I/O magazine

ICT RESEARCH PLATFORM NEDERLAND

PAUL KLINT

Before the deadline!

Deadlines are useful for achieving goals. But how do you set an achievable deadline for a ginormous goal?

Most people have a complex relationship with deadlines. We all hate them. But we also know that they help to obtain results. Deadline for an article submission approaching? Work day and night until minutes before the deadline and then push 'send'. Or cheat a few hours when it is Anywhere on Earth.

The common sense advice to start earlier is not heard and is at odds with Parkinson's law that work expands to fill the time allotted for its completion.

Managers and politicians are deadline-driven: a deadline has been agreed upon after much debate in the political or business arena and should be met whatever it takes. But in some cases, "whatever it takes" is not enough. Gaps between design and reality, missing focus, skill or execution issues, to name a few, may simply block the successful completion of a project. Even the (self-perceived) power of managers and politicians cannot change this. Reality is harsh.

We can learn something from cost estimation: estimating the costs of a large project as a whole is impossible and leads to the wildest speculative numbers. However, breaking up the project into the smallest possible parts and estimating the cost of each part gives more realistic numbers. One reason is that people have more experience with smaller projects and can more accurately estimate them. The shock comes when the costs are accumulated for the entire project and the total is much higher than the available or anticipated budget. A wise manager or politician will either increase the budget or reduce the scope of the project. Unfortunately, this does not happen in too many cases. Lowering estimates does not change the reality.

So what can we learn for setting deadlines? Estimate times, dependencies and availability of resources at the lowest possible level and aggregate. Deadlines created from the bottom up have a higher chance of being met than top-down imposed ones.

How does this all apply to your article deadline? I'm convinced that starting earlier leads to more sleep, more time for reflection and ultimately better articles. Submitted before the deadline.

ICT-ONDERZOEK PLATFORM NEDERLAND

NWO

BRINGING BIG DATA RESEARCH CLOSER TO THE MARKET

The Commit2Data research programme has a valorisation branch to bridge the gap between designing solutions that work in the lab and building products that work for people. This programme, which employs a valorisation coach, might be an example for other Dutch research programmes.

By Bennie Mols Images iStock, Henk Veenstra, ECP, Bram Saeys

'Many researchers underestimate the gap between showing that an idea works as a prototype and showing that it works as a product for people', says professor Alexander Lazovik, head of the group Distributed Systems at the University of Groningen. Lazovik received a Commit2Data valorisation grant in 2021 for the project ECiDA: Evolutionary changes in distributed data analysis. Although the grant of 40,000 euros is relatively small, it allowed Lazovik and his partners to create a minimum viable product over a period of six months in 2022. In the ECiDA project, they work together with Vitens, the largest drinking water company in the Netherlands, trying to solve various data challenges that the company faces in its water management. Centrum Wiskunde & Informatica (CWI), TNO and the start-up companies Anchormen and Researchable are also part of the partnership to bring big data research closer to the market.

Alexander Lazovik

'There is a gap between data science and software engineering'

Bridging the gap

Data can help monitor and distribute water, predict and maintain water quality, and keep water pipes reliable. Although Vitens collects all kinds of sensor data to improve their water management, the company felt it was not using these data to their full potential. Lazovik: 'It transpired there was a gap between the algorithms as developed by the data specialists and how these same algorithms run in practice at the company. Basically, it comes down to a gap between data science and software engineering.'

Aldert de Jongste

'Support can take all forms, from finding funding to organising coaching'

Lazovik believes that thanks to the valorisation grant, they have created a solution to bridge that gap: 'Our solution takes into account the entire life cycle of the data science pipeline. It requests that for each component, developers explicitly state what it is about. How should data be fed into the component? What data comes out of the com-

ponent? For different types of data, you need to do different things. Furthermore, components must be dynamic and changes shouldn't result in malfunctioning.' Together with Vitens, Lazovik and his colleagues are now exploring how well their solution works in practice.

Discovering what works

The Commit2Data valorisation grants grew out of the public-private research and innovation programme Commit2Data, which focuses on bridging the gap between academic research in the field of big data and business applications (see box on page 7). 'Although valorisation is already embedded in the goal of the research programme, we saw that much potential still remained untapped', says Boudewijn Haverkort, chairman of Commit2Data. 'Therefore, we created a separate valorisation plan in 2019 for which we managed to get funding through the Ministry of Economic Affairs and Climate Policy: about 2 million euros to be spent on support for the valorisation of research results between 2020 and 2024.'

An initiative like this, bringing academic research so close to the market, did not exist before in the Dutch public research landscape. Therefore, the Commit2Data board had to find out what type of valorisation plan works in practice. 'We first considered organising general courses and meetings', recalls Haverkort, 'and we thought we would roll these out to PhD students who could then accumulate credits. We learned that there was little enthusiasm for this. It is too complicated and universities already organise things in this field.'

'However, we discovered that what did work was employing a valorisation coach, Arie Brouwer, who contacted researchers personally', states Aldert De Jongste, general secretary of Commit2Data. He continues: 'Brouwer contacts researchers from all 60 Commit2Data projects, acts as a sounding board and offers customised support. Support can take all forms, from finding relevant funding to organising the coaching of a start-up by an experienced entrepreneur. Often part of this process is finding the focus: what is the next doable step? Together with the researchers, and sometimes also companies, he looks at the research findings and the potential to take these one step further to market or towards a societal application. Where wanted, the coach also helps with writing the grant applications, which are then evaluated according to the regular NWO criteria.' This kind of customisation can yield surprising results, says De Jongste: 'We saw that the different perspective the valorisation coach brought to the table could both inspire and guide the process.'

Two other projects that received a valorisation grant are "Protection of electricity networks through simulation" and "Physicians Implement Exercise as Medicine (PIE=M)". The first project is about designing a new simulation platform for a nationwide electricity network. 'By using measurement data, the researchers developed an algorithm that predicts peaks and troughs in the electricity network and

helps stabilise it', explains De Jongste. 'The simulation platform has been successfully tested on the electricity grid of Iceland.' The second project, "Physicians Implement Exercise as Medicine", builds on the scientifically proven insight that daily exercise reduces the occurrence and severity of many chronic diseases. It examines why exercise as a medicine is not yet being implemented and what physicians are up against. The ultimate goal of the project is to develop a tool that generates personalised exercise advice based on big data, making the adoption of exercise as medicine easier and more widespread. De Jongste: 'During the research phase, there were two successful trials in hospitals in Amsterdam and Groningen. During the valorisation phase, the applicability within other hospitals was explored. The project consortium is now looking at the possibility of setting up lifestyle advice desks at hospital locations.'

