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I/O Magazine is a publication of the ICT Research Platform Nederland (IPN) and is sent free of charge to ICT researchers and relations of IPN four times a year. IPN consists of the ICT research schools ASCI, IPA, and SIKS; the ICT-related themes of NWO domains Science (ENW) and Applied and Engineering Sciences (AES); the institutes of the technical universities, united in NIRICT; the institutes of the general universities; SURF; e-Science Center; CWI; Dutch Platform for Mathematics; Data Science Platform Netherlands; Dutch Tech Center for Life Sciences; VERSEN; TNO and COMMIT.

IPN (ICT Research Platform Nederland) unites all Dutch academic research groups that have ICT science as their core, and as such acts as a single point of contact for all matters relating to ICT innovation and its importance for our current and future society. IPN is supported by the NWO Domain Science.

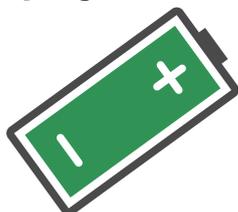
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IPN ICT-ONDERZOEK
PLATFORM
NEDERLAND

PAUL KLINT

The Multi-Tunnel Deception

We humans like the idea that we can shape reality and that everything can be engineered by us. Grandiose vision or self-deceit?

We are the imagineering species: from Taj Mahal, Pyramids of Giza, and the Eiffel Tower to space travel. That is humanity at its best. A shared vision, perfectly executed. When things happen that fall outside the scope of our imagination, we are thunderstruck: 9/11, COVID-19, or the fall of Kabul.

In between are all those human endeavours that aim for the best but produce disappointments. Let's, in the context of I/O magazine, take science policy as an example. This is a multi-tunnel situation.

The scientist populates the science tunnel and knows what is best both for the progress of science in general and his/her career. Multidisciplinary and economic impact are second-order concerns, and scientists are masters in relabelling their work to fit the latest fashion.

The policy maker resides mostly in the national interest tunnel (what is best for the country?) but the question what is best for the policy maker's ministry is never far away. The idea that everything can be engineered is strongly ingrained in the policy maker's mind: you are a policy maker or not.

Industry is located in the shareholder value tunnel: direct impact is better than long-term knowledge creation.

The participating citizen hides in the what-you-see-is-what-you-get tunnel: he or she is confronted with the outcome of the science policy, is unaware of the underlying political battles and minefields, and asks common sense questions like Why so much funding for that topic? Are X, Y or Z not much more urgent?

With very few exceptions, science policies disappoint, despite the best effort of all participants. The tunnels are to blame. A solution, you ask? Gustave Eiffel, John F. Kennedy and Jennifer Doudna (who won the Nobel Prize for inventing CRISPR-Cas) have sold grandiose visions. These visions were believed by many people. That contributed to their realisation.

Science policies are uninspiring constructs produced by far too many parties hiding in their tunnels.

Let truly visionary leaders or citizens in civic councils, as proposed by David Van Reybrouck, determine science policy rather than the tunnel-based process we use today.



SYSTEMS AND NETWORKS IN THE SPOTLIGHT

Computer systems and networks are at the root of any ICT application, and therefore should not be taken for granted. The new IPN Special Interest Group 'Future Computer Systems and Networking' wants to ensure this. The group's Manifesto on this topic calls for action through Dutch research and education.

By **Bennie Mols** Images iStock, Ivar Pel

Though many of us may be tired of Zoom replacing yet another physical meeting, it is thanks to platforms like Zoom that we can communicate smoothly with many people, even during a period of lockdowns and restrictions. If the pandemic had happened twenty years ago, this would have been technologically impossible.



Paola Grosso

'Computer systems and networks are too often taken as given'

A platform like Zoom is an example of a large-scale computer system: it needs a network of personal computers, each with an internet connection and various information-processing capabilities, and the Cloud to make all kinds of features of Zoom happen. Computer systems range from the small scale of smart sensors via computers and networks of computers to the large scale of data centres. Yet, though Zoom is a computer system built for communication, a Zoom user cannot speak directly to users of Microsoft Teams or the open-source application BigBlueButton, even if these systems offer similar features. 'They can best be considered as ecosystems with complex interactions between their essential parts', tells Alexandru Iosup, Professor of Massivizing Computer Systems at VU Amsterdam.

Together with Paola Grosso, Professor of Multi-Scale Networked Systems at the University of Amsterdam, and Fernando Kuipers, Professor of Internet Science at TU Delft, Iosup took the initiative to create the new IPN Special Interest Group on 'Future Computer Systems and Networking.'



Fernando Kuipers

'The challenge is how to tame the ever-growing complexity'

'Computer systems and networks are too often taken as given', says Paola Grosso. 'That is an important reason to start the new Special Interest Group. In general, it is the applications that run on the infrastructure that catch the news and receive most of the funding. But those applications cannot work without the underlying infrastructure.' Kuipers adds: 'Historically, the Netherlands has been at the forefront of networking. For example, Amsterdam is one of the largest internet

exchange hubs in the world. But the field of systems and networks is changing tremendously fast. Technology from ten years ago is already outdated. Therefore, if we don't continue to invest, we run the risk of falling behind.'

Nowadays, an estimated 60 percent of Dutch GDP depends in one way or another on computing, and organisations and people use computing computer systems and networks for daily activities even without realising it. For many companies, to out-compete in the market means to out-compute their competitors. The number of applications running on the basic infrastructure is rapidly growing as are data volumes and models in artificial intelligence. 'What is still successful now might soon run into trouble', says Iosup. 'This is called Jevons Paradox: the more something works well, the more people want to use it and the higher the risk that you run into problems when you scale up the system without fundamentally renewing the infrastructure.'

