces graph structure: disk graph (DG)
 - Vertex per device, edge if disks intersect
- All devices equal: unit disk graph (UDG)
- Polynomial time approx. schemes (PTAS)

Connected dominating sets

- Backbone for network communication
 - Each disk has neighbor in or is in CDS
 - CDS induces connected graph
- For UDGs: PTAS using shifting technique
 - Partition plane into squares
 - Optimize per square using treewidth-bound
 - By shifting partition, approximate optimum





Maximum Independent Set

- Prevent interference, resolve access
 - Disjoint set of disks
 - Maximum size
- DGs: PTAS by leveled shifting technique:
 - Partition disks into levels by radius
 - Apply shifting technique 'per level'







Open questions

- Approximating Minimum Connected Dominating Set in disk graphs?
- How to turn algorithms into distributed algorithms?

References

- van Leeuwen, E.J., "Approximation Algorithms for Unit Disk Graphs", WG 2005, LNCS 3787, pp. 351-361.
- van Leeuwen, E.J., "Better Approximation Schemes for Disk Graphs", SWAT 2006, LNCS 4059, pp. 316-327.

Part of this research has been funded by the Dutch BSIC/BRICKS project IS3.

Van Leeuwen serves as a good example of a typical 'BRICKS researcher': in his work he combines fundamental research in the field of both mathematics and computer science. In BRICKS all research topics are inspired by societal problems. The project is funded out of the Dutch national gasreserves and most of the subsidy is invested in training young talented scientists.

At the symposium young researchers played a central role. Keynote speaker Professor Peter Sloot (Computational Science, University of Amsterdam) stressed the importance of educating young talented people. According to Sloot the Dutch schoolsystem should pay more attention to science. BRICKS senior researchers presented their research highlights and Professor Emile Aarts (Scientific Program Director Philips Research) discussed the future of Ambient Intelligence: the vision of a world in which technology, in the form of small but powerful silicon chips, will be integrated into almost everything around us.

BRICKS is a research consortium of Centrum Wiskunde & Informatica, NWO, Eindhoven University of Technology, Delft University of Technology, University of Twente and Utrecht University.

Best Student Paper Award at ECIR, 2-5 April, Rome

We are happy to announce that CWI researchers Roberto Cornacchia and Arjen de Vries have won the Best Student Paper Award at the 29th European Conference on Information Retrieval (ECIR) in Rome for their paper *A Parameterised Search Engine*. ECIR is the main European forum for the presentation of new research results in the field of information retrieval.

Finalist at New Ideas Contest

Valentin Robu (research group Computational Intelligence and Multi-agent Games) was one of the five finalists of the New Ideas Contest 2007 at Science Park Amsterdam. On 14 June, Jort Kelder presented the elevator pitch of this competition to an audience of about a hundred investors and researchers. In 90 seconds each finalist should present the significance of his idea. Robu pled for an innovative freight auction using intelligent agents - research he is doing with Vos Logistics Organizing. With this, Robu won the third prize in the public's vote. Winner of the jury prize was Harro Stokman (University of Amsterdam), with his idea for a copyright content filter.



Jort Kelder



Paul Vitányi and Hennah Buyne

CWI spin-off Software Improvement Group wins national Innovator Award 2007

CWI spin-off Software Improvement Group (SIG) won the national Innovator Award 2007 during the National ICT Event on 23 October. This award, an initiative of the Ministry of Economic Affairs and issued by PricewaterhouseCoopers, is one of the most important ICT prizes of the Netherlands. The jury said: “The Software Improvement Group won the Innovator Award 2007, because it offers companies the opportunity to challenge their software product a quality mark. Furthermore, the product contributes to the entire ICT-branche.”

SIG gives fact based insight in the technical quality of software systems: “We analyse any software source code in an automated manner. Whether it is a 30 year old mainframe system, or a brand new web application, it can map out the quality of the system, measure the changeability and assess the situation - all based on automated analysis of source code.” “Innovation is all about timing”, says Paul Klint - head of CWI’s Software Engineering Department and co-founder of SIG. “As researchers we always think it is easy to get an idea across, but the people at SIG know as no others how much effort that requires. They have developed the right feeling for combining market needs with innovative ideas.”

CWI is very proud to be the founding father of this successful company which in 2005 also won the Research & Development Innovation Award.

Decorations

Royal honour for Paul Vitányi

Paul Vitányi has been appointed ‘Ridder in de Orde van de Nederlandse Leeuw’. He received this royal honour from the Amsterdam alderman Ms. Hennah Buyne during the CWI Lectures in Mathematics and Computer Science on 7 September. For over 35 years Paul Vitányi has been an excellent scholar in the area of theoretical computer science, in particular in algorithms and complexity theory. He has brought the principles of complexity theory and information theory to such a high level that today his work became an international standard. With the book that he wrote with Ming Li (University of Waterloo, Canada) on Kolmogorov complexity, in principle a quite theoretic problem, he showed that Kolmogorov complexity can be implemented in diverse research areas through which new practical applications were made possible.



To act as a breeding ground for academic staff and young researchers

At any time, CWI employs a large number of PhD students and post-docs. A large percentage of current Dutch full professors in mathematics or computer science have held or hold positions at CWI. The retirement of the first generation of computer scientists in five to ten years and the expected increase of computer science create a continuing need for a setting in which a new generation of researchers, temporarily shielded from teaching and administrative duties, can mature.

Appointments

Jaco van de Pol full-time Professor at University of Twente

On 1 September Jaco van de Pol left CWI to work as a full-time Professor at the Chair Formal Methods and Tools at the University of Twente. There, amongst other things, he will continue his BRICKS research on a verification grid for enhanced model checking.



Jaco van de Pol



Kees Oosterlee

Solving financial problems efficiently

CWI researcher Kees Oosterlee was appointed Professor of Hierarchical Numerical Methods at the Delft University of Technology on 15 October. Oosterlee efficiently solves mathematical problems from industry with numerical methods. His focus is on engineering problems, such as problems in computational finance that require heavy and fast computation. One of the examples of his research is the development of numerical methods in credit portfolio loss modelling. This is related to the current subprime mortgage crisis at many banks: The risk of loss resulting from obligor's inability to meet its obligations has to be computed.

At CWI, Oosterlee works four days a week as a Senior Researcher in the Scientific Computing and Control Theory group, in the field of numerical analysis and computational science and engineering. He is specialized in an efficient method - the multigrid method - which employs different problem scales or 'hierarchies' during the solution process. Oosterlee will concentrate his research at the Delft University of Technology on the efficient combination of deterministic and stochastic solution methods.

PhDs

Configurable input devices for 3D interaction using optical tracking

Three-dimensional interaction with virtual objects is one of the aspects that need to be dealt with in order to enlarge the usability and application possibilities of virtual reality. When several degrees of freedom (DOFs) have to be checked at the same time, users have difficulties in understanding 3D spatial relationships and the manipulation of 3D user interfaces. Conventional interaction concepts, such as a mouse or a keyboard, may not be sufficient or applicable for specific 3D interaction tasks.

In his thesis *Configurable input devices for 3D interaction using optical tracking* Arjen van Rhijn developed concepts and techniques to improve this 3D user interaction. These techniques enable researchers to construct and apply new input devices in virtual surroundings. Devices can be constructed in such a way that spatial structure reflects the 3D parameters of the interactive task. The interactive technique becomes a one-on-one relation between device and task. The developed configured input devices can be used to design spatial configurations. They also enable researchers to quickly evaluate new device configurations and to carry out studies in the relation between spatial structure and task parameters.

The research presented in this thesis was performed using the Personal Space Station (PSS). The PSS is a near-field desktop virtual reality system, which is developed at CWI. In the PSS, a head tracked user looks into the mirror in which stereoscopic images are reflected, such that a 3D virtual environment is created behind the mirror. By using a mirror-based setup, a user can reach under the mirror and interact with 3D objects without blocking his own projection.



Arjen van Rhijn

Van Rhijn received his PhD on 18 January at the Eindhoven University of Technology. At CWI he was part of the research group Visualization and 3D Interfaces. Currently Van Rhijn works at Personal Space Technologies, which originated as a spin-off company of CWI.

More efficient combinations of web services by mobile channels



Juan Guillen Scholten

With the software concept mobile channels web services can be combined in a more efficient and flexible way. How these mobile channels operate is described in the thesis *Mobile Channels for Exogenous Coordination of Distributed Systems* of Juan Guillen Scholten. On 19 January he received his PhD at Leiden University.

In the last few years the interest in distributed computer systems like the internet has risen considerably. A distributed system consists of several independent computers belonging to a network of which users consider the network to be one coherent system. On each computer at least one software component is present that communicates with components on other computers. Think of databases, web services or peer-to-peer applications to exchange data in for example Skype, Kazaa or Napster. These spread components operate simultaneously. Therefore, suitable theories and infrastructures are needed to establish efficient coordination.

Guillen Scholten developed the MoCha coordination-framework that contains both models and software (middleware). It is capable of coordinating components from the outside. MoCha is able to change the system behaviour without having to adapt the software components. It can also dynamically change the connections between components. This feature is very useful when components themselves are mobile. MoCha can efficiently be applied on Grids, in service-oriented architectures (SOAs), component-based software and also in, for example, homenetworks.

Guillen Scholten's research has been carried out at CWI at the Coordination Languages research group of the cluster Software Engineering. He now works as a management consultant at Atos Origin where he is specialized in enterprise architecture.

Coordination software structures plugin chaos

How to deal with software expansions such as plugins? What to do when these plugins contradict each other? Who wins? Often there is arbitrariness. The ToolBus coordination software can bring structure in the chaos by acting like superglue, says Hayco de Jong.

On 1 February he received his PhD degree with his thesis entitled *Flexible Heterogeneous Software Systems*.

Plugins are supplements on a computer program. Browser Mozilla Firefox, for instance, uses thousands of plugins to block advertisements, to archive bookmarks on a central location or to inform online users about the weather forecasts. These plugins are developed (written) by several people. It can occur that two plugins interfere with software at exactly the same time. One of them recommends the user to provide a more complicated password, whereas the other does not require the use of a password at all in order to promote user friendliness. Which of them gets to go first? Now the outcome is random: this time it is safe, the next time it is not, but the user is unaware of this.

By offering a coordination layer that takes care of priority, the chaos caused by plugins disappears. To do so De Jong used ToolBus, a programme developed in 1994 by Paul Klint (CWI and UvA) and Jan Bergstra (UvA and UU). De Jong investigated several popular software products, such as Firefox, Winamp and Eclipse. The latter being an integrated development environment (IDE) for Java developers. He studied how possible shortcomings can be dealt with by using a component coordination architecture. The results of his thesis can contribute to a cheaper way of developing software.

De Jong performed his research in the Interactive Software Development and Renovation research group of Paul Klint. De Jong accepted a position as software engineer at GameSquare.nl.



Hayco de Jong



Rudi Cilibrasi

Discovering similarities by compressing data

Rudi Cilibrasi studied and extended a new method for statistical inference, based on data compression. It is based on determining the similarity between two random files by using the concept of a universal information metric. Cilibrasi defended his PhD thesis entitled *Statistical Inference Through Data Compression* on 23 February at the University of Amsterdam.

The more similar files are, the smaller their distance. Considering files with a small mutual distance as a group creates a whole new kind of cluster analysis. The method can be used for, e.g., literary texts, DNA sequences and music files. Contrary to earlier methods no a priori knowledge on the domain is required. All kinds of files are analysed with the same computer program, based on simple data compression methods like gzip or bzip. The results are often surprising and their quality is often comparable to those obtained by specialised, much more complicated software.

Furthermore, Cilibrasi shows in his thesis that a variant of the universal information metric can be based on the World Wide Web. Concepts - like food or love - can automatically be clustered and classified by means of their context on the web. This can lead to intriguing results. For four years Cilibrasi explored the connection between information theory, artificial intelligence, pattern recognition, and machine learning. He performed his research at CWI's research group Quantum Computing and Advanced Systems. After receiving his PhD Cilibrasi started working as a software consultant in Silicon Valley, USA.

Multi-level optimization: space mapping and manifold mapping

When design problems occur in real life, mathematicians always strive to optimize their models to the latest specifications. Nowadays there are many applications in which the calculating of mathematical models takes a considerable amount of time. Often expensive mathematical models can be simplified, for instance, by implementing a rougher arithmetic schedule or by providing a simplified description of the underlying physical process. For many design problems so-called space mapping and manifold mapping are efficient optimization techniques. These belong to the multi-level type. In his thesis *Multi-level Optimization: Space Mapping and Manifold Mapping* David Echeverría Ciaurri investigated applications of both space mapping and manifold mapping for practical design problems. The applications originate from the fields of magneto statistics and electronics. By making a comparison with several other optimization techniques he shows how the multi-level approach can help to minimize rich calculating design processes. Echeverría Ciaurri defended his thesis on 29 March at the University of Amsterdam. His research was carried out at CWI where he belonged to the Scientific Computing and Control Theory research group. He accepted a position as a postdoc in the Department of Energy Resources Engineering of Stanford University, USA.



David Echeverría Ciaurri

Safe and efficient software for elevators

Can elevator doors slide open while the elevator moves? How should the system be controlled to transport people as fast and as safe as possible? For elevators to be safe and efficient the control software must be checked carefully. This can be achieved with model checking. Anton Wijs received his PhD on this subject on 2 October at the VU University Amsterdam. His

thesis is entitled *What to Do Next? Analysing and Optimising System Behaviour in Time*.

Model checking means modelling and systematically verifying complex software systems. Verification ascertains whether a representative model - like an elevator, or, for instance, an analyser of chemicals - possesses the proper characteristics or not.



Anton Wijs

Wijs investigated what it takes to check time-critical systems with model checking. This implies making models in which system behaviour is described in time units, such as 'it takes the elevator five seconds to get to the next floor' or 'the chemical reaction lasts three seconds'. In his thesis Wijs compares several modelling languages in their relation to the use of time. He also demonstrates the verification of some time-critical systems.

Another aspect is searching through time-related models. Wijs gives a survey of existing search methods and proposes extensions. Next he focuses on one particular method - beam search - and makes this more efficient and generally applicable.

At CWI Anton Wijs was a member of the research group Specification and Analysis of Embedded Systems. He now works as a postdoc at INRIA in Dijon, France.

Structural features in XML retrieval

Retrieval systems help us to find information in digital data collections by retrieving documents that might be relevant to our search query. Unfortunately, it can still be a time consuming task to scan through the retrieved documents in search for the precise piece of information. It would be of great help if retrieval systems would provide access to the relevant parts of documents instead of the complete documents.

On 2 November Georgina Ramírez Camps received her PhD at the University of Amsterdam for her thesis *Structural Features in XML Retrieval*. Her thesis investigates if the structural characteristics of XML documents can help retrieval systems to perform a more effective search. It contributes to the understanding of the use of structural features for XML element retrieval, by identifying the potential benefits of different structural features for retrieval and proposing new ways to exploit them.

Ramírez Camps developed a retrieval framework where the evidence of four different types of XML element representations can be combined: the element content, the element context, the element metadata, and the document metadata. Subsequently, this framework has been used to reveal the possible improvements of different structural features for retrieval effectiveness. Finally, her research has investigated the value of contextual information in this



Georgina Ramírez Camps

domain. An interactive user study provided the basis for an analysis of the correlations between different contextual features of the information need and the structural characteristics of the relevant XML elements.

Ramírez Camps has now joined Yahoo! research labs Barcelona, Spain, where she works on new approaches for multimedia retrieval using tags, to be applied in Flickr, Yahoo!'s online photo management and sharing application.

PhD with honours for Jeroen Wackers

Jeroen Wackers received his PhD degree 'cum laude' (with honours) on 5 November at the Delft University of Technology (TUD). The PhD committee concluded that the research is "highly innovative and of superior quality, with respect to both mathematics and physics". The PhD thesis is entitled *Surface Capturing and Multigrid for Steady Free-Surface Water Flows*.



Jeroen Wackers

Wackers did trail-blazing research on computational methods for two-fluid flows, like water-air flows around ships. Together with thesis supervisor Barry Koren (CWI and TUD), he developed a robust and efficient method to compute turbulent water-air flows around ship hulls. A new approach for studying the energy exchange between fluids was introduced. Tests on benchmark problems show that the accuracy of the models and methods developed is excellent.

At CWI, Wackers worked in the research group Scientific Computing and Control Theory, in a project financed by the research programme BRICKS. Currently, Wackers continues his two-fluid flow research as a postdoc at the Ecole Centrale de Nantes, France.

Better automatic updates for component-based software

Software companies regularly launch new releases of their products. Providing these software updates is a crucial aspect of quality assurance, customer satisfaction and safety. Extensions and repairs should be installed as soon as possible. This is usually an expensive and error prone process. Even when updates are installed automatically, things can go wrong. Remember the recent problems with the automatic update functionality of Microsoft Windows: Installing a certain update left the system in a corrupt state. Other systems also regularly suffer problems when actualizing software applications. In his PhD thesis *Component-based Configuration, Integration and Delivery*, Tijs van der Storm studied how software delivery can be automated in the context of software composed of many components. Van der Storm developed techniques to enable software producers to automatically provide users with new releases any time a change is made in the source code. Users can install these updates with a minimum of effort. In the end, these techniques might facilitate the development of self-updating applications. The resulting tool Sisyphus is used in the development of the Meta-Environment, a framework for language development, source code analysis and source code transformation.

Tijs van der Storm received his PhD on 20 November at the University of Amsterdam. At CWI, Van der Storm was active in the Interactive Software Development and Renovation group. He continues his research as a postdoc at CWI.



Tijs van der Storm



Pawel Mateusz Zaręba

Representations of Gaussian processes with stationary increments

In recent years, analysis of experimental data in several areas showed the occurrence of self-similarity and long-range dependence phenomena. Important examples are telecommunication and computer network traffic, prices of financial assets or hydrology, to mention just a few. Self-similarity refers to the invariance of the statistical properties of a process under a suitable change of scale. Long-range dependence indicates that even after a long time a process is still influenced by its past. Popular and attractive applications and the fact that classical models often do not incorporate these phenomena brought great attention to the class of random processes exhibiting self-similarity and/or long-range dependence.

PhD student Pawel Mateusz Zaręba described a new method in representing a moving average. The main goal of his thesis was to establish a theory that allows to obtain (finite past) moving average representations and series expansions for the whole class of Gaussian processes with stationary increments. A theory that includes the representations of fractional Brownian motion as special cases, and that can be applied to any stationary increments process.

Zaręba obtained his PhD for his thesis *Representations of Gaussian processes with stationary increments* from the VU University Amsterdam on 11 December. Zaręba's work was supervised by CWI researcher Kacha Dzhaparidze. He belonged to the research group Probability and Stochastic Networks and continued his career in banking.



3

To transfer knowledge to society and increase public interest in mathematics and computer science

Knowledge transfer takes place in various forms, besides the dissemination via scientific publications. CWI is involved in various activities to raise public and industrial awareness. By organizing and participating in events, courses and competitions CWI aims to point out the significance of fundamental research in mathematics and computer science.

Leve de Wiskunde!

'Leve de Wiskunde!' (freely translated: Long live Mathematics!) is initiated to offer high school teachers a look behind the scenes of the lives and loves of a scientific mathematics researcher by means of:

- organizing scientific lectures;
- giving popular presentations about mathematics;
- setting up an information market; and,
- making proposals for class projects and other material.

On 13 April the conference was organized for the fifth year in a row. Over 60 mathematics teachers, pupils and other interested people attended the programme. Lectures were given by renowned researchers; among them CWI researchers Harry Buhrman (quan-

tum computing) and Arjen Doelman (mathematics and deserts). 'Leve de Wiskunde!' was held at Science Park Amsterdam so an extra field trip to SARA Computing and Networking Services, the Amsterdam Internet Exchange and CWI were included. Visitors stated that these trips were very useful to expand their idea of what mathematics is all about.

Puzzling cards

BRICKS won the 'Best of Bsic: the Battle' which was organized by SenterNovem to enthuse youngsters for research and innovation and to stimulate them to choose a beta profile in high school. With the slogan: Wiskunde & Informatica: Reken maar! (freely translated: Mathematics & Computer Science: You bet!) the BRICKS consortium (Basic Research in Informatics for Creating the Knowledge Society) together with ICTRegie, Platform Bèta Techniek and Pythagoras designed five different puzzle cards. These BRICKS cards were available at 650 high schools and could be found at Boomerang card stands from 7-20 May. The puzzles challenged high school students between the ages of 12 and 19 to actually think about mathematics and computer science in a positive and fun way. By participating they had a chance of winning popular gadgets such as iPods and the newest brain buster puzzles.

Een rechthoekige legpuzzel heeft 35 stukjes. Elk stukje heeft een van deze vijf vormen:

Heb jij wel oren naar een iPod? Denk, surf, win!

Hoeveel stukjes zijn er van elke vorm?

Wiskunde & Informatica? Reken maar!

wel oren naar een iPod? Denk, surf, win!

? €'s

25 munten. Als je er willekeurig 19 uit de vis pakt, 1 munt van 2 euro, 2 munten van 1 euro en 0 cent. Hoeveel zijn de 25 munten samen waard?

& Informatica? Reken maar!

Heb jij wel oren naar een iPod? Denk, surf, win!

Wiskunde & Informatica? Reken maar!



Python designer Van Rossum

It was a great pleasure to have our former CWI colleague and Python designer Guido van Rossum (Google) give a lecture at our institute on 5 July. He talked about the Python 3000 road map, status, and what this means for the average Python user. Programming language Python has many users, like Google, Yahoo!, Walt Disney, ABN AMRO and NASA. Guido van Rossum designed the language in the early 1990s, while he was a scientist at CWI. Python is an interpreted object-oriented language and belongs to a group of languages with members like Java, Perl and PHP. It can be used for scripting, web services, system administration and rapid prototyping. Being a fan of the series 'Monty Python's Flying Circus' Van Rossum called this language Python.



Summer course for mathematics teachers

Informative and inspirational meetings about mathematics, that is what the summer course for mathematics teachers stands for ever since 1946. The topics are a mix of interesting and up-to-date mathematical applications which show the significance of this science. Invited speakers talk about the diversity of their practical profession.

This year's theme was particularly relevant for the current organization of mathematics courses at high schools. In August a new subject was introduced to the fourth grade of havo and vwo pupils: Mathematics D (Wiskunde D). This subject broadens and deepens certain mathematical aspects and offers pupils the opportunity to choose from specific themes and modules. The summer course for mathematics teachers 2007 presented possible combinations in order for mathematics teachers to assist their pupils in their options. The summer course is organized by CWI, in cooperation with the Dutch union of mathematics teachers (NVvW). Each year at the end of August the course is held at CWI in Amsterdam and at the Eindhoven University of Technology. It aims to keep mathematics teachers up to date on the developments in their occupation. An additional benefit is to enthuse pupils for mathematics through these teachers. This year 130 teachers participated. The summer course is sponsored by NWO, the Netherlands Organisation for Scientific Research.



The tip of the iceberg

It was pleasantly busy during the science day at CWI on 20 October. In the central hall there was an opportunity to artistically hack ice. The assignment to create a mathematical ice sculpture led to impressive results, of which the remains stayed visible in the grass at the entrance of CWI for a long time.

The science day is a combined project with Science Park Amsterdam and the day is linked up with the national knowledge week. This year's theme was 'the tip of the iceberg'. CWI responded to this with a mini-class on climate changes, serving out ice creams, an ice sculpture course and a competition around a melting ice cube. The sculptures were popular and even led to a picture in Metro, a daily newspaper.

Besides the ice theme there was attention for mathematics in the form of puzzles, riddles and brainteasers from Pythagoras, the math magazine for young people. In the labs kids in the ages from 4-14 years were challenged to construct, draw or solder their very own mathematical toy. Cordula Rooijendijk, author of the best-selling book *Alles moest nog worden uitgevonden* (All still had to be invented), reported on Dutch pioneers. Even the Spyker sports car seems to benefit from mathematics as we learned from Barry Koren during his lecture on flowing numbers around the Spyker sports car. Jason Frank showed how a mathematician models climate changes.

Again this science day was a perfect opportunity to show the public how the world benefits from mathematics and how practical it is.



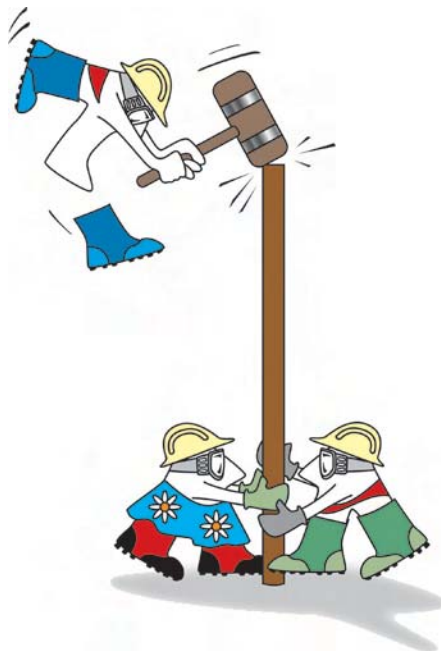
Cordula Rooijendijk



Rob van der Mei

CWI in bedrijf

This year the open day for (industrial) contacts, on 20 November, was entirely dedicated to the introduction of CWI's strategy plan 2007-2012 and its four strategic research themes. The research theme leaders informed the audience about how CWI will implement these themes in their future work. Arjen Doelman was the first for the theme earth and life sciences, followed by Martin Kersten and Jacco van Ossenbruggen for the data explosion. Rob van der Mei, Sander Bohte, Nicole Immorlica and Rudesindo Nunez-Queija opted for a group presentation on societal logistics. The closing lecture on software as service was given by Farhad Arbab, together with Rob van der Mei and Zeljko Obrenovic. At the end of the presentations all attendees were led outside to witness the festive start of CWI's new wing.



Work in progress

CWI is in full swing. Our employees literally get more room to do fundamental research in strategic research themes. In the summer of 2009 an additional 4000 square meters will become available for our excellent research. On 20 November the building activities of our new wing officially started. Peter Nijkamp (chairman of the Governing Board of NWO), Cees de Visser (general director of NWO), Pieter Adriaans (chairman of the Governing Board of CWI) and Jan Karel Lenstra (general director of CWI) personally grounded the first pole, encouraged by more than 120 cheering visitors and a brass band. This building event completed CWI in Bedrijf, CWI's annual day for relations.

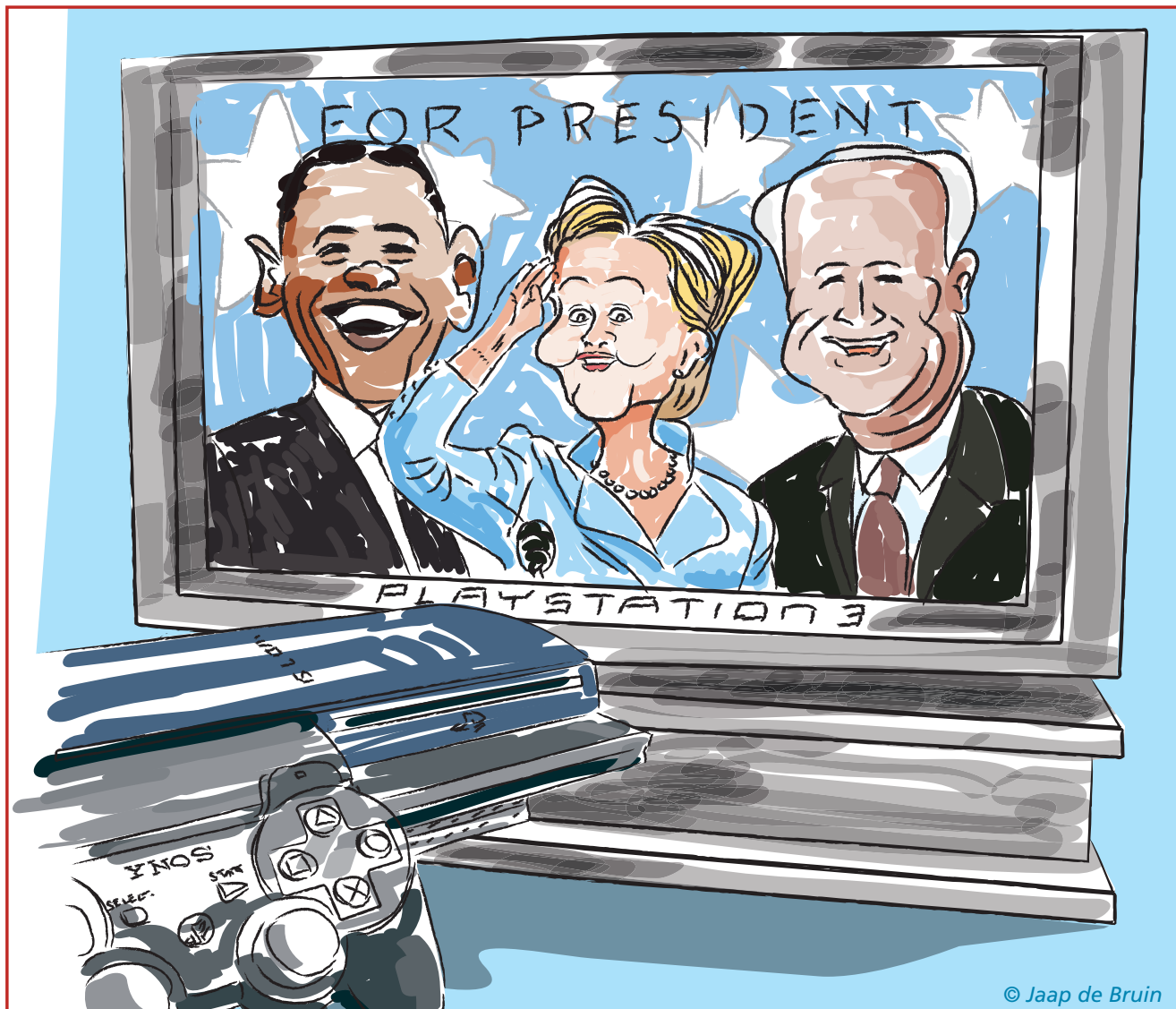


From left to right: Pieter Adriaans, Jan Karel Lenstra, Peter Nijkamp, Cees de Visser.

PlayStation 3 used to predict next US President

Can scientists correctly predict the outcome of the 2008 US presidential elections? That is the big question of the new Nostradamus website, launched on 30 November by researchers Marc Stevens (CWI, Amsterdam), Arjen Lenstra (EPFL, Lausanne), and Benne de Weger (Eindhoven University of Technology). To avoid influencing the public debate on the elections, the researchers will keep their prediction secret in a pdf file until the day after the elections. Until that time, they only reveal the MD5 hash value of this file. Such a hash value or checksum can be compared to a digital fingerprint or signature of a document. Many people use the MD5 hash to check if downloaded software is exactly the same as the original. "But

MD5 is not safe anymore," Benne de Weger says. "In 2004, it was already proven that two equal hash values could be constructed for files that differed 128 bytes in a row." But by now, the three researchers can even construct equal hash values for files that are different in an unlimited amount of bytes - in less than two days! "We did this with a PlayStation 3 because of its computing power," Marc Stevens explains. "Using a normal PC, it would take about 30 times longer." At the end, constructing equal hash values turns out to be the secret behind the new Nostradamus website. "Actually, we made 12 different predictions with the same hash values," Marc Stevens smiles. "After the elections we can pick the right one. Although this is a kind of trick, we have a serious message: People really should change their hash procedures from MD5 to safer techniques, like SHA2!"





CWI and the popular press

CWI's research has not gone unnoticed outside the scientific world. Several newspapers as well as (inter)national popular scientific journals and magazines featured articles on diverse topics.

