CWI

Centrum Wiskunde & Informatica

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Boosting revenues with maths and statistics

Leader of research cluster Probability, Networks and Algorithms, Rob van der Mei, is researching revenue management, a relatively young branch of mathematical and economical science. Businesses can boost their revenues by devising clever, dynamic pricing strategies. Various mathematical and statistical models and theories are the essential means to this end.

About two years ago, CWI defined four research themes. One of these themes is societal logistics. Van der Mei explains: "This theme is about systems in which resources are scarce. Traffic jams and logistics are two obvious examples, but it also applies to call centres, for instance. How many operators does a call centre need to make average waiting times acceptable? Every company with a help desk wants to know the answer to that question." The concept of revenue management also falls within the scope of this theme. Van der Mei: "It is about using clever pricing strategies for limited resources to optimize revenues. Airline companies were among the first to apply dynamic pricing. Of course they prefer their airplanes to be fully booked on every flight, without having to say no to potential passengers. So they started asking themselves how much a business class seat should cost, and whether late bookers should be charged more for their seat. Nowadays, the cost of a seat depends on the booking date and the flight date."

Scientific fundaments

"Airline pricing is a textbook example of revenue management", Van der Mei says. "There are others: In the United States, airports have parkings next to the terminal. But there are also parking lots further away. The operators of these parkings attract customers by charging less money, and for instance by offering shuttle service to and from the airport and washing parked cars at no extra costs. Some years ago, one parking operator contacted CWI with the question if it could help him determine an optimal price. That is how we got involved in revenue management." At the moment, Van der Mei is working with conference centre RAI in Amsterdam on a similar problem: "What is an acceptable price for parking at RAI? And what if the lot is full? Should RAI make a deal with Amsterdam Arena, so that its visitors can park there at a reduced cost? If so, should there be a shuttle service to and from RAI? We are investigating these questions."

"Revenue management combines fundamental research with real-world applications", says Van der Mei: "It may sound like this is all economy, but the basics are pure maths. Choosing an optimal strategy is a dynamic process: what works best, partly depends on what others are doing."

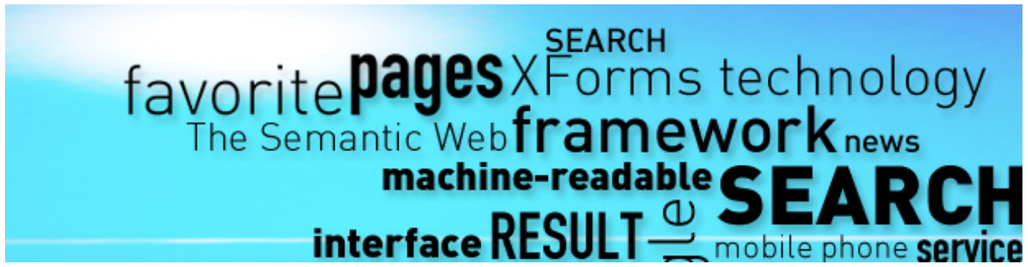
The field of operational research investigates complex decision-making processes and ways to find optimal or near-optimal solutions. It combines mathematical modelling and statistical analysis. Van der Mei: "Good revenue management also requires reliable models to predict consumer behaviour. Also, game theory plays an important role in creating the tools for revenue management. So we apply fundamental research to find answers for real-world dilemmas. It also works the other way: by looking for answers to these dilemmas,

we expand the scientific fundaments of revenue management. It really is an exciting new area of research."

"We apply fundamental research to find answers for real-world dilemmas."

Bridging the gap

At the moment, a lot of the science on revenue management still has to be worked out. Van der Mei: "If you search for literature, you do find that there has been research on the topic. But it is still a young field of research that is just gaining momentum in the business world. In recent years, other markets than aviation and parking have been investigating dynamic pricing strategies. For instance, recently I heard a speech on dynamic pricing in restaurants; guests at a table next to a window with a nice view could be charged more for their meals than guests at a regular table. This is just one example of new ideas on revenue management in markets where it is not in use at the moment." Together with VU University Amsterdam and specialist in planning software Ortec, CWI initiated the Pricing and Revenue Management (PreMa) platform. Van der Mei: "In most companies, only a few employees are working on pricing strategy. They have no one to talk to on that subject and to exchange experience, although they would very much like to. PreMa organizes two or three meetings every year, where these professionals as well as scientists come together to discuss topics related to revenue management. This way, we want to bridge the gap between science and the business world. So far, we have had three meetings. Already, people that did not even attend are asking us if they can join the next meeting. In the end, we hope that PreMa will become a national network that will help us create more knowledge in the field of revenue management."



Designing the web technology of tomorrow

CWI-researcher Steven Pemberton's work focuses on Computer-Human Interaction. The interface is vital for the success of web technology. How can system architecture contribute to usability? In 2009 he received the international ACM CHI Lifetime Service Award for his contribution to the growth of SIGCHI, the ACM Special Interest Group on Computer-Human Interaction. The technology developed by Pemberton and fellow researchers is now being used by Google, Yahoo and Facebook.

The Semantic Web is a recent revolution in web technology. Up to now the web mainly consisted of information for human readers. The Semantic Web adds machine-readable information as an extra dimension, so that the computer 'understands' the content of a website. Together with Mark Birbeck, a colleague from the UK, Pemberton originated the Resource Description Framework in Attributes (RDFa), an important component of the Semantic Web. They proposed it in 2004 to the World Wide Web Consortium. It was ratified in 2008.
The RDFa-technology allows you to mark up a – human-readable – web page so that a computer program can derive useful information from it. The research contributes to the data explosion which is a strategic theme at CWI and the emphasis on the user role in web technology.

Rich Snippets

Pemberton explains what this means: "Assume you are looking at a web page about Amsterdam.
A human being instantly understands that it is about a city. Browsers and search engines don't. Adding a layer of machine-readable information enables software to recognize that it is about a city. Moreover, a search engine can distinguish pages about the city of Amsterdam from, for instance say a book on Amsterdam. A browser could offer to show the location on the map or look for flights or hotels."

Google – under the name of 'Rich Snippets' – and Yahoo are now implementing RDFa in their systems. Facebook has also recently announced that it will be using RDFa. A lot of interest in developing the Semantic Web comes from government initiatives; RDFa is already being applied to government websites in the UK and the USA. As application of RDFa based on version one goes on, Pemberton and his colleagues are now busy developing the next version.

XForms

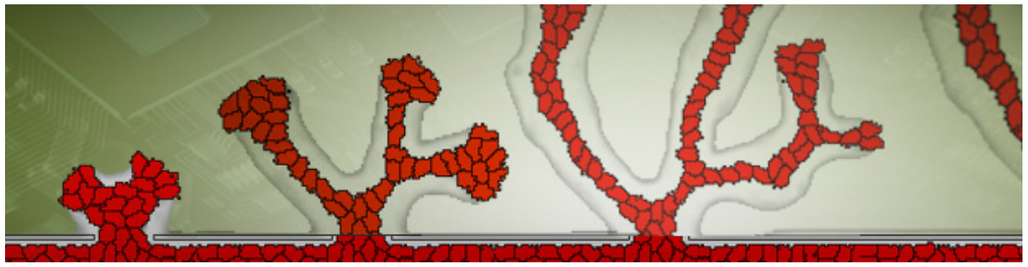
Another technology currently developed at CWI is XForms. Pemberton is chairman of the World Wide Web Consortium working group developing this technology. He oversaw recommendations for these standards in 2003 and of a later version in 2008. Originally XForms was a format for the creation of forms in Extensible Markup Language (XML) and for their user interfaces.

It now proves the technology is much more versatile. "Because we defined it in a very general way, we could do much more with it than just define forms. Since it has input, output and a processing engine, you can use XForms to define applications

in a very concise and abstract manner." Pemberton cites a test implementation of Google Maps using XForms where this technology was used. "The input is the location and the output is the map of that area, so you don't see it as a form", says Pemberton. "For programmers the XForms technology saves a lot of coding work thanks to the way XForms is defined. It makes it much easier to define your application. We have seen several examples where the production costs have been reduced by an order of magnitude", says Pemberton. Pemberton is now collaborating with the Open Document Format Alliance to integrate both XForms and RDFa into the Open Office format.

Device independence

The interface is vital for the success of web technology. "The web is so successful because of its human orientation", says Pemberton. "Therefore we should be planning for the long term to ensure developments go the right way." User friendliness still is not what it should be. One of the current problems is device-independence. A website must be developed for a PC. For mobile use, a new dedicated website has to be written in order to make the same information accessible on a cell phone. "One of my interests is how to represent information on a server so that it does not matter on what device the information is accessed. I think device-independence is essential for the future", says Pemberton.



The computer is the new microscope

"To better understand diseases like cancer you need mathematical and computational methods. In this way, the computer is the new microscope", Gunnar Klau, group leader Life Sciences at CWI says. "With our computational network models we can simulate biological pathways that in turn can be verified in experiments. This approach can lead to ideas for new drugs and contributes to prediction of developments in patients. In due time this will enable early diagnosis and treatment in a personalized medicine setting." The ultimate goal of this interdisciplinary approach: understanding the overwhelming complexity of living systems.

The cost of sequencing the genome of an organism has dropped dramatically. The yield consists of massive amounts of data. These data in itself are rather meaningless; the meaning is hidden within them. A key question is how to extract the meaning from the data. By now it has become clear that genes do not work in isolation but by several complex and interacting networks. The key to understanding diseases like cancer lies in understanding these networks. Klau: "Without the application of novel mathematical, statistical and computational methods, this cannot be done. Computational methods make sense of the enormous amounts of noisy experimental data and provide insight in the meaningful mechanisms at work in the cells."

Blurry picture

This is for instance done with micro array screening data of gene expression with breast cancer patients. "These micro arrays establish which genes generate RNA and which proteins are being built. This data on 20.000 to 30.000 genes provides an extremely blurry picture of what goes on in the cells of hundreds of patients", Klau explains. The patients can be divided into those with metastasis within five years after the occurrence of breast cancer and those without metastasis. Advanced algorithmic and statistical methods contribute to a much sharper picture and reveal characteristic gene expression patterns in these two groups.
The differences between the two groups of existing patients offer potential explanations for the occurrence of metastasis. "Once you have found meaningful differences between the two groups, you can start looking for mechanisms that explain why patients in the one group got metastasis and patients in the other group did not", Klau explains. In this way, the computations, simulations and predictions of the CWI Life Sciences group suggest new wet lab experiments. "The networks are very difficult to understand indeed, but we know the key lies in intelligent data analysis and computational models of biological processes. Biologists realize this more and more and understand the perspective. The more we all see the complexity of biological networks, the more everybody realizes that an iterative cycle of 'wet' and 'dry' research is the best way to study living systems. Suggestions for experiments on the basis of math-based simulations enable biologists to proceed much faster."

New drugs

For example, these experiments can verify suggestions about signalling pathways in a research cycle

between computational suggestion and wet lab verification. “We only started in 2009”, says Klau, “and still have a long way to go along this research cycle. On the computational side this asks for a whole spectrum of mathematical methods, from discrete algorithms to partial differential equations. Typically, mathematicians work in one specific field. New in our approach at CWI is that we need to combine mathematical methods to get useful results.”
The simulations might point out differences between the two patient groups, revealing that in one group a certain genetic pathway is blocked. Then the biomedical experts can start thinking of ways to influence this pathway with new drugs. Klau: “Furthermore, the research leads to certain profiles for patients. This contributes to better classification, prognosis and treatment for new patients. In this way you can get a step ahead of the disease.”

“Operations research from telecom and logistics is helpful to understand biology”

The research will not stop at distinguishing between two patient groups, but work out ever more refined profiles. “Eventually, this will lead to tailor-made drugs for every individual patient: personalized medicine. But this will take at least ten years before we get there in a lab setting and another ten years before we get it into the clinic”, Klau says.

The Life Sciences group at CWI

Earth and life sciences is an important theme at CWI. The Life Sciences group stands out for its multidisciplinary composition and wide range of work, in close co-operation with biologists and medical researchers. Besides cancer research, current research topics include phylogeny/evolution, computational neuroscience, metabolic networks, models of angiogenesis, tumor growth and microbial communities, optimization of the genetic code, structures of protein and RNA molecules, proteomics, developmental biology, bio-fuel engineering and detecting pathogenic microbes. Klau: “We not only have mathematicians, computational scientists and bio-informaticians, but also theoretical biologists as bridge-builders towards the biology world. This is rare at a mathematics institute.” And as part of a mathematics institute, the group is able to develop novel fundamental mathematical approaches, for instance, to reveal complex dynamic network patterns at work. “Strangely enough, other well-established fields at CWI like business process management research on telecommunications and logistics prove helpful to understand biology, as similar kinds of mathematics are involved”, Klau says.

Metaprogramming made easy

Metaprogramming, the creation of programmes that use other programmes as input or output, has been a research subject at CWI for many years. In order to deal with a wider variety of software, including different programming languages and formats, Paul Klint, who coordinates the Interactive Software Development and Renovation Research group at CWI, introduced the concept of ‘grammarware engineering’ in 2005. Application areas include computer maintenance, forensic science and computational auditing.

Rascal

In June 2009 the group introduced the domain-specific language Rascal, a metaprogramming language for the automation of software analysis and transformation. “The resemblance to Java makes the software easily accessible to programmers”, says Klint. One of the ways Rascal can be used is to extract facts from source code. The language can also be used to extract information about the structure of software by using execution traces, that is, by taking it through all the possible paces and seeing what happens. Other applications include code generation and the creation of new domain-specific languages.

“The strong point of Rascal, however, is that it is a much higher-level language than many of the existing languages. You can take an algorithm from a text book and you can almost literally translate this into Rascal and execute it”, says Klint. This comes at a price though: slow execution speed. The team is now looking for a new optimization technique that will allow the programme to execute much faster. They hope to achieve this by a deeper analysis of the Rascal code and by finding ways of increasing the speed of execution. They are also looking for ways to make the software suitable to run on multicore computers.

Forensic science

An illustration of Rascal’s ability to extract information from many types of software and different platforms is that it can be used as a forensic tool. The team is now working with the Netherlands Forensic Institute in the area of data carving, that is, the reconstruction of incomplete and partially erased data. Instead of writing code for the programmes that would be required to analyse these formats, Rascal generates Java code that does the analysis. “An interesting point is that the description of the data format is an order of magnitude smaller than the Java code it generates, resulting in a tremendous speed-up in the software creation process,” explains Klint.
Computational auditing

Another application now investigated by the team is an accounting and auditing technique called computational auditing for which recent events in the economy have shown an increasing need. “We have seen from the ENRON scandal and the current turmoil regarding mortgages, that these financial systems are very opaque and that there is a very strong need for transparency”, says Klint. The software will be used to extract data from a company by scanning its business processes and from the authorisation rules, thus generating a high-level model for the operation of the company. When the company submits its financial data,

they can be checked against this model, and any flow of money that deviates from this model can immediately be flagged. “The interesting thing here is that by alternating accounting and auditing, real-time auditing reporting becomes feasible”, says Klint. “You could obtain a daily report proving that your business is doing real legal business.”

Klint reports that although the latest version of Rascal has been finalised only recently, companies are already experimenting with the software. For companies to collaborate with a research institute as CWI is particularly advantageous because much of the costly and time-consuming research is taken out of their hands. “We have a wide range of knowledge and technologies at our disposal to carry out such a project”, says Klint.

“There is a big future for small programmes.”

A long-term project on the table is the reduction of the size of software code — much software now in use has the potential to be significantly downsized. “If you look at the size of current software systems, you see that you are often dealing with tens to hundreds of millions of lines of code which nobody can understand”, says Klint. By searching this software for repeating patterns and structures, one can replace these structures by new, much smaller code that can be reused, thus downsizing the software. “My slogan is that there is a big future for small programmes”, says Klint. The research of Klint contributes to software as service and the data explosion, both important themes of CWI.

The real cost of dry feet

In a country half of which lies below sea level, sea dikes, river dikes and dunes are of predominant importance. For more than fifty years already, the Dutch government uses mathematical models to calculate the optimal height of its dikes. In 2009, CWI refined the model used, by enabling the incorporation of uncertainties in rising sea levels and economic fluctuations. Leader of research cluster Modelling, Analysis and Simulation Barry Koren: “The old model created an illusion of exactness.”

Large-scale floodings are a real and continuous threat to the Netherlands. In 1953, a storm caused dikes in the provinces of Zeeland and Brabant to break. The North Sea flooded 1,600 square kilometres of land. Koren: “This disaster made clear that the Netherlands needed a way to assess the risk of flooding and the economical consequences of a flood. The statistician David van Dantzig of the Mathematical Centre in Amsterdam – the current CWI – developed a method for that. He started out simple: there is a certain probability that water levels reach a certain height. This means the chance of flooding depends on the dike’s height. For simplicity’s sake, Van Dantzig assumed that a flood would always cause total destruction of the hinterland. Multiplying the economic value of the hinterland with the probability that it would flood resulted in what Van Dantzig called the ‘expected flooding cost’. He then defined the ‘total cost’ of a dike of a given height as the cost of building and maintaining it, ‘the investment cost’, plus the expected flooding cost. Minimizing the total cost resulted in an optimum dike height.”

Uncertainty

The Ministry of Transport, Public Water Works and Water Management has been using Van Dantzig’s model for years on end to determine the desired height of all major dikes in the sub-sea-level part of the Netherlands, about 3,600 kilometres length in total. Koren: “It calculated the economic value of the hinterland for every dike ring, and the desired dike height. The economic value is the sum of the monetary values of all goods, vegetation, animals and even human beings in that hinterland. Currently, the life of a single person is valued at 2.2 million. The Zuid-Holland dike ring, containing part of Amsterdam and the cities of Rotterdam, Den Haag, Delft and Leiden, is of great economic value. Here, the dike heights are such that, statistically, there will be one flooding per 10,000 years. For areas with less economic value, that period may differ.”
Over the years, Van Dantzig’s model was expanded and refined by Carel Eijgenraam of the Netherlands Bureau for Economic Policy Analysis (CPB). Koren: “The economy of the Netherlands was growing. Eijgenraam extended the model to take economic growth and shrinkage into account.” The Ministry used this new improved model to continuously assess if dikes were adequate. Koren: “This enabled it to determine whether they had to increase or maintain the dike heights. The CPB model decided for instance to stop maintaining the dikes of the island Tiengemeten (province Zuid-Holland), when its local economy was shrinking. Tiengemeten is a natural reserve now.”
However, the CPB model doesn’t live up to present demands either. “Rising sea levels and economic growth and shrinkage are not one hundred percent predictable. This uncertainty has to be incorporated in the model.” Koren says: “In 2008, CWI researcher

Jan van Schuppen proposed the use of optimal control theory, leading to a Hamilton-Jacobi-Bellman equation or variational inequality, to do this."

"Rising sea levels and economic growth and shrinkage are not one hundred percent predictable"

Put simply, varying water levels and economic growth and shrinkage are modelled as sets of probabilities. Koren: "The former model used exact values for these variables, but that merely created an illusion of exactness." The renewed model itself does not output one 'real cost' for a given dike. Instead, it gives a bandwidth of possible scenarios and corresponding costs. Koren: "Given that bandwidth, one can decide to remain on the safe side."

One billion

National water and dike research institute Deltares authorized the improvement of the model. It may incorporate the new version developed by CWI in their system to determine optimum dike heights. Koren: "Led by CWI researchers Kees Oosterlee and Jan van Schuppen, the model that accounts for uncertainties has been worked out in different, state-of-the-art computer programs, and validated on the dike ring of the island of Texel. The new software turned out to be very useful." Making a dike insufficiently high could of course cause economical damage and a lot of hardship. But making a dike higher than necessary can also be very costly, Koren explains: "In Amsterdam, for instance, hundreds of houses have been built on dikes. Consider the hypothetical scenario in which the Ministry decides to make these dikes higher. That would mean relocating all people living in these houses. You don't want to do that unless you are certain it is necessary." There is yet another economic incentive to make the model more accurate, Koren says: "The Netherlands spend one billion euro's per year on dike maintenance. A more accurate model saves a lot of money." The various dilemmas illustrate what Koren likes about this project: "We are working with tide models, climate change models and economic data. The project is widely varied, highly mathematical and at the same time very applicable to the real world." This research contributes to the CWI strategic theme earth and life sciences.

Societal and scientific relevance

CWI concentrates on fundamental questions that are inspired by practical problems. Very important is the transfer of knowledge to society. This knowledge is of very high quality as is shown in this section, by means of a number of major achievements of the institute and its researchers.

New mechanism for Internet security wins Best Paper Award

On 29 April in Cologne, Dennis Hofheinz (right) and Eike Kiltz (left) from the CWI in Amsterdam received the Best Paper Award at the IACR Eurocrypt 2009 conference. IACR Eurocrypt is a leading international cryptography conference.

The two mathematicians won the prize for their article on Practical Chosen Ciphertext Secure Encryption from Factoring, which discusses a new Internet security mechanism. Potential applications resulting from their research include improved security for web browsers, e-mail, online shopping and Internet banking.

Secure Internet connections (recognizable by the https in the Internet address) include electronic banking interfaces based on the RSA encoding system that was developed in the 1970s. Due to the fact that all web browsers use the RSA system, millions of copies of it are available. The security provided by the RSA rests on the fact that the mathematical problem of factorization – the dissolution of integers into prime numbers – is very difficult to solve in everyday practice. This is owing to the fact that computationally, the factorization of large numbers is exceptionally intensive.

Hofheinz and Kiltz have discovered a variation on RSA that is based on the factorization problem, which is almost as efficient as RSA. Using this, they can mathematically prove that the highest level of security – chosen ciphertext security – is achievable. They have thereby solved a major problem that had been occupying cryptographers since the 1980s.
The CWI researchers article was chosen from over 200 entries as the most interesting cryptographic research.
The research was partly funded by Dennis Hofheinz's NWO Veni subsidy and by the Sentinels PASC project, a research programme funded by the STW, the NWO and the Dutch Ministry of Finance.

More information
www.cwi.nl/crypto
Eurocrypt:
www.iacr.org/conferences/eurocrypt2009

Dominik Wojtczak receives Best Paper Award during ICALP 2009

Dominik Wojtczak (second from right), postdoctoral researcher at the CWI and former PhD student at the University of Edinburgh has won, together with Michael Ummels (RWTH Aachen), the ICALP Best Student Paper Award Track B for an article on The Complexity of Nash Equilibria in Simple Stochastic Multiplayer Games in July.

The award, in the form of a certificate, was presented by Giorgio Ausiello (chairman of EATCS) and Wolfgang Thomas (Programme Committee chairman of ICALP 2009 Track B) at the general meeting of the ICALP 2009 conference.

More information
http://www.eatcs.org/index.php/eatcs-awards

Lacramioara Astefanoaei wins Best Paper Award

PhD student Lacramioara Astefanoaei (CWI) won the Best Paper Award 2008 at the 11th Pacific Rim International Conference on Multi-Agents (PRIMA 2008) in February 2009. The winning article, entitled A Verification Framework for Normative Multi-Agent Systems, forms part of the NWO CoCoMas project. In this project, the researchers are investigating multi-aqent systems. Those systems consist of agents: software programs that autonomously can make decisions based on observations of a dynamic environment. This could include agents making offers at auctions, for example. The CoCoMas project has been developed to address the coordination and composition of multi-agent systems. The research is being carried out in cooperation with the Intelligent Systems Group in Utrecht.

More information
http://www.ai.soc.i.kyoto-u.ac.jp/prima/

AMC CHI Lifetime Service Award for Steven Pemberton

Steven Pemberton (CWI and W3C) has won the prestigious international ACM CHI Lifetime Service Award. He has received this prize for his major and long-standing contribution to the work of SIGCHI, the ACM Special Interest Group on Computer-Human Interaction. Pemberton was awarded the prize for his dedication to SIGCHI, his scientific activities and impact in the scientific community. Part of the prize includes a trip to Boston to attend the prize-giving ceremony in April.

Steven Pemberton is a researcher in the CWI research cluster on Information Systems.
In addition, he leads the HTML and FORMS activities for the World Wide Web Consortium (W3C). He has long been a significant contributor to SIGCHI's activities. Pemberton was editor of the SIGCHI bulletin between 1993 and 1999, and editor of ACM/Interactions between 1998 and 2004. He was actively involved in the organization of various SIGCHI conferences, which included chairing the CHI 97 conference. In addition, he sat on the SIGCHI Executive Committee for ten years.

About SIGCHI

SIGCHI is a special interest group at the ACM. It was founded in 1982 to establish the field of human-machine-interaction. SIGCHI is the most important organization in the world in its field. It organizes the annual CHI conference, which has around 2500 participants, and publishes several leading journals. It has about 50 regional groups across the world.

Trust4all receives Bronze Achievement Award

The Trust4all project, which includes CWI members Frank de Boer (photo) and Farhad Arbab, has won the 2008 Bronze Achievement Award from Information Technology for European Advancement 2 (ITEA 2). The Trust4All project has developed a model to determine the confidence level of embedded software. This validation of embedded systems can be used to determine whether machines are able to perform critical assignments. For example, the confidence level of embedded software is important in new medical equipment for home use, such as defibrillators. ITEA 2 praised the project's successful outcome: a solid, flexible and reliable architecture for embedded systems in various domains. ITEA 2 stimulates European projects that promote European excellence in Software-Intensive Systems and Services (SISS). Several companies and institutions from the Netherlands, Finland and Spain are participating in the Trust4all project, under the management of Philips.

VLDB Ten-Year Best Paper Award for hardware-aware database technology

On 27 August, CWI researchers Peter Boncz (second from right), Stefan Manegold (right) and Martin Kersten (left) won the prestigious VLDB Ten-Year Best Paper Award. They received the prize for their article on Database Architecture Optimized for the New Bottleneck: Memory Access. The prize was awarded during the 35th International Conference on Very Large Data Bases (VLDB) in Lyon, France.

The VLDB conference is one of the most important international events for database researchers, suppliers, application developers and users. The winning article discusses exploiting the possibilities presented by modern hardware, by means of new database technology. The award was also granted for the CWI researchers' pioneering research in the field of column-oriented database technology. Their MonetDB open-source database system forms part of modern column-oriented database technology available to researchers, users and database developers. The VLDB Ten-Year Best Paper Award is awarded annually for the best article that was presented ten years ago at the VLDB-conference, and which has had the most impact over the last ten years. The CWI group's paper was selected from 50 papers. Controlling the data explosion is one of the CWI's main areas of focus, of which this research is a prime example.

More information
http://monetdb.cwi.nl/

CWI database team wins Best Paper Runner-Up at SIGMOD 2009

On 1 July, the CWI database team (from left to right: Niels Nes, Martin Kersten, Milena Ivanova, Romulo Gonçalves) received the SIGMOD Best Paper Runner-Up Award during the international ACM SIGMOD 2009 conference in Providence, Rhode Island (USA).

The award was given for an article entitled An Architecture for Recycling Intermediates in a Column-Store, written by Milena Ivanova, Martin Kersten, Niels Nes and Romulo Gonçalves from the CWI. The annual ACM SIGMOD conference is a leading international forum for database researchers, developers and users, where state-of-the-art ideas, results and tools are shared. The level of competition was fierce, with more than 400 articles submitted. The CWI article was selected from 63 accepted papers.

The database team received the prize for innovative research for the realization of Sloan Digital SkyServer, an extensive database that contains information about planets, stars and other celestial bodies. The researchers extended the MonetDB database system using a new relational algebra recycling technique. This technique re-uses common computations in query streams without a priori planning of a database administrator. Researchers demonstrated the great efficiency of this method by comparing query logs – lists with handled searches – from the SkyServer database with the MonetDB database system. It appears that this is the first open source solution that can perform as well as the original system developed by J. Gray for Microsoft SQLServer. This important finding shows that MonetDB/SkyServer is a valuable and mature experimental platform, whereby advanced techniques can be developed for scientific data management. This research formed part of the FOCUS/BRICKS project.

CWI plays leading role in NCSB research programme

The Netherlands Consortium for Systems Biology (NCSB) officially started its research programme on 15 October. This 30 million-euro research programme (2008-2013) marks the start of a new area in life science. It brings together expertise from various Dutch scientific institutes, combining experimental biological research with mathematical and computational modelling.
NCSB will implement systems biology in Dutch biomedical, pharmaceutical, agricultural and biotechnological research. Topics will range from flower development and the improvement of tomato flavours to the functioning of intestinal flora and the metabolic syndrome. Until now, the extreme complexity of biological systems prevented us from understanding how these systems functioned in detail. By mathematically and computationally modelling biological systems, predictions can be made about their behaviour. Within the NCSB, the CWI's research group on bio-modelling and bio-systems analysis has become an expert centre for the development of computational and mathematical models.

A unique feature of the NCSB's approach is the fact that every week, a group of modellers from systems biology institutes all over the Netherlands gathers at the CWI to work collaboratively on the development of models. The NCSB is co-financed by the Netherlands Genomics Initiative (NGI) and participating Dutch research institutes and universities.

Best Paper Award for Peter Bosman

At BNAIC 2009, the annual Benelux Conference on Artificial Intelligence, Amsterdam-based CWI researcher Peter Bosman received a Best Paper Award for his paper, On Empirical Memory Design, Faster Selection of Bayesian Factorizations and Parameter-Free Gaussian EDAs. According to the jury, his article was a must-read for the discipline. The results of his research can be applied in various areas, including logistics and the social service sector.

Peter Bosmans research focuses on computational intelligence and multi-agent games. Fifty-nine papers were submitted for the award in the Recently Internationally Published category, and Bosmans paper was eventually selected from three final nominations. Bosmans fundamental research concerns Estimation of Distribution Algorithms (EDAs), a specific type of evolutionary algorithm for optimization goals. His research shows how an EDA can be adapted using learning techniques in such a way that similar results can be obtained with the use of fewer computing resources. The results of his research can be applied to numerous areas in society and industry. In logistics, for instance, it can be applied to optimize processes in supply chain management. Hospitals can also benefit from the research, facilitating optimization of the use of resources such as beds and staff, which improves the total throughput of patients.

Breeding Ground

Researchers at CWI are able to fully concentrate on their scientific work. More than half of the permanent research staff maintains close contact with universities. The personal and institutional research networks attract talent from all over the world. The metamorphosis of the CWI building facilitates contact between researchers in an energising and sociable atmosphere. This section highlights the new professorships and PhD degrees of 2009.

Bert Zwart appointed Professor at VU University Amsterdam

As of 1 January, CWI researcher Bert Zwart has been appointed Professor of Applied Stochastic Processes at VU University Amsterdam. In this position, he will carry out research, give lectures and supervise graduate students.

Stochastic process is the mathematical term for a process that occurs randomly over time. Such processes occur in many situations, including mobile networks, factories, call centres, and the financial world. One socially relevant area of Zwarts research is that of revenue management, a growing field of research that involves stochastic processes.

A further major application is in the area of societal logistics. This might involve, for instance, how to optimally determine seatpricing in aircraft. The challenge is how to effectively combine techniques from stochastic processes, statistics and operations research.

Bert Zwart carried out his doctoral research at the CWI and the Eindhoven University of Technology (TU/e), where he received his doctorate in 1997. After one year of postdoctoral research at INRIA (France), Zwart worked as a senior lecturer at TU/e and as an associate professor at the Georgia Institute of Technology in Atlanta (USA). Last year, he received a 600,000-euro Vidi grant and the Applied Probability Societys Erlang Prize for best researcher under the age of 36 in the field of applied probability.

Willem Hundsdorfer appointed Professor of Numerical Mathematics

CWI researcher Willem Hundsdorfer has been appointed part-time Professor at Radboud University Nijmegen. As of 1 May 2009, he holds the Chair in Numerical Mathematics at the Faculty of Physics, Mathematics and Computer Science. He will study mathematical aspects of numerical methods for evolution equations.

Willem Hundsdorfer works as a senior researcher in the CWI's Multiscale Modelling and Nonlinear Dynamics (MAS3) research group. At the CWI, he studies numerical methods for evolution equations and their applications. Examples of these include atmospheric transport-chemistry models and gas-discharge models (in cooperation with Ute Ebert). Numerical methods and computer simulations are increasingly being used in many of the applied sciences, which makes ever-increasing demands on the reliability of simulations and the computational efficiency of the underlying numerical algorithms.

Lynda Hardman appointed Professor of Multimedia Interaction

Lynda Hardman has been appointed Professor of Multimedia Interaction at the University of Amsterdam (UvA). Lynda Hardman has always worked on improving the human interface of developing technology. For instance, as the World Wide Web emerged at the beginning of the 1990s, she investigated navigation interfaces for hypertext. Lynda's work on computer support for hypertext led her to become interested in the extra dimensions of time-based, interactive media, and how these could be supported using generic web technologies. Her PhD thesis (University of Amsterdam, UvA) on modelling and authoring hypermedia documents and her contributions to the W3C SMIL Recommendation resulted from this interest.

More recently, as the Semantic Web is being developed, she has been working on improving human access to the growing linked data cloud. In collaboration with colleagues at the UvA, she will further investigate how methods can be improved for designing human-oriented interfaces for state-of-the-art technology, and the extent to which humans can steer the direction of technological developments.

Monique Laurent appointed Professor at Tilburg University

Monique Laurent has been appointed Professor of Combinatorial Optimization at the Faculty of Economics and Business at Tilburg University. The field of combinatorial optimization deals with how to identify optimal solutions where there are many possibilities; so many, in fact, that it would be too time-consuming to check every one. Examples can be found in areas such as logistics, production planning and schedule making. Laurent designs efficient algorithms to tackle these combinatorial problems, using techniques from algebra, geometry and discrete mathematics.

Monique Laurent studied mathematics at the Université Pierre et Marie Curie (France), and received her PhD in 1986 in the same field at the Université Paris Diderot. She taught at the City University of New York and New York University (USA) between 1985 and 1986, and was a researcher at the Centre National d'Etudes des Telécommunications in Paris between 1986 and 1988. From 1988, she worked as a researcher at the Centre National de la Recherche Scientifique for Paris-Dauphine University, and from 1992 as a researcher for the Laboratoire d'Informatique de l'Ecole Normale Supérieure in Paris.

Jan van Schuppen appointed Professor at TU Delft

Starting on 1 September 2009, Jan H. van Schuppen has been appointed Professor of Mathematical System Theory at the Department of Mathematics of the Faculty of Electrical Engineering, Mathematics and Computer Sciences at TU Delft. This is a part-time appointment for one day per week.

Together with Karen Aardal, Professor of Optimization at TU Delft, Van Schuppen will lead a research group and will focus on control and system theory. He will also collaborate with the Civil Engineering, Chemistry and Management of Technology departments at TU Delft.
Jan H. van Schuppen will remain at the CWI for four days per week, and will lead the Control and System Theory research group. In addition, he will lead the project on Control for Coordination of Distributed Systems that is financed by the European Commission. Van Schuppen is also collaborating with the Netherlands Ministry of Transport, Public Works and Water Management, Directorate General Rijkswaterstaat, and is involved in systems biology research. For Rijkswaterstaat, Van Schuppen has studied routing problems on main roads in order to reduce journey times and traffic congestion.

Jan Rutten appointed Professor Radboud University Nijmegen

On 1 October 2009, Jan Rutten has been appointed Professor Coalgebra at the Institute for Computing and Information Sciences of the Radboud University Nijmegen (RUN).

Coalgebra is a formalism that is very suitable for modelling the infinite behaviour of various types of systems and computational phenomena: examples are infinite sequences (streams) and processes, reactive systems and computer protocols.

As such, coalgebra is positioned at the intersection of computer science and mathematics. Jan Rutten is senior researcher at CWI (since 1985) in the research group SEN3. He is also Professor of Theoretical Computer Science at the VU University Amsterdam since 2001.

PhDs

Chao Li

PhD: 04-02-2009 Eindhoven University of Technology

Joining particle and fluid aspects in streamer simulations

Multiscale Modelling and Nonlinear Dynamics 2009

Supervisor: Prof. dr. U. Ebert (CWI, TU/e)
Advisor: Prof. dr. W.H. Hundsdorfer (CWI)
URL: http://www.cwi.nl/en/news/A-step-towards-understanding-X-rays-from-lightning

Jana Nêmcová

PhD: 02-12-2009 VU University Amsterdam

Rational Systems in Control and System Theory

Modelling, Analysis and Simulation 2009 / MAS2

Supervisor: Prof. dr. ir. J.H. van Schuppen (CWI, VU)

Ina Maria (Maaike) Verloop

PhD: 29-11-2009 Eindhoven University of Technology

Scheduling in Stochastic Resource-Sharing Systems

Probability, Networks and Algorithms 2009 / PNA2

Supervisor: Prof. dr. ir. S.C. Borst (CWI,TU/e)
Advisor: Prof. dr. O.J. Boxma (TU/e, Eurandom), Prof. dr. R. Nunez Queija (CWI, UvA)
URL: http://www.cwi.nl/en/node/2068

Lorenzo Sella

PhD: 01-12-2009 VU University Amsterdam

Computation of symbolic dynamics of low-dimensional maps Modelling, Analysis and Simulation 2009 / MAS2

Supervisor: Prof. dr. ir. J.H. van Schuppen (CWI, VU)
Advisor: Dr. P.J. Collins (CWI)
URL: http://www.cwi.nl/en/node/2075

Fernando Mario de Oliveira Filho

PhD: 01-12-2009 University of Amsterdam

New Bounds for Geometric Packing and Coloring via Harmonic Analysis and Optimization

Algorithms, Combinatorics and Optimization 2009 / PNA1

Supervisor: Prof. dr. A. Schrijver (CWI)
URl: http://www.cwi.nl/en/people/2007

Maksat Ashyraliyev

PhD: 20-10-2009 University of Amsterdam

Modelling, Simulation, and Inferring Regulatory Networks

Modelling, Analysis and Simulation 2009 / MAS

Supervisor: Prof. dr. J.G. Verwer (CWI, UvA)
URL: http://www.cwi.nl/en/node/1581

Ferdi Smit

PhD: 12-11-2009 Eindhoven University of Technology

A Programmable Display-Layer Architecture for Virtual-Reality Applications

Visualization and 3D interfaces 2009/ INS3

Supervisor: Prof. dr. ir. R. van Liere (CWI, TU/e)
URL: http://www.cwi.nl/en/node/2000

Marcin Zukowski

PhD: 11-09-2009 University of Amsterdam

Balancing Vectorized Query Execution with Bandwidth-Optimized

Storage Database Architectures and Information Access 2009 / INS1

Supervisor: Prof. dr. M.L. Kersten (CWI, UvA)
Advisor: Dr. P.A. Boncz (CWI, VU)
URl: http://www.cwi.nl/en/node/1577

Alex van Ballegooij

PhD: 17-09-2009 University of Amsterdam

RAM: Array Database Management through Relational Mapping

Database Architectures and Information Access 2009 / INS1

Supervisor: Prof. dr. M.L. Kersten (CWI, UvA)
Advisor: Prof. dr. ir. A.P. de Vries (CWI, TU Delft)
URL: http://www.cwi.nl/en/2009/1026/New-array-database-technology-for-scientists

Taolue Chen

PhD: 23-09-2009 VU University Amsterdam

Clocks, Dice and Processes

Software Engineering 2009 / SEN2

Supervisor: Prof. dr. W.J. Fokkink (CWI, VU)
URl: http://www.cwi.nl/en/events/Promotion-of-Taolue-Chen

Valentin Robu

PhD: 02-07-2009 Eindhoven University of Technology

Modeling Preferences, Strategic Reasoning and Collaboration in Agent-Mediated Electronic Markets

Multi-agent and adaptive computation 2009/ SEN4

Supervisor: Prof. dr. Han La Poutré (CWI, TU/e)
URL: http://www.cwi.nl/en/news/2009/1013/Decentralized-software-arranges-more-efficient

Alexander Broersen

PhD: 03-03-2009 Eindhoven University of Technology

Feature Visualization in Large Scale Imaging Mass Spectrometry Data

Visualization and 3D Interfaces 2009/ INS3

Supervisor: Prof. dr. ir. R. van Liere (CWI, TU/e)
Advisor: Prof. dr. R.M.A. Heeren (AMOLF, UU)
URl: http://www.cwi.nl/en/News/Faster-biomedical-image-processing-with-CWIresearch

Erik Jan van Leeuwen

PhD: 16-06-2009 University of Amsterdam

Optimization and Approximation on Systems of Geometric Objects

Probability, networks and algorithms 2009 / PNA1

Supervisor: Prof. dr. A. Schrijver (CWI)
URl: http://www.cwi.nl/en/events/2009/PhD-defence-Erik-Jan-van-Leeuwen

Peter van Heijster

PhD: 26-05-2009 University of Amsterdam

Front interactions in a three-component system Dynamical Systems and Numerical Analysis 2009/ MAS1

Supervisor: Prof. dr. A. Doelman (CWI, VU)
URl: http://www.cwi.nl/en/events/PhD-defence-Peter-van-Heijster

Fabian Groffen

PhD: 10-06-2009 University of Amsterdam

Armada, an Evolving Database System Series

Information Systems 2009 / INS1

Supervisor: Prof. dr. M.L. Kersten (CWI, UvA)
Advisor: Dr. S. Manegold (CWI)
URL: http://www.cwi.nl/en/events/2009/PhD-defence-Fabian-Groffen

Wemke van der Weij

PhD: 23-04-2009 VU University Amsterdam

Queueing Networks with Shared Resources

Probability and Stochastic Networks 2009 / PNA2

Supervisor: Prof. dr. R.D. van der Mei (CWI, VU)
URL: http://www.cwi.nl/en/node/1029

Regina Egorova

PhD: 05-02-2009 Eindhoven University of Technology

Sojourn time in processor-sharing systems

Probability and Stochastic Networks 2009 / PNA2

Supervisor: Prof. dr. ir S.C. Borst
Advisor: Prof. dr. A.P. Zwart
URL: http://www.cwi.nl/en/node/967

Helle H. Hansen

PhD: 14-05-2009 VU University Amsterdam

Coalgebraic Modelling : Applications in Automata Theory and Modal Logic

Software Engineering 2009 / SEN3

Supervisor: Prof. dr. J.J.M.M. Rutten
URl: http://dare.ubvu.vu.nl//handle/1871/13247

Robbert de Haan

PhD: 11-03-2009 Leiden University

Algebraic Techniques for Low Communication Secure Protocols

Cryptology and Information Security 2009 / PNA5

Supervisor: prof. dr. R. Cramer (CWI and Leiden University)
URl: http://www.cwi.nl/node/1001

Andreas Witzel

PhD: 03-09-2009 University of Amsterdam

Knowledge and Games: Theory and Implementation

Algorithms, Combinatorics and Optimization 2009 / PNA1

Supervisor: Prof. dr. K.R. Apt (CWI and UvA)
URL: http://www.cwi.nl/node/1623

Transfer to Society

There are many ways to disseminate scientific results to society, other than by scientific publications: cooperation with industry, grant licenses, establishing spin-off companies, organizing meetings for a general public, and maintaining a website are just a few examples of activities to raise public and industrial awareness. This section highlights some means of knowledge valorization.

Lecture Lex Schrijver at DIAMANT Day

On 18 April Lex Schrijver (CWI and UvA) gave a popular lecture on the algorithms behind the Dutch railway timetable in the national railway museum, Spoorwegmuseum Utrecht. This took place during the DIAMANT Day 'Algoritmen Alom', on the occasion of 50 years of algorithms in the Netherlands. Other speakers were Niko Beerenwinkel (Max-Planck-Institut für Informatik Computational Biology and Applied Algorithmics) and Edward Schaefer (Department of Mathematics and Computer Science Santa Clara University, California). CWI sponsored this day. In 1959 the Dutch computer scientist Edsger Dijkstra (Mathematisch Centrum, later CWI) conceived his so called Dijkstra's algorithm,

graph search algorithm that solves the single-source shortest path problem for a graph with non-negative edge path costs, producing a shortest path tree. Fifty years later this algorithm is of fundamental importance in society. It is often used in routing.

Ingres VectorWise

In July 2009 Ingres Corporation, the leading open source database management company and VectorWise, a CWI spin-off from the leading database research team, announced the Ingres VectorWise project.

This collaboration provides superior database technology that allows industry developers to fully take advantage of advances in modern processor and storage hardware. Ingres VectorWise enables businesses to perform data analysis tasks that were previously not feasible.

Initial results show that the Ingres VectorWise project achieves more than 10x performance gains. The project continues to show very good progress and by the end of the year the product started to be evaluated by dozens of companies worldwide.

Summer course for maths teachers

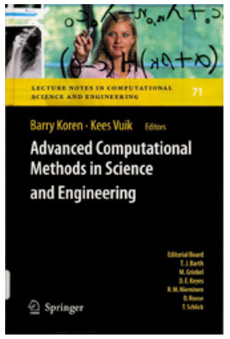
From 1946 on, CWI organizes annually in cooperation with the Netherlands society of mathematics teachers (NVvW) informative and inspiring summer meetings for maths teachers – the 'Vakantiecursus voor Wiskundeleraren'. This years theme was Mathematics in finance and games (in Dutch: 'Tel uit je winst – wiskunde in geld en spelen').

The goal of this years' course was to make clear that, whether it's about tactics in sports and games, or the strategy for negotiations on financial markets, whether it's about the real marbles or the proverbial ones, mathematics is everywhere. Lectures covered, e.g., an introduction to mathematics in

financial products and markets, mathematics and sports, playing with group theory, insurance and pensions in the 17th and 18th centuries, pricing of derivatives in the binomial tree model, 'bribe money' to assist in education, social software about the mathematics of human activities, and the mathematical impossibility of democracy.

The course took place in Amsterdam on 21 and 22 August and in Eindhoven on 28 and 29 August. About 170 math teachers attended the course.

Barry Koren: Advanced Computational Methods in Science and Engineering



Upon request by Rector Magnificus Jacob Fokkema of the Delft University of Technology, Barry Koren and Kees Vuik composed the book Advanced Computational Methods in Science and Engineering, which was published by Springer.

The book gives a well-balanced, state-of-the-art overview of the field of computational science and engineering, through in-depth articles by specialists from the separate disciplines. Examples of topics addressed are: fast and accurate numerical algorithms, model-order reduction, grid computing, immersed boundary methods, and specific computational methods for simulating a wide variety of challenging problems, problems such as: fluid-structure interaction, turbulent flames, bone-fracture healing, micro-electrical-mechanical systems, failure of composite materials, storm surges, particulate flows, and so on.

Science Park Amsterdam Open Day 2009

On 10 October, during the national October Science Month, Science Park Amsterdam was open to the public, thus welcoming about 1250 visitors from all over the country during its annual Open Day. At CWI, hundreds of people enjoyed contributions of Vierkant voor Wiskunde (puzzle market), Pythagoras (mathematics for children), and Arabesk (mathematical puzzles). Children participated in both Pretlabs, one of which was particularly for girls. Two researchers gave minilectures: Journey to the Sun on Earth – about mathematics and nuclear fusion by Barry Koren, and The origin of sprites – giant lightning flashes above clouds by Ute Ebert.

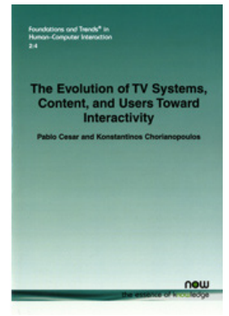
Math fight makes no sense

No relation has been shown to exist between the didactics used and the mathematical proficiency of Dutch children in primary schools. The Royal Netherlands Academy of Arts and Sciences reaches this conclusion in its report Mathematics teaching in the primary school; analysis and keys to improvement. The study was motivated by the public debate about math teaching, which focused on realistic versus traditional math education. There is still a good reason to be worried, since math proficiency is steadily decreasing. The key to improvement lies in the teachers' training, which pays far too little attention to mathematics, and in post-graduate courses. The report was written by a committee chaired by CWI-director Jan Karel Lenstra.

Pablo Cesar: The Evolution of TV Systems, Content, and Users Toward Interactivity

TV viewing has undergone a tremendous change during the past twenty years. Originally,

TV viewing was a social activity, fostering social interaction with communities of viewers. A host of technical developments has caused TV viewing to become more personalized, but less communal. According to researcher Pablo Cesar (CWI), it is time to bring social communications back to TV viewing. In November his new book The Evolution of TV Systems, Content, and Users Toward Interactivity, was published. This book, part of the respected series Foundations and Trends in Human-Computer Interaction, examines how viewers interact with TV content and comprehensively studies the development of TV systems during the past twenty years.



BRICKS

December 2009 the national project BRICKS (Basic Research in Informatics for Creating the Knowledge Society) came to its end. BRICKS was initiated in 2003 by CWI and the Council for Physical Sciences of NWO and has been carried out by researchers from CWI and the universities of Utrecht, Twente, Delft, Eindhoven, Leiden and Nijmegen. BRICKS obtained substantial support from the governmental BSIK-program (subprogram ICT), aimed at strengthening the innovation climate in the Netherlands through innovative ICT research.

BRICKS has contributed to this aim through research on distributed and parallel computing, modelling, simulation and visualization, intelligent systems and algorithms and formal methods.

A highlight has been the completion of thirty-six PhD-theses on subjects from these fields. A second highlight was the publication of the book Omringd door Informatica (Dutch, author Bennie Mols) which explains important BRICKS results for the general audience. The book can be ordered for free at:

info@bsik-bricks.nl

CWI in the media

In 2009 CWI issued over twenty press releases about its researches and gathered a wide range of media coverage from daily newspapers to technical trade publications.

Some highlights are the Ingres VectorWise collaboration, which gained national and international media exposure. Research from Alejandro Luque (Universitat Politecnica de Catalunya) and Ute Ebert (CWI) about huge lightning flashes above clouds (sprites) received great media attention from NRC Handelsblad, Het Parool, Hoe?zo! radio and Q-music radio. Het Parool covered the developments on Science Park Amsterdam and interviewed Harry Buhrman (CWI) on quantum computing. Research from Marcin Zukowski (CWI) about MonetDB/X100 was published in Automatisering Gids. Wemke van der Weij (CWI, photo) was filmed by television channel AT5 about her PhD research: Shorting waiting times with mathematics. NRC Handelsblad covered an in-depth interview with Turing Award winner Richard Karp, who was speaking at the CWI Lectures in June 2009. In November CWI-director Jan Karel Lenstra was interviewed by among others national newspaper de Volkskrant in his position of chairman of the 'Commissie Rekenonderwijs Basisschool'.

Leading role

CWI aims at playing a leading role in setting the national research agendas in mathematics and computer sciences.Together with other top institutions such as INRIA (France) and the Max Planck Institute (Germany) CWI forms the backbone of European research in mathematics and computer science. Some of the results are highlighted in this section.

CWI Lectures 2009: Starting Life Sciences

In January 2009, a new research group in the life sciences started at CWI. This was celebrated with the CWI Lectures in Mathematics and Computer Science on 4 June, 2009. ACM Turing Award winner Richard Karp (USA) gave a presentation on his research and vision during his lecture Combinatorial Methods in Computational Molecular Biology. Luigi Preziosi (Italy), specialist in tumor modelling, talked about novel interactions between mathematics, computer science, and cancer research. CWI researchers Gunnar Klau and Roeland Merks presented examples from life sciences research at CWI. Co-organizer was the Netherlands Institute for Systems Biology (NISB). An interview with Karp was published in the national newspaper NRC Handelsblad.

www.cwi.nl/CWILectures2009

Better software through meta-programming

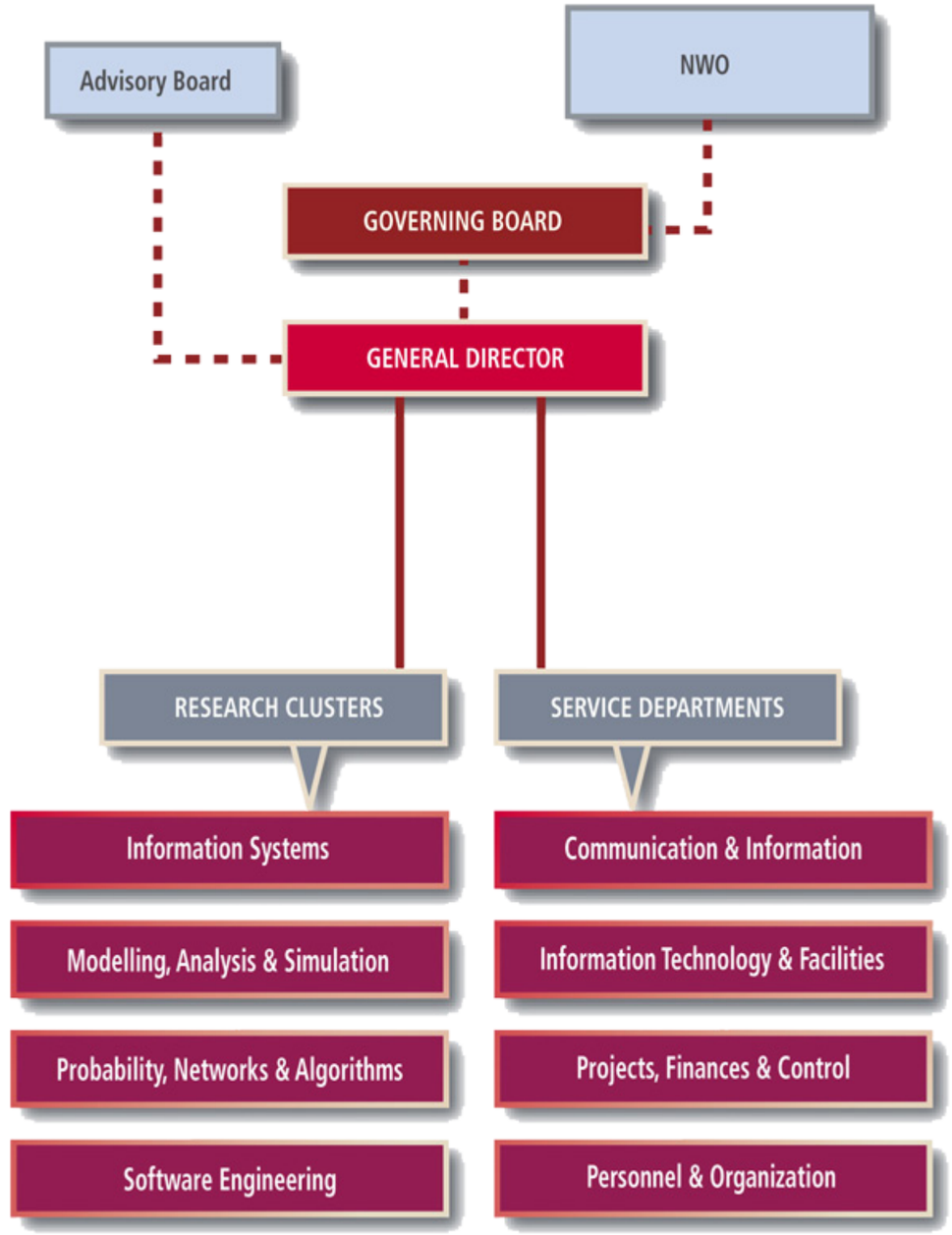
ATEAMS, the first IT project in the Franco-Dutch cooperation between CWI and INRIA (Institut National de Recherche and Informatique et en Automatique) started on 25 June. The project deals with analysis and transformation of software, with the aim to create better software. The objective of the cooperation is to strengthen the European research infrastructure.
One of the applications of the ATEAMS project is about analyzing and improving software written in various programming languages. Tools like so-called code sniffers can detect bad smells in the code and remove them from the software by refactoring it. This is meta-programming: improving a program with another program. The results will be available for a wide range of users by integrating them with Eclipse, one of the most widely used open source development environments. The project runs until 2013.

(From left to right): Signing the cooperation agreement: Paul Klint (CWI), Michel Cosnard (INRIA) and Jan Karel Lenstra (CWI) .

EIT ICT Labs

In December, the European Institute for Innovation and Technology (EIT) launched its first three Knowledge and Innovation Communities (KICs), amongst which EIT ICT Labs. EIT ICT Labs aims at the combination of innovation, research and education in ICT, and is currently in the building-up phase. Berlin, Eindhoven, Helsinki, Paris, and Stockholm serve as national co-locations. In the Netherlands, main partners are Philips, NIRICT, Novay, TNO-ICT, and CWI. CWI is participating in EIT ICT Labs together with four other ERCIM (European Research Consortium for Informatics and Mathematics) members.

Appendices



Organization

Research

Cluster	Cluster leader
Group	Group leader
Information Systems	**Martin Kersten**
Standardization and Knowledge Transfer	Martin Kersten
Database Architectures and Information Access	Martin Kersten
Semantic Media Interfaces	Lynda Hardman
Visualization and 3D Interfaces	Robert van Liere
Quantum Computing and Advanced Systems Research	Harry Buhrman
Modelling, Analysis and Simulation	**Arjen Doelman**
Dynamical Systems and Numerical Analysis	Jason Frank
Scientific Computing and Control Theory	Barry Koren
Multiscale Modelling and Nonlinear Dynamics	Ute Ebert
Probability, Networks and Algorithms	**Arjen Doelman**
Algorithms, Combinatorics and Optimization	Monique Laurent
Probability and Stochastic Networks	Rob van der Mei
Signals and Images	Eric Pauwels
Cryptology and Information Security	Ronald Cramer
Software Engineering	**Paul Klint**
Interactive Software Development and Renovation	Paul Klint
Coordination Languages	Frank de Boer
Computational Intelligence and Multi-agent Games	Han La Poutré
Distributed Multimedia Languages and Infrastructures	Dick Bulterman

Organization

Management

Management Team

Jan Karel Lenstra (general director)
Dick Broekhuis
Judith Coster (till 1 July) – Marga Sutherland (from 1 September)
Ids Dijkstra (till 1 April) – Dick Broekhuis (till 31 December)
Arjen Doelman
Martin Kersten
Paul Klint
Angelique Schilder

Governing Board

Pieter Adriaans (University of Amsterdam), chairman (till 1 May) – Peter van Laarhoven (Group Director Strategy TNT) chairman (from 1 May)
Anton Franken (Radboud University Nijmegen)
Frank den Hollander (Leiden University)
Joost Kok (Leiden University)
Sylvia Roelofs (ICT~Office)

Research clusters and groups

INS - Information Systems

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

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.

Database Architectures

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

The research activities of the group center around the design of models, optimization algorithms and system architectures to cope with the data explosion happening in many fields of science, information systems and data warehouses for business intelligence. Innovations at all levels of the DBMS (Database Management Systems) are called for to cope with the scalability, performance and fault tolerance requirements.

Highlights

- MonetDB, the groups' open-source solution, reached its download count of 100,000 users from all over the world for education and business solutions.
- The group received the VLDB 10-years Best Paper Award for its impact on the database community with the column store solutions.
- Two spin-off companies – MonetDB BV and VectorWise – have been established to bridge the gap between science and deployment.
- PhD defences of Marcin Zukowski, Alex van Ballegooij and Fabian Groffen.

Interactive Information Access

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

Dataspaces refer to all information associated with an entity, e.g. a person or an enterprise. Information within a dataspace is scattered, fragmented and administratively controlled by different bodies, but needs to be organized to be delivered succinctly, compactly and informatively to users. The research goal is to advance scientific knowledge on interactive information access to dataspaces, with models, methods and tools focused on discovery, exploitation and human interaction with semi-structured elements. The ultimate goal is to redesign information access tools in a way that users feel that they, rather than the system, are in control of the search process.

Highlights

- Lynda Hardman was named Professor by special appointment of Multimedia Interaction in the Faculty of Science at the University of Amsterdam. The chair has been designated on behalf of Stichting Bèta Plus.
- In May 2009, Arjen de Vries gave his inaugural lecture 'Zoektocht op schema' on the occasion of his appointment in September 2008 as Professor Multimedia Dataspaces at Delft University of Technology.

Visualization and 3D Interfaces

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

Scientific computing is a rapidly growing field and scientists are critically dependent on interactive visual data analysis techniques. This groups 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.

Highlights

- PhD defences of Alexander Broersen and Ferdi Smit.

Quantum Computing and Advanced Systems Research

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

The group focuses on quantum computing, learning theory, complexity information theory and computational biology. They design and analyze new algorithms and communication protocols, study fault tolerance, and develop quantum cryptographic protocols. The group also works on Minimum Description Length (MDL) learning, prediction, and model selection. Both Kolmogorov complexity and computational classes are studied. We address the origin of early proteins and the genetic code, researching the robustness and fault tolerance in the genetic code.

Application areas include DNA sequences, computation devices and the evolutionary origin of the sleeping sickness parasite. They collaborate with various international experimental groups. The research covers the data explosion, earth and life sciences and societal logistics – important themes for CWI.

Highlights

- Five keynote lectures at the most important international conferences in this field.
- Several activities for the general public, including lectures and a radio interview on BNN Today.
- Co-organizing several conferences in this field.
- Inaugural speech of Peter Grünwald in November 2009 on the occasion of his appointment as Professor at Statistical Learning at the Mathematical Institute of Leiden University, November 2008.

MAS – Modelling, Analysis and Simulation

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

The research programme of MAS is based on three mathematical research tracks: scientific computing, dynamical systems and partial differential equations (PDEs), 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 and plasma dynamics, computational finance, and other industrial and technological fields. Altogether, the research covers all four strategic themes of CWI.

Dynamical Systems and Numerical Analysis

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

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

numerical algorithms. Applied research addresses problems in atmosphere and ocean sciences, phytoplankton dynamics and vegetation patterns, energy technology and electromagnetics. The work largely contributes to the theme earth and life sciences, but can also serve societal logistics and the data explosion.

Highlights

- Arjen Doelman was appointed director of the Lorentz Center, Leiden.
- Daan Crommelin had the top-rated proposal in NWO/ALW Program Feedbacks in the Climate System.
- Two MAS1 PhD students were awarded Rubicon grants for research abroad: Peter van Heijster and Svetlana Dubinkina; Dubinkina turned it down.
- PhD defence of Peter van Heijster.
- PhD defence of Maksat Ashyraliyev.

Scientific Computing and Control Theory

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

Scientific computing enables the investigation of phenomena that are expensive, dangerous, difficult or simply impossible to study otherwise. Mathematical models for the improvement of technology of future energy resources are studied by numerical techniques, as well mathematical models as for financial and economic investment decisions.

Control theory is a major factor in the effective functioning of technological systems, in modelling and control of biological systems, as well as in the mathematical analysis of physical systems. The research in Scientific Computing and Control Theory contributes to the strategic themes societal logistics, earth and life sciences and software as service.

Highlights

- The book Advanced Computational Methods in Science and Engineering, edited by Koren (MAS2) and Vuik (TU Delft) was published.
- PhD defence of Jana N mcová at the VU Amsterdam – a chapter of her thesis has been accepted in Mathematical Biosciences; PhD defence of Lorenzo Sella.
- A workshop Dike-Height Control was organized at CWI, with presentations from Deltares, HR Wallingford, CPB, Tilburg University and CWI-MAS2.

Multiscale Modelling and Nonlinear Dynamics

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

The group combines the development of fundamental methods in scientific computing and in pattern and coherent structure formation (in particular interface interaction and stability analysis) and model reduction with practical, application oriented questions. A recent focus lies on connecting stochastic microscopic modelling with deterministic density approximations, which is an important branch of multi-scale modelling. Main application areas are transient discharges in lightning and other atmospheric discharges and closely related phenomena in plasma technology and pulsed electric power. Population dynamics and atomic particle interactions are investigated as well.

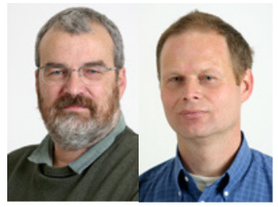
The research fits into the earth and life sciences theme. It also has strong components of scientific computing, and contributes to research on energy and health.

Highlights:

- Willem Hundsdorfer was appointed (part-time) Professor of Numerical Mathematics at the Radboud University in Nijmegen.
- Ute Ebert was co-applicant of two successful research programs: the STW program Building on Transient Plasmas and the FOM-program Active control of magneto-hydrodynamic modes in burning plasmas. Within the STW-program, she has 3 projects with one PhD student each; within the FOM-program, there are two PhD students for Ebert (MAS3) and Koren (MAS2).

- Publication by Luque and Ebert about simulated emergence of sprite discharges above thunderclouds in Nature Geoscience; the media coverage of lightning related work continued.
- Publication by J. Rademacher, J. Sherratt (Heriot-Watt) and M. Smith (Microsoft Research) in the Proceedings of the National Academy of Sciences.
- PhD defence of Chao Li.

PNA - Probability, Networks and Algorithms



Cluster leader:
Bert Gerards (till 1 March) Arjen Doelman (from 1 March)
Bert.Gerards@cwi.nl and Arjen.Doelman@cwi.nl

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
Monique.Laurent@cwi.nl

This group does fundamental and algorithmic research in combinatorics, optimization and game theory, motivated by real world problems, like transportation planning, time-tabling, scheduling, network routing, traffic control, and internet auctions. Such problems are combinatorial in nature and often have game theoretic components. They can be formulated as discrete optimization problems involving selfish agents aiming primarily at achieving their own individual objectives.

Research focuses on developing efficient algorithmic methods for such problems. It requires understanding and exploiting the mathematical structure of the problem, investigating game theoretic aspects, and using tools from various mathematical areas, including algebra, geometry, discrete mathematics, game theory, complexity, and optimization. The research is relevant to the themes societal logistics and earth and life sciences.

Highlights

- Frank Vallentin won an NWO Vidi grant.
- Dominik Wojtczak received the Best Paper Award at ICALP 2009.
- Monique Laurent was appointed Professor at Tilburg University.
- The Veni grant of Tobias Mueller started.
- Three PhD defences: Fernando de Oliveira Filho, Erik Jan van Leeuwen and Andreas Witzel.

Probability and Stochastic Networks

Group leader:
Rob van der Mei
Rob.van.der.Mei@cwi.nl

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, queuing theory, stochastic scheduling, spatial stochastics and stochastic geometry. This way the group addresses challenging research problems in the context of the themes societal logistics and earth and life sciences.

Highlights

- Proposal for Mathematics cluster Stochastics – Theoretical and Applied Research (STAR) was awarded by NWO (Rob van der Mei).
- ICT Innovation Platform (IIP) Vitale ICT Infrastructuren (co-founded by CWI, TNO-ICT and UT) was formally recognized by ICTRegie (Rob van der Mei).

- Highly prestigious grant for ESF Research Networking Programme Random Geometry of Large Interacting Systems and Statistical Physics was awarded with Vladas Sidoravicius as chairman.
- Bert Zwart was appointed Professor at VU University Amsterdam and area editor for Stochastic Models at Operations Research.
- PNA2 co-initiator of the national Pricing and Revenue Management (PreMa) seminar series (jointly with VU Amsterdam and ORTEC), a national platform for knowledge exchange between academia and industry in the area of Revenue Management.
- Three PhD defences: Regina Egorova, Wemke van der Weij and Maaike Verloop.

Signals and Images

Group leader:
Eric Pauwels
Eric.Pauwels@cwi.nl

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 databases. 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

- Invited talk by Eric Pauwels at the first International Conference on Computational Sustainability, Cornell Ithaca, USA.
- Kick-off of FP7 EU STReP Project Firesense (Camera and sensor networks to monitor cultural heritage sites for the detection of fire and extreme weather conditions).

Cryptology and Information Security

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

This groups 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. In addition, there is special focus on interplays with algebra, number theory, geometry, combinatorics, probability theory, complexity theory, formal methods, quantum physics and information theory, as advances in modern cryptology increasingly rely on deeper understanding of these interplays. All research is closely linked with the themes the data explosion and software as service.

Highlights

- Best Paper Award EUROCRYPT 2009, Eike Kiltz and Dennis Hofheinz.
- Best Paper Award CRYPTO 2009, Marc Stevens (and co-authors).
- STW Sentinels Project Revocable Privacy (Cramer, jointly with TNO RUN) awarded.
- PhD defence Robbert de Haan, Mathematical Institute, Leiden University.

SEN – Software engineering

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

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

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 analysis and understanding, program refactoring, domain-specific languages, and large-scale program transformation. It aligns with the theme software as service.

Highlights

- The ATEAMS research team was officially created, a joint CWI/INRIA research group that is part of SEN1 and focuses on software analysis and transformation.
- A first, alpha, release of the new meta-programming language Rascal was completed.
- In the former SEN2 group: PhD defence of Taolue Chen.

Coordination Languages

Group leader:
Frank de Boer
F.S.de.Boer@cwi.nl

This research group develops models, methods, and tools for engineering and analysis of software intensive concurrent systems, including compositions of distributed services and multi-core programming. Developing solid mathematical foundations on which such technology is based is integral to SEN3's approach. The research in SEN3 fits within CWI's software as service theme.

Highlights

- Jan Rutten has been appointed Professor at the Radboud University in Nijmegen.
- The third edition of the book Verification of sequential and concurrent programs, authored by K.R. Apt, F.S. de Boer and E-R. Olderog, has been published by Springer.
- The EU STREP project Credo (coordinated by Frank de Boer) was evaluated good to excellent by the second annual review.
- In the Vrije Competitie NWO, the following project has been awarded: CoRE: Coinductive Calculi of Regular Expressions. It will fund two PhD positions, one at LIACS (Leiden University) and one at CWI.

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 health care logistics, energy markets, transportation logistics, service markets, and market simulation. In this way, it contributes to the themes societal logistics and software as service.

Highlights

- The project IDeaNeD (Intelligent and Decentral Management of Electricity Networks and Data) has started, in cooperation with Eindhoven University of Technology, KEMA, Phase to Phase, and electricity companies.
- The project TRANSFORM on container and truck logistics at the Rotterdam harbour terminal has been awarded.
- Peter Bosman has been awarded the Best Paper Award for recently internationally published papers, at BNAIC 2009 (Belgium-Netherlands Conference on Artificial Intelligence).
- PhD defence of Valentin Robu.

Distributed Multimedia Languages and Infrastructures

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

The group's focus is temporal specification languages, declarative interaction models and distributed media delivery and rendering architectures. Combining both analytic and experimental approaches, DMLI studies models for the temporal combination and navigation through heterogeneous media objects, interactive media object synthesis based on socially-driven service-oriented architectures and low-level distribution of media content on non-monolithic, distributed rendering architectures. While this work is related primary to the software as service theme, the group also contributes as a significant cause of the data explosion.

Highlights

- Steven Pemberton received the Lifetime Achievement Award from ACM SIGCHI.
- Keynote presentation at WebMedia-2009 in Fortaleza, Brazil (Dick Bulterman).
- Publication of the book: The Evolution of TV Systems, Content, and Users Towards Interactivity, in the series Foundations and Trends in Human-Computer Interaction (FnTs-HCI) by Pablo Cesar.
- Publication of Media Fragments URI 1.0 by W3C by Jack Jansen.

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).

European programmes

COMPAS – Compliance-driven Models, Languages and Architectures for Services
2008–2011
Vienna University of Technology, University of Claude Bernard, University of Stuttgart, UT, University of Trento
F. Arbab

CON4COORD – Control for Coordination of Distributed Systems
2008–2011
Universiteit Gent, Universidade do Porto, Center for Research and Technology Thessaly, Universita degli di Studi di Verona, Hesse-Noord Natie, OceanScan, Océ Technologies, Trinite Automatisering
J.H. van Schuppen

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

DISC – Distributed Supervisory Control of Compex Plants
2008–2011
University of Cagliari, Universiteit Gent, Technical University of Berlin, University of Zaragoza, INRIA, Akhela s.r.l., Czech Academy of Sciences, Ministry of Flemish Government, CyBio AG
J.H. van Schuppen

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

Firesense
2009–2012
Centre for Research and Technology Hellas, Bilkent Universitesi, Ecole Supérieure des Communications de Tunis, Xenics nv, Marac Electronics S.A., Bogazici Universitesi, Hellenic Ministry of Culture, Titan Bina Elektronik Sistemleri Technoloji Sanayi ve Ticaret, Consiglio Nazionale delle Richerche
E.J.E.M. Pauwels

HATS – Highly Adaptable and Trustworthy Software using Formal Methods
2009–2013
Chalmers Tekniska Högskola, Universitetet I Oslo, Kunglia Tekniska, Universodad Politecnica de Madrid, Technische Universität Kaiserslautern, Alma Mater Studiorum, Universita di Bologna, Norsk Regnesentral Stiftelse, Fredhopper B.V. Fraunhofer, Katholieke Universiteit Leuven
F.S. de Boer

iNEM4U – Interactive Networked Experiences in Multimedia for You
2008–2009
Telematica Instituut (Novay, May 2009), Philips Electronics, NEC Europe, Logica CMG, Fraunhofer Gesellschaft, Hewlett Packard, Telenor ASA, Institut für Rundfunktechnik, Philips Consumer Electronics
D.C.A. Bulterman

QAP – Qubit Applications
2005–2010
36 Partners from different countries
H.M. Buhrman

TA2 – Together Anywhere, Together Anytime
2008–2012
EURESCOM, British Telecommunications, Alcatel Lucent-Bell, Fraunhofer Gesellschaft, Goldsmiths College University of London, TNO, The Interactive Institute II AB, Hasbro, Philips, Limbic Entertainment, JONNAEUM Research Forschungsgesellschaft
D.C.A. Bulterman

VITALAS – Image Indexing and reTrievAL in the Large Scale
2007–2010
EADS Defence and Security Systems, Faunhofer Gesellschaft, INRIA, Fundacion Robotiker, Institut National de l'Audiovisuel
A.P. de Vries

EU networks

ECRYPT II
2008–2012
Katholieke Universiteit Leuven, Ecole Normale Supérieure, Ruhr-Universität Bochum, Royal Holloway and Bedford New College, Università degli Studi di Salerno, University of Bristol, France Telecom S.A., IBM Research GMBH, Technische Universiteit Eindhoven, Technische Universität Graz, Ecole Polytechnique Féderale de Lausanne
R.F.J. Cramer

Life Watch
2008–2011
27 Partners from various countries
E.J.E.M. Pauwels

PASCAL-2 – Pattern Analysis, Statistical Modelling and Computational Learning
2008–2013
Partners from various countries
P.D. Grünwald

Plantsysmodel – Integrating modelling into plant systems biology: Applications to auxin-driven plant morphogenesis
2008–2011
R.M.H. Merks

NWO

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

Algebraic Geometric Foundations of Cryptology – The Case of Practical and Unconditionally Secure Computation
2007–2011
Vici project
R.J.F. Cramer

Analysis of Distribution Strategies for Concurrent Access in Wireless Communication Networks
2007–2010
Lucent Technologies
R.D. van der Mei

CoCoMAS – Coordination and Composition in Multi-agent Systems
2006-2010
UU
F.S. de Boer

CooPer – Coordination with Perfomance Guarantees
2005–2009
SEN3 (F. Arbab)
R.D. van der Mei

Computational Topology for Systems and Control
2005–2010
Vidi project
P.J. Collins

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

DIACoDeM – Distributed Implementations of Adaptive Collective Decision Making
2006–2009
SEN3, SEN4
K.R. Apt

DIAMANT – Discrete, Interactive & Algorithmic Mathematics, Algebra and Number Theory
2007–2010
TUE, UL, RU
A.M.H. Gerards

EFS – Efficient Flow-scheduling in Resource-sharing Networks with Variable Service Rates
2005–2009
R. Núñez Queija

Hefboom-project
2005–2009
Hogeschool Amsterdam, VU, UvA
J.J. Vinju

High Dimensional Service Systems
2008–2013
Vidi project
A.P. Zwart

Inequalities and Random Spatial Processes
2009–2013
J. van den Berg

Interactions of Pulses and Fronts
2005–2009
A. Doelman

Learning When All Models Are Wrong
2005–2010
Vidi project
P.D. Grünwald

MatE – Matroid Structure – for Efficiency
2009–2011
A.M.H. Gerards

MEMESA – Microbial Ecosystems and Multiple Environment Stoichiometric Analyses
2008–2011
F.J. Bruggeman

Mending the Unending – Machine Assisted Reasoning with Infinite Objects
2008–2011
Veni project
M. Niqui

MON-LM – Monotonicity Preservation for General Multisteps Methods
2007–2010
W.H. Hundsdorfer

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

NDNS – Nonlinear Dynamics of Natural Systems
2005–2012
A. Doelman

Phase Transitions in Random Nearest Neighbour Graphs
2009–2012
Veni project
T. Müller

Pushing the Factoring Boundary to 768 Bits
2008-2012
H.J.J. te Riele

Quantum Computing – Fault Tolerance, Communication, and Classical Spin-offs
2008–2013
Vidi project
R.M. de Wolf

Quantum Cryptography – Achieving Provable Security by Bounding the Attacker's Quantum Memory
2008–2012
S. Fehr

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

QUASID – Quantitative Spatial Interaction Design
2005–2011
TUE
R. van Liere

Querying while Transforming Large Graph Databases
2009–2013
P.A. Boncz

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

SEGMAO-PMF – Segmentation and motion analysis using polygonal Markov field
2009–2013
M.N.M. van Lieshout

Strengthening Modern Cryptography by Automatable Proving
2008–2009
Veni project
D. Hofheinz

SYANCO – Synthesis and Analysis of Component Connectors
2006–2010
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

Talmas – Teaching and Learning in Multi Agent Systems
2009–2013
S.M. Bohte

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

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

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

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

STW

PASC – Practical Approaches to Secure Computation
2005–2009
TUE
R.F.J. Cramer

The Start-up of Lightning – Streamer discharges in Lamp Ignition, Electric Switches and Materials Processing
2008–2012
TUE, Philips
U. Ebert

Miscellaneous

Molecular Systems Biology at Science Park Amsterdam
2008–2010
AMOLF, SILS
J.H. van Schuppen

Spinoza Award project
2005–2010
A. Schrijver

SenterNovem (including IOP)

BASIS – Biometric Authentication Supporting Invisible Security
2004–2009
UT, TUE
E.J.E.M. Pauwels

IDeaNeD – Intelligent en Decentraal Management van Netwerken en Data
2009–2012
Alfen B.V., Continuon, Eneco Infra, Eneco NetBeheer, Kema, Phase to Phase, Technische Universiteit Eindhoven
H.L. La Poutré

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

SEQUAL – Service Optimization and Quality
2008–2012
TNO-ICT, IBM, Ericsson, UT, Mobilaria
R.D. van der Mei

Research Agreement Rabobank International
2008–2012
Rabobank International
C.W. Oosterlee

XIRAF – XML-based Indexing and Querying for Digital Forensics
2007–2009
NFI
P.A. Boncz

Bsik projects

BioRange – Biomathematics in Mass Spectrometry Based Proteomics and Modelling of Protein Networks
2006–2010
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, P.A.N. Bosman

MultimediaN – Multimedia Next Generation
2004–2009
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
2006–2009
W3C
D.C.A. Bulterman

LHM – Leonardo-HySpirit-MonetDB
2008–2009
Universiteit Delft, Queen Mary University of London, Apriorie Ltd
A.P. de Vries

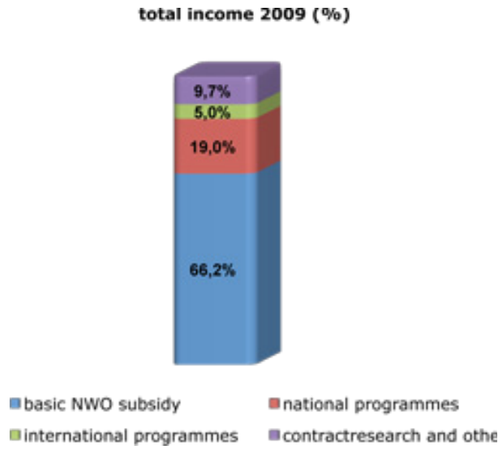
Optimal Dike-Height Control
2009–2010
Deltares
B. Koren

CWI 2009

Founded in 1946, Centrum Wiskunde & Informatica (CWI) is the national research institute for mathematics and computer science in the Netherlands. It is located at the Science Park Amsterdam and is part of the Netherlands Organisation for Scientific Research (NWO). The institute is internationally focused and renowned for its high quality research.

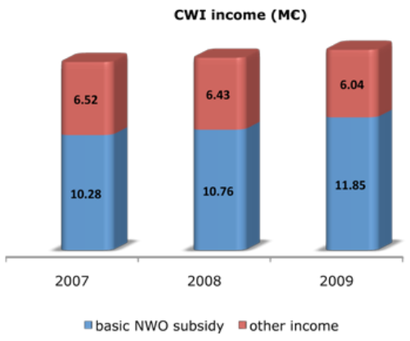
Over 160 researchers conduct pioneering research and share their acquired knowledge with society. Approximately thirty researchers are also employed as professors at universities. The institute has generated approximately twenty spin-off companies.

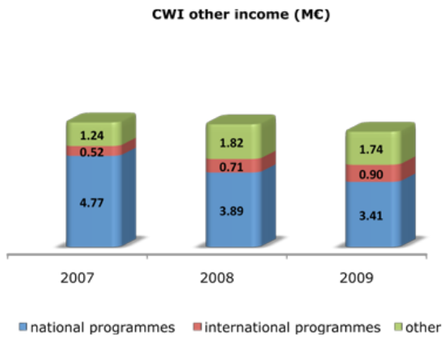
Budget



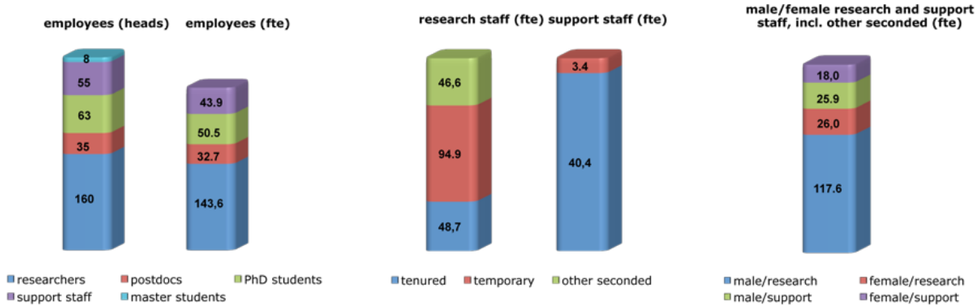
Figures

The figures presents a selection of data from the Centrum Wiskunde & Informatica, concerning budget and staff. The reference date is 31 December 2009.





Staff



Total national and international staff