CWI

Centrum Wiskunde & Informatica

Annual Report 2011

In times of monetary crisis, environmental concerns and globalization, it becomes clear that the challenges our society faces require increasingly complex solutions. Now more than ever we need to expand the boundaries of our knowledge to bring solutions within reach. For CWI, tomorrow's challenge is today's research. We want our fundamental research to contribute to solutions to the major challenges the world faces, both in deeper understanding and in practical solutions.

As of 1 October 2011 I succeeded Jan Karel Lenstra as general director of CWI. We are very grateful for what he accomplished for CWI during his eight years as general director. As his successor I will lead the institute for the coming years. I am confident that we are sound and healthy enough to keep pursuing our mission to conduct pioneering research, generate new knowledge and convey this to society. This view is strengthened by our successful evaluation in the past year, in which we received a rating of 'excellent' for the institute.

2011 was the year of our 65th birthday. In 1946 we started our mission to conduct pioneering research in mathematics and computer science and transfer our knowledge to society, and after 65 years we still hold true to that. This Annual Report is a summary of our efforts to this end in 2011, and accounts for what we have done with the resources entrusted to us by society and our public and private partners.

This document is meant to be browsed through, reading it criss-cross in no particular order. In it, you will find four articles where we highlight our research on traffic prediction, cryptology, automated monitoring of endangered animals and managing very large databases. In five overviews we further present a bird's eye view of our work on our research themes Life Sciencs, Earth Sciences & Energy, Societal Logistcs, The Data Explosion and Software as service. These texts are interwoven with snippets of information concerning other events and activities at CWI in 2011 and facts & figures about our institute.

2011 was yet another fruitful year for CWI. In this document we want to show you why. I hope you will enjoy reading and browsing through our Annual Report 2011.

Jos Baeten
General director

About centrum wiskunde & informatica

Mission

Centrum Wiskunde & Informatica (CWI) is the national research institute for mathematics and computer science and part of NWO, the Netherlands Organisation for Scientific Research. The mission of CWI is to conduct pioneering research in mathematics and computer science, generating new knowledge in these fields and conveying it to trade and industry and society at large.

Vision

Results of mathematics and computer science are the invisible driving forces behind our economic growth and welfare, and are instrumental to developments in other scientific disciplines. They provide new insights and powerful tools for societal problems in energy, health care, climate, communication, mobility, security and many other domains.
CWI serves as national knowledge platform for mathematics and computer science and aims to expand its position in safeguarding the interests of these research fields and playing a leadership role in science policy. To achieve this, CWI is in the forefront of developing new lines of long term research in high risk areas and serves as a breeding ground for academic staff and young talented researchers. Knowledge transfer has a high priority. This is not only achieved by scientific publications and public lectures, but also through educating PhD students, bringing high-potential researchers to the workforce, collaboration with private and public partners and the foundation of spin-off companies.
CWI is also committed to the development of innovative software tools, and makes these available to the research community and industry.

Milestones

CWI has a unique talent pool of researchers. Since its foundation in 1946, **180** of its researchers have become **full professor**. Researchers at CWI have been awarded a **Spinoza Prize**, **22 NWO Innovational Research Grants** and one **ERC Starting Grant**.
CWI has a long-standing tradition of **excellence in research** that is both fundamental and societally relevant. CWI's track record includes **building the first computer in the Netherlands**, computing the **dike heights for the Dutch Delta Works**, **connecting Europe to the internet**, developing the **Python programming language used by Google**, computing the **train timetables for the Dutch Railways**, breaking **factorization records of RSA encryption codes**, and developing the **open source database system MonetDB**.
CWI plays a central role in various programs and organizations, including the **housing of the W3C Benelux Office**, the **IMO Foundation** (the office of the International Mathematics Olympiad) and **COMMIT**, an extensive programme from universities, research institutions and the industry bringing together leading researchers in computer science in the Netherlands.
Since its foundation CWI has commercialized its research in the **foundation of 21 spin-off companies** that have generated millions of turnover to date.

cwi in 2011

Jos Baeten new general director

Jos Baeten is the new general director of CWI since1 October. After eight years of service, Jan Karel Lenstra stepped down as CWI's leading man. He was honoured with the symposium 'Jan Karel Lenstra: the traveling science man', where renowned speakers such as Alexander Rinnooy Kan and Robbert Dijkgraaf were present. Lenstra's successor Jos Baeten worked at CWI between 1984 and 1991 as a researcher. Since 1991, he has been affiliated with the Eindhoven University of Technology as Professor of Theoretical Computer Science, and since 2010 as Professor of Systems Engineering.

cwi in 2011

Top sectors

Starting 2012, scientific research in the Netherlands will be partly funded in nine top sectors appointed by the Minister of Economic Affairs, Agriculture and Innovation. In 2011 CWI worked on preparing innovation contracts between research institutes and companies and in drafting NWO's research propostions concerning the top sectors. CWI is involved in the top sectors Energy, Logistics, Creative Industry, Life Sciences & Health, High Tech Systems & Materials and the top sector spanning research line ICT.

cwi in 2011

Evaluation

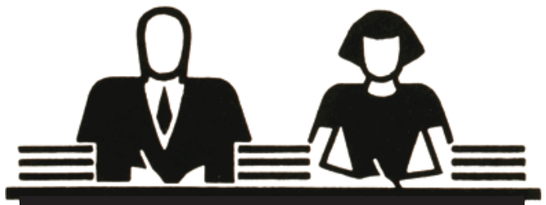
Excellent news for CWI: the institute was awarded with the highest possible score in the evaluation over the period 2005-2010. In its report, the evaluation committee called CWI 'an excellent research institute', with 'research output of excellent quality', which is 'a very attractive place for excellent young scientists to grow.' The six-yearly evaluation was commissioned and organized by the Netherlands Organisation for Scientific Research (NWO). The committee visited CWI in May 2011 and assessed the research quality, productivity, societal relevance and vitality of the institute. At the moment of writing, formal approval of the evaluation by NWO's Governing Board still awaits.

cwi in 2011

Royal decorations

The achievements of CWI researchers did not go unnoticed in the Dutch society. No less than three royal decorations were awarded in 2011. Jan Verwer (19 January) and parting director Jan Karel Lenstra (4 November) were named Knight in the Order of the Netherlands Lion for their exceptional achievements in science. Herman te Riele (2 December) was appointed Officer in the Order of Orange-Nassau to honour his special merits for society. Sadly, Jan Verwer unexpectedly passed away shortly after his retirement. We will remember Jan as a highly dedicated, modest and honest person, enjoyed and respected by his colleagues.

Facts & figures
Output in 2011



Refereed papers	312
Book contributions	20
Dissertations	11
Other publications (software, editorships, media)	183

Highlight

The underwater world of coral fish and sea turtles

Pollution, climate change and disturbance of natural habitats are rapidly changing the balance in ecosystems all over the planet. For effective protection of endangered species, conservation biologists need to understand the effects of environmental changes on animals. Therefore, biologists carefully monitor the quantity, distribution and habits of endangered species. This is mostly manual work: counting individual organisms or tagging larger animals. A new development in conservation biology is the automated observing of animals. CWI is involved in two projects to automate the monitoring of sea animals.

Coral reef fish

Coral reefs are one of the most diverse and delicate ecosystems in nature. They occupy only 0,1% of the ocean surface, yet account for 25% of all marine species. Coral reefs are increasingly under threat from climate change, water pollution and overfishing. To monitor the health of coral reefs, marine biologists regularly count and identify the various species in the reefs. The Fish4Knowledge project aims to develop a system that automatically detects fish in undersea video data. Underwater video cameras, placed in a coral reef in Taiwan, continuously generate raw video images of the coral reef.
Transforming the enormous amount of video images into useful information requires close cooperation between computer scientists and biologists. 'The cameras easily generate 20 GB of raw data per hour,' says Lynda Hardman, research team leader on behalf of CWI. 'Analysing this data to count fish inevitably introduces uncertainties. Images are sometimes blurry, other animals or moving objects can erroneously be counted as fish and sometimes there is not enough information to determine the species. As computer scientists we cannot determine what level of uncertainty is acceptable for the particular scientific question a biologist is trying to answer.'

The team at CWI focuses on the interaction of biologists with the system. 'We try to make clear how the automatically deduced results relate to the raw video data,' says Lynda. 'The system gives no exact numbers, but best estimates based on specific demands for certainty. By giving biologists access to different layers in the analysis, they can set these demands themselves. It is for instance possible to take averages over different time periods, or exclude results where the computer is not more than 50% sure that a moving object is a fish. We could set these parameters ourselves, but placing biologists themselves in control makes the system more flexible. And what's maybe more important: it creates confidence in this new method of doing scientific research. Analysis of underwater video data can ultimately provide much more reliable data on fish numbers than the snapshot data of manual counting, but it needs a different mindset.'

Leatherback sea turtle

A contemporary of the dinosaurs, the leatherback sea turtle is the largest turtle species on earth. Adults can measure over 2 meters in length and weigh more than 900 kg. The turtle is critically endangered as a result of fisheries, nest disturbances and ingestion

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Research theme

Software as service

Metaprogramming with Rascal

The software of companies and governments is often large and complex. It needs continuous adaptation to deal with changing circumstances. This makes the software increase in size, which in turn increases the costs of software maintenance. CWI is developing the open source meta-programming language Rascal to help solving the issues related with such complex software. Software written in Rascal can analyze and transform other software. It helps understanding complex software and can (semi-) automatically improve existing software.

Software for digital forensics

Forensic investigators need to recover and investigate evidence of crimes like terrorist activity and child pornography from laptops, mobile phones and hard disks. Because of the rapid development of digital devices and file formats, keeping the forensic analysis software up-to-date is a challenging task. Using Rascal, CWI is developing a domain-specific programming language (DSL) for digital forensics that can automatically generate such software based on high-level descriptions of file formats.

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Combining services

Some online services actually consist of several combined services. A website where you book a flight, make a hotel reservation and rent a car combines existing services into a single system. The services are joined together by coordination software. We developed coordination software that takes quality of service into account. It can analyze the performance of the combined services and pinpoints the bottlenecks in the system, for instance when components are waiting for the input of others.

Negotiating software

Products and services with economic value are scarce and their price is determined by a process of supply and demand. Strategic negotiation for products and services in for instance energy networks and logistic planning systems will be more and more performed by intelligent software. When multiple agents act together, negotiation is necessary to reach a satisfactory outcome for all agents. CWI develops models and solutions for such decision-making problems, for instance when uncertainty or conflicting interests are involved.

Together anywhere, together anytime

Many enduring experiences are family or group events. Current technology does not address this well: modern devices such as computers and phones tend to be owned and operated individually. With partners such as Philips, British Telecom and Ravensburger, CWI develops models and architecture for technology that supports group to group communication. An experimental living room of the future is set up at CWI were media content can be shared on interactive interfaces.

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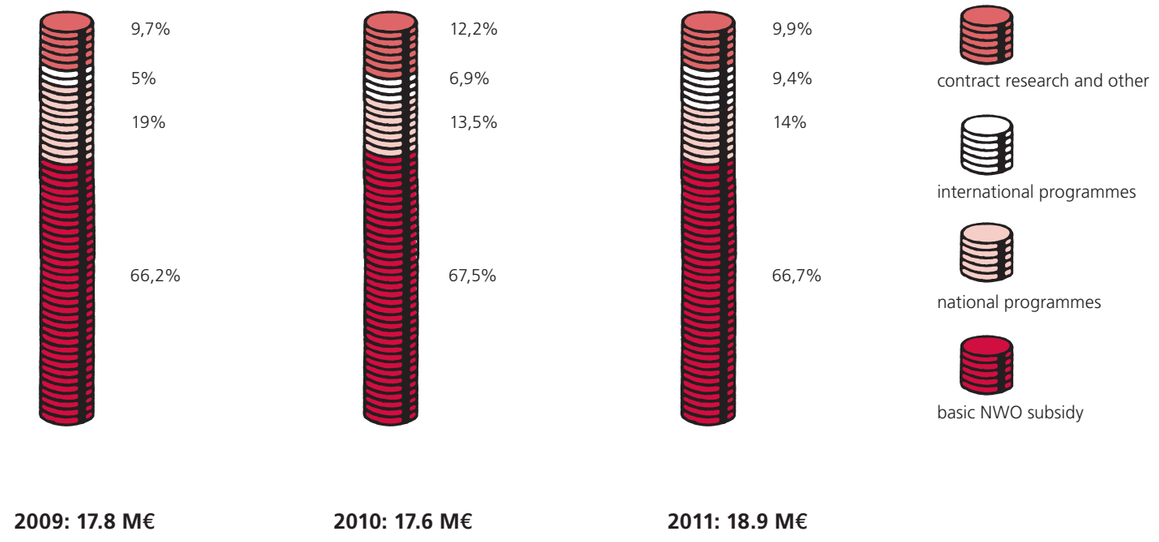
of marine debris. To learn more about their habits and distribution, biologists would like to be able to monitor individual turtles. This is difficult, for the turtle is long-lived and travels between seas and oceans all over the world. Traditional methods rely on the use of tags or transponders. Not only are these tracking methodologies costly and time consuming, but they also cause stress and discomfort to the animal.
CWI-researcher Eric Pauwels devised an non-invasive method that automatically recognizes turtles from the pink spots on their heads. 'The shape of the pink spot on a leatherback's head is as unique as a fingerprint,' says Eric. 'A photograph of the head therefore in principle suffices to identify a specific individual. Biologists and volunteers photograph the animals when they come ashore to lay their eggs during nesting season. Their pictures are uploaded to a database with thousands of other pictures and automatically matched against pictures of turtles photographed at earlier occasions to determine which animals have been seen before.'
The real challenge of the project was to devise an robust image recognition algorithm. 'It is difficult for a computer to spot similar but non-identical images', says Eric. 'If the same turtle is photographed under different conditions, variation between the images will occur due to lightning, viewpoint and camera settings. The automatic image recognition algorithm we designed looks for points in the picture with a clear light-to-dark transition. It then draws a shape through these points, and looks for other pictures were similar shapes are found, up to geometric transformations such as rotations, resizings and stretchings.
The goal is to apply similar image recognition techniques to other sea animals, resulting in an information system showing the distribution and migration patterns of large sea vertebrates. Previous research of CWI already used pattern recognition to identify humpback and sperm whales, using tail profile and pattern of spots and stripes.

Facts & figures
Total income



2009: 17.8 M€

2010: 17.6 M€

2011: 18.9 M€

Research theme

Life sciences

Retracing the steps of evolution

Evolutionary relationships among biological species are usually depicted in a phylogenetic tree. This tree of life shows how present-day species developed by splitting away from earlier lineages. These trees are generated from DNA data. However, some lineages of plants, bacteria and fungi can combine, for instance by exchanging genetic material or hybridization. The evolutionary history of such species should be described with a network instead of a tree. We are developing methods for constructing such phylogenetic networks.

Growing blood vessels

Blood vessels can grow new branches when tissues demand more oxygen or food, for instance during wound healing or tumor growth. Such new vessels are not built according to a central plan, but by self-organization of cells. Our mathematical models show how individual cells collectively form a new blood vessel in response to chemicals released by the cells themselves or adjacent tissues. Knowledge about blood vessel growth is essential for stimulated wound healing, stopping tumor growth and building artificial blood vessels.

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Research theme Life sciences

Spiking neural networks

Our brains consist of billions of neurons. These communicate with each other by means of electrical pulses called spikes. Spiking neurons somehow compute our actions and thinking. Our neuroinformaticists try to understand how this works. It appears that information is not only contained in the rate with which spikes are emitted, but also in the amount of time between individual spikes. By working out these mechanisms, neuroscientists one day hope to build artificial neural systems like the brain.

Breeding plants on demand

Human civilization has practiced plant breeding for thousands of years. Traditionally, this is done by selection on outward appearance. With the rise of genetics, professional plant breeders now are able to select on specific genes. In cooperation with molecular genetics company KeyGene, we have developed mathematical models to find the quickest way to breed a plant with specific properties. This allows plant breeders to improve the quality, yield and resistance of their crops more quickly.

The origins of life

All organisms possess the same genetic code, the language in which DNA gives instructions for building proteins. Our research suggests that its resistance to mutations might account for this success. Small changes in the code often results in the same amino acid or one similar to the original. Computer analysis shows that only a fraction of the possible genetic codes possess similar qualities. The properties of the genetic code are essential for understanding the evolution of early life.

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Highlight

Will the future be secure?

Security of digital communication is essential for our daily life, yet cannot be taken for granted. Are our Internet transactions safe? Can my electronic vote be traced back to me? Even if we are safe today, there is no guarantee that future developments won't make current encryption methods obsolete. At CWI, cryptologists are working on the digital security of the future. 'We need to be five steps ahead of new technological developments,' says Ronald Cramer, group leader of the Cryptology group at CWI. 'We have to, for if we wait until problems actually arise, we are probably twenty years too late.'

Cryptologists study methods for secure communication and cooperation in the presence of malicious adversaries. This requires a deep understanding of both mathematics and computer science. One of the most used techniques in cryptology, public key cryptography, is based on the complexity of certain mathematical problems. 'Public key cryptography uses two keys: a public key and a secret key', says Cramer.' Everyone can use the public key to send an encrypted message, but only the intended receiver can decrypt it, using the secret key. The public key and the secret key form a mathematical pair. Their link is usually an intricately chosen mathematical problem that can efficiently be decrypted with knowledge of the secret key, but that is intractable without. An important task that cryptologists set themselves is to find such intractable mathematical problems.'

Sufficiently large

Since the '90s, most public key cryptography uses RSA-encryption, which uses two large prime numbers as secret key and their product as public key. It is used in all web browsers to make secure Internet connections, for instance for Internet banking or credit card payments. If the number used as public key is sufficiently large, computers cannot derive its prime factors in any reasonable amount of time. The term 'sufficiently large' is however ambiguous. In 1999 a team of CWI-cryptologists used the so-called Number Field Sieve to factorize a 512-bit long prime number in months that supposedly would take a computer billions of years to compute. This development forced industry to use substantially larger numbers, and shows that ongoing cryptographic research is necessary to guarantee optimal security. Cryptologists worldwide are always in search of alternative intractable mathematical problems. Recently, elliptic curve cryptography is increasingly being used, most notably as US government standard for secure communication since 2005. This type of cryptography is based on problems involving the discrete logarithm problem on elliptic curves.

Quantum attacks

However complex the computations that cryptologists devise, one technological development can make most currently deployed encryption schemes obsolete: the quantum computer. 'Quantum

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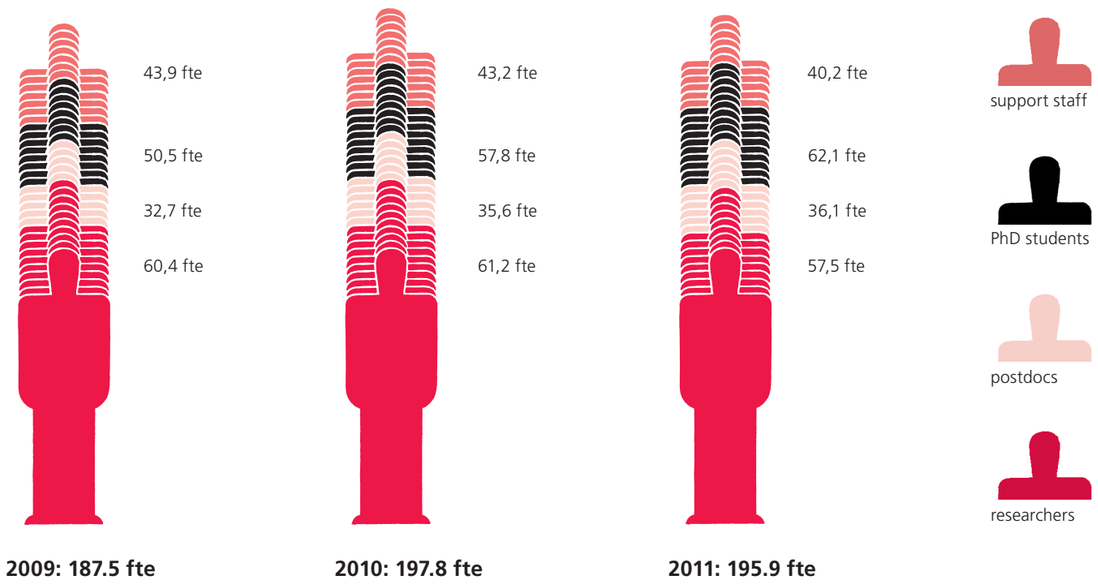
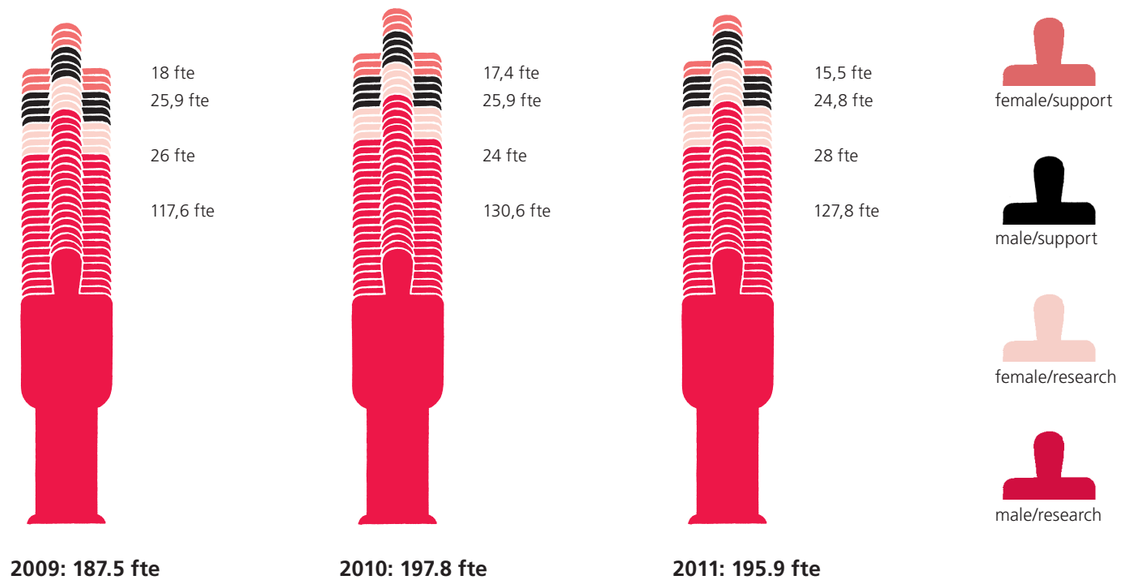
Facts & figures
Employees overview



Facts & figures
Employees male / female



Position-based quantum cryptography

One of the new areas that cryptologists at CWI investigate is the possibility of position-based cryptography. Using geographical location as a cryptographic key is an attractive idea: encrypted messages can only be decrypted in a specific location, for instance a bank or a military base. Earlier methods based on distance bounding are insecure against multiple collaborating adversaries who coordinate their actions to fake a geographical location. This process requires adversaries to copy the signal. Recent ideas suggest exploiting quantum mechanical effects, as quantum information cannot be copied without changing the information itself.

Such quantum cryptographic schemes seemed like a promising way to create a secure scheme, until CWI researchers surprisingly showed that adversaries could theoretically use another quantum mechanical effect to cheat. Two particles in quantum entanglement instantly affect each other's state. This counterintuitive quantum mechanical effect allows for collaboration without exchanging information. This unexpected turnout, which CWI researchers Harry Buhrman and Serge Fehr provided with Christian Schaffner from the University of Amsterdam and researchers of the University of California and Microsoft Research India, was prominently featured under News & Views in 16 November's issue of Nature.

As the use of quantum entanglement for this purpose requires the use of large-scale quantum computers, the interesting challenge remains to design schemes for position-based cryptography that are secure in more realistic settings, when the quantum capabilities of adversaries are limited.

computers use fundamentally different algorithms for computations,' says Cramer. 'Certain structures that are intractable for regular computers can be efficiently processed by quantum computers. They would be able to factorize prime numbers or compute discrete logarithms of elliptic curves within a blink of the eye, rendering most of our currently used public key encryption schemes useless. To be prepared, we are already working on so-called post-quantum security: encryption schemes that are resilient to attacks with quantum computers.' One promising development is lattice-based cryptography. Mathematical problems based on lattices, grids in multidimensional space, have no apparent structural handle to launch quantum attacks, making it a strong candidate for a post-quantum cryptography scheme.

The search for secure communication methods is far from over. 'A cryptographic scheme is as strong as its weakest link,' Cramer says. 'This makes security a relative concept. We are always searching for alternatives and exploring new fields, such as secure cooperation between mutual distrusting partners, or the use of geographical position as a key instead of hard mathematical problems. Our research is fundamental, but it is essential to current and future applications.'

Facts & figures

In 2011, CWI cooperated in projects with the following industrial partners:

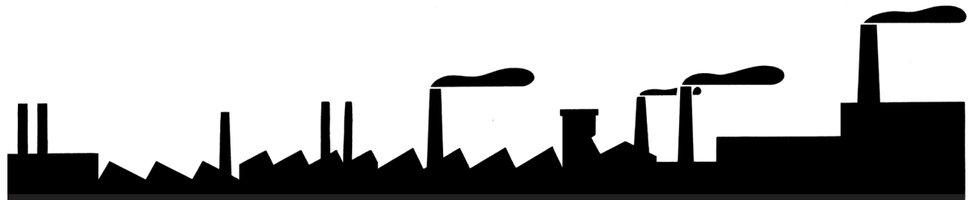


ABB • Actian • ADT Fire and Security • Advanced Computer Systems • Alcatel-Lucent • Alfen • Almende • APG • APM Terminals • Arcadis • ASIT • Auxillium • Blitz Games Studios • Bradford Engineering • British Telecom • Circlair • CityGIS • Computational Auditing.com • Condat • Connexxion • Continuon • Cosmo Company • Crystalloids • CTVC • Cybio • De Rijke Trucking • Deal Services • Deutsche Forschungsgemeinschaft • Disney Research • Early Minute • ECN • Eneco • Ericsson • ESA • EuroCottage • Exalead • Favela Fabric • Fredhopper • GreenA • Hebra Containervervoer • Hesse Noord Natie • Hyves • IBM • Ilse Media • INFO Support • ING • Insilico Biotechnology • KEMA • KNMI • Liandon • Limbic Entertainment • Marac Electronics • Mobile Service Factory • MonetDB • Motivication • MuniSense • Nederlands Kanker Instituut • NLR • Noterik • Océ • OceanScan • Open Knowledge Foundation • Oranjewoud • PCM • Peeman Transport • Phase to Phase • Philips • ProRail • PT Comunicacoes • PwC • Rabobank • Rundfunk Berlin-Brandenburg • Semantic Web Company • Siemens • Skytech • Software Improvement Group • Sogeti • STIO • Stoneroos • Talking Trends • Tastelink • Teezir • Tenforce • Textkernel • Thales • TimeRime • TNO • TomTom • TrendLight • Trinité Automatisering • Van der Heidegroep • Video Dock • WCC • Wolters Kluwer • Xenics • Xerox

Research theme

Earth sciences & energy

Efficiency in wind farms

To exploit the high wind speeds and available space at sea, large scale wind farms are being constructed offshore. In such wind farms, the turbulent wakes created by upstream turbines affect the efficiency of those placed downstream. Consequently, the power output of a turbine in the wake of another turbine can decrease with more than 40%. Researchers at CWI investigate the aerodynamics in wind farms and how to position the turbines to obtain maximum efficiency.

Investing in dikes

More than half the area of the Netherlands needs protection from sea and rivers by dikes. These dikes are a costly investment that requires careful analysis of costs and benefits. For instance, dikes protecting urban areas justify higher expenses than those in rural areas because of the higher potential damage of a flood. We provide advice on the models that the Netherlands Bureau for Economic Policy Analysis (Centraal Planbureau) uses to determine the costs and benefits of long-time investments in dikes.

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Towards nuclear fusion

Nuclear fusion could well be the solution to our energy problem: it is clean, emits no greenhouse gases and the fuel is abundant. There are still a large number of difficult technical problems to address before nuclear fusion becomes feasible. One of the problems is that the hot plasma rotating inside the nuclear reactor tends to become unstable. Researchers at CWI contribute to a solution of this problem by developing models of the behavior of plasmas trapped in a strong electromagnetic field.

Sprites on Venus, Jupiter and Saturn

Lightning does not only occur below, between and inside thunderclouds but also above them. The largest giant electrical discharges above clouds are called sprites. Only in 1990, these reddish-orange flashes were first reported in scientific literature. We wondered whether they could also exist on other planets. By modeling and simulating electrical discharges in the atmospheric conditions of other planets, CWI researchers predicted that sprites could also occur on Venus, Jupiter and Saturn.

Smart energy systems

Future energy networks are expected to fluctuate strongly in both supply and demand. Supply from renewable energy sources such as wind and sun is highly variable, demand is unevenly distributed over the day. Together with energy partners such as KEMA, Enexis (Essent), Stedin (Eneco) and TU Eindhoven, CWI works on models for smart energy systems that use fluctuating energy prices as a counterbalance. Smart software systems negotiate for energy and prices, so that for instance electric cars will be automatically charged at times when sufficient supply and network capacity is available.

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Highlight

Cracking databases for science

Gathering data has never been easier. Automated systems gather data just about anything: Internet surfing patterns, climate, stock exchanges, seismological activity, DNA or faraway galaxies. In 2007, database software pioneer and Microsoft researcher Jim Gray identified data-intensive research as the fourth paradigm of scientific discovery. Besides empirical, analytical and computational research, analysis of big data is more and more used as a separate method.

The indexing problem

Scientists often find themselves with much more data than they can possibly organize and analyze. Installations such as the LOFAR radio telescope or the ORFEUS earthquake observatory easily generate multiple terabytes of data per day. This data is not ready to use: before a request for information (query) can be made, some sort of data structure is needed to organize the data. This process of building a data structure is known as indexing. Indexing takes time and needs to be done by an expert who knows the meaning of the data. For very large databases, indexing is a major bottleneck in the database management process. It takes time before collected data can be used and can even cause a deadlock if data is more quickly added to the database than it can be indexed.

Database cracking

To resolve this problem, CWI researcher Stratos Idreos proposes a radical new approach to database management with a method called *database cracking*. 'In database cracking, there is no indexing at all beforehand,' says Idreos. 'The data can be immediately queried. The index is automatically built on the fly. Every time a query is made to the database, the system builds the part of the index that is needed to answer that specific query.' Idreos illustrates the database cracking principle with searching a disorded stack of playing cards: 'If someone asks for a two of hearts, the system selects all hearts along the way and

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Very large databases

Developing new database management systems for data-intensive science is a major research topic at CWI. World-leading experts on database architecture work on new methods for managing big data. The results of this research are accumulated in the open source database management software MonetDB. Since 2011, column store technology as pioneered in MonetDB has found its way into the product offerings of all major commercial database vendors. At the same time, the landscape for major innovations remains wide open. In an award-winning paper at the 2011 International Conference on Very Large Databases, CWI researchers Martin Kersten, Stratos Idreos, Stefan Manegold and Erietta Liarou presented their visionary research agenda for very large databases.They propose a radical rethinking of the strict requirements for database systems to allow for quick exploratory queries.

Research theme

The data explosion

Database machine SciLens

The databases that are nowadays used in data-intensive scientific research can grow over 1 petabyte in size. Existing supercomputers are not optimized for managing very large databases: they perform a huge number of computations on a single data item, instead of simple computations on a huge number of data items. CWI is building the SciLens machine, which is optimized for database management. SciLens currently has 3 terabyte of RAM and 1,5 petabyte of storage space in a cluster-like architecture.

Mapping the stars

The LOFAR radio telescope is a unique telescope with a diameter of more than 1000 km. It consists of thousands of small antennas placed throughout Western Europe. Together they monitor the sky for low-frequency radiation that indicates events millions of light years away, such as cosmic rays and the formation of galaxies. The telescope can produce over 25 terabytes of data per hour. With database management software MonetDB and database machine SciLens, CWI provides data management for LOFAR.

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Future television

There is a large potential for integrating TV and the Web, but current attempts often just enable traditional web browsing on the TV screen. CWI is working on true integration of TV and Web by linking broadcast material automatically with Web content. While users watch broadcasted media content, they will be offered extra snippets of information, for instance about people or objects in the broadcast

Tomography with video cards

Electron tomography is used to create 3D-images of biological samples such as micro-organisms, cells and tissues. However, the algorithms to create sharp images impose major computational demands. CWI researchers developed algorithms that use the capability of video cards to perform massively parallel calculations. The commercially available video cards form a very cheap supercomputer for creating 3D-images from tomography data. Further research at CWI is aimed at optimizing these techniques to gain further speed-ups.

Looking at atoms

CWI pushed the limits of perception event further this year. In a paper published in Nature, we reconstructed the position of individual atoms in a small crystal of 784 atoms from electron microscopy data. Further development should make the algorithms suitable to process large datasets from measurements on larger materials. Being able to map the atomic structure of materials greatly contributes to the development of nanomaterials with revolutionary properties, for instance catalysts, solar cells and computer chips.

more on p.12

builds a stack with hearts and a stack with non-hearts. Now if the next query asks for all clubs, the system only needs to look in the non-hearts stack.' The first few queries take some time, but response times quickly decrease to values comparable with those of a manually indexed system.

Major speed-up

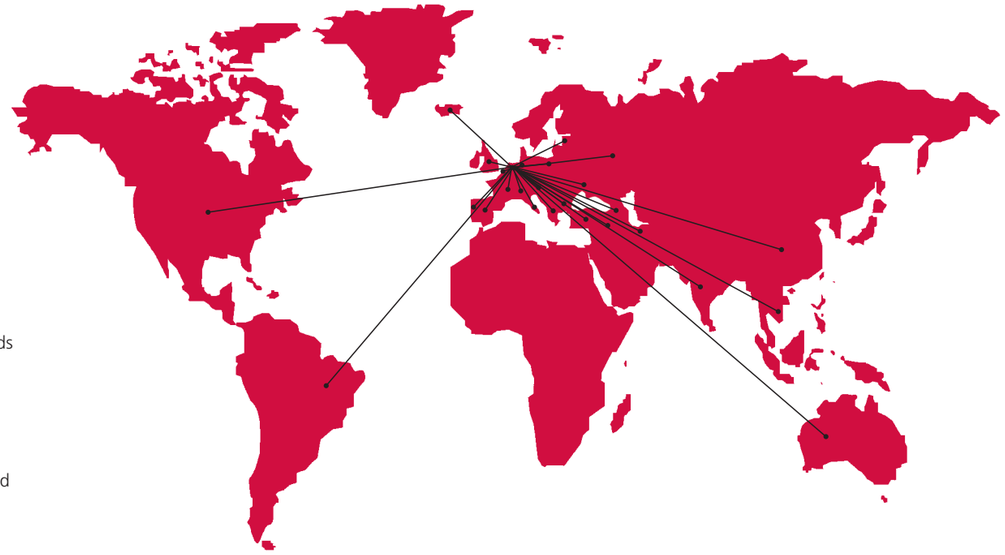
Database cracking is a huge improvement over conventional database management methods for big data. Idreos: 'The system starts with no initialization time and zero knowledge about the content of the data, but manages to build an index comparable to or even better than one built offline by an expert. By removing the initial indexing time, the bottleneck in the process is removed, enabling the handling of much larger data sets.' Tests on the Sloan Digital Sky Survey, the world's largest scientific database which contains several petabytes of astronomical data, showed that database cracking could speed up the search process with a factor ten to twenty.
After finishing his doctoral thesis on database cracking, Idreos is now a tenure track researcher in the Database Architectures group at CWI, where he continues his research on database management. The database cracking technology has been implemented in the database management software MonetDB and has already attracted considerable attention.

Cor Baayen Award 2011

Stratos Idreos's thesis on database cracking did not go unnoticed in the field of computer science. His PhD thesis earned him the prestigeous Cor Baayen Award 2011. This prize is awarded each year by the European Consortium for Informatics and Mathematics (ERCIM) to the most promising young researcher in computer science and applied mathematics. The jury called database cracking 'a remarkable result in an area that is fundamental for database systems and has been studied for decades' and named 'the potential impact very promising'. Earlier in 2011, Idreos's thesis was already awarded with the SIGMOD Jim Gray Award 2011 for best doctoral dissertation in database research.

Facts & figures
Nationalities

1	Armenia
1	Austria
2	Belgium
1	Brazil
2	Bulgaria
6	China
5	France
14	Germany
5	Greece
3	Hungary
1	Iceland
2	India
2	Iran
2	Italy
1	Latvia
139	Netherlands
2	Poland
2	Portugal
3	Russia
4	Spain
1	Switzerland
1	Turkey
3	UK
1	Ukraine
4	USA
2	Vietnam



cwi in 2011

CWI in the media

Many of CWI's research projects received media attention this year. For example, the announcement that CWI started a project on improvement of the quality and effectiveness of ambulance services was covered by most national daily newspapers, news website *nu.nl*, *Radio 1*, regional newspapers and vertical journals. Research concerncing sprites (large electrical discharges above thunderclouds) on Venus, Saturn and Jupiter made it to several (inter)national newspapers, including a large article in daily newspaper *de Volkskrant*.

cwi in 2011

Cum laude for thesis on decision making

Of the eleven dissertations submitted this year at CWI, one in particular catches the eye. On 27 January 2011, Wouter Koolen defended his PhD thesis 'Combining Strategies Efficiently: High-quality Decisions from Conflicting Advice' at the University of Amsterdam and graduated with honours ('cum laude'). In his research on machine learning, Koolen developed computer programs that automatically learn to make the best decisions by combining the (sometimes conflicting) opinions of all available experts. The media also expressed interest in the topic: Koolen was, amongst others, interviewed by *Intermediair*, *Automatisering Gids* and *BNR Radio*.

cwi in 2011

CWI core partner EIT ICT Labs

In 2011, CWI was granted the status of core partner in EIT ICT Labs, the European consortium that aims at accelerating ICT innovation in Europe. To reach their goal, EIT ICT Labs connects European organizations in education, research and industry. The Eindhoven Node of EIT ICT Labs currently consists of core partners Philips, 3TU.NIRICT, Novay, CWI and TNO. Apart from Eindhoven, EIT ICT Labs operates from Nodes in Berlin, Helsinki, Stockholm and Paris, with associated Nodes in London, Budapest and Trento.

cwi in 2011

IMO in Amsterdam

The Netherlands took pride in hosting the 52nd International Mathematical Olympiad (IMO) from 17 to 23 July. Over 560 very talented young mathematicians from 101 nations visited Amsterdam to solve the hardest mathematical problems. Multiple staff members of CWI participated in the organization of the event. Eighteen-year-old German contestant Lisa Sauermann won IMO 2011 with a perfect score of 42 points, making her the best participant in the history of IMO. Since July, the IMO Foundation, which supports the organization of the annual event, is located at CWI.

cwi in 2011

Discussion on women in science in NEMO

Lynda Hardman took part in an expert panel at a high school discussion on 8 March in Science Center NEMO in Amsterdam. Inspired by Gender Day, the theme of the event was women in top positions. About 120 high school students spent the afternoon preparing posters with their suggestions for increasing the number of women in top positions. The posters were evaluated by an expert panel consisting of several high-ranking female scientists. The event was organized as part of the European project TWIST (Towards Women In Science & Technology).

cwi in 2011

COMMIT housed at CWI

As of 1 September 2011, CWI houses the staff of public-private research community COMMIT. With a total size of 110 M□, the COMMIT programme brings together both public and private ICT researchers from universities, institutes and companies in various projects on topics such as search engines, parallel computing, databases and knowledge technology. COMMIT is a FES-program, partly funded by Dutch natural gas revenues, and will run for four to five years. Arnold Smeulders, director of COMMIT, also joined CWI as researcher in the Interactive Information Access group.

Highlight

Traffic prediction changes the future

A new prediction method for traffic flow uses inflow on highways to predict traffic congestion up to half an hour in advance. This information can be used to prevent future traffic jams. The system was designed in the Control for Coordination (C4C) project, which CWI directed.

The ring road around Amsterdam is infamous for its traffic jams during rush-hours. Badhoevedorp, De Nieuwe Meer and Coenplein should be familiar names to frequent listeners of Dutch traffic news. Much is said and done about traffic congestion, and a wide range of tools is available to regulation centers to influence traffic flows, including metered ramps, dynamic speed recommendations and electronic boards displaying traffic information for alternative routes. Traffic regulation centers get their data from detection loops that are placed at every 500 meter in road and ramps. These loops detect every car and its speed. The resulting data about car density and congestions is used for control measures. To inform road users, the location of congestions is also shown on digital displays above the road.
Control measures could improve traffic flow substantially if it was known in advance how the flow would develop in the near future. Traffic could already be directed away from a certain part of the road if predictions show that congestion will develop there. The algorithm to make predictions from traffic data is already available. It is derived from a program that energy suppliers use to predict short-time energy demand in their networks. The problem is that it takes the current system too long to collect all data and perform the calculations for a successful implementation. Researcher Jan van Schuppen worked in the C4C-project on a more efficient system to make these traffic predictions possible.

Distributed systems
The loops in the road that detect the cars and their speed, and the units that perform the calculations on this data together form a distributed system. Here, different parts of the system perform operations and communicate with each other through a network. The performance of distributed systems is very much dependent on the method of control that is used. 'A simple form of control is central coordination', says Jan van Schuppen. 'The parts of the system send their data to a central coordinator, who collects the information and sends it back to all separate parts.' Central coordination for the traffic control system would mean that every detection loop communicates directly with a central computer at the regulation center. While this works fine for small systems, for larger systems the system easily gets clogged, causing long waiting and processing times. 'There are more advanced control systems,' Jan van Schuppen explains, 'where the parts of the system communicate with each other without central

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Control for Coordination of Distributed Systems

The Control for Coordination of Distributed Systems (C4C) project, which CWI directed, is a European project aimed at developing new ways of coordinating distributed systems. Six European universities, two research institutes and four companies carried out research on five case studies involving coordination. Besides the traffic regulation system, on which CWI worked with TU Delft and IT company Trinité Automation, teams also worked on the coordination of underwater vehicles, aerial vehicles, automated guided vehicles on a container terminal in the harbour of Antwerp and coordinating the parts of a complex Océ printing machine. The C4C project started in May 2008 and continued until August 2011.

Research theme

Societal logistics

Dynamic pricing

Digital prices are easily adjusted. Therefore, following airlines and hotels that change their rates according to immediate supply and demand, more and more sellers are interested in dynamic pricing. We develop algorithms that decide on the right price at the right moment. The algorithms keep improving their decisions based on price experimentation and accompanying sales figures. Various parties, such as congress center RAI and the Netherlands Philharmonic Orchestra, cooperate in the dynamic pricing research.

Ambulance efficiency

The timely arrival of an ambulance can be a matter of life and death. Uncertain factors such as traffic and location of the accident are essential, but hardly taken into account in existing planning methods. Together with a number of ambulance service providers, we are working on new planning methods that include uncertainty and anticipate where ambulances will be needed. By dynamic relocation of the available ambulances, the system will provide optimal coverage of the region at any time.

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Fast mobile networks

Smartphones and tablets significantly increased the demand for fast mobile communication networks. To meet this demand, innovative solutions are needed to improve the capacity and performance of mobile networks.
In cooperation with Thales Netherlands BV, CWI devised methods for making mobile communication up to ten times faster by using multiple mobile networks at once. Dividing data streams over multiple networks increases efficient use of the available bandwidth.

Toll optimization

To reduce traffic congestion and its corresponding negative economic and environmental impact, it has been suggested to impose tolls on certain roads in the network. We investigated whether it is possible to find optimal tolls that guarantee that selfish choices by road users will serve the desired common interest. To be applicable in practice, these tolls shouldn't be too high. Our results show that for certain types of networks, such optimal tolls can be determined.

Stacking containers in Rotterdam

When the containers in the port of Rotterdam are loaded off ships, they wait in stacks for further transport by trucks. Due to delays, the order in which the trucks arrive is uncertain. To minimize restacking of containers, we are working with research company Almende, APM Terminals Rotterdam, three trucking companies and TU Delft on an adaptable planning algorithm for stacking containers such that the required container is most likely to be on top.

more on p.16

coordination. If correctly designed, various subparts perform operations simultaneously and decentralized, decreasing the operation time.'
However, a purely decentralized system is also not practical for a traffic control system. When a system consists of a large number of parts, the network gets too complex if all parts communicate with all other parts. The new traffic control system is therefore designed as a hierarchical coordinated system.
'A hierarchical system consists of several layers interacting with each other,' Jan van Schuppen says. 'The detection loops on a certain part of the road interact with the local coordinator for that particular ramp or part of the road. The local coordinators communicate with a coordinator for the entire road, who communicates with a coordinator for the ring road as a whole, and in theory this can go on to the road network of the Netherlands or even Europe.'

Traffic regulation

Because operations are performed in different parts in the system, calculations for predicting traffic flows are much quicker. In tests on the Amsterdam ring road, Van Schuppen's system succeeded in predicting traffic flows up to half an hour in advance: the actual traffic flow closely followed the predictions. In the future system, the predictions will be integrated with the existing control measures. The regulators then can also implement (combined) measures such as offering alternative routes or changing car admission on the metered ramps into the predictions. This allows for more efficient implementation of traffic regulation measurements.
The system will be further developed by Trinité Automation, the IT company providing the digital information systems for the Dutch motorways, and also partner in the Control for Coordination project.

cwi in 2011

CWI: 1946 - 2011

In 2011 we celebrated our 65th anniversary. In 1946 CWI, at that time called Mathematisch Centrum, was founded. On the official celebration on 10 February in the Oude Lutherse Kerk in Amsterdam, the five-yearly Van Wijngaarden Awards were awarded to the New Zealander mathematician John Butcher and the Hungarian computer scientist Éva Tardos. For all current and former CWI employees, a special Christmas reunion was organized on 16 December.

cwi in 2011

25 year .nl

On 25 April 1986, CWI's system administrator Piet Beertema was given authority over the .nl internet domain. This made the Netherlands one of the first country in the world with an active country code, and cwi.nl the first .nl domain name. In 2011 a number of festivities to celebrate 25 years was initiated by SIDN, the spin-off that CWI co-founded in 1996 to take over the authority of .nl-domains. Piet Beertema was interviewed by several media, including *RTL News*, *3FM Radio* and daily newspapers *Trouw* and *Algemeen Dagblad*. The first copy of the special magazine '25 jaar .nl' was presented by SIDN to CWI director Jan Karel Lenstra.

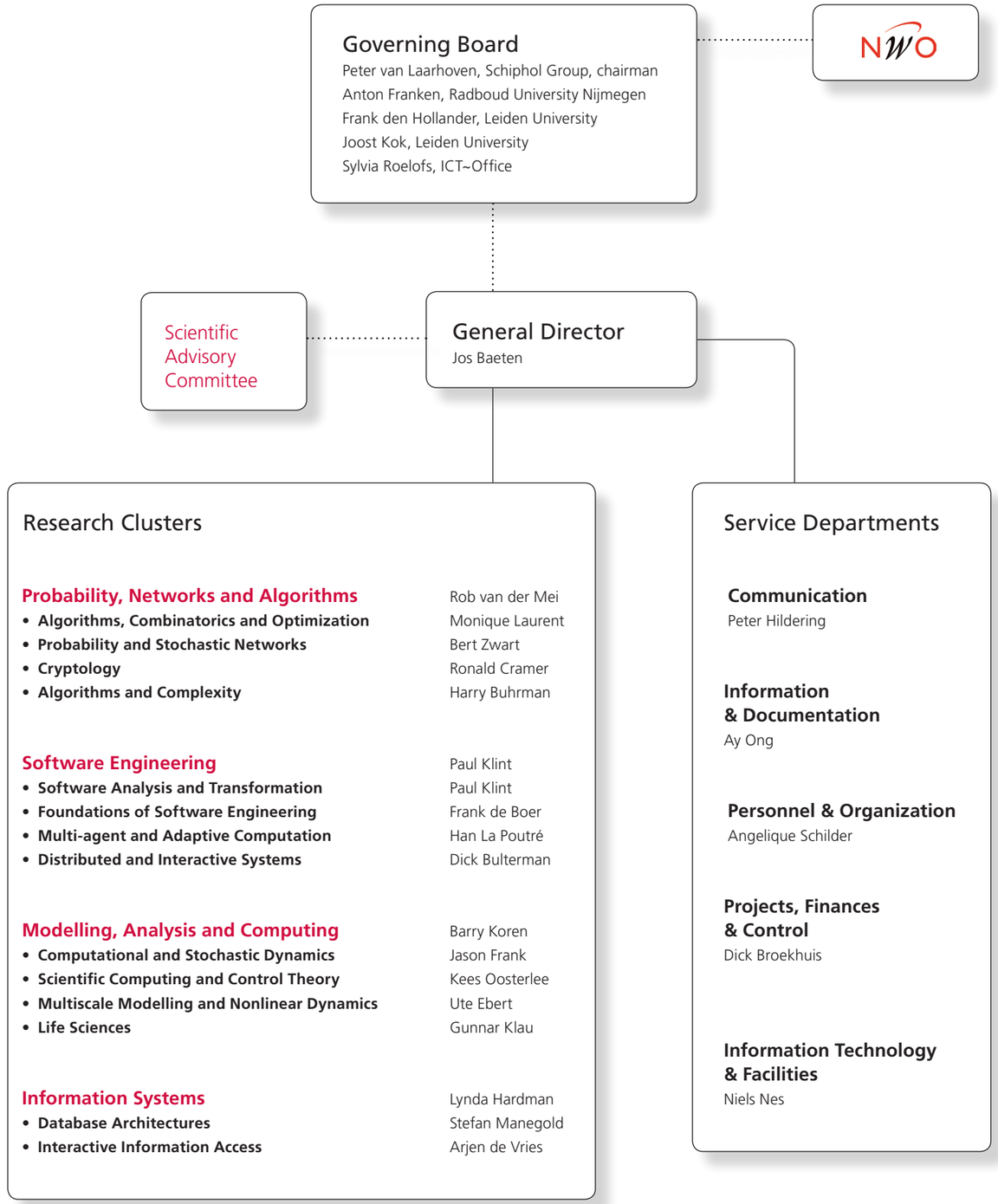
cwi in 2011

Summer course for math teachers

CWI organized the 65th annual summer course for mathematics teachers. On 26 and 27 August, 130 math teachers from the Netherlands and Belgium participated in the program Symmetry, the theme of this year's course. CWI organized the event for the last time. After 65 years, the summer course will be passed on to Platform Wiskunde Nederland (PWN), the recently founded Dutch organization for mathematics that CWI has been housing since 2010. CWI will still provide hosting for part of the course.

Facts & figures
Organogram

per 31 December 2011



Centrum Wiskunde & Informatica (CWI) is the national research institute for mathematics and computer science in the Netherlands. The institute's strategy is to concentrate research on five broad, societally relevant themes: earth sciences & energy, life sciences, the data explosion, societal logistics and software as service.

Visitors address
Science Park 123
1098 XG Amsterdam

Postal address
P.O. Box 94079
NL-1090 GB Amsterdam

Phone +31 (0)20 592 93 33
info@cwi.nl

www.cwi.nl

Editors
Peter Hildering
Coby van Vonderen
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