DELFT OUTLOOK
NO. 3 | OCT 2018 | YEAR 35
TU Delft

Best Professor Cees Dekker

'Awe is what drives me in my research'

HOW TO BUILD ONE MILLION ADDITIONAL HOUSES?

Why we are building a quantum computer

THEME
Artificial intelligence

Cover:
The quantum computer looks like a large dense metal tube, hanging from the ceiling to a meter above the ground. The inside looks a lot more exciting, too bad that this is not visible when the computer is in operation. (Photo: Sam Rentmeester)

Editorial
Saskia Bonger

Artificial intelligence

A self-driving car performs an emergency stop after sensing a bump in the road. Another car crashes into its rear. Who is to blame for this accident: the road builder, car manufacturer, software supplier, tailgater? This is one example of the complex issues that arise when using artificial intelligence, to which we will return later in this edition. Make no mistake: self-learning systems are not only the future, they are here already. Social media is alive with self-learning algorithms, there are self-driving cars in the US, facial recognition programmes in China and computers processing our insurance claims. Alongside applications such as transformable apartments and flying robots, this edition particularly focuses on the ethics behind artificial intelligence. We asked TU researchers to look at the issue, but also alumni like yourself. This resulted in interesting conflicting opinions. Some of you see AI as a black box that is incomprehensible and difficult to control, while others have every confidence in legislation and human intervention to ensure that we remain on top of self-learning systems. All experts agree that transparency is vital if the public are to gain trust in AI. And transparency is therefore also a key concept within AiTech, a new TU Delft research programme. After all, Delft wouldn't be Delft if we didn't try to tackle problems. Or as one of the AiTech founders describes the job of the university: "Not just to issue warnings; but also to develop solutions."

Saskia Bonger, editor-in-chief

PHOTO: SAM RENTMEESTER

Page 07
Artificial intelligence

03

COLOPHON
Cover photo Sam Rentmeester
Editorial staff Saskia Bonger (editor-in-chief), Dorine van Gorp, Katja Wijnands (managing editors), Tomas van Dijk, Sam Rentmeester (image editor), Connie van Uffelen, Jos Wassink
T +31 (0) 15 2784848,
E-mail delftoutlook@tudelft.nl
Contributing writers Martijn Engelsman, Auke Herrema, Desiree Hoving, Christian Jongeneel, Tonie Mudde, Roos van Tongeren, Stephan Timmers
Design Maters en Hermsen
Typesetting Liesbeth van Dam
Printing Quantes
Subscriptions
delftoutlook@tudelft.nl

Delft Outlook is the magazine of TU Delft

DELFT IN BRIEF

Another win for Nuna

They could hardly believe it, but after suffering a series of setbacks, the Delft Nuon Solar Team won the Sasol Solar Challenge in South Africa. Lasting 8 days, the biennial race ran from Pretoria to Stellenbosch. With 4,030.40 kilometres, the Nuon Solar Team covered the greatest distance. The Japanese team Tokai, their main rivals from the outset, travelled 3,941.4 kilometres. The last two days of the competition were particularly exhausting. The electrical system played up, and the Japanese team accused the Nuna team of spying.

Fly like a fruit fly

Experiments with the Delft robot insect DelFly Nimble revealed the secrets of fruit flies' manoeuvrability. Once researchers controlled the 29-gramme robot, they programmed it to simultaneously rotate along the longitudinal and transversal axes. During a rapid, banked turn, the Nimble suddenly also turned around the vertical axis: a third orientation. The researchers concluded there is a passive aerodynamic effect at play, which couples torques over orthogonal axes. This effect helps fruit flies to stay in control while making sharp, speedy turns. *Watch the video via the QR-code.*

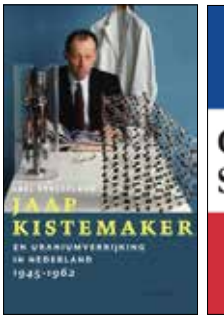
Owee

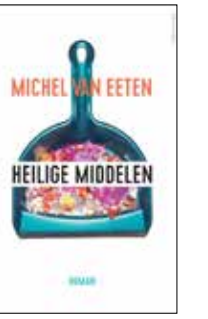
Late this August, some 3,400 new arrivals flooded the Delft campus for OWee, the traditional introduction week. For the first time in 45 years, the event featured a joint programme for Dutch and international students.

New microorganism

'From an evolutionary perspective, this is akin to discovering a new mammal'. Professor of biotechnology Mark van Loosdrecht (AP) is unequivocal about the significance of his colleague Dimitri Sorokin's recent discovery. Sorokin, who divides his time between TU Delft and the Winogradski Institute for Microbiology in Moscow, studied the microbiology of Siberian soda lakes and discovered a completely new class of microorganisms. These organisms grow in sodium carbonate brines with a pH of 10 and convert organic material into methane gas. Earlier this year, Sorokin successfully cultivated the microorganisms responsible for this process in the lab. He called them *Methanonatronarchaeum thermophilum* and *Candidatus Methanohalarchaeum thermophilum*.

Reading material





- It is common knowledge that the Netherlands is an international superpower in the field of uranium enrichment. In his book Jaap Kistemaker and Uranium Enrichment in the Netherlands 1945-1962 (title translated from Dutch), university historian Abel Streefland describes how this came to pass. An adaptation from his dissertation, the book outlines an intriguing period in history in which technology and politics were intertwined.
- Professor Andy van den Dobbelsteen also published a book this summer, albeit in a completely different genre. He witnessed the arrogance, but also vulnerability, of Dutch holidaymakers on a French campsite and penned the thriller Campingsmoking (Campsite Dinner Jacket), in which all does not end well for everyone.
- And finally, cyber professor Michel van Eeten wrote Heilige Middelen (Sacred Remedies), a novel about the choices made by protagonist Ludo, who discovers that not everything in life needs to have a point. 'Well written, packed with fine sentences and lots with intrigue until the final page', is how Delta summed it up.

Making sailing exciting

The Sailing Innovation Centre (SIC), a collaboration involving researchers from Delft Sailing, is working to make sailing more accessible to a wider audience and help introduce more advanced technology into the sport. Earlier this year, the European Union awarded the SIC a subsidy of more than €4 million to help establish an open-air laboratory in the North Sea to research sailor-supporting technology. The lab also plans to develop visualisation technologies that make sailing more exciting for spectators back on dry land, such as video streams from drones and augmented reality.

Listen to non-existent sounds

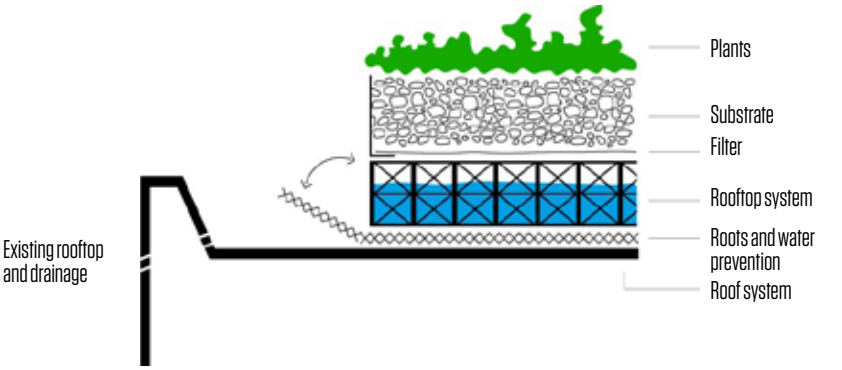
What will a wind farm sound like? Or a new type of train soon to race along the tracks? For his doctoral research at EEM&CS, electrical engineer Dr Reto Pieren developed a calculation method called 'auralisation' (analogue and visualisation), which enables him to simulate sounds that do not actually exist. 'I can use my models to simulate the sound of future wind farms. The model can take various scenarios into account.'

Human Power Team wins

This September, students from Delft and Amsterdam left the competition for dust with their self-built aerodynamic recumbent bike during the annual race in Nevada (USA). Lieke de Cock achieved the winning top speed of 120 km/h in the VeloX8, although the world record remained out of reach. The current holder is Barbara Buatois, who reached a speed of 121.8 km/h in 2010. This year, the team participated with their VeloX8, an aerodynamic recumbent bike tailor-made for the cyclists using 3D scans. A newly-designed gear system was used in order to save space.

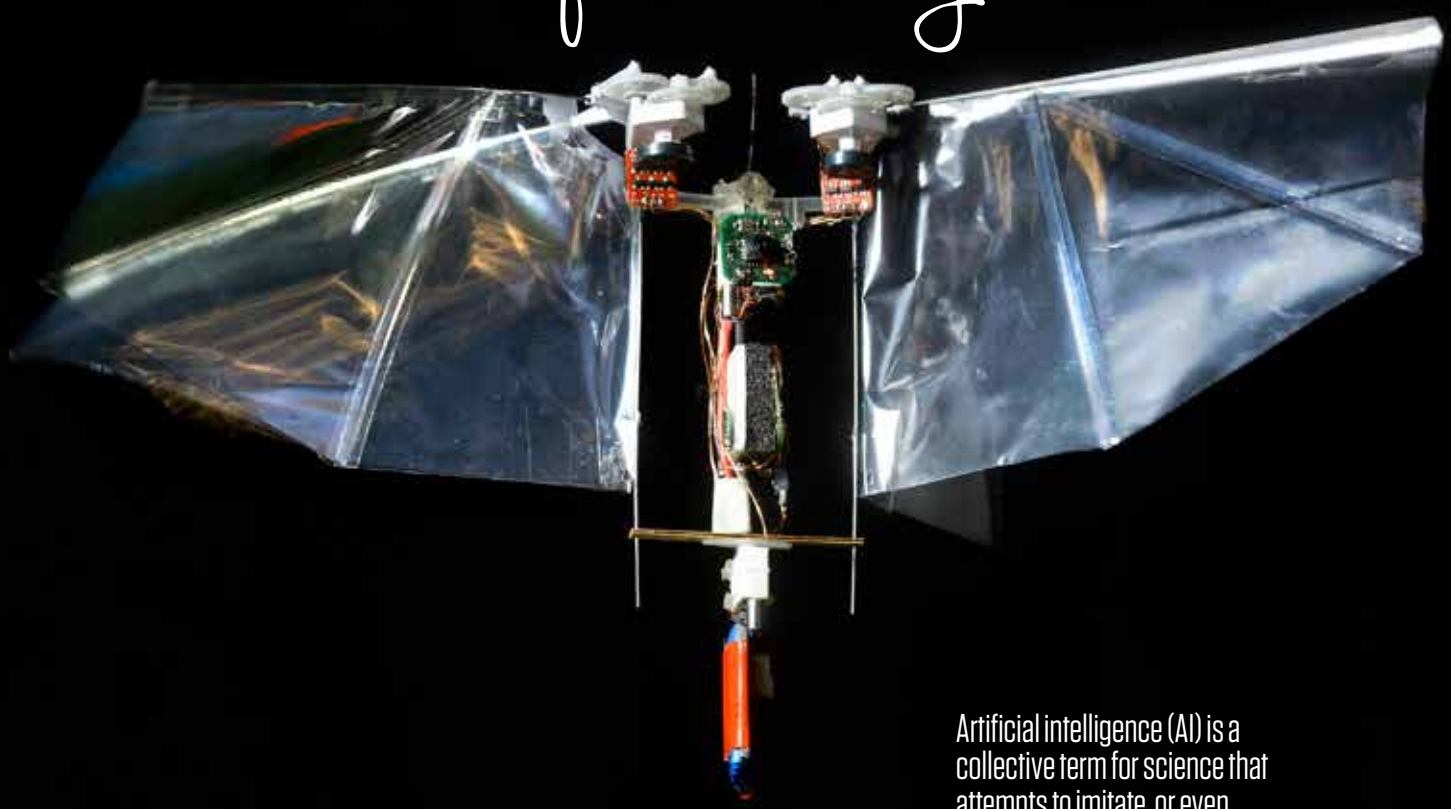
Green roof on CEG

Following the installation of a 500m2 'green roof', researchers can now conduct water management research atop Civil Engineering and Geosciences. The roof was fitted on top of a 60mm deep layer that stores rainwater. This water buffer, directly beneath the green roof, makes it possible to grow agricultural crops. Researcher Olivier Hoes plans to record precipitation levels, the temperature on and just below the roof, wind speed, UV rays, water drainage and the lecture hall ceiling temperature. Hoes also wants to research the possibility of farming close to homes.



THEMA

Artificial intelligence



Artificial intelligence (AI) is a collective term for science that attempts to imitate, or even surpass, human intelligence using computers. Devices become self-learning or self-organising to be able to make decisions without human intervention.
This photograph shows Delfly, a flying robot weighing just 29 grams. Specific algorithms enable it to orientate and navigate independently using camera images.

PHOTO: SAM RENTMEESTER

Human control of artificial intelligence

How can you design autonomous systems like robots, self-driving cars or IT systems to be transparent and always open to human intervention? This is the question that eight post-docs from four faculties will spend the next two years working on. Welcome to AiTech.

'Computer says no.' About ten years ago, the makers of the TV series Little Britain signalled the advent of artificial intelligence in the service industry. In those days, artificial intelligence was also dubbed artificial incompetence because of the incomprehensible decisions made by the software systems, or because of automatic carts getting stuck in the complexity of the traffic. It was funny. But that was then.

Two years ago, the VSNU (Association of Universities in the Netherlands) launched the Digital Society research programme in answer to the omnipresent digitisation that was unsettling society. Then-Rector Magnificus Karel Luyben contacted Prof. Inald Lagendijk (Computing-based society, EEMCS) and Prof. Jeroen van den Hoven (Ethics of information technology, TPM) to see whether and how TU Delft could play a role in the research programme.

While walking around the campus, Lagendijk and Van den Hoven saw just how much artificial intelligence and autonomous systems was already being used. Applications included both pure software such as decision support programmes, as well as embedded programming in robots, virtually self-driving cars and in drones. Although the researchers they spoke to were enthusiastic, in-depth questioning revealed that most of them weren't entirely sure how such an artificial brain worked. Or what the effects of errors in input or processing would be.

Ethical questions

Lagendijk explains: "Everyone faces the same questions: how can I keep control? How do I understand what's going on? How can I justify the decisions the system makes? All kinds of legal, ethical and social questions arise, which lots

WHAT MAKES HIM SO SPECIAL?

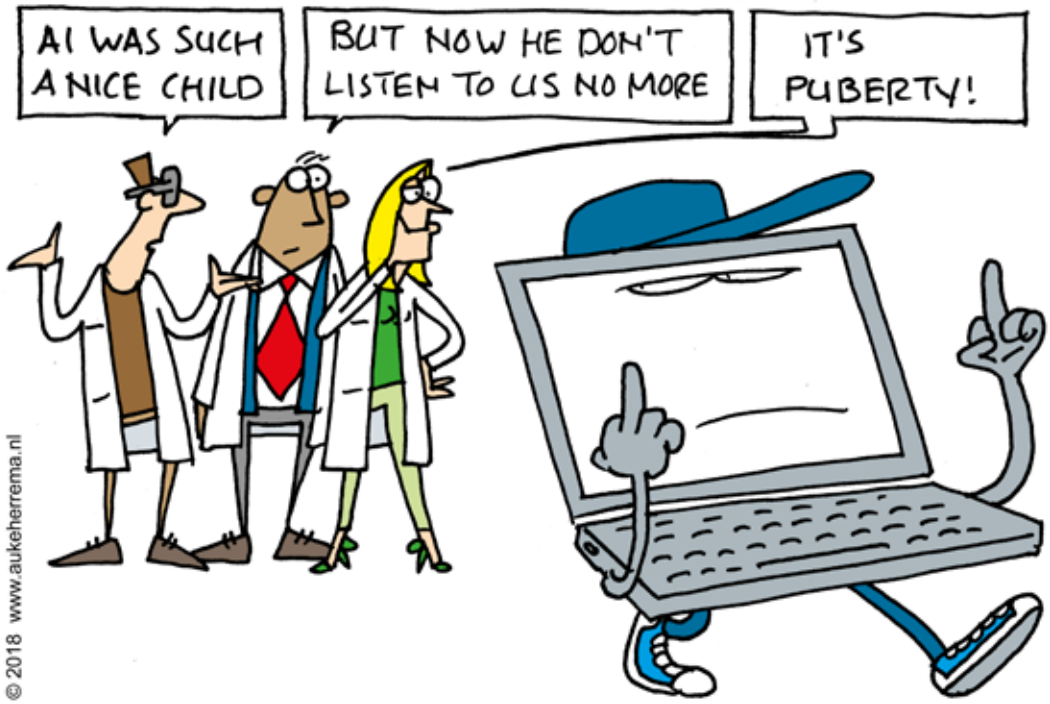
In the not-too-distant future, your electric car won't automatically charge when you connect to a charging station. The capacity is insufficient and the cables aren't thick enough. So who has priority? The person with a plus-subscription, the neighbour who's a doctor, or the woman over the road who starts work early? How does the system decide, and how can you convince users that the system is acceptable and fair? This is the field of Prof. Elisa Giaccardi, who teaches interactive media design at IDE.

WHO IS RESPONSIBLE?

A bump in the road causes a self-driving car to make an emergency stop. It brakes so suddenly that the car behind hits it. Who is responsible? The company that built the road, the car manufacturer, the software developer or the driver of the second car? Questions like this will become increasingly important. Van den Hoven is promoting a system of tracking (knowing what the user wants) and tracing (working out what happened afterwards) to keep control of autonomous systems. Prof. Bart van Arem wants to apply these terms during the transition from driving yourself to self-driving.

A DISCREET HELPING HAND

A navigation aid for people with visual impairment, that is flexible enough to help someone catch a bus one day and cross the road the next. This is an example of a Socially Adaptive Electronic Partner (SAEP), which Dr Birna van Riemsdijk (EEMCS) is currently working on. The underlying software must be flexible enough to adapt smoothly to deviations in unforeseen circumstances. Because you usually go home to sleep, but not always.



HUMAN CONTROL OVER ARTIFICIAL INTELLIGENCE

of people are working on. Institutes impose codes of behaviour along the lines of 'thou shalt...', but little attention is given on how to technically achieve it through research, design and engineering."
This is now the focus of TU Delft's contribution to the AiTech research programme: technical measures designed to safeguard human control of autonomous systems. The team was reinforced by the addition of Prof. Elisa Giaccardi (IDE) and Prof. Martijn Wisse (3mE), with Dr Luuk Mur as secretary.

Built-in control

For the next two years, eight post-docs from the Faculties of EEMCS, TPM, IDE and 3mE will conduct research into the meaningful human control of artificial intelligence systems. They will divide their time between two faculties and the AiTech Centre based on the Construction Campus. Half of the € 2 million funding has been allocated by the Executive Board and the other half by the faculties concerned.
The researchers, who are currently being recruited, are asked to supplement their applications with a research proposal that meets three criteria. The project must contribute to raising awareness of human control of applied artificial intelligence. The researcher must draw up criteria for what the human control entails in this particular case, and be able to quantify it. Finally, the research must lead to a technical application.

Open character

The open strategy chosen by AiTech is known as 'mission-driven research initiative'. Devised by the British economist Mariana Mazzucato as an innovation model, the programme focuses on a distant goal but allows researchers to plan their own path. Including, and particularly, when competing with each other. Lagendijk and Mur also stress that other people can take part in AiTech. The initiative is open to anyone connected with the field. The open character will probably take shape in lectures and other gatherings.
What results does Lagendijk expect in another two years? "I'll be delighted if we have four or five examples in which we've de fined meaningful human control more clearly and built it into technical systems." TU Delft hopes that AiTech will give direction to government and corporate bodies intending to implement artificial intelligence, but perhaps unaware of the long-term implications. According to Lagendijk, this is the task of the university: "Not just to issue warnings; but also to develop solutions." JW

'Businesses aren't advertising their

How do professionals see the future of artificial intelligence and the role that TU Delft can play? We asked two alumni.

'People will still have to make the decisions'

MARIELLE DEN HENGST
Project leader (representing the police) of the Real Time Intelligence Lab (RTI lab)
Degree in computer sciences (EEMCS), PhD in TPM

'The RTI lab is a collaboration between the police, TNO and the HSD (Hague Security Delta, ed). We support security organisations when updating real-time intelligence, and experiment with new methods and techniques, including AI. We always take account of different perspectives: what does AI mean to people or processes, what are the technical issues, and which legal and ethical questions arise? The police always want to use the latest technology, so we experiment to learn more about the next step. Take imaging, for example. The Netherlands is full of security cameras. Can you use AI to detect deviant patterns in all the image material they provide? There's another new technique that could be used in the control room. When every second counts, you need to quickly understand what's going on. But what if someone is speaking a different language? Could a computer interpret the situation swiftly through its ability to learn from previous calls and understand many different languages? There are numerous examples of how AI can assist us, mainly because it can base itself on enormous data sets. But AI is also a challenge, particularly for the police. Take algorithms that can calculate the risk of a criminal career. How can you make a system like this competent and transparent, without bias (prejudices, ed.)? How can you expose the reasoning of a system and prove that it isn't biased? It's for challenges like this that we need institutions like TU Delft.

This is a big step, for the police too. We're an organisation that likes doing things, while a university works towards long-term knowledge development. Luckily, the police know that knowledge and innovation are essential and both worlds are gradually converging.'

REINOUD KAASSCHIETER
AI specialist at Capgemini consultancy agency
Degree programme: Industrial Design (IDE)

'I focus on knowledge acquisition and knowledge use within organisations. AI is a way of extracting knowledge from data. At Capgemini, we mainly use practical AI solutions that work now: self-learning online product recommendations, fraud analysis of documents or processing damage reports. In the end, trust will determine whether AI is accepted or not. People and businesses want to know what a system does, but AI is a black box. Social media like Facebook and security systems are full of intelligent algorithms. China uses automatic facial recognition for its population. What happens if there's a false recognition, or if the system starts selecting on the basis of gender or skin colour? It's impossible to recall why a self-driving car made a particular decision among all those thousands of lines of code, partly because the codes influence each other. AI doesn't know enough about

use of ai'

'Ai is a black box'

PHOTO'S: SAM RENTMEESTER

the world around it to place decisions in a context. AI is 'autistic'. This is reinforced if biases slip into the systems. The ethics governing AI are highly complex, particularly because AI systems are self-learning and change their behaviour over time. For now the consequences are usually easy to gauge as most businesses use AI for small processes and sub-systems. But this will change in the future. Is it up to me as a simple employee to say that I think that an expensive, self-learning system was wrong in rejecting an application? I'm more afraid that the opposite will happen. That we'll put blind trust in artificial intelligence, as we do other technology. People will think: if the system says so, it must be right. AI is being accepted faster than society wants. Our current discussions are too late. We need ethical, empathic artificial intelligence. Universities in Europe must take ownership of this debate at an interdisciplinary level. AI isn't a hype and is already present in many systems. Businesses aren't advertising this fact, for fear of negative publicity if things go wrong.'

SB

How do care robots learn?

"Care robots have to learn from their mistakes, only then can they work together with humans," says prof. dr.ir. Pieter Jonker (biomechatronics & human machine control, 3mE) in a video.

Because they have to perform various tasks, like picking up things and reminding patients to take their medicine, they have to be intelligent. Jonker uses the method of declarative learning, just like babies do. By looking, they learn to recognize objects, and so they build up an entire database of objects. Then they learn how to pick up such an object. This learning process involves trial and error, or reinforcement learning. You learn what they have to do and reward them for it. Then they learn how they should do it themselves. After about 40 hours they can do it.

Have **neural networks** gone beyond our understanding?

Artificial intelligence has seen an enormous growth spurt with the application of 'deep neural networks'. Such networks are taking over more and more tasks from humans in a nearly unparalleled manner. But who still understands how they work?

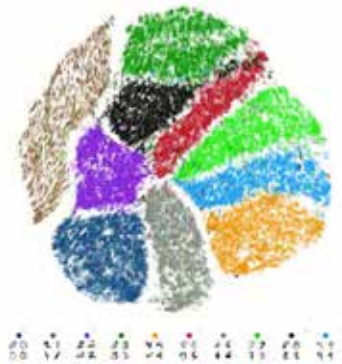
Neural networks are being used increasingly often and with increasing success. For example in driverless cars, medical diagnosis, the board game 'GO' or recognising animals in pictures. Rather than programming a computer explicitly for a certain task, researchers let deep neutral networks (DNN) figure out for themselves what the typical characteristics are of the input and tell us what this input means.

This usually concerns big data, and is always about high-dimensional datasets. Because each pixel is a variable, photographs, for instance, easily have tens of thousands of dimensions. Medical data, such as the results of a gene expression test, are high-dimensional as well.

People understand the input and output of a neural network. But its inner workings are a black box. It feels unsettling to have computers make judgements in a way that we ourselves do not understand.

Improving the algorithm

Nicola Pezzotti, TU Delft doctoral candidate in the Computer Graphics and Visualisation group (Faculty of EEMCS), did a work placement at Google. There, he improved the algorithm (t-distributed Stochastic Neighbour Embedding, or t-SNE) used to visualise the data in a high-dimensional dataset as a number of low dimensions, suitable for human beings. The algorithm can be used, for instance, to display a large dataset of 60,000 digitalised hand-written numbers (28x28 pixels) as clusters in a two-dimensional figure. In addition, Pezzotti's improved algorithm is a powerful tool for understanding the workings and quality of neural networks.



A test dataset of 60,000 hand-written numbers (28x28 pixels), displayed by the tSNE algorithm as ten almost completely unoverlapping clusters.

Visual representation

If a neural network is poorly designed, or poorly trained, it will make mistakes when interpreting new data input. But going through a large validation dataset by hand to separate out unexpected and undesired results would be a hopeless task. After all, the output from a neural network is also extremely high-dimensional as well and hard for people to visualise. In recognising animals, the output for each new figure may comprise, for instance, a long series of numbers, with each number representing the probability of the figure being a dog, pigeon, elephant, etc.

A visual representation of this data, using the tSNE algorithm, gives very quick clarity. Is there too much overlap between clusters, or have some small clusters unexpectedly appeared, perhaps? For computer scientists, these are signs that they need to redesign or retrain the DNN.

Nicola Pezzotti made his implementation of the algorithm so fast that anyone can use it, at home on a simple desktop computer or even via a web browser. In the meantime, Google has added it to its open source software platform for the design and validation of neural networks ('Tensorflow.js'). The basis for the greatly improved algorithm was to use the physics concept of a 'field'.

Off-label use

Biomedical researchers at Leiden University Medical Center (LUMC) have applied the tSNE algorithm, but without using a neural network. The researchers measured from large batches of individual cells the extent to which certain proteins appeared on the cell surface.

Visualisation with the tSNE algorithm showed them that undiscovered human immune system cell types and new intermediary stages of stem cells could still be present, and how these could be identified. The researchers were subsequently able to demonstrate the presence of these types of cells by searching for them specifically. ME

When is the best time to do the laundry?

The advent of a new power system will turn the distribution and consumption of electricity upside down. This, and driverless cars were discussed at a conference on artificial intelligence and planning in Delft.

Two significant changes are in store for us: the advent of the smart grid, and driverless cars. Many of the studies presented at the ICAPS event, one of the world's largest conferences on artificial intelligence and planning, had to do with these two developments.

'This field is all about automated solutions to planning problems', says mathematician Dr Mathijs de Weerdt of the department of Software and Computer Technology (EEMCS) and one of the conference organisers. 'We use reinforcement learning algorithms for that.'

De Weerdt is engaged in the optimisation of the smart grid. At present it is still easy to match electricity supply to demand. With their gas-powered plants, large electricity companies can increase or decrease production accordingly. But if solar and wind energy soon account for a greater share of production, that production may not be so flexible. 'In that case, it's important to create flexibility on the demand side. By lowering the price of electricity when there is a lot of wind or sunshine, you can encourage people to do their laundry, for instance, at times when a lot of electricity is being produced. This is a very simple form of optimisation. The reality is much more complicated. You also have to take account of industry. Industrial processes themselves are very complicated to optimise. Factories cannot adapt their operations to the price of electricity just like that.' With reinforced learning algorithms, De Weerdt is trying to make the system as flexible as possible.

Co-organiser and mathematician Dr Matthijs Spaan does similar research, but with the focus on driverless cars. He is involved in the i-CAVE project, a collaborative effort that includes TU Delft and Eindhoven University of Technology and which is investigating the most efficient way possible for semi-autonomous vehicles to deliver parcels. 'The cars are driverless in certain areas that are relatively uncomplicated and for which we have detailed maps. They can't handle complex locations, like the city centre of Delft, independently, so there a driver has to take over. We are looking into how we can optimise this system so that as many parcels can be delivered as possible without the intervention of a driver. But autonomous driving involves more than just route optimisation. Sign recognition is crucial as well. Professor of Intelligent Vehicles Dariu Gavrila (3mE) is doing research on this. Artificial intelligence is extremely good at individual tasks, such as recognising images. But in traffic, you have to anticipate the actions of other road users in situations that are continuously changing. AI is not so good at doing that yet.

'The scientific challenges lie mainly in the complexities of urban traffic and in dealing with cyclists and pedestrians', said Gavrila two years ago during his inaugural address as a professor. Technologies that learn automatically, with the help of big data, what road users look like and how they generally behave, could help to better assess traffic situations.

Should we be afraid of self-learning

Self-learning algorithms determine internet search results, choose which messages you see from friends on Facebook, and may eventually even decide which drugs you will be prescribed and your punishment if you commit a crime. So should we be afraid?

PHOTO: SAM RENTMEESTER

Ibo van de Poel: "I think we need more transparency.about how algorithms work."

YES/NO

Two researchers from Delft who work in this field answer the question. Virginia Dignum, associate professor in the Faculty of Technology, Policy and Management (TPM) and one of the 52 members of the High-Level Expert Group on Artificial Intelligence is positive. She expects that legal regulation will manage and control artificial intelligence. She is part of an Expert Group which advises the European Commission about policy regarding artificial intelligence.

Ibo van de Poel, Anthoni van Leeuwenhoek Professor in the Ethics of Technology and head of the department of Values, Technology & Innovation at TPM appears more concerned. 'In the United States, an offender can be given a sentence that has been partly set by a self-learning algorithm for which only a company knows the code.'

'There are certainly causes for concern when you consider self-learning algorithms. One of the problems is that unintentional biases (a sort of prejudice) are sometimes inherent. Take for instance the algorithms for facial recognition used at airports to pick out suspicious subjects from the crowd. If they were only trained to recognise white faces – which does actually happen - it could mean that they lack the distinguishing ability to recognise black faces. This may mean that this software, which links faces to a database, would raise the alarm for black people more often.

In the United States, they make more use of self-learning algorithms than we do here. They use the COMPAS algorithm, for example, to predict the risk of recidivism in offenders. This risk plays a role when deciding on the sentence. But this software is also rumoured to show a racial bias.

We don't know exactly how the programme works, as it's the intellectual property of a company which refuses to publish the code. So it's entirely feasible that you could be given a sentence in the USA without ever knowing what reasoning it was based on.

I've heard from people working in the Ministry of Justice and Security that this would never be possible in the Netherlands because you always have the right to ask for the reasoning behind your sentence. Self-learning algorithms are often a sort of black box. You can of course go through the code (if it isn't kept secret), but the exact details of how it works are often incomprehensible. Is this what we really want? I think we need more transparency about how algorithms work. The problem with this is that demanding full transparency will have an adverse effect on the self-learning capacity of the algorithm. This is something that needs to be weighed up very carefully indeed.'

algorithms?

Virginia Dignum: 'There's always a human strategy behind using algorithms.'.

YES/**NO**

'No, we really don't need to be afraid of algorithms. They're artefacts. You don't need to be afraid of hammers either. What you should be concerned about are the people who use hammers to do bad things. We can also make and use chemical weapons, but there are all kinds of regulations in place to stop us actually doing this. There's always a human strategy behind using algorithms.

Algorithms are there to provide support. It's up to us to decide what to use them for

I see that there is more and more awareness of the way that algorithms can be used, and of the need for regulation. I think that we'll also see lots more legal constructions determining what we can and cannot do with algorithms. I'm optimistic. Self-learning algorithms are some times called a black box because people don't fully understand how they make their predictions. I would partly agree with this. The underlying process is simple mathematics – regressions – and we understand these. But a self-learning algorithm can involve thousands or millions of factors. It is the sheer volume makes it so difficult for people to follow the process.

I'm not scared that algorithms will soon make all our decisions. But I expect we'll see a lot of very strange experiments. Algorithms probably won't have the final say about who can and who can't get a bank loan, for example. They are there to provide support. It's up to us to decide what to use them for and what not. We mustn't blindly follow algorithms simply because they can predict things.'

Learn more about robots

Will robots of the future have a free will or take control of the world?

The online course (MOOC) 'Mind of the Universe: Robots in Society, Blessing or Curse?' looks into the potential social and ethical impact of robots. Learn about the design principles you must comply with when developing robots and how to take a critical look at factors such as robot autonomy, consciousness and intelligence. You can also work on pioneering solutions that robot designers may actually implement in the future.

This free online course is a spin-off from the documentary series Mind of the Universe (VPRO). It was devised by TU Delft. The course is supervised by Delft AI experts Virginia Dignum, Jordi Bieger and Rijk Mercuur. You can start the MOOC individually whenever you like, but the next group starts on 12 November.

More information: bit.ly/cursusrobots

Learning to fly on their own

Teaching a robot new tricks by trial and error is less than ideal. 'For flying robots, such a teaching method – reinforcement learning in AI jargon – is altogether wrong, because they are even more fragile', says Dr Guido de Croon, head of the research project of the Micro Air Vehicle Laboratory.

Earlier this year, De Croon received a 'TOP' grant from the Dutch government. He and doctoral candidate Frederico Paredes Valles are trying to make flying robots, like the fluttering Delfly – capable of learning on their own. The robots have to learn to judge distances using deep neural networks. 'This is a radically different approach than reinforcement learning', De Croon says.

The robot has stereo vision and can, just like people, perceive depth. But the information received by each separate eye (camera) also contains depth information, packed in the texture and colour of objects, for instance. The robot learns completely on its own during the flight to use that information to avoid obstacles. 'By combining the information from the stereo image with the extra information from each eye, our aim is to make the robot see even better. Eventually, after lots of practice, the robot should even be able to perceive depth accurately with only one eye. That's really necessary. This will enable the robot to keep flying even if one of the cameras breaks down.'

De Croon worked on such a self-learning robot vision system for space flight for ESA and NASA some years ago. The system that he is working on now needs to be even more advanced.

Three generations in 50m²

A luxury flat does not have to be big. Every wall, door and piece of furniture should be able to change shape or location.

'That's how things are heading in mega cities like Hong Kong and New York', says Dr Henriette Bier of the Architecture group Robotic Building. 'Pioneering architects are building tiny flats which can be reconfigured, making it possible for even three generations to live in 50 square metres of space. At present, you still have to make all the changes to the interior by hand. This will be automated in the future.'

Bier is making her own contribution to this development. She and doctoral candidate Alex Liu Cheng have been working on sensors that enable a flat to tell what room the occupants are in, the room temperature, what the air quality is, etc. 'Combined with artificial intelligence, a flat should ultimately be able to adapt itself to the needs of its occupants.'

Bier is also working on a reconfigurable workshop space that will be installed in the Science Centre in Delft.

View

Prof. Catholijn Jonker, Professor of Interactive Intelligence in the faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS), is in search of the logic of artificial intelligence.

'Research into machine learning in the sense of artificial neural networks goes as far back as the 1960s. The computers in those times lacked the processing power to really get anywhere. It was not until years later that the Belgian Lernhout and Haspie came up with their speech recognition technology – and we thought we had natural language down to a fine art. The technology was excellent, but it still did not work as well as expected in practice. Now that risk is back. Since about two or three years, there's this feeling that neural networks are the solution to everything; but things aren't so simple in practice. The annoying thing about artificial intelligence is that it always gets ahead of itself. The ideas are bold, future-looking and innovative. But it takes extremely powerful computers to make them work. For a long time, that was the bottleneck. Not surprisingly, today's great breakthroughs were set in motion by large companies with huge processing power, such as Google, IBM and Apple.

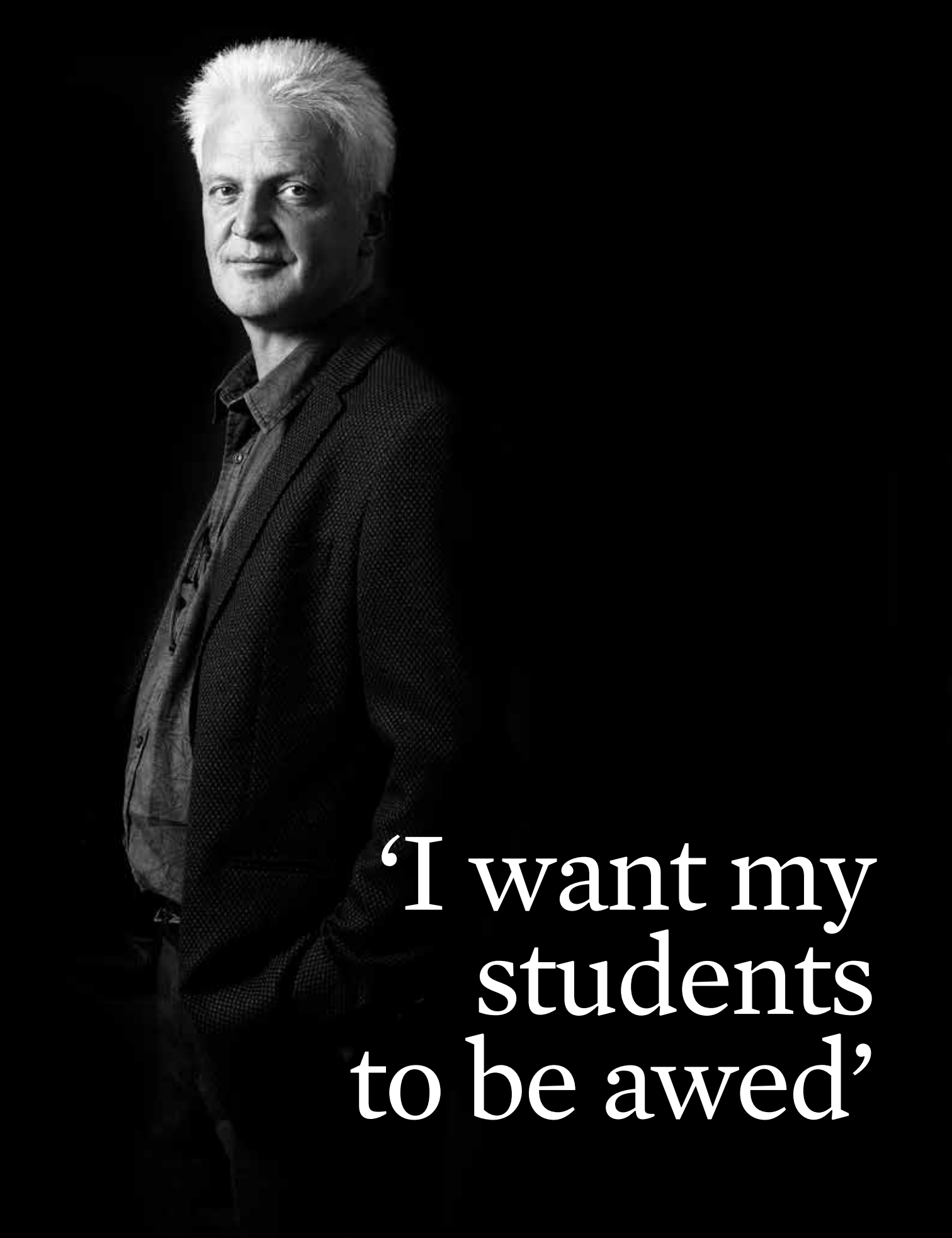
Universities lack the resources for such research. Intelligent Systems, my own department within EEMCS, deals with everything in this area of machine learning. We can advise on what works, and what doesn't. What's real, and what's a hype? Reinforced learning systems are fantastic as long as you are working in a limited context. The generalisation of these results is still going to take loads of research, and we are certainly doing our bit.

Take driverless cars, for instance. On the one hand, the world is hugely dynamic and complex: almost anything can happen. On the other, a car is relatively simple. You can brake, accelerate and steer away from obstacles – that's not so complex. But interpreting your surroundings, determining what is heading towards you: that's the crux of the matter. Not only must driverless cars know the rules of the road, but they must also apply them in a safe manner. The rules of the road are a finite set of rules, but the variety of situations that cars can encounter is endless.

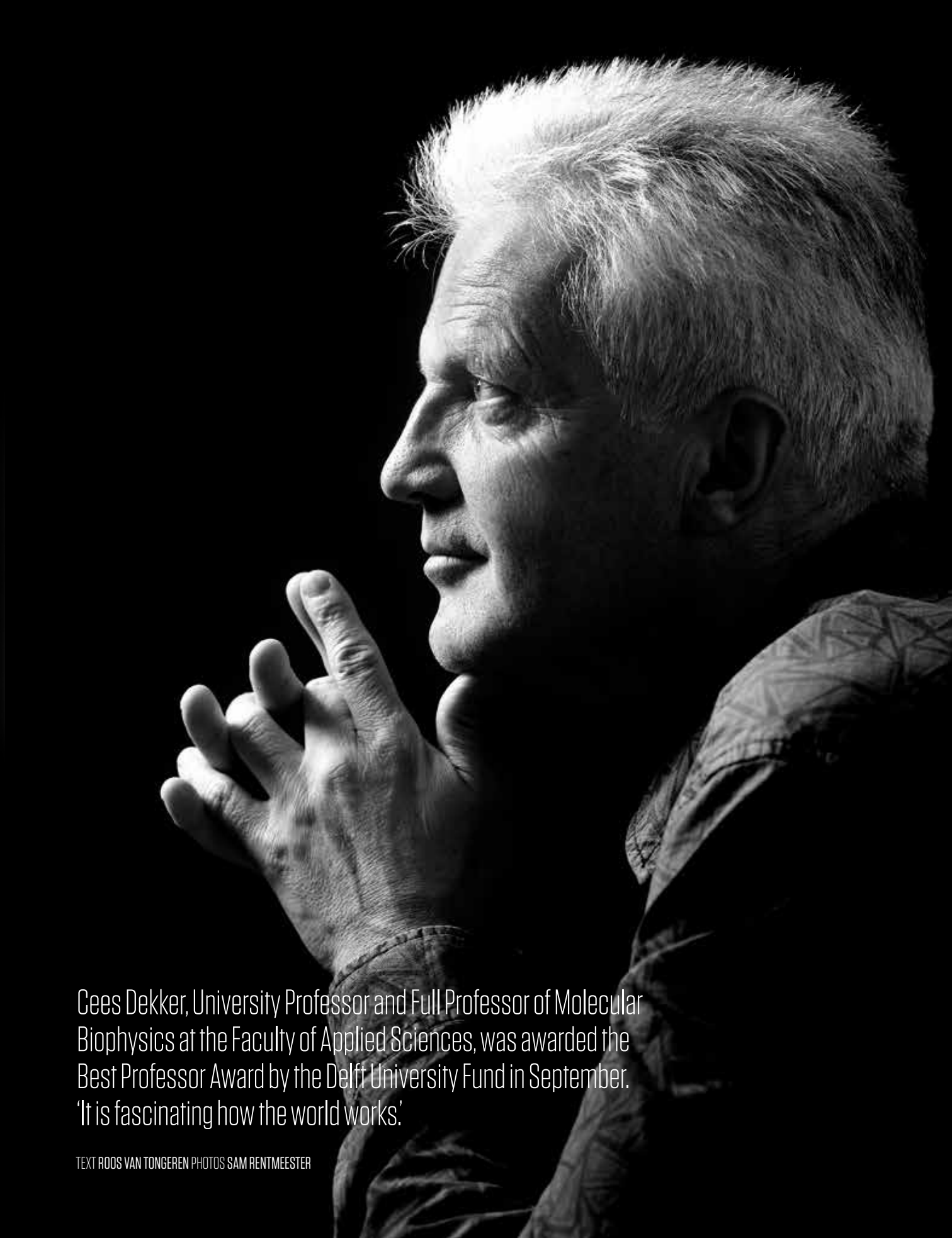
People have to get their driving licence before they are allowed to drive. Why should that be any different for a computer system? I haven't heard of a single one of them getting its driving license, but they do drive around nevertheless.

The challenges for the time to come lie in combining machine learning with the ability to reason in what is known as 'knowledge engineering'. These are reasoning-based systems with a logic orientation. If we get that connection made, we can also ask the system questions about why it took a certain decision. The system will then put forward bits of knowledge rather than saying 'that was just the best pattern that I had learnt'. The aim is to frame the knowledge within reinforced learning systems in explicit terms, which is the domain of knowledge engineering. The next breakthrough in artificial intelligence will be when we succeed in combining reinforced learning with logical systems.' JW

PHOTO: SAM RENTMESTER



‘I want my students to be awed’



Cees Dekker, University Professor and Full Professor of Molecular Biophysics at the Faculty of Applied Sciences, was awarded the Best Professor Award by the Delft University Fund in September. 'It is fascinating how the world works.'

TEXT **ROOS VAN TONGEREN** PHOTOS **SAM RENTMEESTER**

Dekker is no stranger to TU Delft. His carbon nanotubes became world famous and the Nanobiology degree programme he set up has since become a complete department. His contribution to research on DNA reading, among other things, has enabled us to develop personalised medicine and track down criminals.
Since 1994, the Best Professor Award is granted for an outstanding contribution to research and education. Instead of points or a jury, the winner is chosen by the students and PhD candidates.
'I'm really proud to win this award,' says Dekker. 'It's good to get recognition for my work and I'm happy to be able to set a good example.'

When did you hear you had won the Best Professor Award?
'I had an appointment with the dean in my diary, but that was obviously a trap. A Nanobiology student came in while we were talking to say there was a problem. When I went back there was a bottle of champagne waiting and they congratulated me.'

The Best Professor Award is about the human side of a professor. Why are you so popular with your students and PhD candidates?
'Students and PhD candidates are all very different individuals, and each has their own motivation for studying at the TU. Some want to discover how the world works, like amateur philosophers. Others are much more practical and want to learn how to apply technologies in the industry. My goal is to meet the needs of each of these students. I have divided my group of students and PhD candidates into teams that function as each other's sounding boards. I do not only look for scientific excellence, but communication skills and empathy as well. This is very subjective. I have learned to trust in my intuition to find candidates that have these human qualities too.'
'I want students to be awed. Awe is what drives me in my research. I am continually amazed at what I see and want to know how it all fits together. This is also reflected in the painting 'Curiosity' that hangs in my office. I made it together with a research group at my house. It consists of separate parts that together form a whole.'

Which lecturer inspired you the most?
'Hans Mooij. I obtained my PhD in Utrecht and came to Delft in 1993. He taught me to focus on the scientific challenges of tomorrow, rather than the funding opportunities of today. Instead of following the funding landscape, you can try to steer it in a particular direction.'

The Best Professor Award was established 25 years ago, exactly the period you have been with TU Delft. What have you done all that time?
'I was interested in fundamental science and a position became available with the solid state physics group. I launched a new line of research there. We conceived the idea of measuring the electrical conductivity of an individual molecule. We succeeded in placing a promising conductive polymer molecule between two electrodes. But what happened? It didn't conduct at all.'
'It was very discouraging, because I had set my sights on this line of research. Luckily, new material had become available; carbon nanotubes, tiny tubes of grapheme rolled in a certain way. I was able to obtain some from Houston for our tests. It conducted perfectly! It enabled us to demonstrate, for the first time, that you can measure electrical conductivity through an individual molecule and build a transistor with it.'

'I was fascinated by the idea of all those molecular motors in our bodies'

'It was a great success. I was forty, was made full professor, and had years of experimenting with carbon nanotubes ahead of me. But there was something missing. I was more and more interested in biology. I was fascinated by the idea of all those molecular motors in our bodies. But the mechanical workings were as yet unknown. I started a new Biophysics research group to focus on Nanobiology, a term that did not even exist yet. That has now grown into a complete Bionanoscience department.'

How do you stay enthusiastic?
'It happens automatically! The work is just so engaging! Reality is always fascinating to watch. We now have the technology to study what is happening inside individual molecules that are only a millionth of a millimetre. I am not only interested in how these mechanisms work, I also want to

CV
Prof. Cees Dekker (1959) is Professor of Molecular Biophysics and head of the Cees Dekker Lab (Bionano-science) at the Kavli Institute of Nanoscience Delft, which he also directed for 8 years. For the first 20 years of his career, he focused on solid-state physics, before switching to biophysics and examining how living systems are constructed. Dekker's CV runs to 62 pages and he is cited some 3,000 times a year.

find out how the molecules cooperate to build living systems. Can we build synthetic cells? How does nature work at this level? I find questions like these endlessly fascinating.'

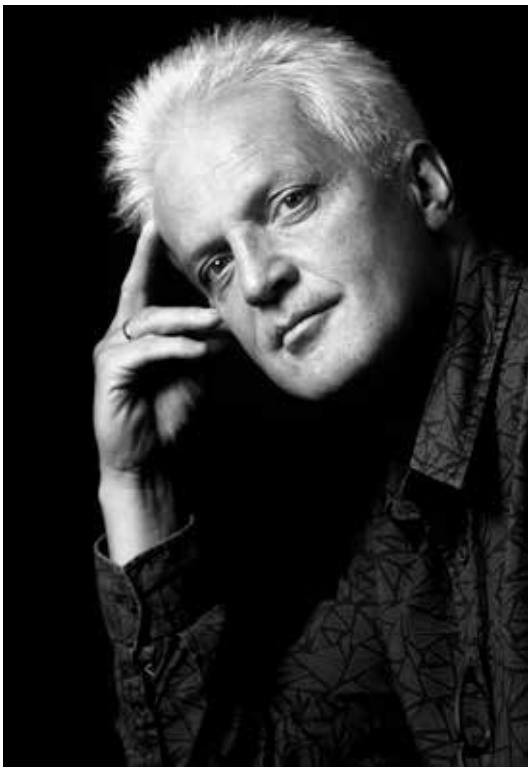
You are a faithful Christian and you are happy to join the debate about faith and science. Has your opinion on this debate changed in the past 25 years?

'On the one hand it hasn't; 25 years ago I was the same Christian who is driven by awe and wants to discover this world through science. I feel it is my responsibility as a scientist to bring together religion and science and explain why these actually form a harmonious duality.'

'On the other hand, I have developed a more profound understanding of belief and science. Fifteen years ago, there was a heated debate about Intelligent Design [ed.: a theory that suggests there is objective proof that nature has a design]. I initially found it an interesting idea, but have since distanced myself from it. The underlying question is which worldview best describes reality; a secular or a religious worldview. I think it is the latter, because it helps justify the "meaning of everything". As well as discussing the existence of God with my atheist colleagues, I am also happy to engage with other believers about creation and evolution. Some people in orthodox Christian circles are very wary of the science of the Big Bang and evolution. I try to explain to both groups why religion and science are mutually compatible.'

'I have edited several books about religion and science. I recently co-wrote a children's book called Topnerd Tycho together with Corien Oranje for Christian children aged between eight and twelve. Children of that age have questions about religion and science too. In our book, a school class has an adventure during which they discuss God, Darwin, evolution and creation. We show how religion and science go together perfectly.'

'I am also busy with other things in addition to this discussion about religion and doing science. I help in the church with intellectual development and also lead church services. I also play guitar and soprano sax in the church band and enjoy a fling on the double bass, mandolin, dobro and banjo during jam sessions at Bluegrass festivals a few times a year. Together with two families I also spent many years running shelters for young people who needed support and I currently volunteer in an asylum-seekers centre.



Where do you find the time!

'Time is about prioritising. You have to make time for things that are important to you. I have a lot of energy. A whole day lying on the beach is not for me; after a couple of hours I start getting restless. My goals are to serve God, to help my neighbours and do fundamental science. I often dream – sometimes literally – of discovering new things, for example how DNA structures play a role in cells. I want to build synthetic cells so that we can discover the basic principles of how cells work.'

You are now 59. Have you started thinking about your pension?

'No, absolutely not. I hope to go on for a long time yet, but the University doesn't make it easy for you. At some point they will stop you getting new PhD students and gradually try to push you out the door. It's different in the US, where you get professors in their nineties. Some peers ask me how long I have to work till my retirement. Ha ha! That's not how I work at all. I want to build cells and work out the DNA structures in them. I plan to continue full speed ahead and have no inclination to stop whatsoever.' <<

TEXT: CHRISTIAN JONGENEEL PHOTOS: SAM RENTMEESTER

How to build **a million** new homes?

Last spring, Minister of Foreign Affairs Kajsa Ollongren suggested that the Netherlands will need a million new homes by 2030. That sounds like a lot, but it isn't really. The important question is: what types of homes? We mustn't repeat the mistake of building endless series of exactly the same homes, says Prof. Dick van Gameren, Professor of Dwelling at TU Delft.

Dick van Gameren has just returned from India, where he leads a housing design studio for students of KRVIA, an architecture degree programme at the University of Mumbai. The Architecture department of the Faculty of Architecture and the Built Environment has formed a partnership with this school and Van Gameren will be visiting there shortly with a group of TU Delft students. 'The problems in the Netherlands are nothing compared with the challenges in India,' he says. 'Millions live in so-called informal settlements, which are in fact slums. Some people have to make do with only 1 to 1.5 square metres of living space per person, conditions which haven't existed here for 150 years. These were the living conditions of workers in Victorian London and nineteenth-century Amsterdam.'

On the one hand, these conditions make Mumbai's current building challenge completely different to that of the Netherlands, but there are also similarities, caused by the global trend of migration to the city, which continues unabated in the Netherlands too. It is no coincidence that the 21 TU Delft students who have joined Van Gameren on the Mumbai project represent 17 different nationalities; urban housing construction is a challenge that affects the whole world.

UNIFORM LIVING

Van Gameren is therefore not impressed with the one million homes the Netherlands wants to build by 2030. 'We've done this before,' he says. 'After the war, for example, and in the 1990s when we built the Vinex suburbs. That also involved nearly a million homes in a good ten years. The risk of an ambition like this is that the emphasis comes to lie on quantity rather than quality. We mustn't repeat the mistake of building endless series of exactly the same homes without taking future needs into account.'

> 'We mustn't make the mistake of now only filling the city centre with tiny homes'

The current trend is to build smaller homes in inner cities. This is the reverse of the trend during the Vinex period, when the population in the city centres decreased because people preferred to live in the suburbs. It is particularly young people, often single, who want to live closer to the amenities of the city centre. The suburbs are not close enough after

In Rotterdam, the Justus van Effenblok had to be carefully renovated and therefore the future residents had no say in the design.

all, while having an apartment without a back garden is seen to be acceptable. The ideal of the single-family home is on the way out.
'But this doesn't mean we now need to fill the city centre with tiny homes,' says Van Gameren. 'That will result in a uniform living environment, which is not a sustainable option. Cities need variation in housing too.'
Space is not the problem. Project developers might find it easier to build in a field, but Dutch city centres are not actually very densely inhabited compared with cities abroad. There are plenty of former business parks that can be built on and empty office buildings that can be redesignated.
New high-rises will be unavoidable to boost up the number of inhabitants per square kilometre. This number has fallen over the last decades, among others due to the increased demand for space (a Dutch citizen today requires five times as much floor space as in 1900). For example, the population of Rotterdam has decreased by 100,000 in 50 years, despite the construction of new suburbs.

DESIGNING RESEARCH

The trick is to use the space efficiently and flexibly. Van Gameren, who is also a practising architect, focuses his research on this aspect of architecture. 'In our research, we examine the past and analyse existing trends,' he says. We ask our students to conceive solutions for the future based on the results. This is also how we are approaching the Mumbai project; it is designing research.'
The research has resulted in a series of books; the DASH series (Delft Architectural Studies on Housing). The latest edition is about transforming dwellings into dwelings. 'Up until 20 years ago, it was a reflexive response to demolish houses that no longer met the requirements of the age,' explains Van Gameren. 'This trend has fortunately turned. The first complex conversions have provided us with valuable insight into how best to build new complexes of dwellings to facilitate future conversions.'
Klarenstraat in Amsterdam is a good example. The original building was constructed in 1952 and comprised forty more or less identical dwellings. The building was divided into 'cubes' of between 35 and 40 square metres, and the new owners each chose which cubes

Read more on page 24

The Funenpark in Amsterdam. (Photo: Landlab Studio for landscaping architecture)

they wanted to convert into a dwelling. The building shell was constructed in a joint effort, while the inhabitants each finished their own interior individually. In Rotterdam, the Justus van Effenblok, a listed historic building dating from 1922, had to be carefully renovated to protect its status while at the same time meeting modern design and insulation requirements. Although the future residents had no say in the design, the project was a good example of how you can convert an old building with respect for history while at the same time meeting modern demands.

Van Gameren's students are also involved in the newest phase of Amsterdam's IJburg district. 'This is a good combination of education and research,' he says. The students work on different approaches to meeting the city's requirements of the new district, and so make a range of different potential living environments tangible.

MIXED DISTRICT

The research into designing an optimum home is obviously intertwined with other specialisations studied at TU Delft and elsewhere. For example, the OTB Research Institute for the Built Environment is investigating the relationship between urbanisation and mobility. This is critical research, as the evaluation of the VINEX projects revealed. One of the goals of these projects was to reduce automobility by ensuring efficient bicycle and public transport networks, however this was seldom achieved in the remoter suburbs, although it was successful closer to the city centre, such as Kop van Zuid in Rotterdam.

A modern-day goal is the construction of climate-neutral homes, however single-family homes have more roof surface available for solar panels per person than flats, creating a seeming conflict between environmental objectives. Materials research may contribute to the solution by helping to improve solar panels or integrate solar cells in façades and even windows. Other fields of research such as energy technology and economic and political studies also play a role.

Professor Dick van Gameren: 'Customised homes can be beautiful, but how do you ensure they remain sustainable?'

The Emerald district near Delfgauw is a typical Vinex location.

An example where many of these factors come together is Funenpark, a small district built on a former railway yard in Amsterdam that Van Gameren helped design. The district was founded on a political decision: this was to be a mixed district, both in terms of the composition of the population and the affordability of the homes. This meant certain restrictions on funding. Another condition, that it had to be made into a park-like and car-free environment, clearly defined the mobility vision for the district.

'Home leasing' could be a solution to long-term sustainability of the housing stock

Buyers could go online to choose from among dozens of options for the design of their home. This precluded series production, but nor was there unlimited freedom. It made it possible for buyers to have semi-customised homes while at the same time protecting the uniform identity of each of the complexes. 'Customised homes can be beautiful, but how do you ensure they remain sustainable?' says Van Gameren. 'Will the home still be usable for the next owners? That is one of the things that we need to explore further.'

CIRCULAR ECONOMY

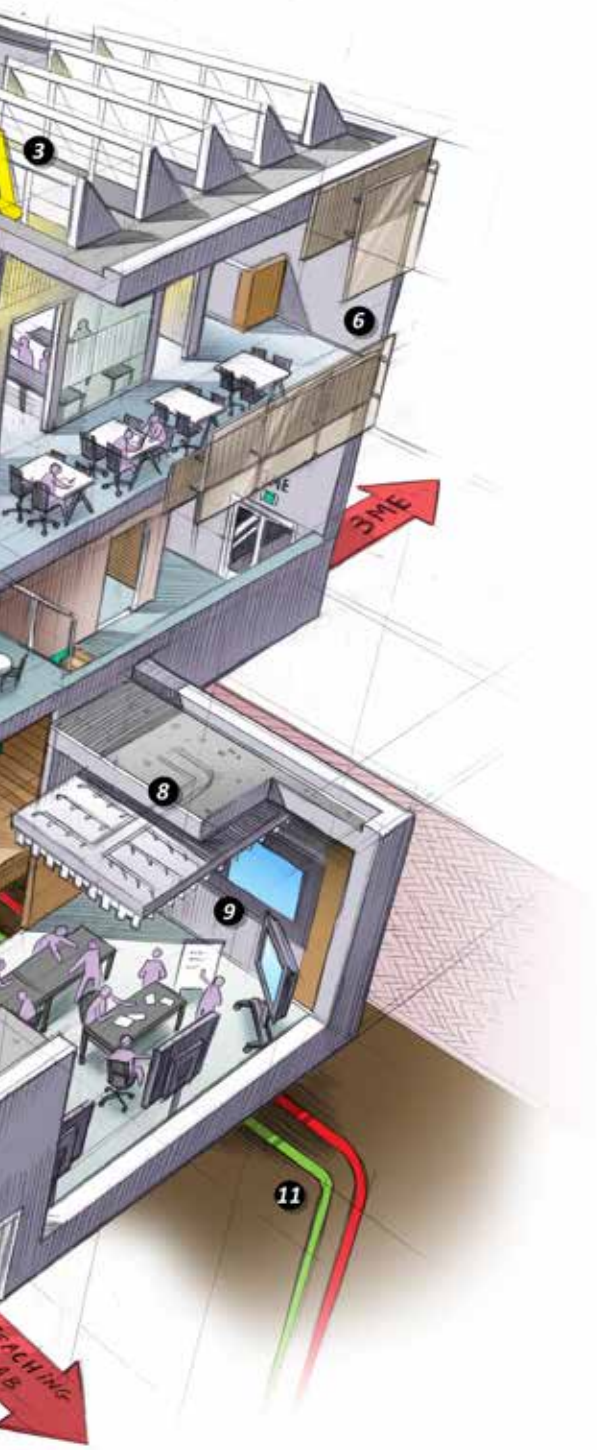
One of the trends in housing construction that Van Gameren is following is the rise of the sharing economy, that already accounts for a considerable portion of inner city mobility; private car ownership is on the way out. 'Why can't we have a separate laundry room for each residential block. These are already commonplace abroad. You could also create home-offices per block of residences instead of having one in every house.'

Ideas like these can contribute to the development of a circular economy, whereby instead of owning a washing machine, people could buy 'washing as a service' from a manufacturer. This means they no longer need to take any action if the machine breaks down; the manufacturer monitors the machines and upgrades or recycles them when necessary. With its home ownership culture, it may still be a step too far for the Netherlands to consider the idea of 'home leasing' in the same manner, but this could well be a step in the right direction to ensure the long-term sustainability of the housing stock. Projects like Klarenstraat would have been much more complex if the block had not been in the hands of a single housing corporation. Now that it has been sold to dozens of private owners, it is questionable whether the method of parcelling out lots could be repeated in 60 years' time. In other words, the housing experts at TU Delft still have plenty of questions left to study! <<

TEXT: DORINE VAN GORP ILLUSTRATION: STEPHAN TIMMERS

Pulse

Thirteen teaching rooms, 1020 teaching spaces, a food market, 750 m² of PV cells and the highest energy label of A++++. The new Pulse building is already being put to good use.

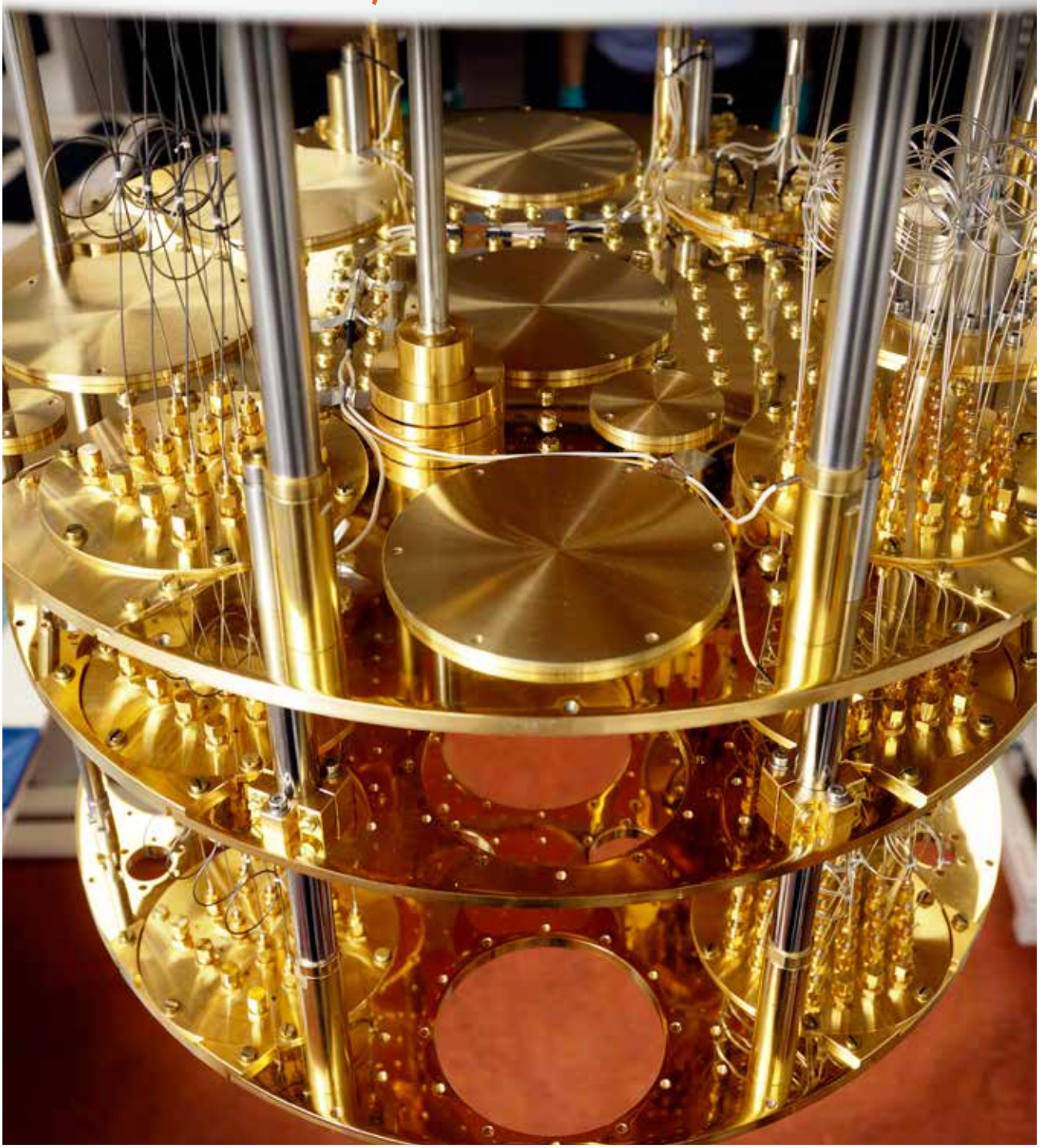


Pulse is the first energy-neutral building on the TU Delft campus and has been designed to provide contemporary motivational teaching. The idea is that students learn more and remember it for longer if they actively participate in the lessons. The building is open to students from early in the morning till late at night.

1. Break Out – Is a small room that can be used for peer-to-peer learning. It is the only room without audio-visual equipment, but the walls can be written on or used as a bulletin board.
2. Ventilation – The ventilation ducts are larger than usual which means that the fans do not have to work as hard.
3. Light – The 'shed' roofs ensure plenty of natural light, reducing the need for artificial lighting and so also reducing energy consumption.
4. DC power supply – The lighting is low voltage DC, which leads to electricity savings of 5 to 10%. The electronic fuse shuts the power down automatically in the event of a surge. If the solar panels do not generate enough energy, the system can switch from DC to AC to enable the regular mains power network to be used. In the future, the new generation of USB-C connectors and the fans can also be connected to the solar panels.
5. Sustainable materials – A lot of bamboo has been used instead of wood, the ceilings are semi-exposed and a huge green wall has been created in the middle of the building.
6. Sun blinds – See-through sun blinds will be installed on the south-west side of the building. These will ensure an optimum balance between light and cooling in the summer.
7. Technical room – Batteries for storing solar energy can be installed here at a later stage.
8. LED lights – Using LED lights connected to the low voltage DC network will save energy.
9. Lecture rooms – Most (10 of the 13) teaching rooms are on the north-east side of the building (require less cooling). These are fitted with digital smart boards, screens for sharing information and CollegeRama cameras. Almost all walls can be written on. The Technology Room is the most advanced room, with tracking cameras and screens that allow communication with students from all over the world.
10. Food market – A food market near the entrance has three eateries: Warung, PokéLabs and Couscous.
11. Thermal energy storage (TES) Pulse will be heated in the winter with warm water that is stored 73 metres deep in the ground during the summer. The cooled water is used in the summer for cooling.

TEXT: DESIREE HOVING PHOTOS: SAM RENTMEESTER

The quantum computer exists, and **it doesn't**



QuTech is a big international player in the field of quantum computing and quantum communications. The Delft institute is yet to bring a quantum computer online, but has introduced the first Dutch simulator. If quantum logic also applies here, the hardware will follow in double time.

Imagine: you want to pick the ace of hearts from a shuffled deck of cards. How many cards do you need to see to have a fair chance of picking the ace of hearts? For a 90% chance, you'd need to see 0.9*52 = 47 cards, is what Indo-American computer scientist Lov Grover would say. A human can do it in under a minute, and a computer much faster, but they would both have to see at least 47 cards one at a time and compare them to the ace of hearts to have a 90% chance of finding the one card.

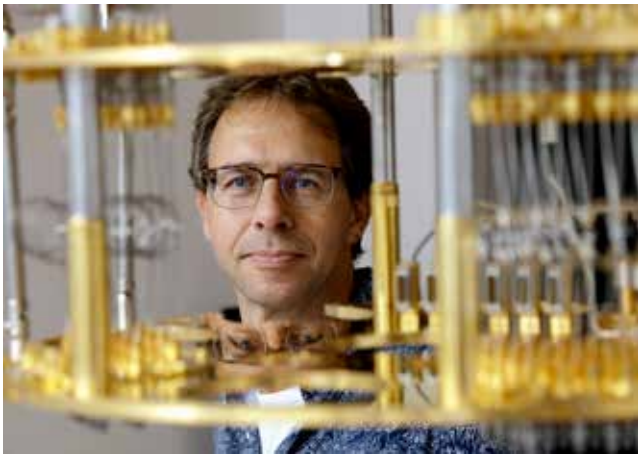
Grover thought that quantum computers would solve problems such as this much faster. In 1996, he wrote one of the first algorithms for this purpose, which we now know as Grover's algorithm. 'The power of the quantum computer is that you only have to make 7 comparisons between the ace of hearts and the deck of cards, almost like only having to check 7 cards to have a 90% chance of finding the ace', explains system engineer Richard Versluis. And he should know, as he was the one who defined the system requirements of the first online quantum computer in the country.

Will a quantum computer be capable of doing more than card tricks? You bet: great things are promised. Researchers hope to discover revolutionary new materials by simulating the behaviour of materials down to the atomic level; encrypt data for almost perfect security; crack codes that are impossible to crack with existing computers, and predict climate change with high accuracy.

For standard computers, a few additional bits hardly matter, but they do in the quantum world

AMAZING CHARACTERISTICS

The power of quantum is best described by using a metaphor: a standard computer talks in bits, where a bit can be 1 or 0, let's say head or tails. In quantum, the coin keeps spinning; a quantum bit (qubit) can see 1 and 0 simultaneously, an amazing phenomenon also known as superposition. Qubits also have the equally amazing characteristic of being able to influence each other without being physically connected, what is known as entanglement. What's most important to know is that this means multiple calculations can be carried out simultaneously. IBM, Microsoft, Google and Intel are all busy building a quantum computer, but they are yet to rival the performance of standard computers. The major challenge is in scaling up to larger numbers of qubits, and controlling them. For standard computers, a few additional bits hardly matter, but they do in the quantum world. 'With each qubit you add, you double the computing power', says Versluis.



Richard Versluis: 'Each qubit added doubles the computing power.'

QUANTUM INSPIRE

QuTech, a collaboration between TU Delft and TNO, is also working on a quantum computer. In contrast to IBM and Rigetti, QuTech is not focusing on a single type of qubit. Instead, it is working on a platform that can support various types of qubits. This is done in the TU Applied Sciences building. The walls are freshly painted, and out of the unplastered ceiling sticks a round white metal pipe, lined on the inside with gleaming copper. Quantum Inspire, the name of the platform launched early this September, shines above the pipe in purple-blue neon letters. Jorrit van Wakeren is the project manager responsible for Quantum Inspire.

Read more on page 30

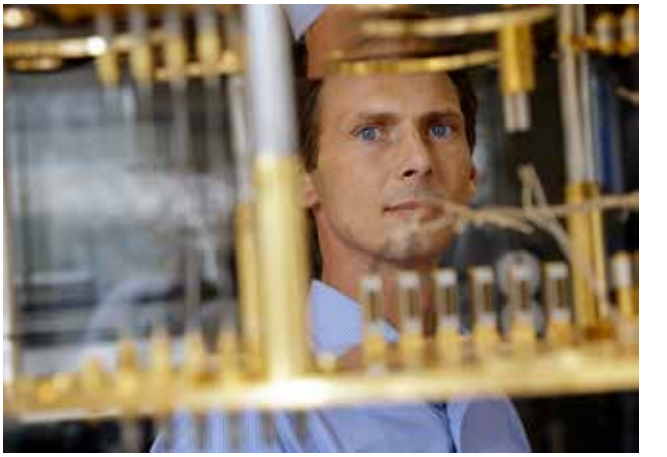
He is keen to introduce the public to the quantum computer and to the invention of new types of algorithms using the new quantum computer language QASM. 'It demands a completely new way of thinking, something that the next generation will have to learn', he says. Van Wakeren also wants to show companies how a quantum computer could help them in the future, so that they understand why they should already start investing in its development.

WORKING SIMULATOR

The first step towards a Delft quantum computer was recently taken: there is now a working simulator of 37 qubits, the maximum capacity the super computers at Surfsara, the national support centre, can handle. 'A simulator like this is essential, you need to find out how so many qubits work together', says Thorsten Last, who is responsible for hardware integration.

He continues: 'Qubits are difficult to work with as they can be constantly interrupted, by temperature fluctuations or the magnetic field, for example, or by loose atoms, shortening their lifespan. That's why it is important to stabilise qubits. We cool our qubits down to absolute zero (-273 degrees Celsius, ed.) to obtain quantum mechanical characteristics. We also use silicon, a material that makes the lifespan of qubits relatively long. Silicon is also standard in the semiconductor industry, facilitating commercialisation and upscaling.
The first chip that QuTech is currently working on, with the team of Professor Lieven Vandersypen – an expert in the field of electron spin qubits – has two silicon spin qubits. This may seem like a small number compared to the superconductive qubits IBM (up to 20 qubits) and Google (72 qubits) are working on, but there is another significant reason behind the team's decision to use silicon instead of superconductive qubits. 'A quantum computer with a million superconductive qubits is the size of a football pitch, which makes this technology less scalable, explains Versluis. Last adds: 'A chip with ten superconductive qubits is already centimetres in length, while ten qubits on silicon only take up 700 nanometres. That is less than a micron'. The team hopes to have the world's first quantum computer with silicon spin qubits online by 2019.


Thorsten Last: 'We use silicon, a material that makes the lifespan of qubits relatively long.'


Jorrit van Wakeren: 'We now offer the first platform for carrying out quantum algorithms.'

THE FUTURE

'But we won't have a quantum computer until you can use it for things that cannot be simulated and that you therefore cannot achieve with a standard computer', says Versluis. 'It will be another 15 to 20 years before we will be able to crack codes and calculate the chemical properties of medication'. And yet Van Wakeren puts things in perspective: such a timeline is comparable to the evolution of today's computers. After all, it was only 20 years ago that the first qubit saw the light of day, and we are now writing the first code for the first quantum computer. And the first transistors appeared in the 1950s, while 20 years later the first home computer was introduced at the Marin Computer Center. He concludes: 'We are now offering the first platform for executing quantum algorithms. It is difficult to indicate the time line moving forward, as we still understand little of the complexity of the quantum computer of the future'. <<

> The major challenge is in scaling up to larger numbers of qubits, and controlling them.

THE FIRM

Drones can be used for anything, from filming from the air and monitoring groups of people to scaring away birds. The founders of Mainblades Inspections found a new use: inspecting aircraft for damage.

Aircraft are inspected regularly, sometimes briefly, sometimes extensively. All aircraft is subject to a tight inspection schedule. An aircraft struck by lightening is inspected straight away, which means it has to be grounded for a few hours.
TU Delft alumni Dejan Borota and Jochem Verboom worked with KLM pilot Mark Terheggen to find an alternative solution. They installed a sensor on a drone that automatically inspects for damage after a lightning strike. 'The technology is very similar to that of a self-driving car,' explains Verboom. 'But you always need to have a human in the loop. Now this is the drone operator, but in the future you will only have a supervisor who monitors the process.'
Borota and Verboom met each other in Zurich when they were studying. Back in the Netherlands, they followed a course for start-ups at YesDelft. They did not have a clear plan yet, but they knew they wanted to start a business. TU Delft connections introduced them to KLM. They both now had jobs; Borota was designing a cleaning robot for Fleet Cleaner, another TU Delft start-up, and Verboom was programming security robots. 'I wondered if we would also be able to clean aircraft,' explains Borota. 'That plan proved to be unprofitable, but I did learn how time-consuming the inspections were, while the drone hype was just starting. So we conceived the inspection drone.'
They launched their company together with Terheggen in 2017. 'We made our first test flight in July 2016. after which we continued development. The second test phase at KLM is scheduled for October, when we will spend about 6 months testing the drone twice a week. If all goes well, we will then commence production.'
Mainblades is not the only company working on this technology. Two companies in France and the UK are roughly in the same development phase. 'It feels like a race against the clock, because we want to be first,' says Verboom. 'Though having competition is good, because it keeps you sharp.'
One of the problems the start-up has is finding funding. 'We do not have a regular paying customer yet.' So, alongside funding from KLM and research grants, they have also invested their own money. 'It can be hard. We need to develop the technology before we can present the product. It will take off once we get our first paying customer, which will help us gain the confidence of other customers.'
While the customers may still lack confidence, the young entrepreneurs have plenty. 'We have a achieved a lot with only a little money in a short time. We're still a bit nervous, because we're taking a risk. We're sometimes forced to let people go we would have preferred to keep. But we're convinced this will become a new tool for inspectors. It will eventually make aircraft safer, because it will enable faster and more thorough inspections.' RvT

Photo: Sam Rentmeester

Name:	Dejan Borota (l) and Jochem Verboom
Degree programme:	Electrical Engineering (Borota) and Mechanical Engineering (Verboom)
Company:	Mainblades Inspections
Product:	Aircraft inspections
Employees:	3 founders, 4 employees, 2 final-year internships
Target group:	Aircraft maintenance companies and airline companies
Five-year target:	Market leader in this field

'It will eventually make aircraft safer, because it will enable faster and more thorough inspections'

TEXT: CONNIE VAN UFFELEN PHOTO: SAM RENTMEESTER

The blue line

Since September a blue line is running across campus. Why?

If you travel far enough north, sooner or later, you will reach the polar circle. A sign sometimes announces your arrival, like in the Finnish city of Rovaniemi. Everyone has heard of other imaginary lines like the equator and the tropics, but now there is also one running straight across campus: the 52nd degree of latitude. When Professor Ramon Hanssen realised this years ago, he came up with the idea of making it visible. After all, results in his professional field of geodesy – which, for Hanssen, involves plenty of earth observation – are often not tangible. Therefore, in November 2011, he furtively sprayed the line on the pavement.

The funny thing about the degree of latitude, says Hanssen, is that it has a time effect. This is because the Eurasian continent is moving towards the northeast. 'So you see the line 'drop'. The line used to be elsewhere, which means we can make the factor of 'time' visible on campus. Calculations have revealed that the continent moves 16 millimetres northwards every year.'

Hanssen's plan remained dormant for a while, until now – seven years, or 11.2 cm later – the line is a fact. It runs between the glass main building of the Faculty of Civil Engineering and Geosciences and 3mE. At the centre of the blue line is a white band containing a 16-millimetre-wide black line, which indicates the position of the 52nd degree of latitude on 1 January 2018. For anyone thinking of measuring it: it is already no longer in the same position. 'The width of the black line represents the shift per year', explains Hanssen.

To illustrate the time effect, six grey lines have been painted parallel to the blue line. These grey lines indicate significant events related to Delft events.

- The first line is 2.79 metres to the north, and marks the foundation of TU Delft in 1842. The following three lines represent events in the Golden Age:
- The first time that Delft researcher Antoni van Leeuwenhoek described bacteria, in 1676. This line is 5.4 metres to the north of the 2018 position.
- The escape of Delft-born Hugo Grotius from Loevestein Castle in a book chest in 1621. This line is 6.3 metres more northerly than the 2018 line.
- The murder of Willem of Orange in Delft in 1584; 6.9 metres to the north of the 2018 line.
- The fifth line is 12 metres from the blue line: this was the position of the 52nd degree of latitude in 1246, when Delft was enfranchised.
- The final line, at a distance of 32 metres, indicates the start of the Western calendar era: the year 1.

'The idea is that if you now start studying here and complete your course within the nominal study period – so, a three-year Bachelor's and two-year Master's – the line will have moved 5 x 16 millimetres = 8 centimetres', says Hanssen.

Watch the video via this QR-code

HORA EST

A film's lack of scientific correctness is not detrimental to its quality.
Timothy Kol, computer science engineer

Batman is a better rolemodel than Superman.
Adreas Hänsel, physics engineer

Technological advancement is mainly driven by laziness.
Hongli Xu, chemical engineer

The evolution of energy carriers also follows Darwinism.
Yaolin Xu, phisycs engineer

Transportation researchers should refrain from using gender as an explanatory variable in choice models.
Jeroen van der Gun, transportation engineer

Like art, physics needs a distinction between the 'modern' and the 'contemporary'.
Casper Versteylen, aerospace engineer

Size does matter, for physical model testing in soil mechanics.
Richard de Jager, civil engineer

The natural response of endangered swimmers shows that humans are not intended to swim.
Max Radermacher, hydraulic engineer

Computer champion

If you're not convinced of the power of artificial intelligence: look at the despair in the eyes of Lee Sedol, grandmaster of the board game Go. The documentary AlphaGo shows how the young South Korean champion accepts a challenge to play a tournament against a self-learning computer.

In the final phase of one of the games, Sedol gets up from the table and walks out onto the terrace. He paces back and forth agitatedly, dragging on a cigarette. Meanwhile, the computer has no concept of stress and makes its next move, on the board covered in black and white stones of which it is said there are more possible combinations than there are atoms in the universe.

Sedol sits down again, looks at the computer's move in amazement, and starts picking at his lower lip. Normally, the South Korean only takes a minute for his next move; now he needs 12. 'I thought that AlphaGo only made probability calculations and that it was just a machine,' Sedol would say later. 'But I changed my mind when I saw this move. AlphaGo is clearly creative.'

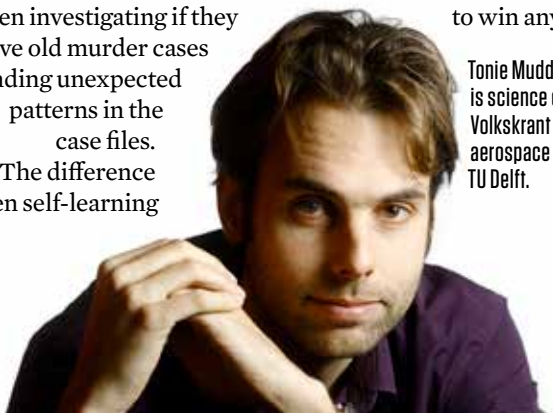
The South Korean lost the tournament, while experts had been sure that human grandmasters would be winning the game from computers for a long time to come.

Artificial intelligence is now used in many different areas. The police are even investigating if they can solve old murder cases by finding unexpected patterns in the case files.

The difference between self-learning systems and conventional computers should not be underestimated. I only started to understand this during a demonstration of the old video game Breakout (where you try to destroy a wall using a ball and ping-pong paddle). A computer can use artificial intelligence to 'discover' if it is worthwhile breaking a hole in the wall so that the ball can destroy it much faster from behind. Human players can learn this trick too after a few games, but the unfair part is that while a human has to sleep, artificially intelligent systems can play a million games to discover other smart strategies.

'My job is so special, no computer will ever be able to do it better,' some people say. I think this is heavily overestimating human ingenuity, and heavily underestimating the rise of self-learning systems. I recently saw a demo movie in which computer giant IBM lets a self-learning computer debate with a human. *De Volkskrant* newspaper asked Dutch top debaters to watch it and they were very impressed with the computer's rhetoric.

Maybe IBM strongly manipulated the demo. Maybe humans will be winning such debates from artificial intelligence for years to come, at least when scored for presentation. But lately, my vision for the future has become this: before long, those computers will be able to win any argument.



Tonie Mudde (born 1978) is science editor at de Volkskrant and studied aerospace engineering at TU Delft.

After Delft

As a young girl, Tineke Bakker – Van der Veen used to sit with her mother and grandmother plane-spotting on a blanket next to the runway. She is now Director of the Benelux and Nordics at Boeing.

But Tineke did not only develop her passion for engineering during those Sunday afternoons at Schiphol. 'My parents took the time to acquaint us with mechanics,' she explains. 'My father was a plumber and taught me how to change a tyre.' She considered both mechanical engineering and aerospace engineering and settled on the latter. 'It is more challenging to get five hundred people safely airborne,' she explains.

After her BSc she went to work full time for Rolls-Royce in Derby (UK). She flew back once every six weeks to complete her Master's programme. In 2005, she graduated on the subject of optimising turbine blade grinding. She continued to work for various Rolls-Royce divisions at various locations as a trainee, and met her Dutch husband there. 'He's a mechanical engineer from Delft!' They moved to Glasgow for his PhD and afterwards decided to return to the Netherlands and start a family.

In 2007 she was made product manager at Heineken, where she learned much about marketing, but also became increasingly sick. She proved to have a gluten intolerance and so returned to the aviation industry. At Fokker Services she was given responsibility for all the engines. She prefers management positions: 'They bring you closer to the places where decisions are made.' She was awarded a Business Degree from Nyenrode Business Universiteit and turned to the space industry in 2013.

She was project manager during the construction of the Tropomi (the weather instrument that can also accurately measure the hole in the ozone layer) at Airbus Defence and Space in Leiden. Fokker - now GKN – asked her to become programme director for the Gulfstream in 2015. 'The fuselage sections, tail, floor sections and landing gear doors for these aircraft are all made in the Netherlands,' she explains proudly. It did not go unnoticed: two years later, Boeing asked her to become their director for the Benelux and Nordics. She is responsible for supporting NATO and the fleet at Schiphol, the place where she once spotted planes. 'I am now the only engineer and woman on Boeing International's European team,' she says. 'My technical background really makes a difference if I have to read a customer report, for example; I understand the data behind it.'

One of her passions is Boeing Global Engagement: encouraging young people to choose engineering. Boeing does this by demonstrating how much fun engineering is, which is exactly how her love of this field was once born. GVU

TEXT: AGAATH DIEMEL PHOTO: GUUS SCHOONEWILLE

'Design is a means to **activate people**'

Industrial design engineer Diego Alatorre is volunteer for TU Delft. 'I had some ideas on design for sustainability, and on what I could learn in Delft, but my time here was really mind-shifting', he says.

Diego Alatorre: "Designing is about having a critical mind, a social perspective and the ability to come up with simple solutions to the world's problems."

'When I finished my bachelor's, I believed that the world didn't really need more saltshakers or chairs', says Diego Alatorre. 'So what could I do with my knowledge?' Coming to Delft gave him the answers he sought: 'I learned that you can use design as an instrument of change and that really broadened my idea of what I could do.'

'I found out that I am very sociable and love to work with people.' Alatorre also realised he was interested in the way people interact with technology. This was a central aspect of his graduation project which he undertook at a company supplying psychological services. 'My assignment was to create a set of tools that could help people with bur-

nout, so they did not have to go on a waiting list for a psychologist. Often, people get burnout because they believe the way to deal with stress is to work even harder, but this causes even more stress and so on.'

TANGIBLE WORLD

The original idea was for an app, the go-to solution nowadays. 'Additionally, it was my idea to create a physical tool to support the app. After all, we live our lives in a tangible world,' Alatorre says. Using some off-the-shelf sensors, he developed a wearable sensor vest that could monitor users' heart rate, breathing and physical activity. 'From this we could deduce their stress levels. The app then encouraged them to reflect on why they were always stressed in the mornings, for example, and would also give tips on moving and breathing.' In the end the product never materialised: 'The cost proved to be too high. Yet, I was content with what I did, because I had had the chance to incorporate so much of what I had learned into the project.' Alatorre is now a fulltime lecturer and researcher at UNAM, (Universidad Nacional Autónoma de México), the country's largest public university, based in Mexico City. 'I was given the chance the set up my own co-design course. I managed to incorporate a lot of the ideas I had brought back from Delft, ideas on design for emotions and creative facilitation', he recalls. 'Now, teaching is about 60 percent of what I do, but I am also interested in education as a research subject, in particular how we can foster education.'. In that respect, taking students out of the confinement of the classroom works really well, Diego found. ' They have to commit to what they do and test out their ideas before they present them publicly.'

WORLD BIKE FORUM

Alatorre likes to link projects to special events, like last year when the World Bike Forum took place in Mexico City. 'A lot of kids don't know how to cycle, but there are also a lot of people that have unused, often broken bikes at home', Diego says. 'We ended up designing a service where we collect those bikes from people willing to donate them, teach high school children how to repair them and then distribute them to schools so children who cannot afford a bike can learn how to cycle.' Thus, the project was a success on various levels. "The kids just wanted to learn to cycle, the high school pupils wanted to learn a skill to make money, and the students wanted to learn how to design services for the public good. Design isn't about having a lot of money, it is a mind tool that allows you to make the most out of what you have.'

MAKERSPACE

UNAM is one of the largest universities in South-America, with hundreds of thousands of students. 'We simply cannot take on more students, so we try to extend the limits of the university in other ways.' That also includes bringing design education to people who don't have access to it now. With them in mind, Alatorre is setting up a low-threshold design workplace, a makerspace where people can come together to create and learn. 'Most children go to public schools, where creativity is not facilitated at all. But you don't need expensive machinery for design', he says. 'It is about having a critical mind, a social perspective, and the ability to come up with simple solutions to the world's problems. About making your ideas tangible, and learning from the way people use them.' The time is just right for his plans, Alatorre knows. 'Mexico City is 2018 World Design Capital, with different groups of people coming together to showcase what we are doing in the design community.' In one activity, six local universities have joint forces. With a little help from the 'Laboratorio para la Ciudad', a local think tank for creativity, the joint design project could result in a permanent design course. In another project, designers calling themselves 'design activists' have come together to question the status quo. 'Design is usually seen as a means to sell products; we see it as a way to activate people. We want to form a network of people who want to design for social change.'

> 'You don't need expensive machinery for design'

ALUMNI VOLUNTEER

In his limited spare time, Alatorre still finds time to act as a volunteer for TU Delft. 'I organise events, like hackathons, and when a group of students in construction management and engineering came to Mexico, I organised an open talk so they could meet with students and companies.' He is also trying to setup an exchange agreement between UNAM and TU Delft, and he visits study fairs to give talks on how to get a student scholarship. He likes working on the social side of academic life. 'When I was a student in Delft, I was part of the Mexican student association. I now organise reunions for TU Delft graduates living in Mexico. The social part of academic projects is very important. You don't get to know people just by sitting in an office with them, but by sharing a meal or a laugh with them.' <<

Are you inspired by this story? Would you like to explore your options for lasting involvement at TU Delft? Please send us an email at alumnirelations@tudelft.nl

ALUMNI NEWS

Alumni Activities

25 October
TU Delft Alumni Backstage Tour
25 October
Dutch Engineers Alumni meeting (Washington)
26 October
Dutch Engineers Alumni meeting (Boston)
28 October
Science Day 2018
29 October
Dutch Engineers Alumni meeting (New York)
19 - 23 November
Dutch Engineers Alumni meeting
19 November (Cologne); **20 November** (Frankfurt); **21 November** (Stuttgart); **22 November** (Munich)
23 November (Hamburg)
23 November
Grand Final BK Booths at the Venice Biennale
11 December
Karel Luyben Lecture (Berlin)

Register via the alumni community tudelftforlife.nl or the website alumni.tudelft.nl.

CONTACT
Questions, comments or ideas?
E-mail: alumnirelations@tudelft.nl
Website: alumni.tudelft.nl
Community: tudelftforlife.nl

'TU Delft for Life' is the online community for all Delft alumni. Expand your network, rediscover old friends from uni and keep abreast of all the latest news and events. You can register at tudelftforlife.nl, where you can also change your address or contact details.

DEAN Events, East Coast US – 26-30 October

The Dutch Engineers Alumni Network (DEAN) from TU Delft, TU/e, UTwente and Wageningen has communities in the US, Australia, Canada, Scandinavia, Spain and Switzerland.

Did you know that North America has one of the largest concentrations of TU alumni outside of the Netherlands, with more than 6,000 graduates? After visiting the West Coast, we will complete our American tour with a visit to the East Coast in late October. Attend one of the events in Boston, New York or Washington to find out more about our unique network. More information is available in the alumni agenda: alumni.tudelft.nl/agenda.

DEAN tour, Germany – 19-23 November

Events are being in organised in Germany for the first time. DEAN will visit five German cities in November and December in the hope of launching new and bustling communities.

Karel Luyben Lecture, Berlin – 11 December

The highlight of the DEAN tour of Germany is the first Karel Luyben Lecture on 11 December in Berlin. The lecture is dedicated to rector magnificus emeritus Karel Luyben and will be held annually, once in Delft and once in a city abroad. Prof. Roel van de Krol, of the Institute for Solar Fuels from the German Research Center for Environmental Health (TU Berlin) and TU Delft alumnus, will give a lecture at the Dutch embassy in Berlin.

Event-in-a-box

Twice a year, Alumni Relations helps alumni from all over the world to facilitate the organisation of an informal alumni meeting. With the Event-in-a-Box concept, they receive a themed box to further enhance the quality of the meeting. Alumni are always especially pleased with the treacle waffles, nuts and cheese snacks.
A photo competition was held as part of this summer's edition of Event-in-a-Box. Some 10 alumni communities, from Melbourne to Quito, competed for the Event-in-a-Box Deluxe for the upcoming Saint Nicholas edition.
If you would also like to organise an alumni meeting, contact alumnirelations@tudelft.nl.

The winning submission is from Mexico City. Congratulations!

WANTED: 10 GOOD FRIENDS

Currently TU Delft has 90 'Good Friends': all of them involved alumni, who support our researchers and students with their network, expertise and a financial contribution. 'Good Friends' contribute to ground-breaking research, education innovation and talent development at TU Delft.

You too can become a Good Friend. The larger the community, the more we can contribute to TU Delft's mission of remaining a world class university. And because friends always support each other, you will be rewarded in return. You will become member of our network and will be our esteemed guests at various top events at TU Delft where you will have the opportunity to meet TU Delft's talented researchers and students. Moreover, you will receive an invitation for the annual exclusive *Taste of Excellence dinner,* which in 2018 takes place on November 6 in the new state-of-the-art educational building PULSE at TU Delft.

It is very simple to become a Good Friend. Just send an e-mail to relations manager Machteld von Oven, and she will respond directly to your informational needs. Of course, she is also just a phone call away. You will find her contact information below. When you sign up before November 1st, you will have the possibility to attend the *Taste of Excellence dinner 2018.*

m.w.vonoven@tudelft.nl **+31 6 81060919** **www.universiteitsfondsdelft.nl/goedevriend**

INVOLVED WITH TU DELFT

DIDI TE GUSSINKLO OHMANN

I am a Good Friend of Delft University Fund since the beginning of this year. As TU Delft alumna (MSC Civil Engineering) I have always been involved with the university. Currently, I am working as Director Operations Offshore Wind at Van Oord.

My education has been very decisive in my life. I am privileged that I have always known very well what I wanted to study. Until now I have been committed to Hydraulic Engineering. I would like to convey my enthusiasm for my profession with current students. With my donation, I am able to give something back to the university to which I owe so much. Moreover, I look forward to meeting many more Good Friends at the annual *Taste of Excellence Dinner.* Will I see you there?

Lab of...
Kouwenhoven

Master student Applied Physics Marta Pita-Vidal from Spain is carrying out her final research project at Kouwenhoven's lab in QuTech. The main goal of QuTech is to create a quantum computer. She uses nanofabrication techniques to create topological qubits. Topological qubits are a specific kind of qubits, the elementary unit with which one could create a quantum computer. In the photo she is inserting one of the devices in a helium tank to study its properties at very low temperatures.

PHOTO: SAM RENTMEESTER