Some highlights:

- Paul Vitányi, his work and the CWI Lectures in Mathematics and Computer Science held in his honour, received a lot of media attention. *NRC Handelsblad* for instance published a large article about Paul.
- The same happened in respect to the research of Ronald Cramer (Cryptography and Information Security) and his inaugural speech held at Leiden University. Both *Leidsch Dagblad* and *NRC Handelsblad* published an extensive interview.
- In *Computable*, a Dutch weekly for ICT professionals, two page filling articles appeared on the research projects of Krzysztof Apt (Algorithms, Combinatorics and Optimization) and Martin Kersten (Database Architectures and Information Access).
- *Computable* also dedicated a large part of their Research and

Development section to the introduction of CWI's strategy plan 2007-2012.

- Many Dutch websites paid attention to the BRICKS puzzle campaign for high school students. Also, several BRICKS researchers and their work featured the centerfold piece of *I/O Informatica-Onderzoek* issued by NWO.
- Peter Grünwald (Quantum Computing and Advanced Systems Research) and his colleague Richard Gill from Leiden University were cited in *Nature*, vol. 445, page 254-255, of 18 January in a news feature about the role of statistics in cases such as Lucia de B. and Sally Clark.
- Harry Buhrman (Quantum Computing and Advanced Systems Research), Monique Laurent, Falk Unger and Alexander Schrijver (Algorithms, Combinatorics and Optimization), were cited in *Nature Physics* (vol. 3, April) in relation to their research on limits of quantum computing.

Paul Vitányi in NRC Handelsblad



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

CWI aims at playing a leading role in setting the national research agendas in applied mathematics and computer science. On an international level, CWI is an active participant in many scientific societies and organizations. The institute hosts researchers from over twenty countries across the world. In this section the (inter)national scientific output is discussed by means of giving short updates on several lectures, workshops, conferences and symposia.

CWI and INRIA sign agreement for scientific cooperation

CWI and INRIA - the French National Research Institute for Computer Science and Control - already have well-established relations, notably through ERCIM, the European Research Consortium for Informatics and Mathematics. On 17 October associations were strengthened when the two research institutes signed a special cooperation agreement. Jan Karel Lenstra, Dick Broekhuis, Paul Klint and Han La Poutré visited their colleagues at the INRIA Futurs premises in Lille. Researchers from INRIA introduced their work and gave a guided tour to provide an overview of their facilities.

In 2008 CWI and INRIA will start joint-research projects in the fields of software service evolution and learning and computational economics. Typical problems that will be investigated are transformation of existing software to trustworthy software services and the optimization of cost-benefit analysis in for instance patient planning. CWI researchers in Amsterdam will closely work together with INRIA researchers based at the new research centre INRIA Lille-Northern Europe. Initially the research will be carried out in Amsterdam, but in the near future the cooperation can be

extended by research projects in France as well.

INRIA covers six research centres in seven major French regions which makes INRIA ten times larger than CWI. "But", says Michel Cosnard, President of INRIA, "I like small groups that work fast better than big slow research groups." For INRIA the new cooperation with CWI is the first step in establishing North European alliances. Jan Karel Lenstra is proud that INRIA decided to work with CWI as the first institute to expand their international research. "We do not need a big smart platform, it is all about smart people. In computer science we literally need to shift boundaries by means of local work and people that know each other. This way a transparent network will be created."

About INRIA

INRIA is devoted to research in the field of Information and Communication Science and Technology (ICST). INRIA employs a workforce of 3,700 people, including 2,900 scientists (INRIA and partner organizations), in six research units based in seven major geographic regions. INRIA has an annual budget of 162 million euros excluding VAT, 20% of which comes from its own research contracts and licences. It is actively involved in five areas of research: communication, cognitive, symbolic, digital and biological systems. INRIA develops numerous partnerships with industry and participates in technological transfers and the creation of companies (83 in 20 years) in the field of ICSTs, particularly through its subsidiary INRIA-Transfert, promoter of four start-up funds.

On 10-11 December INRIA celebrated its 40th anniversary.

For more information: <http://www.inria.fr/index.en.html>



Jan Karel Lenstra, general director CWI and Michel Cosnard, president INRIA



Attendants of the cryptography conference

Events

SoC platform seminars

In the kick-off meeting of the CWI Service-oriented Computing platform (SoC, November 2006), we identified the establishment of a new seminar series as an essential activity. In our SoC platform board meeting in January, we decided to start this seminar series as a recurring event. Our goal is to create a forum for presenting SoC related work that is going on within and outside of CWI. Therefore, we will have two speakers in each meeting of this seminar: one CWI researcher and one 'external' researcher. These events are open to the public and, aside from our CWI colleagues, we hope that this format will make it more attractive for our colleagues from industry, as well as other institutes, to participate. In February and November of this year we organized two meetings on which the following lectures were held:

- *Grid Computing on the Distributed ASCI Supercomputer* by Henri Bal (VU University Amsterdam, Faculty of Sciences, Department of Computer Science)
- *Service-oriented Distributed Verification* by Jaco van de Pol (CWI and University of Twente)
- *Research Challenges in Autonomic Processes and Service* by Schahram Dustdar (Vienna University of Technology, Austria)
- *A Declarative Approach to Services* by Steven Pemberton (CWI)

Fourth IACR theory of cryptography conference

The annual Theory of Cryptography Conference (TCC), sponsored by the International Association for Cryptologic Research (IACR), dealt with the paradigms, approaches and techniques used to conceptualize, define and provide solutions to natural cryptographic problems. The conference is dedicated to the dissemination of results in the area. It is a meeting place for researchers and aims to shape the identity of the theory of cryptography community. In 2007 the conference was held from 21-24 February in Amsterdam at the Trippenhuis, the headquarters of the Royal Dutch Academy of Arts and Sciences (KNAW).

The Cryptology and Information Security group at CWI played an important role in the organization of this major event. Conference general chair Ronald Cramer and Serge Fehr, Dennis Hofheinz and Eike Kiltz (co-chairs) together with the programme committee presented a diverse schedule with many renowned speakers.

Symposium on bioinformatics and biomathematics

In biological and medical research, classical wetlab experiments are more and more supported by mathematical modelling and computer search and simulation. This requires a wide scale of mathematical and computer science tools that should come from a variety of disciplines ranging from numerical analysis and discrete mathematics to statistics and information retrieval; tools that only can be developed fruitfully through intensive interaction between biologists, (bio)chemists, physicists, mathematicians, computer scientists, etc. On 5-6 April CWI brought together a variety of young experts on bioinformatics and biomathematics in a symposium organized by Arjen Doelman and Bert Gerards. The presentations provided a broad overview of these rather heterogeneous but highly relevant fields of research; research for the future presented by researchers of the future.

Future interactive TV visible at EuroITV 2007

Mobile TV, social interactive television, and ambient entertainment: At the fifth European TV Conference - EuroITV 2007 - various topics dealing with the future of interactive television were discussed. The conference was held at CWI from 23-25 May. Over 100 researchers, broadcasters and manufacturers participated. "Television is a social activity", conference organizer Pablo César (CWI) said. "Technology should enhance the social aspects of interactive TV. That's why the subtitle of the conference is 'Interactive TV - a shared experience.'" The BBC and others gave demonstrations. Keynote speakers Maddy Janse (Philips Research), Luiz Fernando Gomes Soares (PUC-RIO, Brazil) and Matthias Rauterberg (TU/e) talked about their recent research. Poster presentations dealt with P2P television, usability, t-learning, 3DTV, and interactive advertising.

The conference was sponsored by CWI, KNAW, and ERCIM, in collaboration with ACM, SIGMM, SIGCHI, and SIGWEB. Co-sponsor was IFIP.

SIGIR 2007

SIGIR is the major international forum for the presentation of new research results and the demonstration of new systems and techniques in the field of information retrieval. In 2007 ACM SIGIR was held in hotel Krasnapolsky in Amsterdam. From 23-27 July top talents in this research area gathered to exchange information about fundamental insights behind the rapidly developing world of search engines, blogs, social tagging and multi media.

Worldfamous keynote speakers from renowned institutes such as MIT, the University of Cambridge and Carnegie Mellon University were presented. A special lecture came from Professor Karin Spärck Jones (University of Cambridge Computer Laboratory). She passed

away in April. Prior to her death she made a video with regard to her winning the ACM Athena Award. Spärck Jones is praised for her fundamental contributions to for instance document retrieval and computational linguistics. The proceedings of SIGIR 2007 were dedicated to her.

On the last day of the conference the first 'Industry Event' was organized. Successful companies such as SAP, Elsevier and IBM gave their opinion on mobile search, enterprise search and e-commerce. Worldplayers Google, Yahoo! and Microsoft, but also the Chinese Baidu, spoke about recent developments in web search. The organization of SIGIR 2007 was made possible by an intensive cooperation between researchers of CWI, TNO, Thaeisis, University of Twente and the University of Amsterdam.



The image shows a promotional poster for the ACM SIGIR 2007 conference. At the top, the logo for SIGIR 2007 Amsterdam is displayed, featuring the text 'SIGIR 07' in a stylized font with a globe icon, and 'AMSTERDAM' below it. The background of the poster is a photograph of a row of historic Dutch canal houses in Amsterdam. Overlaid on the bottom half of the image is a blue banner with white text that reads: 'ACM SIGIR 2007', '30th Annual International ACM SIGIR Conference', 'Amsterdam, the Netherlands, July 23-27, 2007', and 'www.sigir2007.org'. At the very bottom, there is a small line of text: 'SIGIR is the major international forum for the presentation of new research results and the demonstration of new systems and techniques in the field of information retrieval.' Below this, a list of sponsors is provided, including Microsoft, Google, Yahoo!, Collexis, Ask, Q-go, IBM Research, Matrixware, Textkernel, SAP, Nokia, Endeca, WCC, Fredhopper, MultimedIAN, Pascal Network, TNO-ICT, Cambridge University Press (CUP), Scopus, Scirus, Springer, Now Publishers, ACM, Centrum voor Wiskunde en Informatica (CWI), Universiteit Twente (UT), Universiteit van Amsterdam (UvA), Thaeisis, WGI, BCS-IRSG, ARIA, FGI, and SIKS.



Andrew Yao



Leonid Levin



Hendrik Lenstra

CWI lectures

Each year CWI sets up special lectures in mathematics and computer science. The 2007 edition was organized in honour of Paul Vitányi. Paul Vitányi is one of the world's most distinguished researchers in the area of Kolmogorov complexity. At CWI Paul is a founding member of the Quantum Computing and Advanced Systems research group. In 2003 he was appointed CWI Fellow. CWI is thankful and proud that he chose Amsterdam as his home base.

Paul Vitányi's research deserves broad attention. CWI invited three of the world's most important researchers in theoretical computer science. Paul's research was the central theme of the symposium. Keynote speakers Hendrik Lenstra (Leiden University), Andrew Yao (Tsinghua University in Beijing, China) and Leonid Levin (Boston University, USA) paid a tribute to him. Hendrik Lenstra has worked principally in computational number theory and is well-known as the discoverer of the elliptic curve factorization method and a co-discoverer of the LLL algorithm.

Andrew Yao is recipient of the 2000 Turing Award. He has made fundamental contributions to pseudo-random number generation, cryptography and communication complexity and many other areas.

Leonid Levin is co-inventor of the notion of NP-completeness. According to the Clay Mathematics Institute, the P vs NP problem is one of the seven Millennium Math Problems.

Formal methods for components and objects

The annual symposium on Software Technologies Concertation on Formal Methods for Components and Objects (FMCO) is organized to provide an atmosphere that fosters collaborative work, discussions and interaction. CWI's research group Software Engineering is actively involved in the organization of these symposia. In October of this year the symposium was held at our premises. Several European Information Society Technologies projects were represented. Researchers discussed the concepts of reusability and modifiability in component-based and object-oriented software systems. Large and complex software systems provide the necessary infrastructure in all industries today. In order to construct such large systems in a systematic manner, the focus in the development methodologies has switched in the last two decades from functional issues to structural issues: both data and functions are encapsulated into software units which are integrated into large systems by means of various techniques supporting reusability and modifiability. This encapsulation principle is essential to both the object-oriented and the more recent component-based software engineering paradigms.

Workshop control theory for systems biology

From 12-14 November CWI researcher Jan van Schuppen co-organized a workshop targeted at researchers in dynamical systems, control and system theory, biology, and other life sciences and technology. It was held at the University of Groningen. The workshop was devoted to the mathematical modelling and analysis of complex metabolic, genetic, and protein networks, and the challenges this poses to the mathematical and engineering community. The aim of the workshop was to give the participants an introduction to this emerging research area, to put it into biological perspective, and to discuss some of the current mathematical modelling and analysis trends. The emphasis was on mathematics inspired by control theory and dynamical systems, aimed at developing theory and algorithms for modelling, identification, analysis, and control of large-scale biological networks and their dynamics.

Combinatorial optimization symposium JKL60

On 19 December Jan Karel Lenstra, general director of CWI and Professor at the Eindhoven University of Technology (TU/e), reached 60 years of age, which was celebrated with a research seminar on combinatorial optimization on 20 December. Jan Karel Lenstra's scientific work on scheduling problems in the context of complexity theory has made the Netherlands a significant spot on the map of international research on Operations Research and Combinatorial Optimization. Internationally distinguished speakers Michael Pinedo (New York University), Leen Stougie (CWI and TU/e), Rolf Möhring (Technical University Berlin), Rene Sitters (TU/e), David Shmoys (Cornell University) paid a tribute lecture to the work of Jan Karel Lenstra.

The seminar, lunch and reception were generously supported by the research school BETA, the Dutch Network on the Mathematics of Operations Research LNMB, the mathematics research cluster DIAMANT and the Department of Mathematics and Computer Science of the Eindhoven University of Technology.



Other events

Stochastic processes: analysis and applications

On 12 January a symposium was held at CWI on the occasion of Kacha Dzhaparidze's 65th birthday. International speakers such as Ildar Ibragimov (Steklov Institute, St. Petersburg), Michael Mania (Mathematical Institute, Tbilisi), Jean Jacod (University of Paris VI), and Harry van Zanten (VU University Amsterdam) gave a lecture in honour of Kacha's work.

The future of ambient intelligence

In February a mini conference was organized by CWI and Fontys University of Applied Science (Eindhoven) about the future of ambient intelligence. Key question was how to deal with the vast economic and human resources in the Netherlands, its unique saturatedness in terms of infrastructures and excellent planning strategies in relation to a practical living of everyday life, real human problems and challenges.

Theoryday NVTI

On 9 March the yearly Theoryday from NVTI - the Dutch Association for Theoretical Computer Science - took place in Utrecht. This event consists of a scientific part and a business part. In the business part, members of the NVTI discuss the activities of the NVTI and decide what actions and new activities should be undertaken. The scientific part consists of four scientific contributions.

Woudschoten

The Thirty-second Conference of the Dutch and Flemish Numerical Analysis Communities was held from 3-5 October, at the Woudschoten Conference Centre, Zeist, The Netherlands. This year the themes of the conference were coupled heterogeneous problems and numerical optimization techniques. Support is provided by CWI, the Netherlands Organisation for Scientific Research (NWO) and FWO-Vlaanderen.

Stochastics meeting Lunteren

The 36th annual Meeting of Dutch Statisticians and Probabilists took place from 12-14 November in the Conference Centre 'De Werelt' in Lunteren, the Netherlands. Each year CWI is one of the organizers. This year Marie-Colette van Lieshout invited six internationally renowned speakers who gave two lectures of one hour each on topics in statistics or probability. The lectures were open to anyone interested.

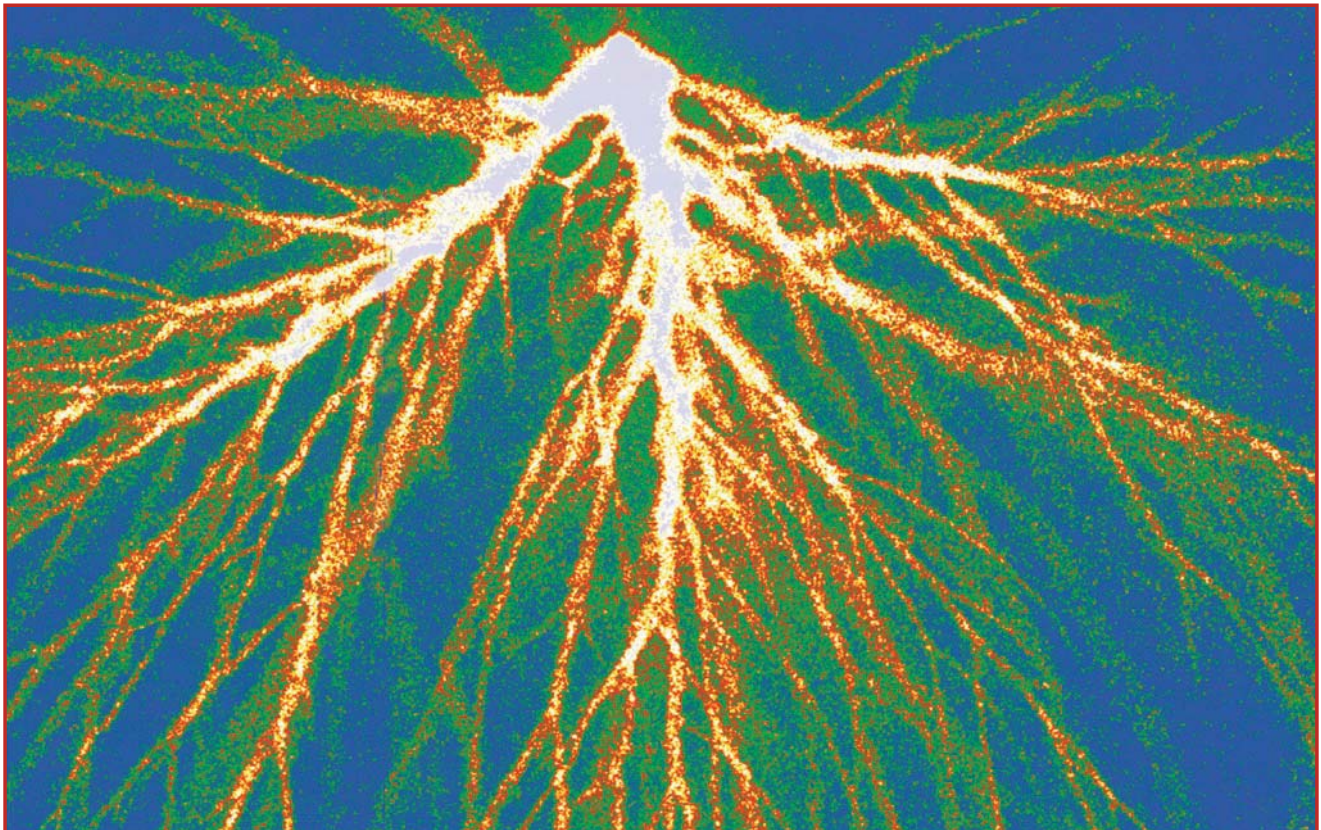
Lectures

Lightning location network on roof CWI

To the general public lightning represents both a threatening and fascinating phenomenon and for experts an exciting and challenging issue in atmospheric research. In January Hans Betz (University of Munich) visited the Multiscale Modelling and Nonlinear Dynamics research group of Ute Ebert. She is an expert on the theory of lightning and she was happy to receive Betz as a guest at CWI. He gave a presentation in which he briefly touched historic views and developments, and focused on the description of present understanding, on measuring techniques, recent findings with the inclusion of high-altitude events, and on several open questions which can be accessed also by non-experts. A central point was the establishment of a new lightning location network in Europe (LINET) which exhibits a number of novel features such as refined locating accuracy and detection of massive cloud-lightning especially as indicator for severe weather conditions. LINET is placed on the roof of the CWI building and is the first network station in the Netherlands. Betz explained why LINET may contribute to improvements of both measurements of lightning events and deeper understanding of the involved complex discharge processes.



Ute Ebert



ICTDelta

In May ICTRegie, established by the Dutch government to stimulate the innovative powers of the Netherlands by means of ICT research, introduced a new congress: ICTDelta. ICTDelta is organized to provide insights in ICT and innovation projects. For ICT professionals, researchers and policy makers it is the place to be. CWI researchers Barry Koren and Rob van der Mei gave lectures on computational science and performance engineering. CWI was also represented on the innovation market with a promotional booth. It showed a demo on multi-agent market-based mechanisms to solve dynamic scheduling problems.

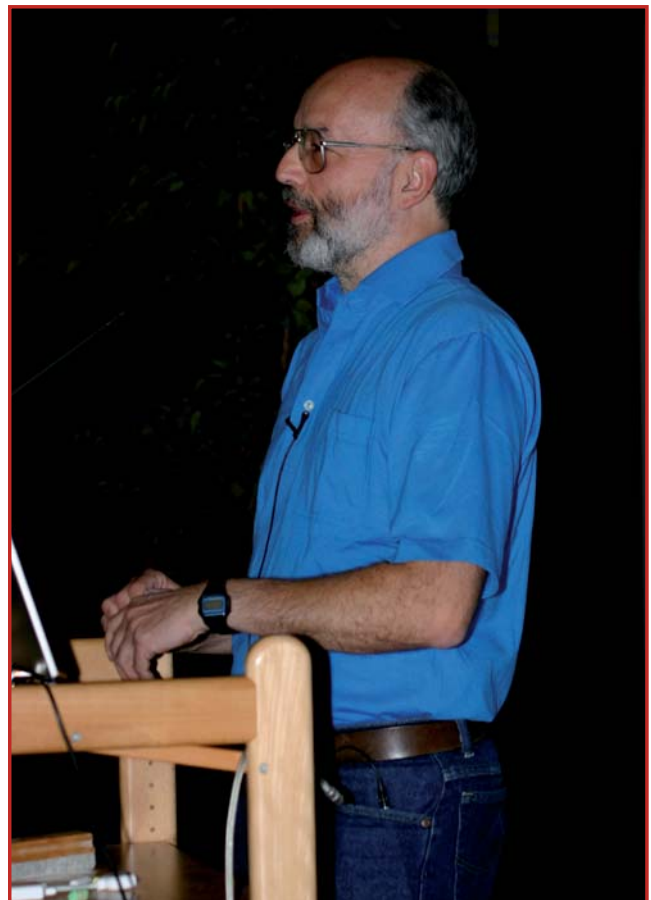
Workshop streamers, sprites, leaders, lightning

In October Ute Ebert organized a five-day workshop at the Lorentz Center of Leiden University. Questions like: How does x radiation arise from lightning? Why do thin streamers branch off quicker than thicker ones? and Why do positive electric discharges travel faster than negative discharges? were being discussed. Researchers in the fields of mathematics, physics, electrical engineering and industry gathered to try and answer these questions. The workshop covered topics ranging from big streamers in car spark plugs to gigantic sprites – discharges with a size of several kilometers in the atmosphere.

World famous cryptographer Adi Shamir

In October Adi Shamir - one of the founding fathers of modern cryptology - visited CWI. Shamir gave a lecture on a new way of cracking the SFLASH multivariate cryptosystem. He is the S in the well-known RSA cryptosystem which he designed in the seventies together with researchers Rivest and Adleman. In 2002 they won the ACM Turing Award, which is commonly known as the Nobel prize for computer science.

Hundreds of millions of copies of the RSA cryptosystem are in circulation worldwide. The system is obtained by web browsers and is a basic part of SSH and https-connections that provide safe internet communication. Shamir - together with Eli Biham - is also famous for his discovery of the differential cryptanalysis for the Data Encryption Standard. He invented secret sharing, he cracked the knapsack cryptosystem and he proved the hypothesis $IP=PSPACE$ of complexity theory. Currently Shamir is Professor in Applied Mathematics at The Weizmann Institute of Science in Israel. Shamir was invited by Ronald Cramer's research group Cryptology and Information Security. This group studies fundamental research questions in a broad scientific perspective, with emphasis on mathematics, computer science and physics.

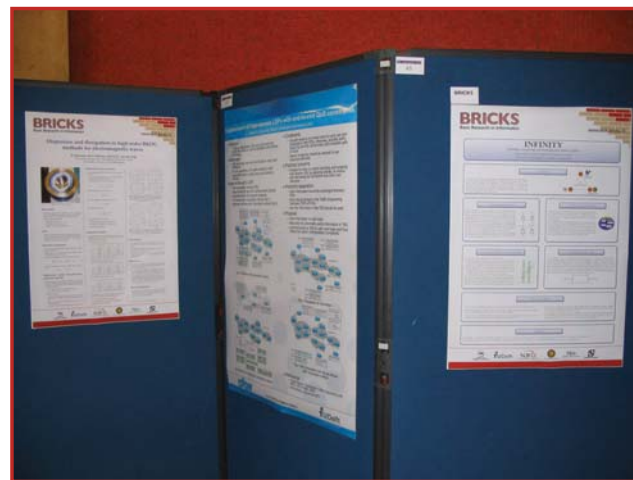


Adi Shamir

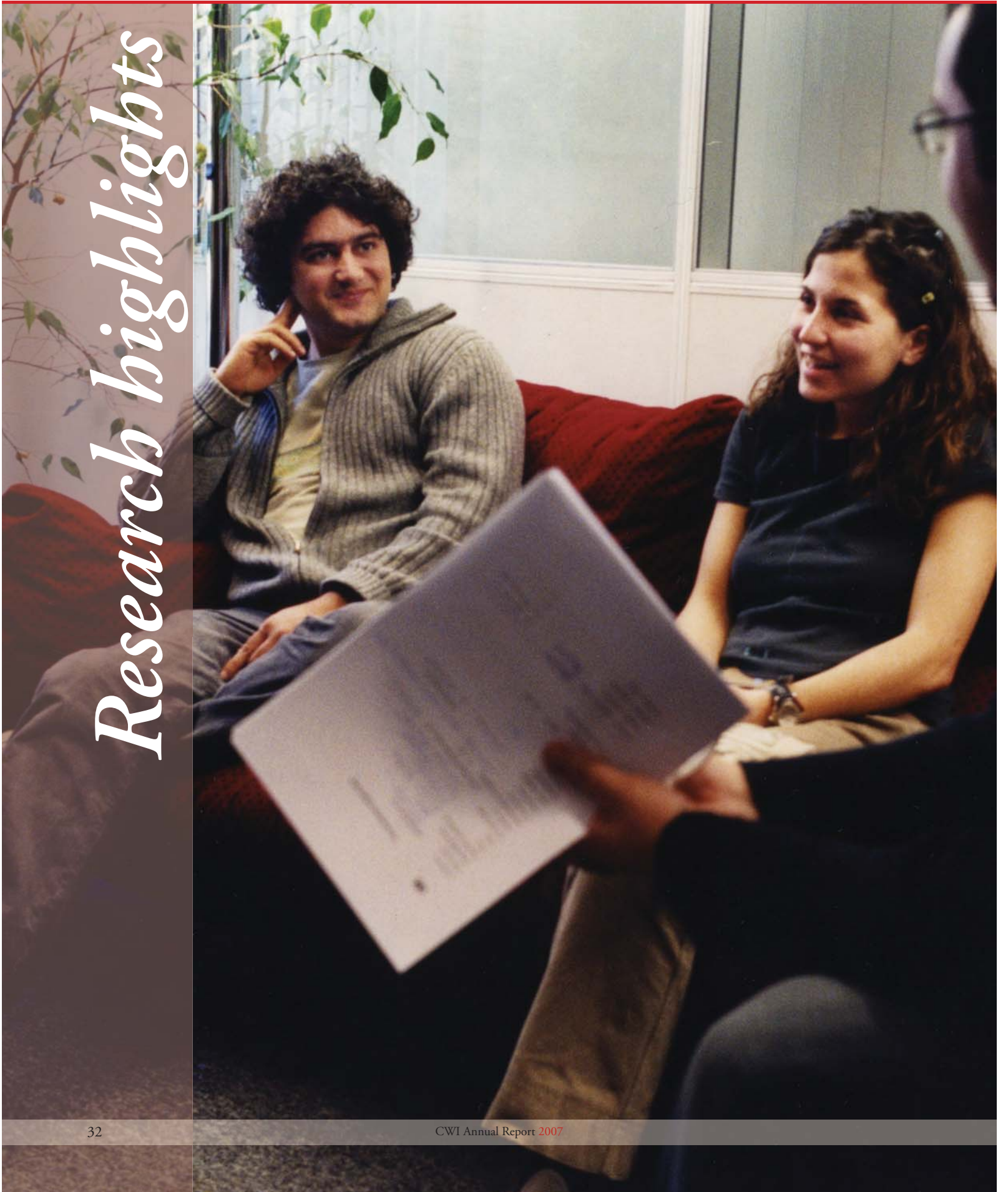
SIREN

Each year the Boards of the Technology Foundation STW and the NWO Council for Physical Sciences (EW) organize SIREN, the Scientific ICT Research Event Netherlands. SIREN is the national meeting place for curiosity driven researchers in computer science and ICT. It especially presents results from projects supported by EW or STW and provides an opportunity to all ICT researchers in the Netherlands, experienced senior researchers as well as starting juniors, in presenting their work.

SIREN was held on 30 October at the congress centre of Delft University of Technology. BRICKS received a special invitation to participate in the event with a designated poster platform on which PhD students could present their research projects. CWI and BRICKS researcher Harry Buhman gave an interesting invited lecture about quantum computing.



Research highlights





Focused research across four themes

CWI forms, together with other top institutions such as INRIA (France) and Max Planck (Germany), the backbone of European research. We want to strengthen our leading position. This requires new priorities and new investment. To further focus our success, we will concentrate our efforts on four broad, societally-relevant strategic research themes that align with the strategy of NWO (the Netherlands Organisation for Scientific Research): earth and life sciences, the data explosion, societal logistics, and software as service. Our fundamental research in these areas will provide a deeper understanding of problems across the health care, climate, communication, congestion, security and service domains.

In this section we highlight four different types of projects that are taking place within these four strategic research themes. On our new and improved website (www.cwi.nl) more detailed information about all of our research can be found.

Earth and life sciences

To protect our planet we have to investigate its dynamics. Mathematics and computer science will take on the challenge of developing advanced methods for modelling and simulating these complex systems. Mathematics and computer science also play a key role in the life sciences. Unravelling the genetic code has resulted in a rapid development of systems biology. This will in turn be a source of inspiration for CWI. Analysing huge numbers of complex data requires a whole range of mathematical and software tools, both quantitatively and qualitatively.

Our ambition

A large gap exists between mathematics and computer science on the one hand, and the life sciences on the other. Interdisciplinary research projects are needed to break this barrier. CWI wants to play a leading role in this. A new generation of biologically oriented researchers needs to be educated in modelling and simulating. Mathematics aimed towards geophysical fluid dynamics and oceanography is one of the subjects of our strategic research theme earth and life sciences. The latest developments in dynamical systems and geometric numerical integration are already successfully being used.

Impact

The integrated approach of systems biology to life's building blocks aims to pave the way for the production of new drugs and an improved production of food. Mathematics and computer science will play key roles in this and related areas of research.

Milk cartons and traffic-jams

In January 2007 NISB, the Netherlands Institute for Systems Biology, was officially launched. CWI is one of the founding partners. Together with the FOM Institute for Atomic and Molecular Physics (AMOLF), VU University Amsterdam (VUA) and the University of Amsterdam (UvA) researchers collaborate in the area of systems biology. Systems biology is a rapidly developing field that investigates how behaviour of biological systems can be understood in terms of their molecular organization. The study of these dynamic systems strongly relies on theoretical and experimental developments in mathematics, physics and engineering. Some key topics at the moment are system identification, experimental design, stochastic phenomena, complex deterministic dynamics, and system control.

The work of researchers Joke Blom, mathematician at CWI, and Frank Bruggeman, systems biologist at NISB, serves as a good example of this collaboration. In their research, sometimes referred to as 'the silicon cell project', they apply and develop theories, methods and simulation-models to study experimental cell-biological data. However, many hurdles have to be taken. For instance, the language barrier between mathematicians and experimental biologists is considerable, a challenge on both sides; common interests and concrete projects are hard to identify at first glance. Even with current experimental methods the dynamics of biological systems remain hard to study quantitatively on a large scale, though the nonlinearity of these systems necessitate this. These issues lead to new mathematical challenges: How to best model partially-identified systems? What system identification and experimental design approaches should one use? Biologists, on the other hand, are challenged to put more effort into generating data and adopt newly developed quantitative experimental methods. Surely mathematics can help optimize experimental design to minimize experimental effort and maximize information content. At least, that is the idea. In the coming years it should become clear how to actually do this. Experience taught us that most of the mathematical approaches still need to be developed.

The ultimate goal of the silicon cell project is to simulate a cell in a computer. What would such a model look like? It would have to simulate the dynamics of about 10,000 variables (number of distinct molecular species: 3000 mRNAs, 6000 proteins, 1000 low-molecular weight metabolites), which vary from 1 to 10⁶ molecules per cell. The concentration of species with a low number of molecules can experience significant fluctuations (a fluctuation of the size of a few molecules may be in the order of the mean number of molecules for that species). For the cell model, this means that some processes need to be described as stochastic phenomena whereas others follow deterministic dynamics. In addition, large

protein complexes may display diffusion gradients whereas small metabolites diffuse so fast that they can be modelled as an ideally stirred environment.

The inherent stochastic nature of molecular processes may give rise to appreciable heterogeneity between cells at population level. Even though much research remains to be done in this area (some being carried out at AMOLF) this much is clear: some of the key cellular processes involved experience significant fluctuations. This was an important discovery in systems biology. In this context, Dobrzyński, Blom and Bruggeman have been investigating the fluctuations in the synthesis of mRNA.

CWI researchers expect to be working on this project to at least 2015. Starting at the level of small molecular networks and slowly growing into larger networks to finally culminate at the level of a cell. The results not only are useful for scientists, they are also important for industry and economy. Already, Unilever shows interest in the outcome. When there is a thorough understanding of the molecular processes this can have a major impact on things like the preservation of food. Take a carton of milk for example with a perishable date of ten days, if refrigerated. Industry modifies the milk substance to prevent it from going off too soon. The milk cannot be sold after the expiration of the perishable date, so all milk in storage exceeding those ten days is wasted, whereas statistically a majority of the milk is still of good quality. Through our research the way cells react on stress aspects such as radicals can be better predicted, resulting in a better control of the modification process without ruining the taste.

While developing the models it turned out that other mathematicians at CWI, working on totally different topics, can be of help. Researchers within the theme societal logistics are applying models in their research on traffic-jams in telecommunication networks. When there is a lot of data circulating in the network and the communication system suddenly comes to a stop, after which all data starts moving again at the same time, the question is how the system needs to deal with all this traffic. Dobrzyński, Blom and Bruggeman borrowed the model used in this research area to describe transcriptional bursts in biology. These bursts are comparable to traffic-jams since transcription molecules moving along DNA may differ in speed and so cause traffic-jams. In this exchange of models there seems to be no language barrier whatsoever: mathematics proves to be a universal language.

Spatial fluctuations in cell biology

In September these three CWI researchers together with the Netherlands Institute for Systems Biology (NISB) organized a workshop focused on exploring the relevance and applicability of mesoscopic models accounting for fluctuations and spatial detail (e.g. Brownian reaction-dynamics, reaction-diffusion master equation) in cell biology.

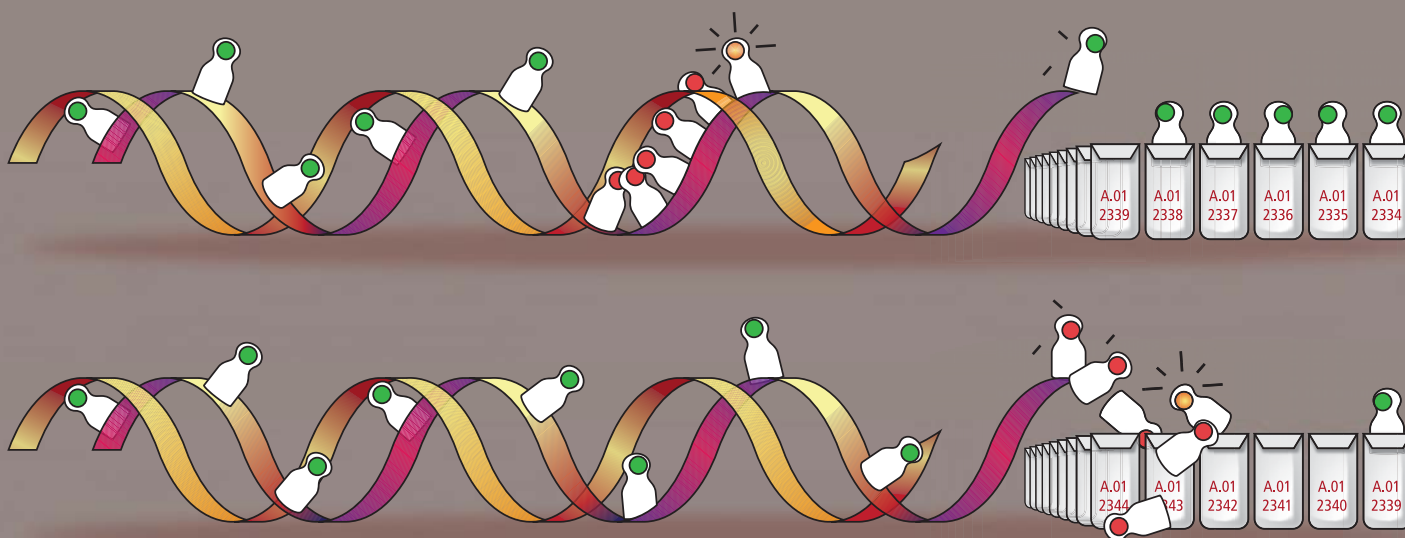
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<http://www.sysbio.nl>



Researchers at CWI

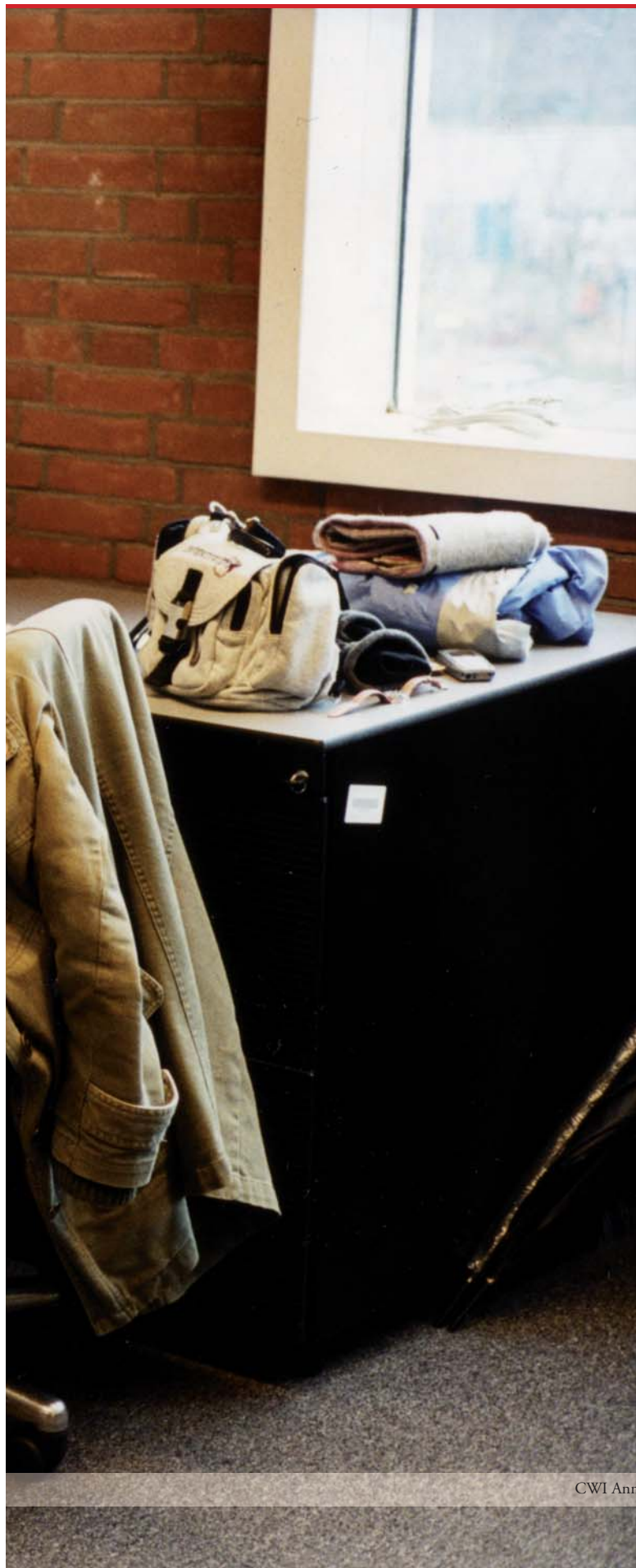
Joke Blom

Frank Bruggeman

Maciej Dobrzyński

Research highlights





The data explosion

The explosion in the amount of digital data confronts society with new questions. How can relevant and compact information be found from a flood of data? There is a significant need for models, methods and techniques that allow the mountain of data to be tun-nelled, to be studied and exploited.

Our ambition

CWI uses its expertise in data management and learning to play a guiding role in the development of technology that will manage the data explosion. MonetDB, our relational database technology, is being employed in various projects, from managing astronomical data to forensic information. Developing a new method of data storage to search for connections between large amounts of rapidly changing information is one of our challenges for the near future. Our prominent position in the field of database technology is being extended to sensor-based systems like the experimental LOFAR radio telescope, which is a network of thousands of radio aerials. CWI is also developing semantic, user-dependent techniques for structuring large data collections. Presenting data in an accessible way is one of our goals in which users will be presented with a visual structure of a dataset by means of 2D and 3D interfaces.

Impact

In the strategic research themes the data explosion and earth and life sciences management and control of huge amounts of data is of utmost importance. In developing these methods CWI is cooperating with both research institutes at home and abroad and universities like Philips Research and the Technical University of Munich, to name just a few.

The web: a work of art

For years, our cultural heritage has been carefully curated by museums, libraries and other archival institutes. Due to the lack of display space, the vast majority of the collected objects is kept in dark, climate-controlled storage rooms, inaccessible to the general public and academic researchers. Fortunately, more and more of these objects are being described in digital form, along with associated digital images and high-resolution scans, and this information is made accessible over the internet by the website of the heritage institutes.

Because each object is described by an individual digital record, it is hard to convey the rich context in which the original object is situated. For most works of art, their art-historic background in terms of relationships to other works, style periods and artists contributed valuable information about the work itself. Ethnographic objects are often hard to appreciate without knowing the role they played in the rituals of a specific culture, their connection to related objects by the same or other cultures. Historical prints require understanding of the events and historical persons depicted, the period in which they were made and the intended message they are conveying.

This contextual information is often missing in the digital representation of the objects. Especially when the relationships cross the boundaries of a single collection, the current software tools used by the museums do typically not allow these relationships to be expressed, even if the curators or other experts are aware of them. This problem is known as syntactic incompatibility. But making tools that allow relationships to be expressed across collections is not sufficient, because the terminology used by different institutes to describe their objects varies enormously: this problem is known as semantic incompatibility.

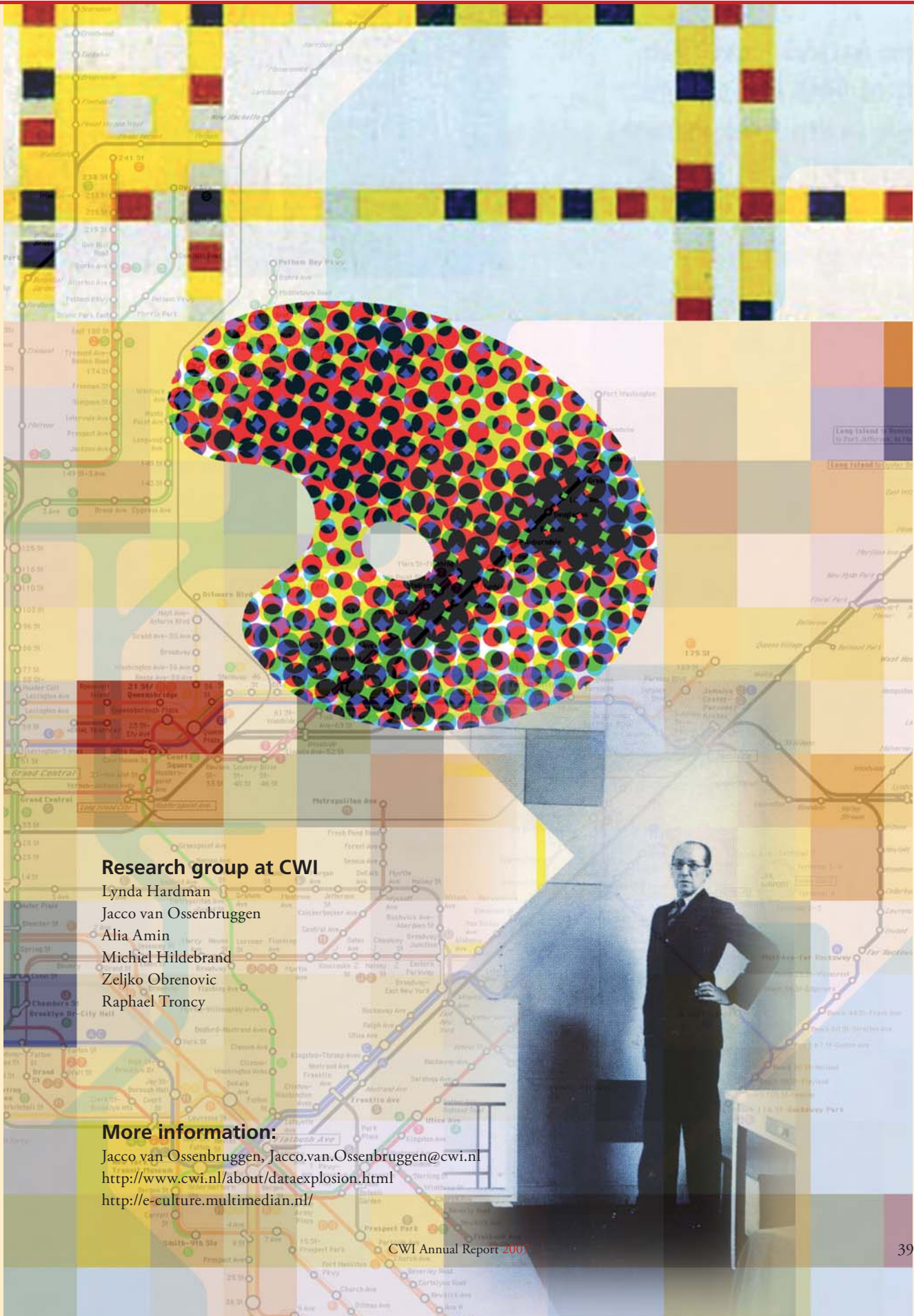
The MultimediaN e-culture project addresses syntactic incompatibility by converting the digital information to modern, web-based and standardized formats that are platform and application independent and allow easy, web-style linking of information. The focus of the project, however, is on solving semantic incompatibility issues. By using the rich, explicit and domain-specific knowledge that is already available in the many thesauri, geographic databases, biographical dictionaries and other sources of encyclopaedic knowledge, we disambiguate different uses of the same terms, connect different terms that mean the same, and make other meaningful relations across the borders of different collections, institutes and disciplines.

The result is a Culture Web, a large, deeply connected graph with related information about artefacts, materials, artists, style periods, cultures, locations and other relevant concepts. Like the current web, it is linked, distributed, heterogeneous and open to everyone

who likes to contribute. Unlike the current web, the descriptions and the relations among them are machine-processable, which allows for new search paradigms, where the search engine makes use of the type of links to find relevant information and meaningfully related information. It allows for new ways of presenting the search results, because the software not only knows that a result is related to the user's query, but also how it is related, and how the search results are related to one another.

In collaboration with the two universities in Amsterdam, the Netherlands Institute for Cultural Heritage (ICN), the national clearing house for ICT and cultural heritage (DEN) and individual museums, archives and libraries, CWI is building the future Culture Web. CWI's particular role in the project is researching the new user interface designs that are required to online search, explore, compare and combine related information across the traditional borders of the institute and discipline. Interfaces used to provide access to closed, in-house developed applications with a fixed, static and controllable data model. Now interfaces operate in an open world where the data, data models and application functionality are partially developed elsewhere. They are shared, rapidly changing, and often not conforming to the local expectations of a specific user group. Conveying information in such a rich, heterogeneous and distributed context in a transparent, trustable manner requires interfaces dealing with data provenance, personalization and term disambiguation.

In close cooperation with museum professionals, CWI researchers are designing and evaluating the properties and performance of new interface designs that address these issues. The goal is to develop reliable interfaces for applications in an open, linked and networked world, that are also applicable in other domains. For example, the MultimediaN software that is being developed to search and explore relationships in cultural heritage collections, is also being tested by the European K-Space project in the domain of news photos and articles. The precise concepts and artefacts that play a role in the news domain may be different, on a more abstract level the problems are very much alike. Users have to deal with vast amounts of information where each individual digital image or article needs to be understood in its original context: when and where did this happen, what happened exactly and who were involved? We make this information explicit in a News Web where images and texts are situated in a distributed, heterogeneous information network of related concepts, persons, events, locations and periods. How to explore such networks in a meaningful way, and how do you know to what extent you can trust the information you find? Building interfaces that provably help users solving these problems is the key challenge of our research group.



Research group at CWI

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Societal logistics

The speed and complexity of traffic, transport and communication in our society is ever increasing. Coordinating the inherent immense and intricate logistics is dependent upon frontier research that addresses the bottlenecks in our civilization: from train scheduling to traffic flows, and from patient waiting lists to communications networks. Societal logistics occupies itself not only with the logistics of a central government, it encompasses the activities of all individual organizations concerned with keeping our society up and running: railways, public service corporations, hospitals and telecommunications companies. CWI is the frontrunner in this particular research area.

Our ambition

As is evident from our most successful work for NS, the Dutch Railways, CWI is able to solve thorny problems in societal logistics. The next few years CWI will address itself to strategic research into these fundamental problems. Mathematics and computer science offer the tools to investigate capacity planning problems within an acceptable length of time. The increase in magnitude of logistic systems demands a splitting-up of its central control. Tuning the individual subsystems calls for fundamental insights into the dynamics of interacting components. A new discipline, algorithmic game theory, a merger of classical game theory and the theory of algorithms, is ideally suited to solving problems arising in these fields.

Impact

Societal logistics is a widely applicable subject. It can be deployed to attack planning problems in health care, to improve public transportation, and to optimize communication networks.

Going once, going twice...

Certain cell phone companies charge higher rates if you call someone who uses a different provider. If you have many friends who use a cell phone of company X, you prefer to use that same company so you can keep in touch with your friends without having to pay too much. Sounds familiar?

Companies would like to predict how people react, and so how to motivate people to use their products. Another example: You would like to buy the latest pair of sneakers and you are searching the Internet for more information. When you enter your search the first couple of hits may not deliver what you are actually looking for. Advertisements pop-up and try to trigger you to click on them. Nike, Adidas, Converse, they all compete for your attention.

At CWI, researcher Nicole Immorlica has been working on such matters. Her research focuses on social networks and algorithmic game theory, studying the 'rules of society' and how these can be designed to optimize the system as a whole. She combines her knowledge of computer science with economics in order to model people's behaviour and personal benefits, and then analyses the expected outcome of economic systems like networks of cell phone users or auctions for online advertisements. Through models the rules can be organized in a systematic way to optimize the global system.

For example, consider the online advertisement auctions of the major search engines alluded to above. Every time a user searches for a keyword on one of these search engines (or reads a weblog or online newspaper, etc.), an auction is run among advertisers who wish to compete for this user's attention. Available ad space (e.g., the right-hand-side of the search results page) is then allocated to advertisers as a function of their bids, and prices are charged if, and only if, the user clicks on the ad. In 2007, advertisers spent over \$20 billion in the online advertising industry [1], providing most of the revenue of Google and Yahoo! as well as significant revenue for many other online services, making it imperative that the industry be efficient and effective.

How should the rules of this auction game be set up? How should the advertisers bid in order to optimally spend their advertising budgets? What revenue might one expect the search engines to generate, and what would be the value to the advertisers or the searchers? The answers might be simple were there only one search for one keyword in all of history. But there are millions of searches each day, giving way to a very dynamic and interdependent marketplace with all the ensuing complications.

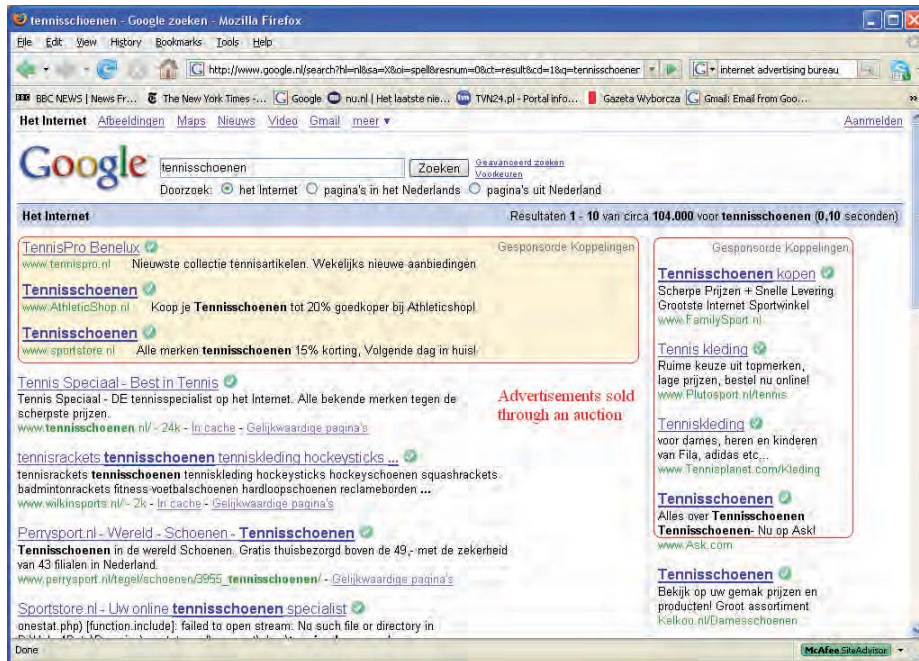
Nicole Immorlica addresses these issues by designing a mathematical model of advertisers' values, and then analyses their expected

behavioural patterns. Her research shows that many desirable properties are unattainable in ad auctions due to the repeated nature and complication of budget constraints. Nonetheless, her insights have led to the design of automated bidding tools for advertisers which help prices converge to the market equilibrium, techniques to combat click-fraud in which advertisers click on each others' ads merely to increase the spending of their competitors, and ways for advertisers to request and search engines to provide minimum supply guarantees. With the recent receipt of the Microsoft Research Beyond Search Award, Nicole Immorlica and her colleagues hope to further optimize the ad-auction industry by studying the effects of different ads on each other (so-called externalities). A succinct model for these effects will allow search engines to display the optimal set of ads for each keyword, thereby increasing advertiser value as well as search engine revenue and user satisfaction. It's a win-win situation for all.

Auctions form a special case of mechanism design which, according to *The Economist*, can be explained as: "How to arrange our economic interactions so that, when everyone behaves in a self-interested manner, the result is something we all like." Whereas Nicole Immorlica focuses on centralized auction designs, Krzysztof Apt studies decentralized mechanisms in which no central authority exists and the decisions have to be taken by the users themselves.

Over the last 30 years society became more and more interested in the area of public economics and auctions. Economists used to work with a model of centralized mechanism design. In some circumstances this point of view is now inadequate: on the internet no central authority exists. CWI researchers have proposed a distributed mechanism system that ensures that desired decisions are taken by the players themselves, even though they can manipulate the information available to them. The system supports a possibility of an initially unknown number of players, can cope with potential crashes, and provides procedures that identify users who abuse the system. Thanks to a hierarchical design in which the distributed computing and mechanism design aspects are properly separated, each application can be realized just by changing the top layer. For example, to design a distributed Vickrey auction, only 18 lines of code had to be modified.

Nicole Immorlica and Krzysztof Apt stress that behind such practical applications there is a large body of research in computer science and game theory. Researchers without an appropriate theoretical background run the risk of designing inefficient systems. In New Zealand, for instance, a large auction was set up for short wave radio frequencies. The organizers expected millions but ended up with a very disappointing revenue. They introduced the Vickrey



an auction rule according to which the highest bidder gets the object, but pays a price equal to the second-highest bid in the auction. Typically bidding in such auctions is simple: it is optimal to bid your true value, and as a result the bidder with the highest value wins the auction. But, due to dependencies between the various frequency licenses, truthful bidding was not optimal in the New Zealand auction. As a result one firm bid NZ\$100,000 for a license, and paid the second-highest price of only NZ\$6 [2]. In contrast, a sound design of a telecommunications auction by the leading British economists Ken Binmore and Paul Klemperer in 2000 assured the British government a profit of £22 billion and a British order of chivalry for Binmore [2]. It is the goal of Nicole Immorlica, Krzysztof Apt, and others in their field to develop sound theoretical guidelines for the design of such significant economic interactions, thereby saving millions and oiling the gears through which society functions.

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1. Internet Advertising Bureau. Annual report, <http://www.iab.net/>, 2008.
2. Milgrom, Paul. Putting Auction Theory to Work, Cambridge University Press, 2004.

Researchers at CWI

Krzysztof Apt
 Nicole Immorlica
 Joint work with Farhad Arhab, Huiyi Ma, Vangelis Markakis, and others

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 Societal Logistics Strategic Research Theme
<http://www.cwi.nl/about/societallogistics.html>





Software as service

With the rise of the digital services economy software is evolving from a product to a service. Combining loosely-coupled distributed applications is increasingly important to our economy. Separating the behaviour from the software realization within an application calls for fundamental research in order that systems are functioning in a reliable and secure way. Service-oriented computing is a new study into this challenging subject.

Our ambition

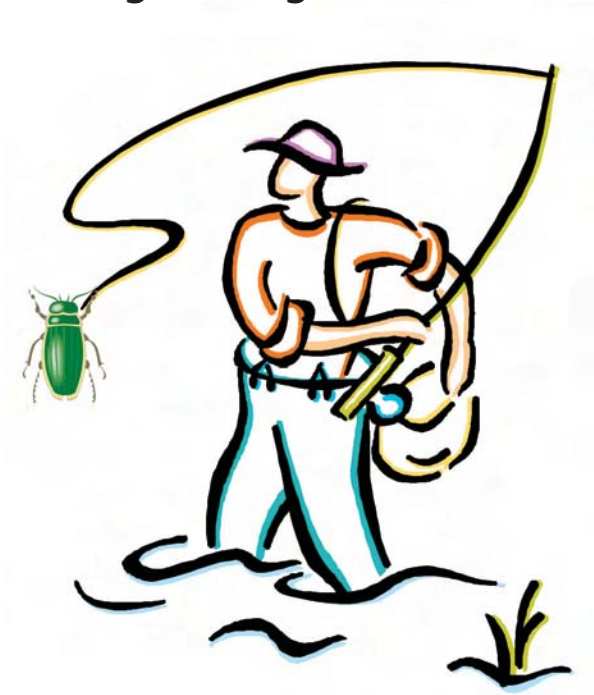
Handling service-oriented computing in a coordinated way, maintaining the quality of compound web services, and keeping them robust are first and foremost questions CWI wants to apply itself to. Controlling of services is not possible because services run on geographically distributed computers within a network. Hardware or network failures and delays may cause a service to break down. In designing services it has to be taken into account that uncontrollable failures may occur. For this, new theoretical as well as practical models have to be developed.

CWI studies classical software integration as well as peer-to-peer architectures and semantic web technologies. These will be used for financial services, embedded systems and in the creative industries.

Impact

Research into digital services is of fundamental importance for software engineering. In this, CWI will partner with Dutch and European universities and institutes. Because of our strong negotiation position with banks and insurance companies, software companies and producers of embedded systems, we can play a key role in designing standards in software engineering. Service-oriented computing plays a vital part in research projects in physics, astronomy and the life sciences.

Fishing for bugs



Before a client can be offered a useful software product a lot of work must be done to ensure its quality. To measure the quality of software, various aspects have to be taken into account, such as the model of the software product (model checking), its source code (static analysis or code reviews) and its behaviour (software tests). Such approaches result in a direct deliverable, for instance, the model is correct or incorrect. The obtained data can be used to improve the product - and often even subsequent ones.

PhD student Jens Calamé performs research on techniques for two means of quality measurements: testing and model checking reactive systems with data. To test whether a product meets the client's requirements he runs a series of software experiments. He follows a fixed structure of planning, specification and execution of the tests and their results. Researchers at INRIA designed the tool Test Generation with Verification techniques (TGV) which is part of a toolset for the Construction and Analysis of Distributed Processes (CADP). At CWI researchers use TGV as a tool for their own developed approach of testing: Behaviour Adaptation in Testing (BAiT).

So far BAiT is mainly being used in academic examples, but in the near future industry might profit from it as well. The tool could be applied to, for instance, the test of embedded software in different domains like financial services.

Let us give an example: A customer wants to withdraw 100€ from

an ATM. The necessary steps to be taken are specified for the software of the ATM but the way the money comes out of the machine is left open. There are many possibilities: These 100€ can consist of ten 10€ banknotes, or two 50€ banknotes, and so on. There are, of course, also ways to do it wrong: If the machine emits nine or eleven 10€ banknotes either the customer or the bank will frown - the ATM's specification does not allow this behaviour. Testing assures the conformance of the ATM to its specification, but can it also handle those cases of different combinations of banknotes correctly? BAiT can!

The first step necessary to run a test against the ATM is the generation of test cases. TGV can automatically generate test cases for a given specification and a scenario to focus on, a so-called test purpose. But just generating test cases suffers from the well-known problem of state explosion and the generated test cases are not even reusable for different scenarios. We first replace data in the system by placeholders and subsequently generate parameterizable test cases, which can be used with different sets of test data. For actual test parameterization, we use a constraint solver as an oracle, which gives the tester possible data combinations.

Now it comes to the test run. The customer wants to withdraw 100€. The ATM is now expected to check whether the correct PIN has been entered, the balance is in order, and if so it should register the amount of 100€ and pay. BAiT selects such a sequence of steps to test this scenario and then executes them step-wise. However, this also implies to predict the denomination of banknotes, for instance ten 10€ banknotes. If the ATM now unexpectedly emits five banknotes of 20€ each, the test would fail because the ATM does not behave as expected. But BAiT does not work this way, it rather looks into the specifications and sees that the ATM reacted correctly. The test trace is thus adapted and the final verdict of the test will have a higher quality than with the naive testing approach.

As said before, testing is not the only way to assure your software's quality. Another method is model checking, which formally verifies whether the specification of a system fulfills certain requirements. Assume the following example from the Positive Acknowledgement Retransmission protocol (PAR): A message is sent from a sender S to a receiver R via a lossy channel. If R receives this message, it sends an acknowledgement back to S via an acknowledgement channel. If S does not receive this acknowledgement within a certain time, it assumes the message got lost and resends it to R. If one specifies the timeout of S too short the system corrupts. Such an error can be found by model checking a system specification resulting in a counterexample as the one described above. The price again is state explosion. In order to overcome this problem, one would abstract, for instance, the timers in the system and model check the abstracted specification. However, abstracting the



timer may lead to unprecise results, so-called false negatives. Such a false negative can be found in the abstract but not in the concrete system. Normally, one would either refine the specification with great effort or throw the false negative away. In his approach of bughunting with false negatives, Calamé abstracts the counterexample further by removing irrelevant steps and trying to find a counterpart of the remainder in the original system specifications using constraint solving techniques.

The research challenge in this project is to be able to automate software quality assurance for systems with data. Validating those systems with conventional methods often leads to state explosion, which is avoided using the methods developed in the course of this research. Furthermore, with regard to parameterizable test cases, Calamé also conveys the reusability of generated test cases.

Researcher at CWI

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<https://www.calame.de/works,published.bib,date,.html>

Appendices



Research

Cluster
Group

Cluster leader
Group leader

Probability, Networks and Algorithms

Algorithms, Combinatorics and Optimization
Probability and Stochastic Networks
Signals and Images
Cryptography and Information Security

Bert Gerards

Monique Laurent
Rob van der Mei
Eric Pauwels
Ronald Cramer

Software Engineering

Interactive Software Development and Renovation
Specification and Analysis of Embedded Systems
Coordination Languages
Computational Intelligence and Multi-agent Games
Distributed Multimedia Languages and Infrastructures

Paul Klint

Paul Klint
Jaco van de Pol
Jan Rutten
Han La Poutré
Dick Bulterman

Modelling, Analysis and Simulation

Dynamical Systems and Numerical Analysis
Scientific Computing and Control Theory
Multiscale Modelling and Nonlinear Dynamics

Arjen Doelman

Jason Frank
Barry Koren
Ute Ebert

Information Systems

Standardization and Knowledge Transfer
Database Architectures and Information Access
Semantic Media Interfaces
Visualization and 3D Interfaces
Quantum Computing and Advanced Systems Research

Martin Kersten

Martin Kersten
Martin Kersten
Lynda Hardman
Robert van Liere
Harry Buhrman

Management

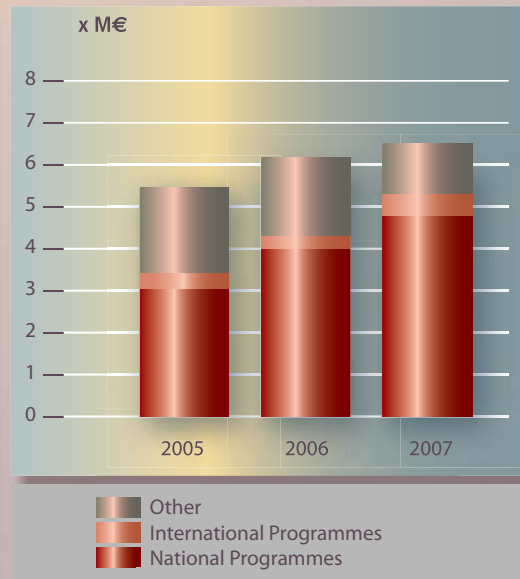
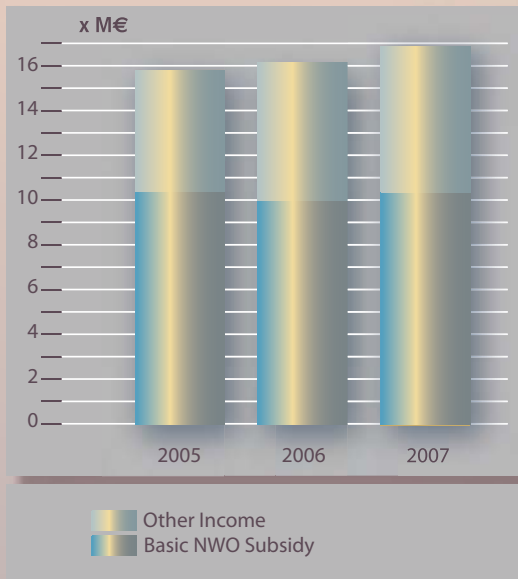
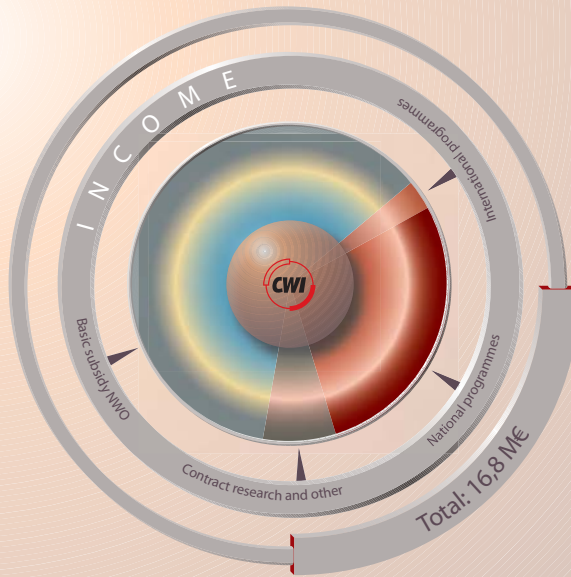
Management Team

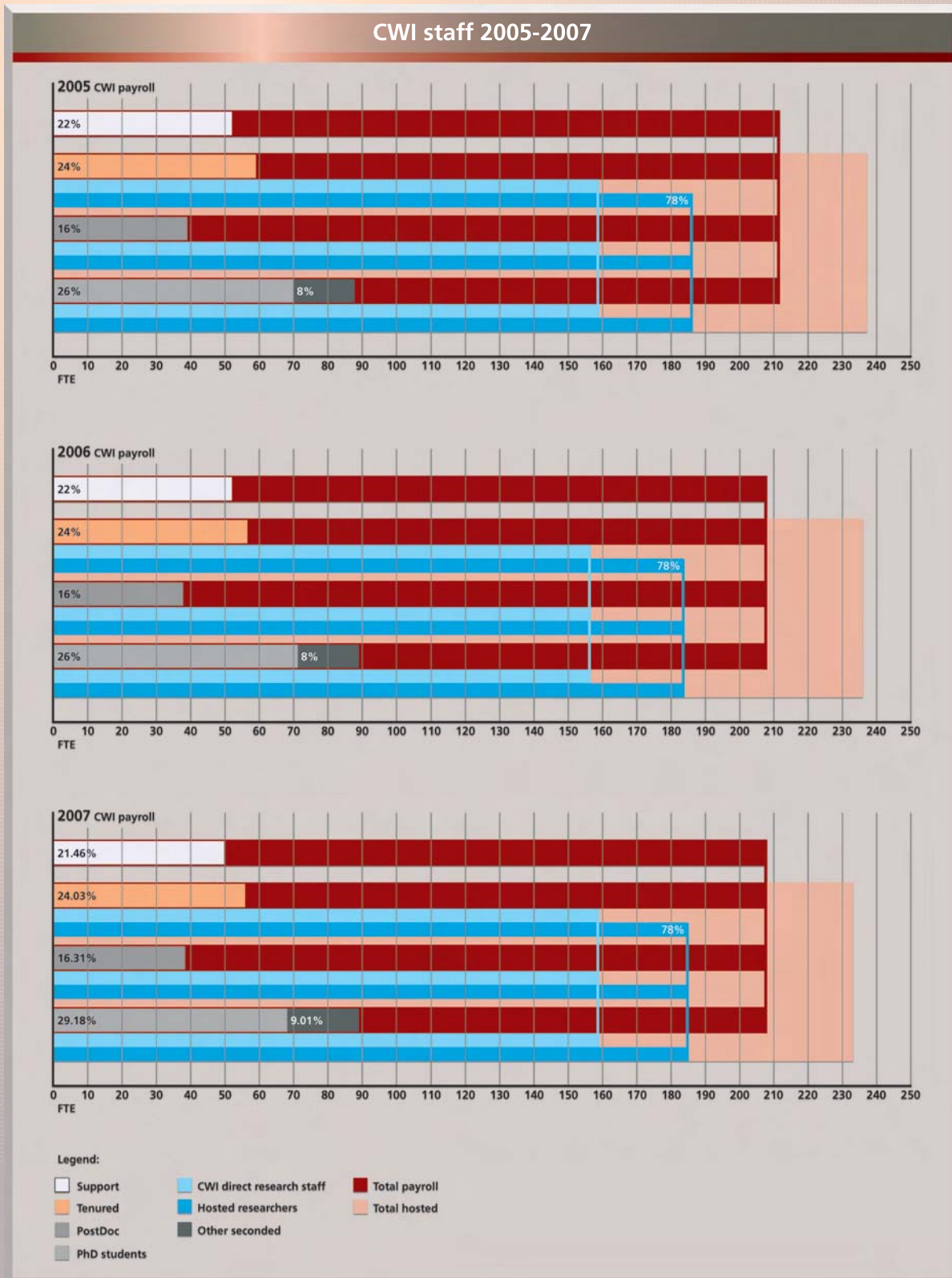
Jan Karel Lenstra, general director
Jos Besteman < November > Monique Bekkenutte
Dick Broekhuis
Ids Dijkstra
Arjen Doelman
Bert Gerards
Martin Kersten
Paul Klint
Angelique Schilder

Governing Board

Pieter Adriaans (University of Amsterdam), chairman
Hans van Duijn (Eindhoven University of Technology)
Frank van der Duyn Schouten (Tilburg University)
Joost Kok (Leiden University)
Sylvia Roelofs (ICT-Office)

Facts and figures





CWI 2007 staff numbers

Male/female staff in FTE at the end of 2007 (CWI payroll)

	Research	Support	
Male	130.15	31.8	
Female	25.5	19.8	

Master students in numbers

2005	2006	2007	
16	15	15	

International staff in 2007



Research clusters and groups

PNA – Probability, Networks and Algorithms



Cluster leader: Bert Gerards
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PNA does fundamental research motivated by society. It finds its tools in a wide range of pure and applied mathematics and computer science. The main application areas are computer technology, security, telecommunication, logistics and transportation, but applications are also found in areas like the life sciences and the environment. The research covers all four strategic themes.

Algorithms, Combinatorics and Optimization



Group leader: Monique Laurent
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This group's fundamental research is motivated by real-world problems, arising for instance in production and transportation planning, routing, scheduling and timetabling, computational biology and network economics. The goal is to design efficient algorithms. This requires understanding and exploiting the mathematical structure of the problems and using tools and methods from various mathematical areas. This research is relevant for the themes societal logistics and earth and life sciences.

Highlights:

BRICKS Dissemination Award 2007.
Microsoft Research Beyond Search Award for the project 'Socially Structured User Behavior and Externalities in Sponsored Search Auctions' – jointly with SEN.

Probability and Stochastic Networks



Group leader: Rob van der Mei
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Many real-life systems and processes are dynamic and essentially stochastic. Examples can be found in areas like communication and information systems, biology, economics and logistics. This group develops and studies stochastic and statistical models that yield fundamental understanding and enable control and optimization of such systems. Analysis of these models relies on techniques from fundamental probability theory, queueing theory, stochastic scheduling, spatial stochastics and stochastic geometry. This way the group addresses challenging research problems in the context of societal logistics and earth and life sciences.

Highlights:

Received the NSF PIRE grant, creating a network linking CWI, Courant Institute, ENS-Paris and IMPA-Rio de Janeiro.

Signals and Images



Group leader: Eric Pauwels
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The research focuses on two related topics. First, the group investigates mathematical methodologies to generate content-specific descriptions of images for efficient retrieval from large image data-

bases. Second, the researchers create semantic meta-data from video and signals generated by camera- and sensor-networks. The aim is to arrive at an appropriate high-level interpretation of observed events. Both topics fit within the strategic theme the data explosion.

Highlights:

Biosecure Research Agenda for the European Commission.

Cryptography and Information Security



Group leader: Ronald Cramer
Ronald.Cramer@cwi.nl

This group's work on the construction of practical cryptosystems as well as the work on cryptanalysis of popular much used systems is in line with the strong need for higher security in the ever expanding digital world. They also research fundamentally new ways to achieve security, including secure multi-party computation and quantum cryptography. All research is closely linked with the themes the data explosion and software as service.

Highlights:

Group member Dennis Hofheinz was credited with a Veni grant.

SEN – Software Engineering

SEN focuses its research on various aspects of software engineering, evolutionary systems and multi-media applications. The ambition is to cover the whole range of activities from fundamental concepts and prototype implementations to the application of these concepts in practice. Many activities fit in the theme software as service.

Interactive Software Development and Renovation



Cluster and group leader: Paul Klint
Paul.Klint@cwi.nl

Research focuses on the question how the development and renovation of large, industrial, software systems can be supported and improved. Focal points are program understanding, program refactoring, domain-specific languages, large-scale program transformation, and configuration/variability management. It aligns with the theme software as service.

Highlights:

Paper on ATerms selected in top 10 of most influential papers of 2000.

Major software releases of ToolBus and ASF+SDF Meta-Environment.

Specification and Analysis of Embedded Systems



Group leader: Jaco van de Pol
Jaco.van.de.Pol@cwi.nl

The research of this group concentrates on formal techniques for improving the quality of software components in embedded systems. They work with a wide range of analysis methods to prove that software systems exhibit their expected functionality. They carry out experiments in the realm of fundamental distributed algorithms, embedded and hybrid control systems, and network protocols. This research fits the theme software as service. This group existed until September 2007.

Highlights:
 Jaco van de Pol became full professor at the University of Twente.

Coordination Languages



Group leader: Jan Rutten
Jan.Rutten@cwi.nl

This group specifically seeks to provide conceptually wellfounded technology for the easy and reliable composition of third-party

services into distributed applications. Integral in the approach is the development of solid mathematical foundations on which such technology is to be based. The research fits the theme software as service.

Highlights:
 Several new European projects and a Veni grant.

Computational Intelligence and Multi-agent Games



Group leader: Han La Poutré
Han.La.Poutre@cwi.nl

The research focuses on the design and implementation of adaptive solutions and rules for dynamic and decentralized decision making. The group works in the areas of computational intelligence and multi-agent systems. Possible application domains include transportation logistics, health care logistics, energy markets, service markets, and market simulation. In this way, it contributes to the themes societal logistics and software as service.

Highlights:
 Microsoft Research Beyond Search Award for the project 'Socially Structured User Behavior and Externalities in Sponsored Search Auctions' – jointly with PNA.
 Han La Poutré was chair of the IEEE Computational Finance and Economics Technical Committee (CFE TC) of the IEEE Computational Intelligence Society (CIS).

Distributed Multimedia Languages and Infrastructures



Group leader: Dick Bulterman
Dick.Bulterman@cwi.nl

In the field of distributed media sharing, this group studies languages, interaction models and distribution architectures that will lead to more personalized, richer and efficient presentation of temporally-based collections of media. The media-as-content-components approach fits well with the theme software as service, but the research also fits the data explosion.

Highlights:

Two new FP-7 projects
Over 70,000 downloads of the Ambulant Player.

MAS – Modelling, Analysis and Simulation



Cluster leader: Arjen Doelman
A.Doelman@cwi.nl

The research programme of MAS is based on three mathematical research tracks: scientific computing, dynamical systems and partial differential equations, and system and control theory. Recently, there is a growing interest in stochastic systems and molecular dynamics. The research approach of all members of this cluster ranges from fundamental to applied. The application areas include geo- and biosciences, fluid dynamics and electro-magnetics, computational finance, and other industrial and technological fields. Altogether, the research covers all four strategic themes.

Dynamical Systems and Numerical Analysis



Group leader: Jason Frank
J.E.Frank@cwi.nl

This group engages in fundamental research on applied dynamical systems theory of PDEs, including asymptotics, low-dimensional dynamics, and stochastic modelling; and numerical analysis, with an emphasis on numerical time integration, geometric integration,

and the dynamics of numerical algorithms. The group applies its research to climate variability, atmosphere and ocean sciences, coastal and seabed morphology, phytoplankton dynamics, vegetation patterns and biomolecular dynamics. The work largely contributes to the theme earth and life sciences, but can also serve societal logistics and the data explosion.

Highlights:

Jan Verwer was appointed CWI Fellow.

Scientific Computing and Control Theory



Group leader: Barry Koren
Barry.Koren@cwi.nl

Scientific computing enables the investigation of phenomena that are too dangerous, too expensive, too difficult or simply impossible to study otherwise. The research contributes to the strategic themes: societal logistics, earth and life sciences and software as service. Control theory is a major factor in the effective functioning of technological systems as well as in modelling and control of biological systems, and in the mathematical analysis of physical systems. This research addresses both earth and life sciences and societal logistics.

Highlights:

Kees Oosterlee was appointed full professor at the Delft University of Technology.

Multiscale Modelling and Nonlinear Dynamics



Group leader: Ute Ebert
Ute.Ebert@cwi.nl

This group combines the development of basic methods of non-linear dynamics and scientific computing for deterministic and stochastic problems with practical, experimentally oriented questions. Subjects are cell and systems biology, atmospheric electricity and closely related subjects of plasma physics and technology. The research fits the earth and life sciences theme.

Highlights:

The Netherlands Institute for Systems Biology was launched.

INS – Information Systems

The research activities of INS focus on various aspects of information systems. Important output of the work is the development of prototypes for demonstrating and experimenting with solutions. The policy regarding their construction is to develop them up to the point that real applications can be built and to support the take up through open-source communities. The work mostly addresses the challenges posed by the data explosion but part of the research relates to earth and life sciences.

Standardization and Knowledge Transfer



Cluster and group leader: Martin Kersten
Martin.Kersten@cwi.nl

The activities in this group are organized in two dimensions: coordination of World Wide Web activities and development of standards. They play a leading role in coordination and scientific direction of W3C standards.

Database Architectures and Information Access



Group leader: Martin Kersten
Martin.Kersten@cwi.nl

The amount of data managed by database systems and accessed through information retrieval systems is enormous. Information retrieval technology of this group focuses on strategies for structural information retrieval. The scalability issue is addressed using adaptive algorithms at the heart of a modern database system. This clearly connects with the theme the data explosion.

Highlight:

Three major releases of the MonetDB code base and hitting 23,000 downloads

Semantic Media Interfaces



Group leader: Lynda Hardman
Lynda.Hardman@cwi.nl

The research goal is to support human users in obtaining correct information from the huge amounts available, in the appropriate amount, relevant to the task in hand and presented in the appropriate way. The challenge is to develop methods to explore and confirm models of storage, selection, organization and presentation of information. This research emphasizes the user role in the theme. The data explosion.

Visualization of 3D Interfaces



Group leader: Robert van Liere
Robert.van.Liere@cw.nl

Scientific computing is a rapidly growing field and scientists are critically dependent on interactive visual data analysis techniques. This group's focus is to study visualization methods that combine the exploratory nature of discovery with the quantitative nature of science. It contributes to the theme the data explosion.

Highlight:
Start of the NWO VIEW 'VEARD' project.

Quantum Computing and Advanced Systems Research



Group leader: Harry Buhrman
Harry.Buhrman@cw.nl

Quantum computers use quantum mechanical effects to drastically and fundamentally speed up certain information processing tasks such as computation, simulations of physical systems, and communication. The researchers develop new algorithms and protocols,

and establish the inherent limitations thereof by means of general techniques in the form of no-go theorems.

The work in machine learning and statistics focuses on the realistic case in which all available models describing the data are wrong, still some are useful though, in the sense that they lead to reasonable predictions. This group theoretically analyses this situation and develops new algorithms for it, based mainly on the Minimum Description Length Principle (MDL). MDL states that the best theory or explanation for the data is the one that allows for the shortest description of the data. The research covers earth and life sciences, the data explosion and societal logistics.

Highlight:
Knighthood for Paul Vitányi.

International and national research programmes

CWI participates in many national and international research projects.

This overview lists all major projects with their duration, partners, and CWI project leader(s).

SPICE – Service Platform for Innovative Communication Environment
2006-2008
Telematica Instituut, France Télécom
D.C.A. Bulterman

VITALAS: Image Indexing and reTrievAL in the Large Scale
2007-2009
EADS Defence and Security Systems, Faunhofer Gesellschaft, INRIA, Fundacion Robotiker, Institut National de l'Audiovisuel
A.P. de Vries

EU networks

ADONET: Algorithmic Optimization Discretization
2004-2007
Various partners: CWI is coordinator of the Dutch Consortium
M. Laurent

BIOSECURE: Biometric for Secure Authentication
2004-2007
48 partners from different countries
B.A.M. Schouten

DELOS: Digital Libraries
2004-2008
60 partners from various countries
M.L. Kersten

EC MOAN: Scalable Modelling and Analysis Techniques to Study Emergent Cell Behaviour
2007-2010
INRIA, VU, Joseph Fourier University, Masaryk University, University of Edinburgh
J.H. van Schuppen

EuroFGI – Design and Engineering of the Future Generation Internet – Towards Convergent Multi-service Networks
2006-2008
Many
R. Núñez Queija

European programmes

European Union

CREDO – Modelling and Analysis of Evolutionary Structures for Distributed Services
2006-2009
Univ. Oslo, Christian-Albrechts-Univ. Kiel, Rheinische Friedrich-Wilhelmus Univ. Bonn, Uppsala Univ., United Nations Univ. (International Inst. for Software Technology), Almende, Rikshospitalet - Radiumhospitalet HF, Norsk Regnesentral
F.S. de Boer

QAP: Qubit Applications
2005-2009
36 Partners from different countries
H.M. Buhrman



K-Space – Knowledge Space of Semantic Inference for Automatic Annotation and Retrieval of Multimedia Content
2006-2008
14 partners
L. Hardman

MUSCLE: Multimedia Understanding through Semantics, Computation and Learning
2004-2008
38 Partners from various countries
E.J.E.M. Pauwels (scientific coordinator)

PASCAL: Pattern Analysis, Statistical Modelling and Computational Learning
2003-2008
Partners from various countries
P.D. Grünwald

National programmes

NWO

ACCOUNT: Accountability in Electronic Commerce Protocols
2004-2007
UT
W.J. Fokkink

Adaptive Multisymplectic Box Schemes for Hamiltonian Wave Equations
2007-2010
-
J.E. Frank

AGP: Spectral Analysis of Processes with Stationary Increments
2003-2007
VU
K.O. Dzhaparidze

**Algebraic Geometric Foundations of Cryptology:
The Case of Practical and Unconditionally
Secure Computation**

2007-2012
Vici project
R.J.F. Cramer

Algorithmic Validation of Widely Used Cryptosystems

2004-2007
Microsoft, TUE, UL
H.J.J. te Riele

**Analysis of Distribution Strategies for Concurrent
Access in Wireless Communication Networks**

2007-2010
Lucent Technologies
R.D. van der Mei

CellMath: Mathematics and Computation for the
System Biology of Cells

2004-2008
VU, UvA, TUE, MAS2 (van Schuppen)
J.G. Blom

CIP: Constraint and Integer Programming Techniques

2002-2007
ERCIM, Univ. Victoria (Canada), Univ. Singapore, Brooklyn
College
K.R. Apt

CIRQUID: Complex Information Retrieval Queries in a DBMS

2003-2007
UT
A.P. de Vries

CoCoMAS – Coordination and Composition in Multi-agent
Systems

2006-2010
UU
F.S. de Boer

CooPer: Coordination with Performance Guarantees

2005-2009
SEN3 (F. Arbab)
R.D. van der Mei

Computational Topology for Systems and Control

2005-2010
Vidi project
P.J. Collins

C-Quattro: Compositional Construction of Component
Connectors

2004-2008
-
F. Arbab

Critical Percolation and Excitable Media

2005-2008
-
J. van den Berg

3D-RegNet: Simulation of Developmental Regulatory
Networks

2004-2008
UvA
J.G. Blom

DEBpump – Understanding the ‘Organic Carbon Pump’ in
Meso-scale Ocean Flows

2005-2008
IMA, UU, VU
B.P. Sommeijer

DIACoDeM – Distributed Implementations of Adaptive
Collective Decision Making

2006-2008
SEN3, SEN4
K.R. Apt

DIAMANT – Discrete, Interactive & Algorithmic Mathematics,
Algebra and Number Theory

2007-2010
TUE, UL, RU
A.M.H. Gerards

**Efficient Flow-scheduling in Resource-sharing Networks
with Variable Service Rates**

2005-2008
-
R. Núñez Queija

Hefboom-project

2005-2009
Hogeschool Amsterdam, VU, UvA
J.J. Vinju

Infinity – Infinite Objects, Computation, Modelling and
Reasoning

2006-2008
VU
J.J.M.M. Rutten



Interactions of Pulses and Fronts

2005-2009

-

A. Doelman

Learning When All Models Are Wrong

2005-2010

Vidi project

P.D. Grunwald

Mathematics and Computation for the System Biology of Cells

2004-2008

UvA, TUE, VU

J.G. Blom

MBA – Moving Ionization Boundaries and Charge Transport

2005-2008

TUE

U. Ebert

Mesoscale Simulation Paradigms in the Silicon Cell

2004-2008

UvA

J.G. Blom

MIA: Medical Information Agent

2004-2008

UM

J.A. la Poutré

MOBI-J: Assertional Methods for Mobile Asynchronous

Channels in Java

2001-2007

UL, Christian-Albrechts-Univ. Kiel

F.S. de Boer

Modelling of Developmental Regulatory Networks

2004-2008

UvA

J.G. Blom

MON-LM: Monotonicity Preservation for General Multisteps

Methods

2007-2010

-

W. Hundsdorfer

MoveBP – Modelling and Verification of Business Processes

2005-2007

TUE

W.J. Fokkink

MRPDE: Multirate Time Stepping for PDEs

2004-2008

-

W. Hundsdorfer

NA – Task Coordination for Non-cooperative Agents
2006-2010
TUD
H.L. la Poutré

NDNS: Nonlinear Dynamics of Natural Systems
2005-2008
-
A. Doelman

Pinwheel –Cracking a Scientific Database
2006-2009
UU, OMEGACEN/RUG
M.L. Kersten

QNOISE – Queueing Networks
2006-2007
TUE, UT
R.D. van der Mei

Quantum Computing: Algorithms, Proofs and Tradeoffs
2005-2008
Veni project
R.M. de Wolf

Quantum Cryptography: Achieving Provable Security by
Bounding the Attacker’s Quantum Memory
2006-2009
-
S. Fehr

Quantum Information Processing
2004-2011
Vici project
H.M. Buhrman

QUASID: Quantitative Design of Spatial Interaction
Techniques for Desktop Mixed-Reality Environments
2005-2009
TUE
R. van Liere

RAPS: Rare-event Analysis of Processor-sharing Systems
2004-2008
Lucent Technologies, TUE
S.C. Borst

RPOS: Realization and Control of National Positive Systems
2005-2009
VU
J.H. van Schuppen

ScaNN: Scalable Reinforcement Learning in Asynchronous
Spiking Neural Networks
2003-2008
Veni project
S.M. Bohte

SPCO: Semidefinite Programming and Combinatorial
Optimization
2002-2007
LAAS-CNRS, Univ. Klagenfurt, Univ. Rennes, TUD
M. Laurent

SYANCO – Synthesis and Analysis of Component Connectors
2006-2008
Rheinische Friedrich Univ. Bonn, UL
F. Arbab

Symplectic Integration of Atmospheric Dynamics: Long-
term Statistical Accuracy for Ensemble Climate Simulations
2005-2009
-
J.E. Frank

The Skeptical Minimum Description Length Principle
2006-2009
EURANDOM
P. Grünwald

TIPSY: Tools and Techniques for Integrating Performance
Analysis and System Verification
2004-2007
TUE
W.J. Fokkink

Universal Learning
2002-2005
HIIT Helsinki, Univ. London
P.M.B. Vitányi

VEARN: A Visual Exploration Environment for Analysing Gene
Regulation in Developmental Processes
2007-2011
UvA, Gutenberg University, James Cook University
R. van Liere

VERMPS – Verification and Epistemics of Multi-party Protocol
Security
2006-2010
TUE, VU, UL, UU
D.J.N. van Eijck



VeriGEM – Verification Grid for Enhanced Model Checking
2005-2007
TUE, UT
J.C. van de Pol

Workflow Management for Large Parallel and Distributed Applications
2007-2010
TUE
F. Arbab

STW

MoveBP: Electric ‘Fracture’: Growth and Branching of Ionised Channels
2005-2008
TUE, Thomas Stieltjes Instituut
U. Ebert

PHOTO-ID: Photo-ID for Cetaceans Using Shape Matching Methods
2004-2007
CML Leiden, Netherlands National Herbarium, UU
E.J.E.M. Pauwels, E.B. Ranguelova

Practical Approaches to Secure Computation
2005-2009
TUE
R.J. Cramer

SenterNovem (including IOP)

BASIS: Biometric Authentication Supporting Invisible Security
2004-2009
UT, TUE
B.A.M. Schouten

DEAL: Distributed Engine for Advanced Logistics
2002-2007
Almende, ERBS, VU, Groeneveld Groep, Post-Kogeko Transport Groep, Vos Logistics
J.A. La Poutré

IDEALS: Idiom Design for Embedded Applications on a Large Scale
2003-2008
ASML, TUE, UT, ESI
P. Klint

IOP-EMVT: Stochastic Methods for Field Computations in EMC Problems
2004-2008
TNO-FEL, TUE
P.W. Hemker

Passepartout
2005-2007
Stoneroots, V2, INS2 en SEN5
D.C.A. Bulterman, L. Hardman

Power Modulation and Corona-plasma for Environmental Purposes
2007-2010
TUE
U. Ebert

Trust4 ALL

2005-2007
Oce, RUL
F. Arbab

Bsik projects

BioRange – Biomathematics in Mass Spectrometry Based Proteomics and Modelling of Protein Networks
200-2009
EUR
J.H. van Schuppen

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

GeoInfoNed – A Multimedia Geo-database Infrastructure
2006-2008
OTB/TUD/Section GIS Technology
M.L. Kersten

MultimediaN: Multimedia Next Generation
2004-2008
CTIT, LogicaCMG, Philips Research, TI, TNO, TUD, UU, UvA, VU, V2_, Waag Society
M.L. Kersten

VL-e: Virtual Laboratory for e-Science
2004-2009
see www.vl-e.nl about VL-e consortium partners
R. van Liere

Contract research

Ambulant II

2006-2007
W3C
D.C.A. Bulterman

Railway Optimization

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

Stagesporen

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

XIRAF: XML-based Indexing and Querying for Digital Forensics
2007-2010
NFI
P. Boncz

Telematica Instituut projects

CHIP: Cultural Heritage Information Personalization
2005-2008
TUE, Rijksmuseum
L. Rutledge

Miscellaneous

Modelling and Inferring Developmental Regulatory Networks

2005-2008
NWO-RFBR Programme (Russisch Nederlandse Samenwerking)
UvA-section Computational Science, The Ioffe Institute of the Russian Academy of Sciences
J. Blom

Molecular Systems Biology at Science Park Amsterdam

2005-2010
AMOLF, SILS
J.H. van Schuppen

Parallelization of Coupled Large-scale Fluid Dynamics and Structural Mechanics Software

2007-2008
-
B. Koren

Spinoza Award project

2005-2010
-
A. Schrijver

STREAMERS-Moscow: Streamer Discharges: Experiments, Theory, Applications

2004-2007
NWO-RFBR programme (Russisch Nederlandse Samenwerking)
TUE, MIPT (Moscow), IVTAN (Moscow)
U. Ebert





Colophon

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