Crucial infrastructure

An important first achievement of IPN's new Special Interest Group is the publication of a Manifesto to draw attention to the fact that computer systems are a vital part of ICT. The Manifesto represents the combined views of dozens of specialists, clients, and societal stakeholders in the Netherlands. In essence, the Manifesto calls for an investment in research to make computer systems manageable, responsible, and sustainable, make them usable as an engine for growth and innovation, and educate experts and the general population about this increasingly important infrastructure. The EU is now largely dependent on non-European technology backed by questionable political or economic policies, so they also want the Netherlands to do its part to help create a sovereign EU technology. 'The fact that systems must be manageable demands research into the complexity of computer systems', says Kuipers, 'and that is an often-overlooked theme. The challenge is how to tame the ever-growing complexity in massive computer systems and networks. After all, as Edsger W. Dijkstra has already pointed out, simplicity is prerequisite for reliability.'

The concept of responsible computer systems refers to systems whose operation we can trust and rely on. How to ensure privacy and security, performance and scalability, availability, and durability? How do we enable ethical ICT for everyone? Grosso and Kuipers are working together on the notion of responsible internet. Kuipers: 'An example is the question of whether the internet traffic of Dutch users is going via devices controlled by non-EU countries, or not. At present, it is very difficult for end-users to know how their traffic gets routed. From the user's perspective, the internet is opaque. We want to turn it a little bit more into a glass box where you can control things, to make the internet more transparent.'

The Manifesto also highlights the question of how digitalisation can be made as sustainable as possible, because increasing digitalisation comes with a significant energy footprint.

From paper to community

Grosso says that the Manifesto will, of course, be shared in the ICT community but stresses that it shouldn't be just a paper. 'We want to make it concrete in research projects, we want to have a community behind the paper document, we want to make policy makers aware and get the industry on board. We believe that computer systems and networks are not only an academic effort.'

In terms of the research to be done, Iosup thinks that the ICT community should take inspiration from the so-called translational research that is standard practice in the development of new medicines and vaccines. Iosup: 'Just as vaccines are developed in various trial phases with increasing relevance to practice and ever-larger trials, we can develop computer systems and networks in a similar manner. On the way, you learn how the science matches the real world, and you can use the new insights to improve the systems that we build. Practice feeds back into scientific research and vice-versa, so they both win. We want translational research to be recognised and funded for computer systems and networks too.'

The new IPN Special Interest Group also hopes to change the educational curriculum, from high schools to universities. Grosso: 'Our field is not recognised enough by younger people, and a whole chain of new training is needed to educate new talent.' 'New talent can also arise from groups that are now underrepresented', adds Iosup. 'There are currently around 50,000 vacancies in our sector, and some 100,000 in the entire ICT sector. Focusing more on diversity will help to find new talent and fill more of the vacancies.'

Because complexity is such an essential characteristic of present and future computer systems and networks, systems thinking needs to become a core part of the curriculum, says Iosup. 'How do we accurately describe complex systems so that we can reason about them? For this, you need holistic thinking, just like you need holistic thinking to reason about climate change or about complex societal problems.'

In recent years there has been an explosion of new ICT applications, new types of devices, and new kinds of networks. Some compare this to the Cambrian explosion of species in evolutionary biology, which occurred after the eye evolved for the first time in a new species, some 541 million years ago. 'In ICT, we don't yet understand well enough how to work with all these new applications, devices, and networks', says Iosup. 'Therefore, we need an experimental approach. We are one

of those fields in science that still has grand experiments ahead of us.'

'And that is also why we wanted to establish the new IPN Special Interest Group Future Computer Systems and Networking', says Kuipers. 'It's not something one

Alexandru Iosup

'We want translational research to be recognised and funded'



person can do. We need to unite as a community to address the grand challenges lying ahead of us. In the Netherlands, we should collaborate and not compete on the path to digital sovereignty.'

SUMMARY OF THE MANIFESTO

IPN's new Special Interest Group on 'Future Computer Systems and Networking' recently published a Manifesto to draw attention to the fact that computer systems, ranging from small, embedded devices to large data centres and the networks that connect them, are a vital part of ICT. In the Netherlands, every euro invested in computer systems generates 15 euros in added value. The Manifesto calls for an investment in research to make computer systems manageable, responsible, and sustainable, to make them usable as an engine for growth and innovation, to educate experts and the general public, and to help create a sovereign EU technology.

To address these challenges, the Manifesto calls for an innovative, multi-year vision and approach. Important parts of this approach are a collective, holistic, groundbreaking technology roadmap, a renewed education that is truly accessible for all, and a concerted answer to the Manifesto's call to action.

More information:

Executive Summary of the Manifesto (2 pages)

bit.ly/ManifestoCompSysNLv12Summary

Full version of the Manifesto (40+ pages)

bit.ly/ManifestoCompSysNLv12

MULTIBILLION EURO INVESTMENTS IN EUROPEAN RESEARCH

By Sonja Knols

Recently the European Commission announced the main work programme of Horizon Europe for the period 2021-2022. A total of 14.7 billion euros in funding is available to accelerate the green and digital transitions and to recover from the coronavirus pandemic. Budget is available for fellowships, training and exchanges; for more connected and efficient European innovation ecosystems; and for world-class research infrastructures.

The work programme contains an investment of 5.8 billion euros in research and innovation to support the European Green Deal. This policy aims to make the EU the world's first climate-neutral continent by 2050. The funds will support projects that advance the science of climate change and that develop solutions to reduce greenhouse gas emissions and adapt to the changing climate.

The development of core digital technologies will be supported with around 4 billion euros. The European Commission wants to make this decade Europe's Digital Decade. Four cardinal points have been formulated to translate the EU's digital ambitions for 2030 into concrete terms: Digitally skilled citizens and highly skilled digital professionals; Secure, performant and sustainable digital infrastructures; