

I/O

magazine

ICT RESEARCH PLATFORM NEDERLAND

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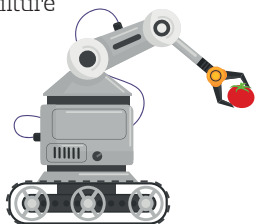
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IPN ICT-ONDERZOEK
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NEDERLAND

PAUL KLINT

Software is eating science

What do we do about it?

A decade ago Marc Andreessen, American entrepreneur, investor, software engineer and co-founder of Netscape, made the provocative statement that software is eating the world. He was right. Let's zoom in and apply this statement to science.

Predictive models are implemented in software. The same holds for the control of scientific instruments, both large and small, for managing clinical trials, model checking, automatically generating proofs of mathematical or logical statements, machine learning, analysing literary texts, designing experimental hardware and software, and for much, much more. Indeed: software is eating science. Happy evolution or reason for concern?

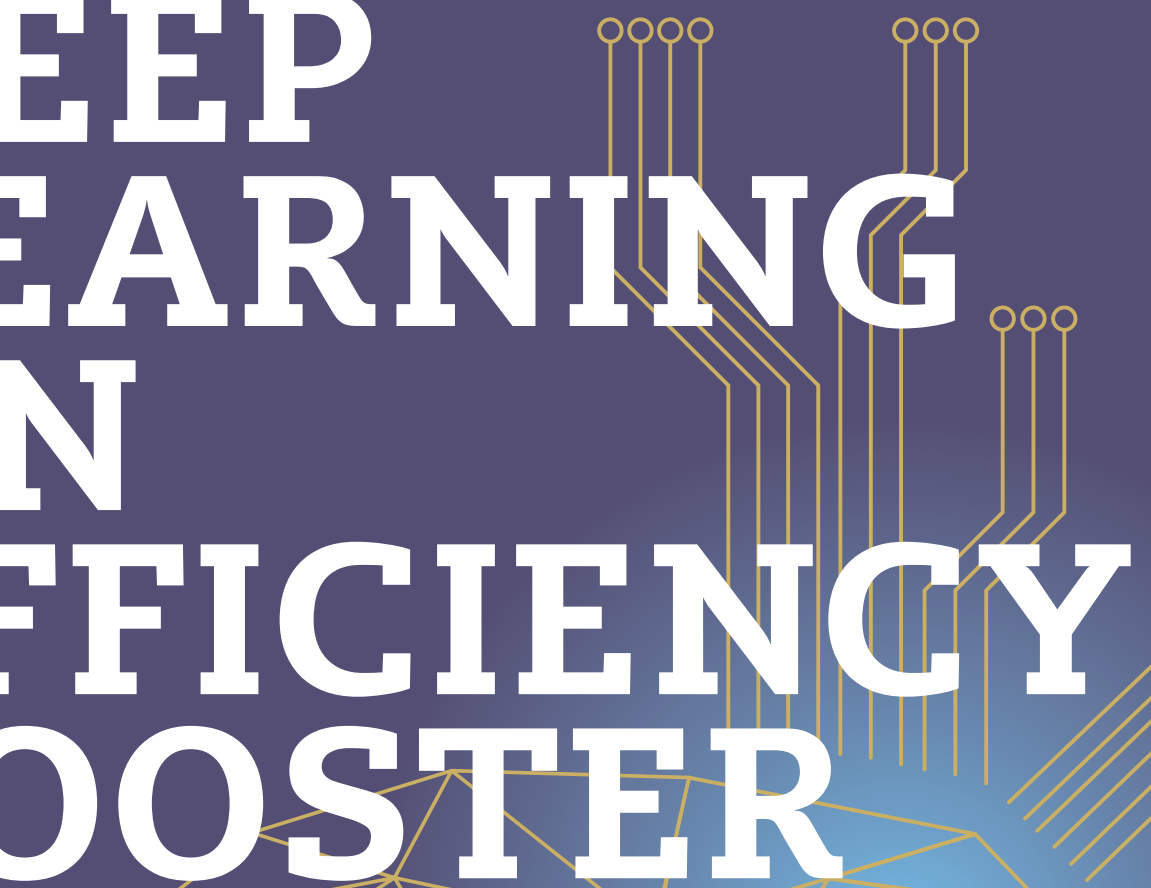
It is not overly pessimistic to assume that software might be the weakest link in the process of achieving a scientific result. Scientific software will combine the use of established libraries with one-off code specific to the experiment or scientific question. The established library may turn out to be the work of an overstretched PhD student who hardly has time to maintain that library. The one-off is also ominous: throw-away code that will be used to obtain one specific result. Shaky foundations. Goodbye to reproducibility.

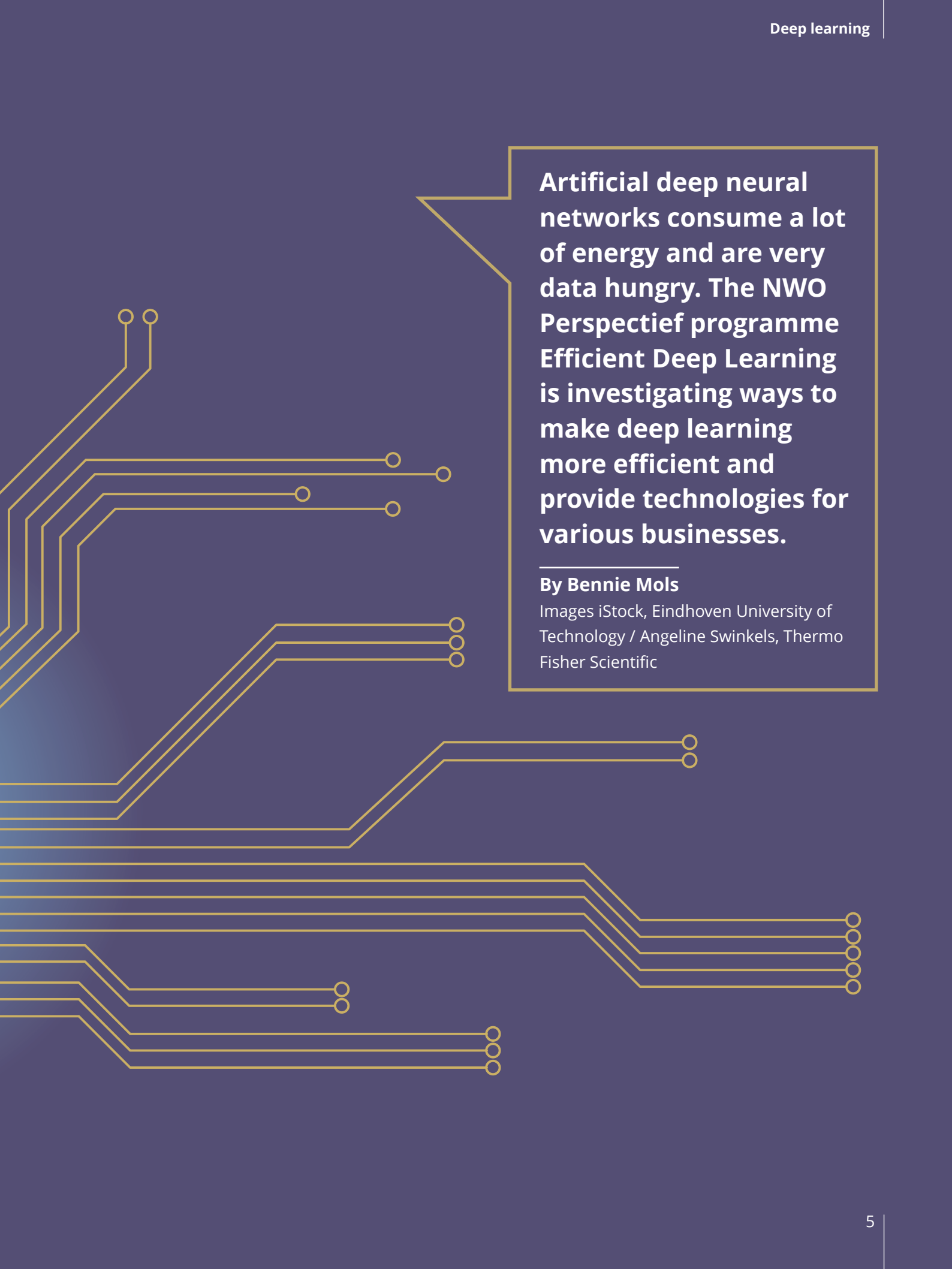
If we focus on how scientific software is created then two main observations can be made: first, the authors of scientific software are experts in their field, but they are not software engineers. And second, their research environment is mostly ignorant of modern-day software engineering practices.

For a long time, I have argued for the introduction of solid software engineering practices for research software. Today, I see several lights at the end of this tunnel. First, *Nature* argues in its May issue that science needs more research software engineers. Second, the Dutch eScience Center is circulating a draft guideline for Software Management Plans. Both are positive developments that demonstrate the scientific community's increasing awareness of the relevance of software engineering for science.

What remains is to increase the awareness of this insight among policymakers and funding agencies.

GIVING DEEP LEARNING AN EFFICIENCY BOOSTER



The background of the page is a dark blue gradient. Overlaid on this are several yellow circuit-like lines that start from the left edge and branch out towards the right. These lines end in small yellow circles, resembling electrical connections or data points. The lines vary in thickness and are arranged in a way that suggests a complex network or data flow.

Artificial deep neural networks consume a lot of energy and are very data hungry. The NWO Perspectief programme Efficient Deep Learning is investigating ways to make deep learning more efficient and provide technologies for various businesses.

By Bennie Mols

Images iStock, Eindhoven University of Technology / Angeline Swinkels, Thermo Fisher Scientific

Over the past decade, deep learning, a specific form of machine learning that uses neural networks with many layers, has revolutionised the field of artificial intelligence and its applications in domains like computer vision and natural language processing. However, despite all its successes, deep learning has some serious efficiency problems. The NWO Perspectief programme Efficient Deep Learning (EDL) addresses these problems.

Co-programme leader Gijs Dubbelman (Eindhoven University of Technology) explains the three most important efficiency issues: 'First of all, deep learning is inefficient in its energy consumption. Running deep neural networks requires a lot of energy. Often it consumes too much energy to run the most capable networks on power-constraint edge devices. Second, there is the issue of data inefficiency. A lot of labelled data is needed to train a deep learning model. However, for quite a few applications, not enough data is available. Humans often use common sense to deal with a lack of data, but deep learning doesn't have common sense. The third efficiency problem is that the accessibility of deep learning technology is at present limited to specialists.'



Gijs Dubbelman

'Deep learning requires a lot of energy, there is the issue of data inefficiency, and the technology is only accessible for specialists'

EDL runs seven research projects to find solutions for all these three issues. On each project, three to five PhD students work together with senior researchers at universities and companies. Dubbelman's colleague at the Eindhoven University of Technology, professor Henk Corporaal, is the EDL programme leader and specialises in making deep learning more energy efficient. Roughly speaking, there are four ways to do that, he says. Three of them focus on more efficient software and one focuses on more efficient hardware.

Corporaal: 'On the software side, you can try to simplify the neural network, for instance by reducing the number of neurons or simplifying a convolution. Another way to simplify data types is to use down to one bit instead of the traditional 32 bits. The third way focuses on the reuse of data by rewriting the computer code so that the distance between the production and the consumption of data is minimised. This avoids many costly external memory accesses. On the hardware side, EDL studies certain types of neuromorphic computing. Neuromorphic computing processes information in ways more similar to the human brain than the GPUs traditionally used in deep learning.'

Huge interest

The interest from companies in deep learning is huge, which is why EDL is supported financially and in-kind by thirty Dutch companies. One of them is Thermo Fisher Scientific, a company specialised in laboratory equipment. Among many other things, they produce electron microscopes both for the industrial and academic markets. Such microscopes can look down to the level of individual atoms. They are used, for example, to study protein folding, for vaccine development, for developing lightweight aeroplane materials and to improve semiconductor materials.

Maurice Peemen leads the digital science group in the R&D department of Thermo Fisher Scientific. 'We want to use deep learning to give our electron microscopes super resolution', he says. Super resolution uses certain contextual knowledge to give the original image a better resolution. Peemen: 'You can compare it with the way you would look at a piece of tree bark, for example. You know that when you zoom in deeply, you should see a certain structure. With that knowledge, you look in the noise to see if you can distinguish that structure again. In the same way we can use software in our electron microscope to give the original image more detail.'

Thermo Fisher Scientific sponsors one PhD student within EDL. His main scientific challenge is to develop an enhancement algorithm that requires far less data to train. 'He has already made quite a bit of progress', says Peemen. 'We hope that we can incorporate his solution in our electron microscopes within a few years. That would especially be advantageous for very delicate materials that will break if you study them for too long with an electron microscope, such as biological cell materials.'

Other examples of projects are the automatic prediction of road user behaviour by autonomous cars, the automatic detection of suspected behaviour by Schiphol's video surveillance system and the automatic analysis of medical images. All these examples involve rare cases and are therefore represented by only small amounts of data. How can deep learning still learn from such small volumes of data? That is a great scientific challenge within EDL.

First results

As EDL has been running for more than three years now, the first results are now emerging. One of these is in the field of the vision system of autonomous cars, research from Dubbelman and his colleagues. 'Basically, we have shown that we can successfully use a deep learning model trained on simulated data to predict all kinds of dangerous situations in real traffic', says Dubbelman. 'We trained our model on relatively simple and basic situations of moving and colliding objects. Some objects are on a safe trajectory, others on an unsafe one. We do this because video footage of real collisions is scarce, and we don't have enough of them to train deep neural networks.'

But when we do the training on the simulated data, which is abundant in a clever way, it turns out that our deep learning model can predict all kinds of dangerous situations on real dashcam videos that are available on YouTube.'



Henk Corporaal

'To improve energy efficiency, you can simplify the neural network, simplify data types, or reuse data'

In the field of neuromorphic computing, EDL has a project on spiking neural networks (SNNs). Such networks have existed for some time but until recently had the major disadvantage that they were difficult to train, which meant that they could not be efficiently applied in practice. Thanks to researchers from the Centrum Wiskunde & Informatica (CWI) a new algorithm can handle such spiking neural networks. Eindhoven University of Technology designed a dedicated neuromorphic chip that can run these SNNs with record efficiency. This will expand the application possibilities of deep learning in wearable chips, such as for speech or gesture recognition, or for the classification of electrocardiograms.

The applicability of the EDL results varies, says Dubbelman. 'Some results are on the level of a technological concept only, other results will show that a certain technology works in a relevant industrial setting.'

Apart from solving specific problems and working towards specific applications, EDL is also important to find and retain talent in the field of artificial intelligence, says EDL programme leader Henk Corporaal. 'All Big Tech companies invest heavily in deep learning, so there is fierce competition for talent. If the Netherlands wants to keep up in the international AI competition, it must invest in interesting research projects and good people. EDL offers exactly that opportunity.'



Maurice Peemen

'We want to use deep learning to give our electron microscopes super resolution'

For companies, EDL is a great way to collaborate with academia. 'I see EDL as a cross-pollination between academia and companies', states Thermo Fisher's Maurice Peemen. 'Apart from running our own project, we also see what happens in other projects, and that inspires us too.'



EFFICIENT DEEP LEARNING IN SHORT

Aim: EDL aims to make deep learning more accessible to business by improving the applicability of deep learning (DL), creating data-efficient training methods, and improving computational efficiency, for both training and inference.

EDL contains seven research projects:

1. DL as a service
2. DL for 3D reconstruction, matching and recognition
3. DL for video analysis and surveillance
4. DL for high-tech systems & materials
5. DL for human and animal health
6. DL for mobile robotics
7. DL efficient deep learning platform

Duration: 2018-2023

Budget: 4.0 million euros basic funding, supplemented by 2.8 million euros from involved companies, civil society organisations and knowledge institutions.

Partners: EDL is a cooperation of 7 Dutch universities, 1 German university, 2 NWO institutes and 5 other research institutes. EDL is also supported by 30 Dutch companies.

Website: efficientdeeplearning.nl



BUILDING A SOLID BASE

By Sonja Knols Image iStock

There is no sector in society or economy where the phrase “Data is the new gold” does not apply. Whether it is in healthcare, real estate, the chemical industry or Netflix recommendation systems: just about every decision made these days is based on vast amounts of data. In a recent vision document, the Data Science Platform Netherlands (DSPN) pleads for further investments in the foundations of data science to ensure our digitalising society is built on a firm foundation.

‘At the moment, machine learning and artificial intelligence get a lot of attention, and rightly so. But we need to keep stressing the fact that machine learning and data science are mutually dependent. It makes no sense to strengthen the one without investing in the other.’ DSPN chair Geert-Jan Houben and secretary Peter Boncz are clear: now is the time to strengthen the foundations of data science to make sure that future applications will not be built on quicksand.

In the recently published DSPN vision, seven areas of data science are mentioned that deserve explicit attention in

future research funding programmes: The foundational data science disciplines Data Systems; Data Quality and Data Integration; Knowledge Representation & Provenance; Data Mining and Exploration; and Information Retrieval. And the two multidisciplinary fields Responsible data Science and Data Science in Interaction with Application Context. ‘These are areas where there is critical mass in the Netherlands and that are crucial to extract knowledge and insights from data in a correct, reproducible, and efficient way’, says Boncz explaining the choice for these topics.

DATA SCIENCE EDUCATION

In addition to this research-oriented focus, the vision document also contains a call to action when it comes to education. Boncz: ‘The computer science sector is under pressure. The number of students has exploded over the past years. VU University alone now harbours 7.5 times as many computer science students as it did a mere ten years ago. At TU Delft, computer science students now make up 10 percent of the entire student population. But the staff has not grown accordingly, leading to undesirably high student-staff ratios.’ Houben adds: ‘On top of that, society and industry express a great demand for data literacy skills across all sciences. DSPN wants to play its role in this, for

‘MACHINE LEARNING AND DATA SCIENCE ARE MUTUALLY DEPENDENT’

example by establishing guidelines for what would be a good data science curriculum for non-computer scientists.’

The DSPN vision is not a standalone document, both emphasise. ‘As a special interest group of IPN, we explicitly align with the overall IPN vision, which basically shares our plea for investments in the foundations of computer science research and education’, says Houben. ‘At the moment, most of the attention in science policy is aimed at developing applications. But solid foundations are indispensable for achieving that.’ Boncz: ‘Over the past decades, computer science as a field has matured. In terms of student numbers we are by far the largest field of study in the natural sciences in the Netherlands. That comes with a responsibility to team up and jointly make sure our field has a future. What’s more, a topic like data science will become a decisive factor in the quality of our society. Now is the time to thoroughly think through the tools that future society will be built upon.’

More information:
[www.datascienceplatform.org/
DSPN-vision.pdf](http://www.datascienceplatform.org/DSPN-vision.pdf)

TWO GRANTS KIC CALL DATA AND INTELLIGENCE

Two research projects have been awarded funding within the KIC call for “Data and Intelligence”. Consortia comprising researchers, businesses and societal organisations will contribute towards better, usable intelligence products to meet the needs of intelligence and security professionals. The two projects will receive almost three million euros of funding, with public and private partners contributing over 800,000 euros more in co-funding, both in kind and in cash.

The two consortia will research the responsible use of artificial intelligence for a safer, more secure society. One consortium, led by Fabio Massacci from VU University, will focus on the use of AI in intelligence gathering; the other is led by Marcel Worring from the University of Amsterdam and will study the use of AI in assessing the evidence used in court.



EIGHT PROJECTS WITHIN KIC CALL KEY TECHNOLOGIES

Eight research projects have been awarded grants within the call “Key Technologies (KIC)”. The eight projects cover various themes, such as: improving the taste and nutritional value of vegetable proteins, reprogramming the genome with CRISPR-Cas without genetic modifications, increasing the safety and lifespan of large infrastructural steel constructions with the aid of digital twins, and improving medication safety for patients with multiple chronic diseases. More than 16 million euros is available for the research.



OPEN MIND ROUND IN DECEMBER

Open Mind is a funding instrument of NWO Domain Applied and Engineering Sciences, which is intended for research plans that, with the help of technology, can lead to applications with a societal impact. In Open Mind, the emphasis is on new and unconventional ideas that the applicant has not previously investigated and which have not yet been studied.

From now on, the annual Open Mind round will open for applications in December instead of May. The deadline for applications is around February 2023. Subsequent editions of Open Mind will follow this same timeline.

NEW BOARD MEMBER KATRIEN VAN LAERE

Katrien Van Laere has been appointed to the Board of NWO Domain Applied and Engineering Sciences (AES) with effect from 1 April 2022. Food scientist Van Laere is currently Vice President Health Innovation, Medical Affairs and Market Access at the French food and beverage company Danone. Van Laere started her career in 1997 as a prebiotics researcher at Numico, which Danone took over in 2007. Before her career in industry, she gained her doctorate in food science and technology at Wageningen University. Van Laere completed her master's degree at Ghent University and Wageningen University.





By Leendert van der Ent
Image RTL Nederland

RTL NEDERLAND LETS DATA AND AI KNOWLEDGE FLOW

The field of media and entertainment is changing. As a consequence of this the relevance of data and AI is increasing. For the core group of data scientists within RTL Nederland, collaboration with universities, universities of applied sciences and international peers is crucial. 'Participation in the yearly study week ICT with Industry is therefore only natural for us', Data Science Manager at RTL Nederland Daan Odijk states.

At RTL Nederland, everything is aimed at permanent learning, says Odijk. 'Fresh knowledge in a dynamic environment is vital to us. We have multiple reading groups, in which we follow the literature in specific fields together. ICT with Industry fits perfectly in that culture.' RTL Nederland has participated in ICT with Industry three times so far, Odijk says. 'We select cases for our long-term goals of automation in which man and machine can work together.'

The traditional task of broadcasting companies has been to reach mass audiences. Now the emphasis is shifting to meeting personal preferences on digital platforms. For that, you need data and AI', Odijk explains. The deployment of data and AI serves a threefold aim. 'We derive relevant knowledge from data to optimise our corporate processes. Think of the prediction of ratings, the optimisation of ad breaks and the right adjustment between ads, public and our movie supply.' The second aim is personalisation. 'Apart from linear TV channels, we operate RTLXL, RTL Nieuws, Buienradar, Videoland, programme websites and apps, making us one of the largest players in the Dutch digital market. We need AI on top of good quality data to create a personalised Videoland or RTL Nieuws for everyone.'

The third aim is related to this development. 'As ever more content is created for a smaller audience per content item, we need automation to keep costs sustainable', Odijk explains. 'One of our cases for ICT with Industry was automated trailer generation for Goede Tijden Slechte Tijden (GTST) based on flashback and preview recognition. Other examples are automated

RTL NEDERLAND

RTL Nederland is part of Bertelsmann AG, which was founded in 1835. The group has an annual turnover of 18 billion euros (2019) and employs about 140,000 people worldwide.

RTL Group is one of the most important divisions. Its commercial private television and radio channels include RTL and Vox in Germany, M6 in France and RTL4, RTL5, RTL7 and RTL8 in the Netherlands. Other divisions are BMG (music), Penguin Random House (publisher), Gruner + Jahr (printing and publishing), Arvato (media services) and Direct Group (book shops).

subtitle generation and the selection of thumbnail images on the basis of expected popularity.'

RTL also works on quality-related challenges. For example: a data science team is trying to establish a longer and more accurate AI-based forecast for the rain radar Buienradar, to better predict when and where it is going to rain. The present prediction is based on two radar station observations at 1,500 metres high. Very low hanging rain clouds are therefore a challenge. AI experts and meteorologists are now collaborating to derive more accuracy in space and time from the same radar data.

KEEN ON KNOWLEDGE

The RTL Nederland data science team consists of eight data and AI specialists. They have a diverse international background and half of them are PhD graduates. RTL hosts around five students at any given time who are working on their master's thesis. These students – and also other associated researchers – stem from virtually all Dutch universities. 'Apart from that, we also work with students from universities of applied sciences and with CLICKNL.'

One example of such a collaboration is DRAMA, which investigates how AI can be deployed responsibly in practice, with due respect for privacy. 'With its GDPR laws, the EU is an example to the rest of the world with regard to privacy. American companies have to comply if they want to operate in the European market. We

value the practical, risk-based approach of the EU to data and AI: if your activities don't pose a risk, your mitigation effort can remain limited. We are committed to diversity and so we are very keen to detect possible bias in our AI models.'

On top of all this collaboration with knowledge institutes, the data scientists also cooperate with their international peers within the RTL Group and its owner Bertelsmann. Odijk: 'We have an international AI expert group in which we share our experiences and tell how we deploy AI in daily practice. So all in all we have a lot of platforms to let knowledge flow.'



Daan Odijk

**'FRESH
KNOWLEDGE IN
A DYNAMIC
ENVIRONMENT
IS VITAL TO US'**



Preparing communication networks for the future

By Bennie Mols Images Ivar Pel



GROUP PASSPORT

RESEARCH FIELD

network security, wireless networks and mobility

INSTITUTION

Design and Analysis of Communication Systems (DACS), Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS), University of Twente

EMPLOYEES (as of May 2022)

3 full professors, 3 associate professors, 2 assistant professors, 13 PhD students, 7 part-time (assistant) professors / researchers.

WEBSITES

www.utwente.nl/en/eemcs/dacs/

people.utwente.nl/geert.heijenk

people.utwente.nl/s.bayhan

people.utwente.nl/r.m.vanrijswijk

The Design and Analysis of Communication Systems group at the University of Twente is a leading international research group in the field of wired and wireless networking, and internet measurement and security. Its aim is to contribute to a trusted and resilient internet.



Geert Heijenck

At this moment, a staggering 84 percent of the world population owns a smartphone and 63 percent has private access to internet. In barely two decades, communication between people has taken on a whole new, digital dimension. The same digitisation also enables more and more communication between people and devices, like smart home applications, and between devices themselves, like autonomous cars and industrial robots. The research group Design and Analysis of Communication Systems (DACS) at the University of Twente aims to prepare digital communication networks for a future with ever-increasing demands. The almost twenty-year-old group is presently led by professor Geert Heijenck and consists of about thirty people. 'On the one hand, we investigate how to make networks more resilient against sudden disturbances like power failures', tells Heijenck, 'and on the other hand, we investigate how to make networks more secure against digital attacks, like DDoS.'

Heijenck himself is researching wireless communication between cars and between cars and the surrounding highway infrastructure to improve the future traffic flow of fully or partially autonomous cars. 'The current autopilot of a Tesla car, for example, is very limited. In my opinion, autonomous driving can only be a real success when cars are able to communicate their plans with each other and with their surroundings.'

A relatively new line of research of the DACS group focuses on the ecological footprint of networks. Heijenck: 'Some researchers have predicted that by 2030, ICT applications will be responsible for 21 percent of the power consumption in the world. And about one-third of that is accounted for by networks. So there is a world to be won if we can make networks more energy-efficient as well.'

One of the characteristics of the group is that it has quite a few researchers who work part-time at DACS, mostly one day per week, and for the remainder of the week at another organisation, like SIDN Labs, TNO, NCSC or at companies like Nedap and Northwave. Heijenck: 'As a group, we have a strong focus on collaboration, both externally and internally. For example, many of our articles are not written by one PhD student and his or her supervisor, as is often the case in our field, but by a team of researchers from our group.'





Roland van Rijswijk-Deij



Suzan Bayhan

Measure what happens

Another key characteristic of the DACS group is the strongly empirical nature of its research. Roland van Rijswijk-Deij is an associate professor in the group who specialises in internet measurement. 'To understand how the internet works, it is not enough to look at the internet protocols used', he says. 'Humans run the internet, so you have to measure what actually happens on the web. We apply statistical and big data techniques to these measurement results to analyse the internet's functioning.'

Van Rijswijk-Deij and his colleagues have operated the largest DNS measurement in the world since 2015, allowing them to distinguish important trends. 'Some trends we have noticed are that an increasing amount of websites are hosted by fewer and fewer parties, that ever more parties have moved their email to the cloud, and that Microsoft has overtaken Google as an email provider.'

On a more fundamental level, the group analysed what happened when the security key of the Domain Name System was changed in 2018. Van Rijswijk-Deij: 'Such a change is a very risky operation that can easily disrupt the internet usage of half the world. We have learned many lessons through our measurements on how such a key replacement can be done in the future with the least possible risk. Our ultimate ambition is to make the internet as safe and as reliable as drinking water from the tap. To do that, we need to map out the internet even better with measurements.'

Design of wireless networks

Assistant professor Suzan Bayhan works in the second main research branch of DACS: wireless networks and mobility. 'I want to put resilience and energy efficiency into the core of the design of wireless networks', she says. 'We design better communication algorithms so that current and future applications can be served efficiently and with a lower energy footprint. Which users should be connected to which base stations? When should the network transmit data and when can it go to sleep?' Bayhan and her colleagues also investigate the resilience of the Dutch cellular network infrastructure. 'How robust is it against attacks? Where are its weak points?'

Before starting at DACS in 2019, Bayhan held research positions in Berlin, Helsinki and Istanbul, so she has some international places to compare. 'What makes our group unique', says Bayhan, 'is that it examines communication networks in depth, from its wireless components at the edge to the protocols at its core. And it combines expertise in measurements, security, and wireless networks. This extensive scope made it very attractive for me to join the group. Another important aspect that I have noted from my very first contact with the group is that the academic environment is very supportive. There is a lot of emphasis on achieving diversity and inclusion. This is not just written on paper, but I really experience it myself.'



Laura Hollink obtained a Master of Arts in Information Science with a minor in Urban Sociology from the University of Amsterdam and a PhD in Computer Science from VU University. After holding research positions at TU Delft and VU University, she came to CWI in 2015. There she has been leading the Human-Centered Data Analytics group since the winter of 2021.

DIVING INTO CULTURAL DATA

Help the culture and media sector in the Netherlands to make optimal use of innovations in data science and AI. That is what drives the work of Laura Hollink, group leader of the Human-Centered data science group at CWI. 'Since the cultural sector upholds high moral standards, it is the perfect context to research how AI and data science impact real people in the real world.'

By Sonja Knols

Image Ivar Pel

What is your group's research about?

'Our main research question is how to responsibly apply AI and data science in the culture and media sector. That sector is characterised by high ethical standards and clear moral principles. We translate those high-level principles like inclusivity or transparency into demands for the AI pipeline. And we evaluate to what extent certain data science methods can help cultural heritage organisations achieve their goals.'

What kinds of topics do you study?

'One of our projects is on the use of controversial terms in cultural heritage collections. Since those collection datasets may be the basis for AI systems that produce automatic descriptions or query extensions, it would be good if we could automatically detect at a large scale which terms are controversial given the context that they are in. A second project is about evaluating the inclusivity of a recommender system for libraries, assessing for example whether or not it favours authors from a specific gender or origin.'

Could you name any striking results?

'In a study on the online newspaper archive Delpher, we were able to identify distinct search patterns depending on people's interests. We discovered that people looking for World War Two-related subjects use very complex search behaviour, whereas people interested in their ancestry typically have

short sessions with only a couple of simple queries and very few clicks or downloads. These results lead to recommendations to digital archives on how to best support the different search behaviours of their users.'

What is the biggest challenge in this field?

'Combining heterogeneous and often cross-media collections, data modelling, and semantic search. Our data consists of physical objects, short pieces of texts in natural language, newspapers, audiovisual archives. And they do not always completely meet our purpose. For example, we have data about which people read which books in the book recommender project. But we do not have any information about the authors. Therefore, a lot of our work involves finding smart ways of combining datasets to distil the information we need.'

Your group is part of two larger-scale research labs. What is their added value?

'Both the Cultural AI Lab and the AI, Media and Democracy Lab bring together different scientific disciplines and societal organisations to collaborate for the longer term. That allows us to build a deep mutual understanding for each other's language, challenges and expertise, which is essential if you want to realise genuine impact.'



PROTECTING POWER GRIDS AGAINST CYBERATTACKS

By Bennie Mols Image iStock

Alex Stefanov from TU Delft just has started an NWO-funded five years research project on making power grids more resilient against cyberattacks.

In December 2015, Ukraine's power grid was hacked, presumably by a Russian state-supported hacker group. Over two hundred thousand citizens were left without power for hours. Cyberattacks on electricity networks are constantly happening worldwide, but most of them are nipped in the bud and never make it to the news.

Alex Stefanov, a TU Delft assistant professor of intelligent electrical power grids, is leading a five-year research project with the aim of making power grids more resilient against such cyberattacks. The project, called RESCUE (Resilience and cybersecurity of integrated cyber-physical energy systems), started in January 2022 and will run till the end of 2026. After the Russian invasion in Ukraine and the resulting high geopolitical tensions, the project suddenly became far more relevant than it already was.

Three challenges

'It has been demonstrated that cyberattacks on power grids are possible and critical', says Stefanov, 'and only state actors have the power to carry them out. The next question is what to do about them.

In RESCUE, we focus on three main research challenges: How do we detect cyberattacks on power grids? How do power grid operators and cybersecurity experts respond in a technical sense? And finally: how do the incident responders react in a human sense, especially while being under stress?'

Each of these challenges will be studied by a PhD student, says Stefanov. 'One PhD student is going to work in my team at TU Delft and will focus on intrusion detection and stopping the attack by using a digital twin of the power grid.' This digital twin runs on a special facility that was opened in October 2021: the Control Room of the Future. It is an ultramodern facility that can simulate any disruption to the power grid in a controlled research environment, from lightning strikes to cyberattacks.

A second PhD student will focus on incident response by studying dynamic security games: how do cyberattackers and cyberdefenders react to one another, as if they are playing a kind of chess game. This PhD student will work with cybersecurity and intelligent systems experts at CWI.

A third PhD student is going to focus on the side of human factors. 'Power grid operators are generally overwhelmed by all kinds of alarms', says Stefanov. 'An important question then is how to train the grid operators to take good decisions

under stress. The PhD student who will study this question is going to work at the TU Delft Faculty of Technology, Policy and Management.'

'AN IMPORTANT QUESTION IS HOW TO TRAIN THE GRID OPERATORS TO TAKE GOOD DECISIONS UNDER STRESS'

In five years' time, Stefanov hopes to develop advanced mathematical and computational foundations to detect cyberattacks on power grids and respond to them. He also wants to develop open source software for this detection and response. This software should be ready for industrial partners to take it over and turn it into a commercial product.

Finally, by the end of the project, Stefanov wants to bring grid operators and cybersecurity experts together in the Control Room of the Future: 'By using a simulation environment for cyberattacks that we will have developed by then, we want to let them work together on responding to a cyberattack. Normally they each have their own control centre. We want to bridge the gap between them in order to improve the resilience of the power grid operation.'

More information

RESCUE video explainer:
www.tudelft.nl/2021/ewi/ese/iepg/alex-stefanov-explains-his-rescue-project-funded-by-nwo

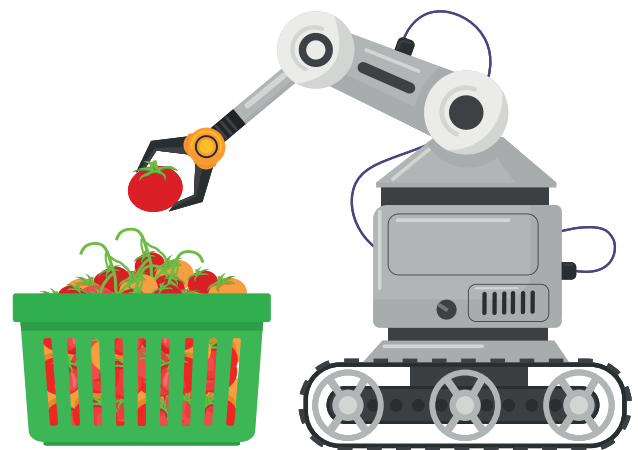
GRASPING THE NATURAL ENVIRONMENT

Picking up a bag of crisps or a slippery chicken fillet is a real brain teaser for a robot. An ambitious, multidisciplinary research team is working on versatile robots for the agriculture and food industry that can deal with natural variation. ICT plays a key role.

By **Amanda Verdonk**
Images WAT ontwerpers

Working in the food industry is not always pleasant. In some cold stores, for example, the temperature is only just above freezing, while in greenhouses, it can be very warm and humid. It is often monotonous and physically demanding work. Food producers therefore struggle to find sufficient personnel. The sector is eagerly looking for robotics solutions to perform repetitive work. Think of robots that pick tomatoes, place chicken fillets in a tray or put packaged biscuits in boxes.

But finding the cutting point of a tomato truss among the leaves, or grabbing a bag of crisps without crushing it, require actions that robots still have great difficulty with. Robotics are already being used in many industrial processes, but agriculture, horticulture and the food industry are lagging behind because of technical challenges. 'Variation is the major bottleneck', says Eldert van Henten, Professor of Biosystems Engineering at Wageningen University and Research. 'No two tomatoes are the same. Robotics works fine if action and objects are the same every time. Food, however, has a huge variation in shape, size, colour and texture, and that is a big challenge.'



'Food has a huge variation in shape, size, colour and texture, and that is a big challenge'

WORLD MODEL

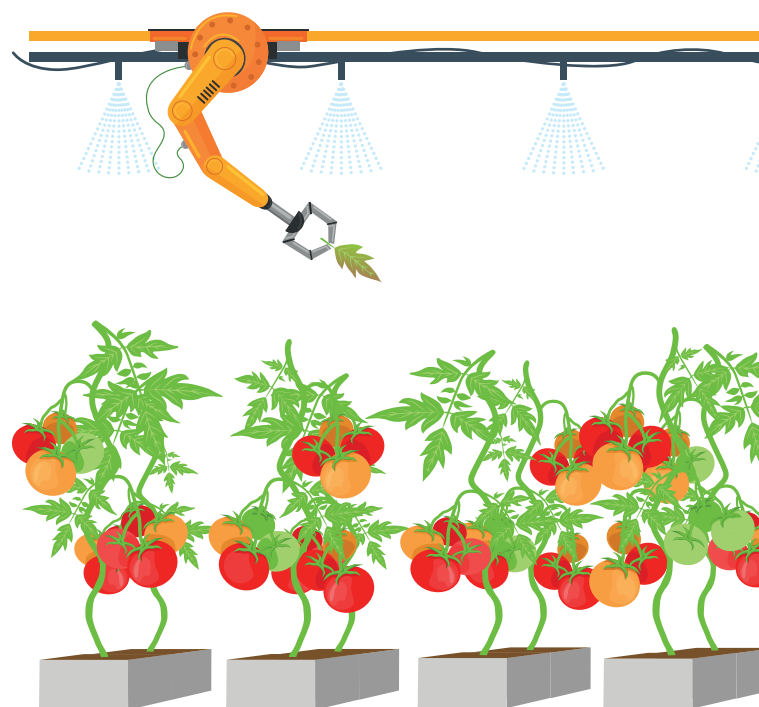
With a large research programme in which five universities and fourteen companies collaborate, Van Henten aims to accelerate automation in the agriculture and food industry. He has been leading the FlexCRAFT Perspectief programme since 2019. The foundation for the programme was already laid about ten years ago, says Van Henten, when he contacted the Mechanical Engineering department of Eindhoven University of Technology. 'At Wageningen University, we know the food sector very well, and we are good at transferring technology to the sector. Eindhoven has a stronger technology base.' Earlier versions of the programme were rejected by various funders, however. 'At the time, people thought it was technically too ambitious. But in 2018, it suddenly fell into place. In the meantime, great advances have been made in the fields of deep learning, vision, sensors, algorithms and control in the automotive and medical sector. We can now build on that.'

'Researchers come up with radical new ideas. That surprises us and creates a nice interaction'

Automating the food industry is largely an ICT challenge, says Van Henten. 'Until five years ago, robotics in this sector worked with a so-called single-shot approach: a robot made a recording of its environment, extracted relevant information, planned a movement with an arm and tried to grab, cut or manipulate something. That's it. If the action didn't work, the robot often didn't even know it.' A new element in FlexCRAFT is "active perception", which allows the robot to continuously acquire new information during the action. 'Before, the knowledge gained by previous actions was thrown away. Now we try to store that in a mathematical model, a so-called world model. A robot then learns, for example, that not the leaves but the truss of tomatoes is interesting. It stores the location of the truss and remembers it for later actions.' The research team is also working on so-called pre-planned motions, so that algorithms do not have to completely recalculate every robot's movement. By drawing on a library of stored actions, the robot, like humans, uses a kind of muscle memory to quickly find the best way to pick up a cookie, for example. Researchers in Delft are working on generating these motions for such a library, using demonstrations of human motions.

SEASONAL PRODUCTS

One of the companies involved in the programme is Marel, a manufacturer of machinery for the food processing industry. The company is looking forward to further automating the processing of poultry – from cutting and sorting to packaging. Marel has already made a gripper that is able to roll chicken fillets slightly and place them in a yin-yang shape in a tray. According to Allard Martinet, Director Logistics and System Engineering at the company, seasonal products are more difficult as supermarkets demand short delivery times. 'When the weather is nice,



ABOUT FLEXCRAFT

The NWO Perspectief Programme FlexCRAFT (Cognitive Robotics for Flexible Agro-Food Technology) was launched in 2019 with a budget of 4 million euros. The programme focuses on flexible robot technology for food production. Five universities are involved, namely Wageningen University and Research, Eindhoven University of Technology, University of Twente, TU Delft and University of Amsterdam. Fourteen companies are involved in three use cases concerning the greenhouse, food processing and food packaging. The programme ends in 2023.



a supermarket wants to have BBQ skewers as soon as possible. But marinating cubes of meat, threading them on a skewer and placing them in a tray is still all manual work.' Marel already has machine learning algorithms running in their machines, but notices that they cannot deal with natural variation. The company is involved in all parts of the research programme and has an employee stationed in Wageningen. In addition to optimisations Martinet also hopes to gain radically new ideas from the programme. 'We are mainly focused on our existing grippers, but the researchers come up with radical new ideas, such as a harpoon-shaped gripper. That surprises us and creates a nice interaction. We hope the programme will generate a number of concepts that we can further develop to provide a solution for our customers.'

Corona has frustrated the programme considerably because many physical meetings were cancelled in recent years. Van Henten: 'We have set the bar very high for ourselves because we want to connect all researchers in all sub-topics. We therefore organise hackathon-like integration workshops every six months,

where we work on demonstrations. Robotics is not just a matter of programming; you also have to do it hands-on, on-site. Fortunately, that is now finally happening. The postdocs associated with the three use cases have succeeded in involving all researchers from the various domains. A unique collaboration has now blossomed that I had not experienced in other research programmes before.'



BACKBONE FOR FUTURE INTERNET

By Amanda Verdonk Image iStock

Although 5G has barely been rolled out in the Netherlands, scientists are already working on the sixth generation of wireless communication networks: 6G. This requires completely new antennas. Bart Smolders, Professor of Electromagnetics at Eindhoven University of Technology, explains why.

'All wireless communication systems use antennas. For example, your smartphone contains about twelve for cellular communication, GPS, Wi-Fi and Bluetooth. There are about five in your car and several in your wireless home devices. Antennas are also connected to cell towers. Once we have the fifth generation (5G) of the communication network, the number of antennas will only increase. 5G, which will be rolled out in the Netherlands in the coming years, has three main goals. First, higher data speeds, or rates: from megabits to gigabits per second. Second, low latency, in other words: little delay and fast response times of only a few milliseconds. And third, low power consumption, allowing sensors to operate without batteries. Scientific research into 5G technology has almost been completed. 6G is an extrapolation of 5G; it should deliver data rates of up to one terabit per second. It is anybody's guess what the exact applications will be, but you can think of self-driving cars, robots and drones. These require high data rates and low latency. In the case of a self-driving car, not a single thing in the environment should escape its attention.'

Antenna-on-a-chip

'The first worldwide standard for 6G is expected in 2030, which is a description of what that system should look like. We hope to contribute to that standard with our research. Higher frequencies in the radio spectrum are needed to achieve higher data rates. And the higher the frequency,

the more bandwidth becomes available. Developing these new antenna systems is still difficult to achieve in practice. More and smaller antennas are needed. Not only the large ones on cell towers and buildings; you could also find them on bus shelters and lampposts in the future. And in your smartphone, car and home devices.'

'Our Electrical Engineering department is working on a new generation of antennas needed for 6G. We call them software antennas. Antennas that are now used in 4G and 5G have a wide viewing range, within which they can receive and send signals. Antennas operating at higher frequencies have a much narrower viewing range. This could cause them to overlook users. That is why software antennas are required to electronically adjust the viewing direction and to be able to continuously keep track of users. As a result, such an antenna system contains dozens of chips and antennas. We are investigating how we can develop an integrated antenna-on-a-chip in which the chips are inter-related so they work as efficiently and energy-efficiently as possible. Energy consumption is a tricky issue because chips that work with high frequencies still consume a lot of energy and a lot of chips are required to form an antenna system. In prototypes, a fan is also needed to cool the chips, which we do not want in future applications. We are investigating how to optimise this.'

Giant development

'Once the new antenna system is developed, a new challenge will arise: how can you measure its performance? And how can chip producers do this in a fast way that fits in high volume production processes? Such measuring equipment does not exist yet. This is a completely new domain; no one has all the answers. The software antenna will soon enable millions of different settings. What are the most important parameters for performance? This giant development of software antennas will keep us busy for the next twenty years. My department is one of the largest in the Netherlands in the field of 6G technology. At the University of Twente, work is ongoing on new chip architectures for areas such as energy-efficient sensors for the Internet-of-Things applications. And at TU Delft, a research group is working on antennas for even higher frequencies in the Terahertz spec-

trum. Their technology is mainly used for space research but may someday become interesting for 6G or 7G. For example, for data-intensive places, such as a busy factory or airport.'

'How many generations will there be after 6G? Maybe one day, we might be using all of the available frequencies. 5G will already make Wi-Fi and glass fibre more or less redundant, at least in a densely populated country like the Netherlands. At a certain point, the infrastructure is so good that further development, and the associated large investments, might become uninteresting. But that is difficult to predict. It depends on how intensively we will actually use all the new possibilities, some of which we cannot even think of today.'



'6G should deliver data rates of up to one terabit per second'



Richard Boucherie is Professor of Stochastic Operations Research at the University of Twente. His research topics include queueing theory, Markov decision theory and probability theory with applications in healthcare logistics, (tele)communications network design, traffic, transport and manufacturing systems. He is co-founder of the Center for Healthcare Operations Improvement and Research (CHOIR) and of Rhythm BV.

ENLARGING THE PIE TOGETHER

By **Leendert van der Ent** Image Gijs van Ouwkerk

Richard Boucherie, chairman of the Dutch Platform for Mathematics (PWN) pleads for more collaboration between his platform and the ICT Research Platform Netherlands (IPN). 'Computer science and mathematics have drifted apart somewhat. But we often work on two sides of the same coin.'

'Where computer science excels in the applicability of its results, mathematics emphasises the underlying proof of its results. We complement each other seamlessly. Take my research, where I provide decision support under uncertainty in healthcare. Think of data-driven prediction of IC bed occupancy over time during the COVID pandemic. Our operations research methods are akin to data science, at the intersection of mathematics and computer science.

Computer science projects often spring from applications with a clear call for more fundamental research. That is where we could build bridges to our mutual benefit and add our own nuance and flavour to the same topics. We could strive for better integration of the entire shared chain from fundamental knowledge to practical implementation, combining mathematics and computer science. Together we can make the pie for research funding bigger.

It is definitely not just my own field at the intersection of theoretical computer science and operations research where mathematics and computer science meet with ample room for collaboration. The same applies to AI, quantum computing, coding theory, scientific computing, and many other areas.'

ORGANISATIONAL COLLABORATION

'Apart from collaboration in research projects, both platforms could also work together on the organisational level. We are currently both drawing up a sector plan, which is a major operation. Admittedly, not all challenges in our fields are the same. For example, in mathematics, we don't face the same pressure on teaching as in computer science. But we do have shared research areas, shared assets such as CWI, and shared challenges, such as the call in society for our graduates and (early) career challenges of our staff. We could address such challenges together.

Over time, both fields have drifted apart. Our mutual interests mean that now is a good time to move closer again. PWN has valuable experience to offer. We represent the entire field of mathematics, including the mathematics curriculum in secondary education. IPN could benefit from our experience and contacts to support further development of computer science education at secondary schools.'