Lessons learned

Haverkort thinks that other Dutch research programmes can learn important lessons from the Commit2Data-experiences when it comes to taking valorisation to the next level: 'Lesson one: customise the support of valorisation. We notice that every project has different needs. No two routes to valorisation are the same. Lesson two: reserve a small part of the total budget upfront for valorisation. Let's say there is a 5 million euros research programme. Then I would spend a bit less on doing the actual research, something like two PhD students less, and use this money to start employing a valorisation coach and introducing valorisation grants in the second or third year.'

Boudewijn Haverkort

'Customise the support of valorisation and reserve a budget upfront'

Thanks to these valorisation grants, researchers can build demonstrators, and with these demonstrators, they can then make a new step towards collaborating with a business partner. The Ministry of Economic Affairs and Climate Policy, which financially supports the initiative, has already expressed its satisfaction with the results. Haverkort: 'Despite being a small-scale programme, we see that the smallness of scale works.'

Alexander Lazovik, as one of the recipients of a valorisation grant, believes the grants provide excellent opportunities for both companies and universities: 'Universities can do something which does not belong to their core business, namely bring ideas to the market. And companies can do something which otherwise is still too risky for them: create a demonstrator which focuses on the added value for businesses, allowing them to assess the market potential of the research results achieved.'
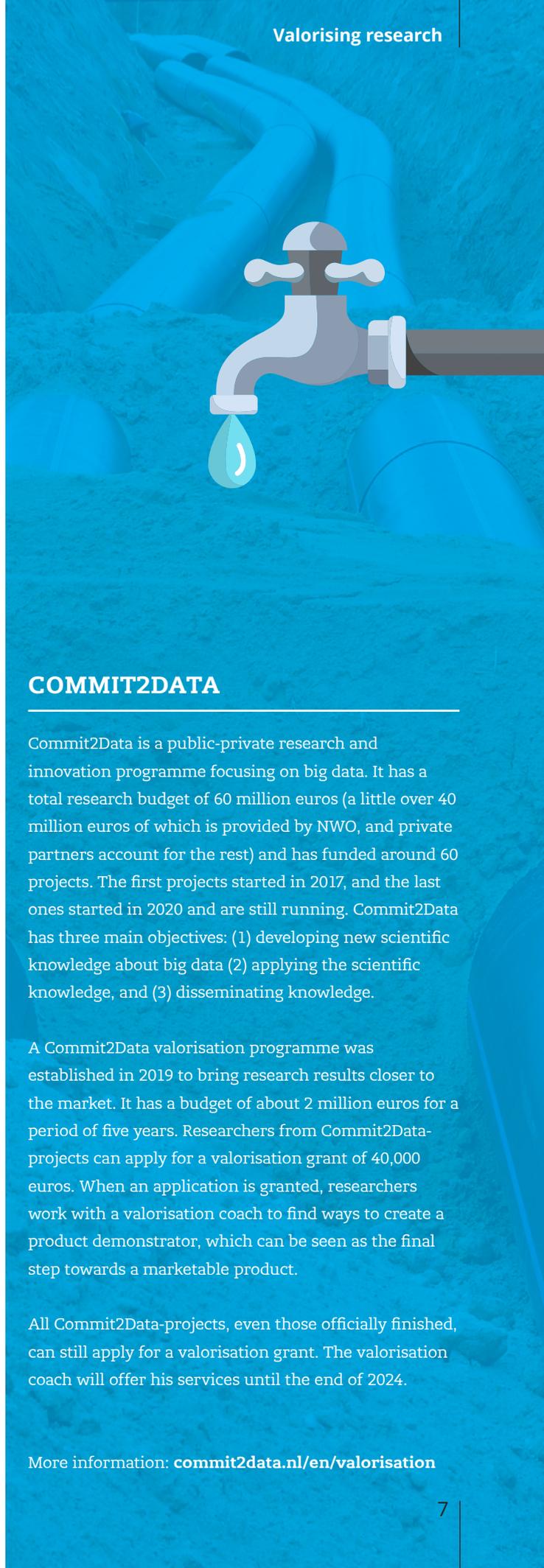
COMMIT2DATA

Commit2Data is a public-private research and innovation programme focusing on big data. It has a total research budget of 60 million euros (a little over 40 million euros of which is provided by NWO, and private partners account for the rest) and has funded around 60 projects. The first projects started in 2017, and the last ones started in 2020 and are still running. Commit2Data has three main objectives: (1) developing new scientific knowledge about big data (2) applying the scientific knowledge, and (3) disseminating knowledge.

A Commit2Data valorisation programme was established in 2019 to bring research results closer to the market. It has a budget of about 2 million euros for a period of five years. Researchers from Commit2Data-projects can apply for a valorisation grant of 40,000 euros. When an application is granted, researchers work with a valorisation coach to find ways to create a product demonstrator, which can be seen as the final step towards a marketable product.

All Commit2Data-projects, even those officially finished, can still apply for a valorisation grant. The valorisation coach will offer his services until the end of 2024.

More information: **commit2data.nl/en/valorisation**

The documents will be published on ict-research.nl. The funding decision is expected this spring.

'It is not a matter of us wanting to grow. The informatics sector simply needs to grow to meet the needs of our rapidly digitalising society', says IPN Board member Gerard Barkema. Together with Cocky de Wolf, policy director at Utrecht University, he explains the ins and outs of the Sector Portrait Informatics and its accompanying Sector Plan that are currently in the making.

Sector plan to strengthen foundations

By Sonja Knols

When Minister of Education, Culture and Science Robbert Dijkgraaf recently announced that he planned to invest 200 million euros per year on sector plans, the deans of the science faculties approached IPN to come up with an integral plan for the entire Dutch academic informatics sector. The financial part of this plan referring to the three technical universities and Wageningen University will be accommodated by the Sector Plan Technology, and the other part will be integrated into the new Sector Plan Natural Sciences.

'The aim is to help consolidate strengths and improve deficiencies'

CONSOLIDATE AND IMPROVE

Barkema sums up why investments in informatics are needed, now more than ever: 'We have the worst student-to-staff ratios of all scientific disciplines, virtually all routes in the Dutch Research Agenda lean on computer science, and the job market is desperately seeking IT talent.' De Wolf adds: 'An international research assessment committee that recently reviewed Dutch informatics research also recommended that the Dutch government invest in academic informatics. Not only to relieve the burden of education but also to make up for the significant lack of funding that has been available for the fundamentals of the discipline over the years.'

BRIGHT, DIVERSE FUTURE

First and foremost, the sector plan will enable the hiring of new staff. Barkema: 'Since eventually the amount of direct government funding for informatics will also grow as a result of the growing student population, I see a bright future. Although they are only a first, perhaps small step, these sector plan funds will certainly help make things better.' 'What's more,' De Wolf adds, 'one of the explicit aims of the sector plan is to increase diversity. At least fifty percent of the sector plan positions will be occupied by women. We need more diversity to build a stronger base for our sector, which in turn is indispensable in shaping our future society.'

THEMATIC DCCS FOR THREE SCIENCE DOMAINS

The formation of three science-wide Digital Competence Centres has started. These DCCs will bring together scientists in three domains: Life Sciences & Health (LSH), Natural and Engineering Sciences (NES) and Social Sciences and Humanities (SSH). The thematic DCCs will work within their domain on improving digital research competencies for exchangeable, accessible and reusable data and software.

As a first step, the Governing Board of NWO has agreed to allocate a total of 4.5 million euros for the appointment of network coordinators. The network coordinators will ensure that the thematic DCCs actually get started by bringing together experts, stimulating cooperation and commencing projects based on the Roadmap plans developed by each thematic DCC together with their respective research field.

NATIONAL GUIDE TO RESEARCH SOFTWARE MANAGEMENT

Recently, NWO and the Netherlands eScience Center issued the Practical Guide to Software Management Plans. This document offers guidance for research institutions, research groups and individual researchers on how to manage research software produced as an output of research projects. It describes core requirements for software management plans, provides resources to guide researchers and research support staff in fulfilling these requirements, and a framework for implementing the core requirements into software management plans.

NWO makes requirements on research software management through its research data management policy. Software developed during a project that is needed to access and interpret research data, should be made openly available as much as possible alongside the data.

The guide can be found at **doi.org/10.5281/zenodo.7038280**

THIRD EDITION ALICE & EVE

On 18 November 2022, the third edition of the annual Alice & Eve workshop took place at TU Delft. Alice & Eve is an event to celebrate women in computing in the Netherlands, which is open to everyone of all genders, from Bachelor and Master students up to full professors. In addition to the keynote talks and the posters, there was an exhibition which portrayed thirty women in computing and their most important contributions, ranging from Grace Hopper, who created the world's first workable compiler, to our very own Felienne Hermans.

Read about all 30 women in the booklet on **fmt.ewi.utwente.nl/events/aliceandeve2020/booklet-13-01-2020.pdf**

TENTH BIRTHDAY ESCIENCE CENTER

Founded in 2012 as an independent foundation by NWO and SURF, this year, the Netherlands eScience Center celebrates its tenth birthday. What started back then with about ten people is now about 100 people. The eScience Center is the national centre with the digital skills to create innovative software solutions in academic research. It awards research projects based on calls for proposals and trains researchers in the use of research software. 'A centre of excellence for research software as a national organisation is unique in the world. Others envy that,' says the centre's director Joris van Eijnatten. 'Besides the collaborative projects we do with research institutions, we want to expand our training programme in the coming years so that expertise on topics such as deep learning, parallel programming and online collaboration also lands within institutions and among researchers.'

More information on **www.esciencecenter.nl**

By Leendert van der Ent
Images iStock, 5GHub

5GHUB:
CONNECTING TECHNOLOGY BY CONNECTING PEOPLE

5G enables real-time connectivity between the cloud and applications. 'It is nothing more than a means to an end', says senior external affairs manager Rene Visser from VodafoneZiggo and the 5GHub Eindhoven. 'It's the same for AI, VR/AR, blockchain and photonics, which we also cover.' Developing applications for these new technologies should contribute to making the High Tech Campus Eindhoven the biggest technology innovation powerhouse in the world by 2030.

'New technology applications should have societal impact: they should enhance the quality of life and support the UN's sustainable development goals', states Rene Visser. 'A prime example of this is last year's winner of the 5GHub Innovation Challenge, Odd.bot. This weeding robot offers an environmentally friendly alternative for weed killers. Using 5G for this robot makes it much more affordable. When the computing power is in the cloud, the individual robots can operate on more affordable hardware.' This year's winner, TechBinder's Smart Vessel Optimiser, does something similar. As it brings data from ship to shore via 5G, it opens the perspective of digital twins and autonomous vessels for the maritime sector.

Visser: 'Four partners initiated the 5GHub: Brainport Eindhoven, the High Tech Campus, Ericsson and Voda-foneZiggo. They had the vision that connectivity is a key element in electronics innovation. Here we have all of the 5G facilities imaginable available for testing. This ranges from the 3.5 GHz frequency to the 26 GHz frequency. Companies can experience here what 5G could mean for their future and their product portfolio. But ultimately, it is not about 5G, but about innovation and applications in general.'

BRINGING ADDED VALUE TO FRUITION

During the first three years of its existence, the 5GHub mainly focused on reputation building and growth – for instance through the annual Innovation Challenges

means besides being a partnering broker, we also function as a talent factory. We support subsidy applications and finance issues.'

The 5GHub intends to merge with the AI Innovation Centre to form an innovation powerhouse for connectivity and AI, including digital twins of factories and the metaverse (VR and AR). The logic is as follows: everything is connected to the internet, data becomes big data, AI is needed to extract meaningful information from the data and 5G is needed for connectivity. The innovation boost to this chain is closely linked to the strategy of the High Tech Campus – which already houses 260 companies and talent originating from 150 different countries. The ambition is to become the world's largest and best-known, high-tech innovation ecosystem by 2030. Visser: 'And if you conclude that we need to surpass Silicon Valley to achieve that, then your assumption is correct.'

GREATEST ASSET

A crucial aspect of realising this ambition might be adopting an even broader scope, including the Eindhoven focal point of photonics-based chips and systems-on-a-chip. These combine far greater data transmission with much lower energy consumption. Visser: 'Apart from that, we are evolving from a hardware-centred region to an integrated technology area with metaverse capabilities. But the most important factor remains our ability to scale up all the concepts we have thanks to the innovation speed of our start-up and scale-up partners. We have a vibrant community with breakfast sessions and symposia. Our greatest asset is people exchanging ideas. Everyone with great ideas is invited to join us and contribute to a better world.'

for start-ups and scale-ups. Some showcase applications have already been brought into practice. An example of this was "slicing", the allocation of guaranteed bandwidth to different parties. During a Red Hot Chili Peppers concert, the responsible operations centre used it on security cameras, crowd flow monitoring and other security aspects. A second slicing application involves a test with Philips. An ER doctor in the hospital, supported by ultrasound equipment, can diagnose a patient the moment they enter an ambulance. This speeds up diagnosis by up to half an hour.

'Since we accomplished that', Visser says, 'we are entering our next phase: bringing value-added, product-market combinations to fruition in the coming years. We want to develop innovative real-life applications for testing, and we want to scale up in a faster way by enhancing companies with a set of fixed methodologies.'

BURNING AMBITION

Visser sets out how the annual Innovation Challenge will further evolve in a continuous process in which start-ups with good ideas and technologies are connected to large companies that wish to boost innovation. Societal issues, such as solutions for smart cities, will also be addressed. 'Many students from Eindhoven University of Technology and Fontys University of Applied Sciences work here to support cases by gathering relevant data to establish case feasibility. That

'BESIDES BEING A PARTNERING BROKER, WE ALSO FUNCTION AS A TALENT FACTORY'

Rene Visser

Advancing the digitalisation of the life sciences

By Bennie Mols Images Ivar Pel
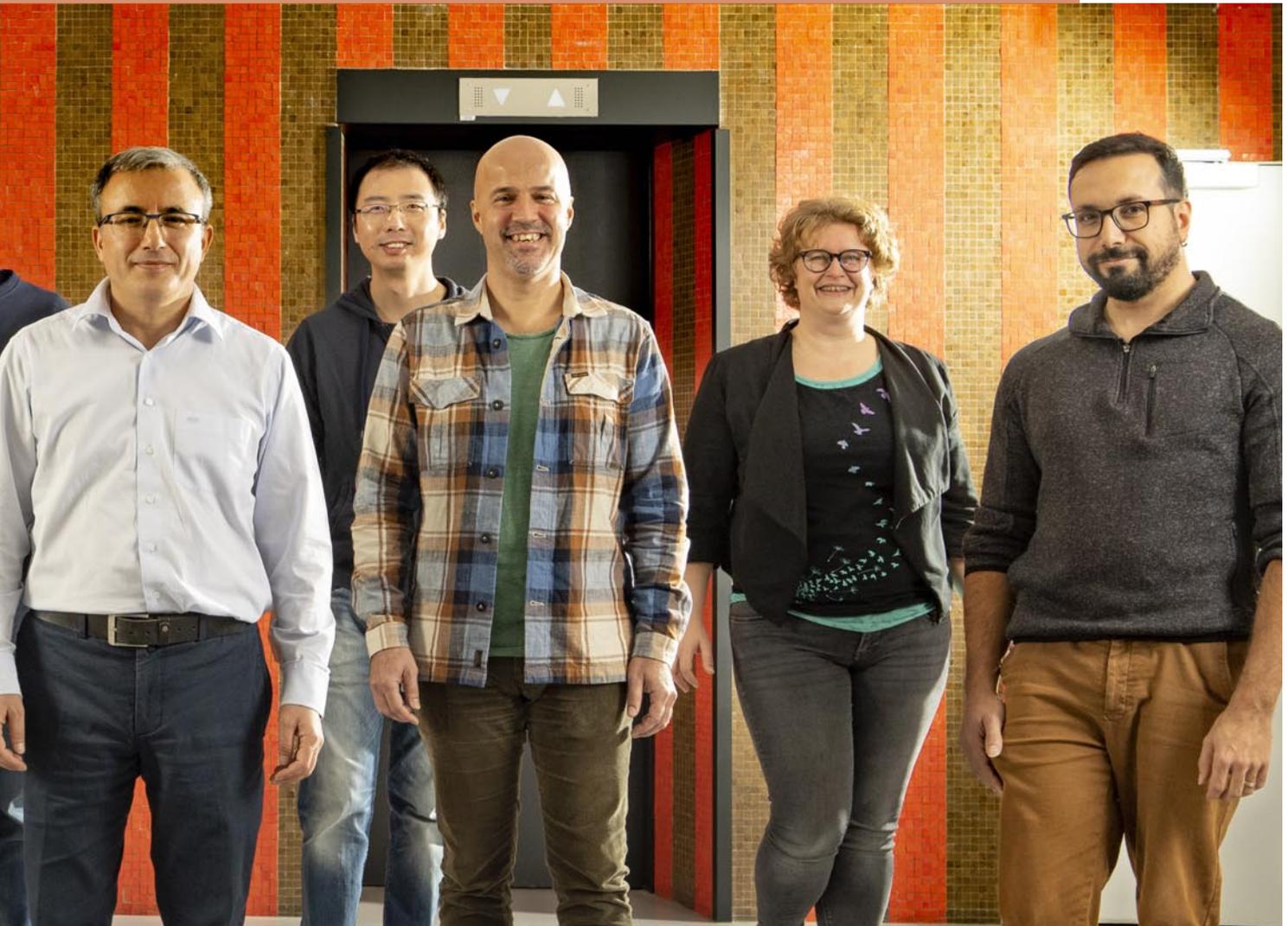
GROUP PASSPORT

RESEARCH FIELD

Software engineering, AI and data science, socio-technical systems engineering

INSTITUTION

The Information Technology Group is part of the cluster Social Sciences at Wageningen University & Research (WUR)

LABS

Drone lab

EMPLOYEES (as of October 2022)

2 full professors

13 assistant/associate professors

5 postdocs, 25 PhD students

5 support staff

WEBSITES

Information Technology Group:

www.wur.nl/en/research-results/chair-groups/social-sciences/information-technology-group.htm

Wageningen University & Research is known worldwide as a centre for life sciences and agricultural research. In recent years, it has also built a strong Information Technology Group. This group not only creates tools for other researchers at the university but is also developing unique expertise in software engineering, AI and data science and socio-technical systems.

The official motto of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Digitalisation is an essential tool for turning that motto into a reality. Professor Bedir Tekinerdogan realised that when he joined the university in January 2015. Tekinerdogan: 'No one escapes digitalisation. But the life sciences have started this transformation rather late.' With his Information Technology Group, he wants to support and accelerate this transformation. Tekinerdogan: 'As far as we're concerned, digitalisation of the life sciences has two main components. First, making systems smarter by making more use of software, data and AI. And second, interconnecting different systems to realise a system of systems.' Smart farming is a good example of this. Using all kinds of sensors and the data these produce, farmers can reduce the consumption of water and energy, and use fewer pesticides and fertiliser. 'Making systems smarter often means increasing efficiency, so doing more with less', remarks Tekinerdogan.

Interdependence

From a group primarily focused on education and that consisted of no more than ten people seven years ago, Tekinerdogan has rebuilt the group into a research and teaching unit of about fifty people, which is still growing. The number of computer science-related courses has jumped from 14 to 30. To achieve this growth, Tekinerdogan focused on two values when hiring new people: everyone should be collaborative and performance-driven. 'Each individual staff member needs to grow within the team', he says. 'Interdependence is more important than independence.'

To the outside world, the group is a computer science group focused on the life sciences, and that is pretty unique. Within Wageningen University & Research, the Information Technology Group is a generic group that can collaborate with all other research groups. Tekinerdogan: 'On the one hand, we aim to develop concepts in our key research fields of software engineering, AI and data science, and socio-technical systems engineering. On the other hand, we want to contribute to doing smarter what Wageningen already does very well. To give an example: when we, with our background in software engineering, look at the software used in the plant sciences, then we see a lot of room for improvement in making the software more modular and adaptive. But we also see that software engineering for the life sciences has different requirements than, for example, software for financial services. New concepts therefore need to be developed. This is covered by the term research software engineering.'

Bedir Tekinerdogan

Will Hurst

Represent a greenhouse

The group already has a drone lab and is planning to build a life sciences-focused, immersive technologies lab that concentrates on virtual and augmented reality and haptics. Tekinerdogan also has plans for a high-performance computing lab and a lab for scientific software engineering. 'The digitalisation of the life sciences in Wageningen is far from crystallised', he says. 'We started with research and education in the themes with the most pressing need: data science and AI. But we want to expand our efforts to other aspects of digitalisation.' Assistant professor in data science Will Hurst, who joined the group in 2020, is already exploring such other aspects. Hurst: 'A concrete example is a project we are doing with the Dutch company Wastewatchers. The idea is to visualise in 3D how much food is thrown away in a restaurant. For example, we can show how big the pile of food wasted each day is compared to the size of a car. Another more futuristic example is building a VR-based digital twin of a greenhouse.' Via this VR digital twin, the greenhouse owner can remotely walk around in the greenhouse and monitor exactly what is going on. Hurst: 'The main scientific challenge is to find out how to interact with the technology. How to make it more user-friendly? What exactly should we present in 3D?'

'I like the fact that the group is more ambitious, forward-thinking and collaborative than I have experienced elsewhere', states Hurst as he describes the characteristics of the group. 'We all want to support innovation in the life sciences and create some tangible output. Another thing I like are the annual outings to promote group cooperation. We have visited the VR Room Ravenstein and the Netherlands Open Air Museum, and we have held a photo competition.'

Sustainable agriculture in Africa

Matthew Ayamga is doing an interdisciplinary PhD, supervised by both the Information Technology Group and the Business Management and Organisation Group, where he had previously done his masters. 'Before joining the group, I thought that information technology was all about coding, but then I learned that it is not just technical and that the socio-technical aspects are just as important. What exactly goes into the software is an important question to ask.'

The multidisciplinary aspect that characterises his research is what he also appreciates in the Information Technology Group as a whole. 'We have diverse scholars, with different academic and cultural backgrounds and that creates a dynamic and open atmosphere.'

Ayamga is currently spending a few months in his home country Ghana where he is collecting data for his PhD research. 'I study digitalisation and business models for sustainable agriculture and I am using Ghana as a case study', he explains. 'Small- and medium-sized enterprises called Agritechs in Ghana develop all kinds of digital solutions for farmers, for example technologies that monitor moisture and temperature or leverage drone or solar technology. I want to know how these Agritechs organise their business models and their associated challenges in implementing such new technologies. My final aim is to propose new ways of doing business with digital technologies.'

Burcu Kulahcioglu Ozkan obtained a Master of Science in Computer Engineering from the Izmir Institute of Technology (Turkey) and a PhD from Koç University (Turkey). She was a postdoc researcher at the Max Planck Institute for Software Systems before coming to TU Delft, where she has been an assistant professor in the Software Engineering Research Group since autumn 2020.

CHALLENGES
OF CONCURRENCY

Almost all software we use today is concurrent and distributed, from the apps on your mobile phone to entire production systems. Assistant professor Burcu Kulahcioglu Ozkan of the Software Engineering Research Group at TU Delft is developing techniques to improve the reliability of such software.

By Marysa van den Berg
Image Sjoerd van der Hucht

What do the concepts of concurrency and distribution in software entail?

'A concurrent programme is a programme that performs multiple tasks simultaneously. Examples are the apps on your mobile phone. Furthermore, if you click on a button within the app, that request does not usually stay within the phone. It goes to a server to be processed and some databasing is performed on another machine. Therefore the software runs in a distributed manner too.'

Why is it so difficult to implement such programmes correctly?

'Let me explain this by making an analogy with cooking in a restaurant. With multiple chefs in the same kitchen, you need to share resources, coordinate tasks and synchronise everything to deliver the best possible meals on time. With software, the app itself may work correctly, but if there is a bug somewhere in the network, then things might still go haywire. The tasks may influence each other in a way that is difficult to predict.'

How do you want to address this problem within your research?

'At the moment, it is difficult for programmers to consider all possible executions during the system design and implementation. It is also costly and time-consuming to test them. My goal is to build automated programme analysis and testing techniques that come up with interesting case scenarios. When you run those scenarios on your system, you can detect bugs automatically. Eventually, we would also like to add automatic debugging tools.'

How far along are you?

'I think my goal is moving as I move towards my goal. New types of concurrent software and systems are being developed every day. For example, multiple cores or blockchain systems wouldn't have been on the research agenda some years ago, but now we cannot do without them. So we try to come up with algorithms and methods to check and ensure their reliability.'

What is so fascinating about your research?

'I like formulating questions, designing methodology, deciphering the results and sharing them with other researchers. Also, I enjoy the challenges of concurrency; to see that something in itself so simple can become really complicated when it interacts with other components. On the practical side, I love creating tools that are actually usable for real-life systems, for example production blockchain systems.'

You also teach and organise events, such as the Alice & Eve event. Why is celebrating women in computing so important?

'Women are less represented in computing science than men. We want to inspire and motivate women to come and work in this exciting field of research, for example by showcasing examples of female computer scientists with great accomplishments in the field.'

ABSTRACT MODELS FOR COMPUTING

By Bennie Mols Image iStock

The landscape of computational properties still contains many unexplored areas. VU Amsterdam researcher Jörg Endrullis is exploring the virgin territory of abstract computational models that transform streams of symbols or graphs. Potential applications are in automated reasoning about computer programs.

One of the fundamental questions in theoretical computer science is what is computable and what is not. Computer scientists have developed all sorts of abstract models to answer that question. The best-known model is the Turing machine, developed in 1936 by Alan Turing. This abstract machine consists of an infinite tape with input data (zeros and ones) and a head that can read, write and erase data on the tape. Anything that can be computed at all can be computed with a Turing machine. This thesis allows scientists to use a Turing machine to test the limits of what is and what is not computable.

'WE TRY TO DISCOVER A CLASSIFICATION HIERARCHY IN FINITE AUTOMATA'

In December 2019, VU Amsterdam researcher Jörg Endrullis started his 5-year Vidi research project entitled "Automata Transforming Streams". In this research, Endrullis uses finite automata, in particular finite state transducers, and another abstract model for certain types of computation. Finite state transducers are a subclass of a Turing machine, and are much less powerful. 'But precisely because they are less powerful, they are much better suited to studying the properties of certain types of computation', explains Endrullis. 'Just like it's easier to use a hammer when building a table than to use a sledgehammer.'

'My research initially concerned automated reasoning about computer programs, in particular about the questions as to whether a program is correct and whether two programs are equivalent so that they give the same output for the same input. This was largely foundational, curiosity-driven research, without any immediate practical implications.' Automata, however, have plenty applications, for example in hardware and software verification, text processing and the construction of compilers.

Finding hierarchy

Turing machines extended with a so-called "oracle" transform an infinite stream of symbols into another infinite stream of symbols. 'Finite state transducers also transfer one infinite stream into another infinite stream', says Endrullis, 'but hardly anything is known about their power. The motivation behind my Vidi research was to explore this unknown computational territory. We study different variants of such finite automata and we try to discover a classification hierarchy in them.'

After almost four years of research, which combined techniques from automata theory and the mathematical theory of combinatorics on finite and infinite words, Endrullis and two of his PhD students have discovered the first parts of a hierarchy of degrees of such abstract machines.

Recently, Endrullis started a second part of his Vidi research, which is about systems that transform one graph into another graph. Such systems are widely used in studying the internet, social networks, routing networks or transport networks because they can all be modelled as graphs consisting of nodes and arrows between them. 'In graph transformations, we strengthened an existing approach and proposed a unifying graph rewriting framework. We expect that this unifying framework can be used in future to automatically reason about graph rewriting systems.'

More information
joerg.endrullis.de/research/finite-state-transducers/

BUILDING BETTER DIGITAL TWINS

By Marysa van den Berg
Images WAT ontwerpers

High-tech systems are becoming more complex and harder to design, produce and maintain. The NWO Perspectief programme DIGITAL TWIN combines data-driven AI-based models with physics-based models. The aim: to create better digital twins that can predict the behaviour and performance of high-tech machines.

Imagine you have a robot, computer or car and you want to know how it works or performs. You can make a virtual representation for that which looks like and behaves identically to its real-world counterpart. Such a model is called a digital twin. For years, engineers have been making these digital twins for all kinds of systems based on knowledge from physics. But they are not as accurate as they should be. Fortunately, another source of information for modelling has recently become available in large quantities: data. Combining data-driven and physics-based models in hybrid digital twins could provide the levels of accuracy the high-tech world requires. Within the DIGITAL TWIN (Data-drIven and model-based enGIneering in fuTure industriAL Technology With value chaIn optimisatioN) research programme, researchers and engineers hope to develop such hybrid methods for many different use cases.

Nathan van de Wouw of the Eindhoven University of Technology leads one of the projects within the programme. 'Digital twins have become increasingly more important in the high-tech industry', he says. 'Without them, you would not be able to accurately design and monitor advanced systems. In our particular project, we focus on building hybrid twins for detecting system failures or degradation as early as possible.'

BEST OF BOTH WORLDS

These failures can be detected in two different ways. The most conventional way involves a physics-based model. 'This digital twin predicts how the machine should be behaving according to the designed physical parameters', Van de Wouw explains. 'If the system behaves differently, something might be wrong. The disadvantage of these kinds of models is that they are rather static and cannot improve themselves by adjusting to real-life information.'

Another – and more recent – approach is based on measurements taken from the operating system. 'The model is trained by using past data from a healthy system and a failing system', says Van de Wouw. This can then be used to decide whether or not the system is currently healthy. 'Such a data-driven AI model can adapt and learn over time but lacks the physical information of the system, which typically obstructs the use of the digital twin in scenarios that are not reflected in the historical data.'

By combining the best of both worlds, physics-based and data-driven models, you get hybrid digital twins. Van de Wouw: 'If your sensors are telling you something different than what your digital twin is predicting as normal behaviour based on both data and physics, there will be a red flag saying there is a failure or anomaly in the system. We can even predict this happening early on, so we can schedule maintenance on time. That could help keep systems safe (for example, with autonomous cars that have a failing sensor) or prevent a company from halting their production for several days.'

'Digital twins have become increasingly more important in the high-tech industry'

MOVING FAST WITH HIGH ACCURACY

Within the project of Van de Wouw there are two main use cases. One is being done together with Canon Production Printing on industrial printers. 'The inks are deposited on a substrate, for example paper, to produce an image', explains Van de Wouw. 'The channels that produce the droplets may get blocked. Hybrid digital twinning could help by detecting these blockages at an early stage and scheduling maintenance before the printing performance deteriorates.'

Another partnership is with ASML and VDL-ETG. ASML is a Dutch high-tech company that produces photolithography machines to make patterns on wafers, e.g. for computer chips. The VDL-ETG-wafer handler robots are a vital part of this machine. 'One of the challenges of these robots is that the wafers need to be transported very fast and with high accuracy', says Jeroen van de Wijdeven, senior researcher at ASML. 'They are used extensively, and just as with all moving parts, things can malfunction.'

Now researchers from the Technology Health Management project are working on building both data-based (using high-level logging) and physics-based digital twins to simulate the function and malfunction of the wafer handler robots. 'The first models have been created and tested', says Van de Wijdeven. 'We are now working on the publication of these results. Then we will start merging the two types of models into a hybrid digital twin.'
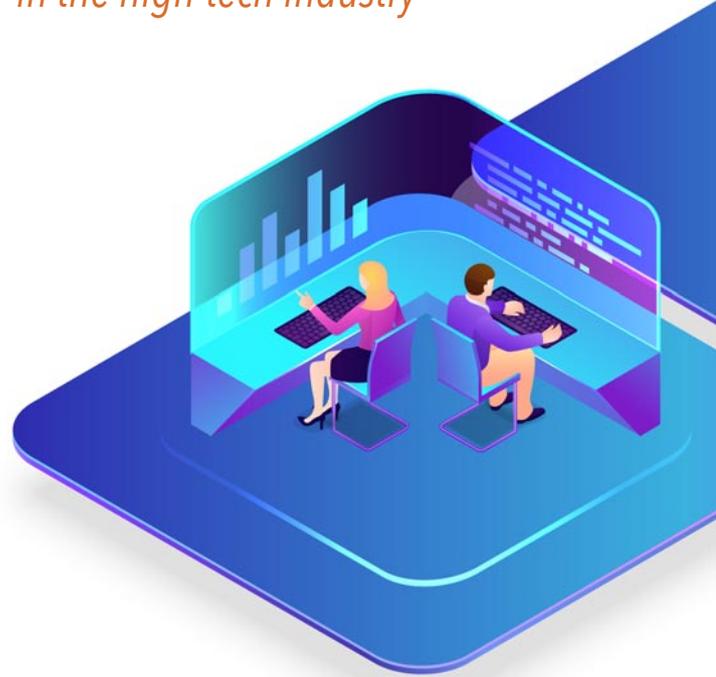
NOT TOO BIG TO HANDLE

ASML has a much broader view on digital twinning for the future. 'I think these models can help us revolutionise the high-tech industry in two ways', begins ASML-system engineering manager Wouter Aangenent. 'First in the design of systems. Highly experienced people are now doing the design of our complex machines as a whole. For the components and smaller sub-systems, we use physical models. By joining the DIGITAL TWIN programme, we aim to learn how to build better digital twins that can eventually help us optimise the design of the higher-level system architecture.'

The second way the hybrid digital twins will benefit ASML and other high-tech companies is by helping to integrate systems. 'Now it takes a lot of time and effort to validate the things we design', explains Aangenent. 'Before you can say something about the performance, you basically have to construct it all. Then test it, take it apart and ship it to the customer. It would be great if we could use digital twins to validate parts of our system before it is actually built. This could make the entire process more efficient, faster and cheaper.'
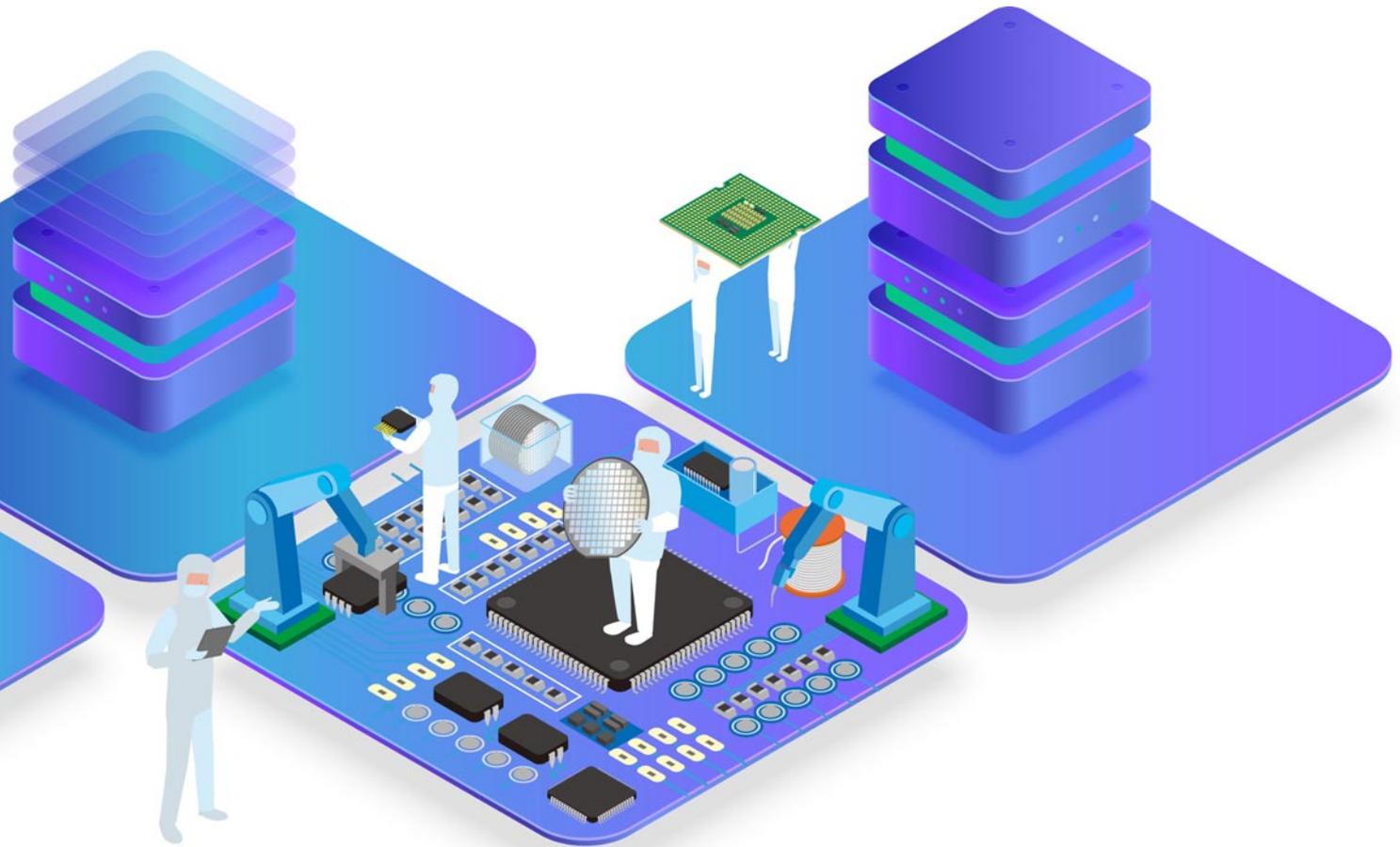
*'Wafers need to be transported
very fast and with high accuracy'*

Before we get to that, there are a lot of challenges to tackle within the programme. 'With digital twins, you can make a model of basically everything, but the real question is: should we?', asks Aangenent. 'Because if you really model every tiny screw of the system, you get a model that is too big to handle. It is better to determine which part or detail you want to have information about to acquire a sufficiently accurate result that helps solve the problem.'

Another challenge, which is more organisational in nature, is the team you work with. Although both Van de Wouw and Van de Wijdeven agree on the joy of working with a large multidisciplinary team, it takes more effort to keep everybody aligned. Still, it is paying off, according to Van de Wouw. 'Just as with hybrid digital twins, researchers and engineers from multiple disciplines need to work together to get the best possible results. I'm absolutely convinced about that.'

More information: www.digital-twin-research.nl

DIGITAL TWIN
research programme

AIM
By linking theoretical models to measurement data and artificial intelligence, the researchers will produce digital models that continually improve and adapt themselves.

DURATION
The programme started in 2019. The average duration of granted projects is 4 years.
Budget: 5.6 million euros, of which over 1.6 million euros is contributed by users.

PARTNERS
Airborne, Altran, ASML, ASM PT, Canon Production Printing, Demcon, Eindhoven University of Technology, Fraunhofer Institute for Production Technology, Leiden University, Philips, QING Groep, Stamicarbon, Tata Steel, Tilburg University, TNO, TU Delft, University of Groningen, University of Twente, VDL Groep

COMPUTER SCIENCE GOING GREEN

By Sonja Knols Image iStock

Each second, Google searches around the world consume more than 10 kilowatt-hours of energy. Whereas in the past, only a few people were bothered by this astonishing fact, now, with the current energy crisis, such figures are starting to raise eyebrows. Under the term Green ICT, researchers and companies are striving to reduce the carbon footprint of both software and hardware.

Recent figures indicate that the ICT sector as a whole is responsible for CO_2 emissions between 2.1 percent and 3.9 percent. This is higher than the impact of the airline industry, and it is growing by 20 percent per decade too. Without any interventions, our rapidly digitalising society's hunger for energy will only increase. On the other hand, the smart use of ICT solutions can also drastically reduce the carbon footprint of other processes, for example, by optimising the energy usage of cars or replacing flying with video conferencing. Green ICT is about both, explains Patricia Lago, Professor of Software and Sustainability at VU Amsterdam.

Gaining importance

'When I started my group in Amsterdam over ten years ago, the combination of software and sustainability was not sexy at all. It was very hard to find funding for research on this topic. Since then, considering the environmental impact of ICT solutions has gained importance.' Several developments have been instrumental in this, she says. 'First of all, computing power was cheap and abundantly available for many years. For instance, if you lacked memory, you just bought an additional memory module. So, there was no need to optimise software. Only when memory is expensive and limited does it once again become imperative to optimise the efficiency of your algorithms.' Secondly, there was a focus on making software programming more accessible to a broader audience. 'This led to a trend

towards visual programming languages, which delivered easy-to-program but bloated software. As a result, many of the current applications are bloated by design.' Third, we are moving towards the Internet of Things, where even the smallest mobile devices are equipped with chips. However, their energy capacity is limited. So, optimising the software to consume as little energy as possible suddenly became a thing. Battery-free computing is the exponent of this development. A rising concern, however, is the data traffic this (and ICT in general) is generating, which has worrisome energy demands, too.

Prevent the patch

The environmental impact of our cloud-based, datacentre-based society is growing enormously, Lago sees with regret. 'As is often the case, many of the currently used technologies have not been thought through from the start, leaving us with some of the nastier consequences. Take blockchain, which is used for cryptocurrencies. That is an extremely energy-intensive technology. Several months ago, a patch was issued that reduced the energy consumption of these types of distributed ledgers by 96 percent. Though that sounds great, it basically means that the initial technology just wasn't good enough. Patching is always suboptimal. We have to tackle this problem at its core.'

That starts with creating awareness, Lago states. 'First, we need research at a large scale to establish reference measures and standards. How much energy does a certain application or device actually consume, and how does that compare to alternatives?' In this field, several initiatives exist. Besides the Green Lab at her own university, which runs experiments on software energy efficiency, Lago also mentions companies that are building software development environments where the energy footprint of applications is estimated before they are executed. 'Furthermore, we need to educate the public. People now install all kinds of apps that unnecessarily drain their smartphone's batteries. We should introduce labels that enable consumers to compare apps regarding energy consumption. For example, how many people are aware of the fact that Microsoft Teams uses two to three times more CPU time than Zoom?'

'People now install all kinds of apps that unnecessarily drain their smartphone's batteries'

Lago is very happy to see how engaged the next generation of students is when it comes to sustainability. 'For example, we have an Erasmus Mundus Master's Programme called Software Engineers for Green Deal. The 22 scholarships we have available in that scheme attract over 400 applications a year from fantastic students worldwide. The next step is to make this a topic of importance for all computer science bachelors and beyond. Just as we teach our students to design correct software, we should also teach them to build ICT solutions that treat energy as the scarce good it is.'

Green ICT research

Multiple Dutch groups are working on Green ICT. A small selection of current activities:

University of Twente houses a pilot data centre to test new energy-efficient components and prototypes.

TU Delft develops state-of-the-art battery-free computing solutions.

Eindhoven University of Technology explores photonics as the energy-efficient alternative to electronics.

University of Groningen works with VU Amsterdam on a project for sustainable cloud software.

CWI works on smart energy systems and reducing artificial intelligence's carbon footprint.

And in addition to the Green Lab, VU Amsterdam will open the Digital Sustainability Centre this January to fuel collaboration on digitalisation, digital transformation and the role of software for sustainability.

LET MACHINES
TAKE OVER

By Amanda Verdonk Image Ivar Pel

According to Bram van Ginneken, Professor of Medical Image Analysis at Radboud University Medical Center, vast staff shortages in healthcare mean machines will have to do more of the work.

'Doctors use medical images to detect, quantify and assess anomalies, such as malignant cells. As researchers in image analysis, we try to do the same with a computer. In many cases, a computer with artificial intelligence can now do this even better than a doctor. When I started automating medical imaging in 1996, using chest images to detect tuberculosis, the technology wasn't good enough. But in 2012, there was a huge breakthrough when a deep learning algorithm called AlexNet recognised objects with a much higher accuracy than previous approaches. Within five years, the first systems that could detect and categorise anomalies as accurately as physicians hit the market and today, there are over two hundred such products. My hospital has founded four companies in medical image processing, for example to detect lung cancer on chest scans. Because the computer takes over the work, doctors save a lot of time.

However, a drawback of this approach is that an AI system can only do one trick. For each new task, it has to be retrained with a different data set. Unlike humans, it cannot learn something new by itself. So healthcare AI companies are focusing on automating the most common tasks in radiology, and even then, these solutions are not yet profitable. Therefore the ultimate goal is to develop self-learning "general AI". However, this development is hindered by current laws. Continuous learning systems, which can be corrected by a user and that can learn from mistakes, are not allowed in hospitals. But there is a lot to gain in addressing less common diseases because, taken together, they also involve a large group of patients.'

KEEPING HEALTHCARE AFFORDABLE

'There is a huge reluctance in society to use new technology. Doctors are often waving with the privacy argument, but if you ask patients to share their data in exchange for better healthcare, most would not hesitate. Moreover, the health crisis is enormous as a result of a massive staff shortage, which is expected to become even more pressing in the future. To keep our healthcare affordable, we need to let machines do most of the work. That's the only solution. Many of my colleagues are working on making healthcare better, and although this is a good ambition, it is even more important to make it cheaper. It will take a long time, but I am convinced automation of healthcare will come.'

Bram van Ginneken is Professor of Medical Image Analysis at Radboud University Medical Center and chairs the Diagnostic Image Analysis Group. He also works for Fraunhofer MEVIS in Bremen, Germany, and is a founder of Thirona, a company that develops software and provides services for medical image analysis. He studied physics at Eindhoven University of Technology and Utrecht University and obtained his PhD at the University Medical Center Utrecht.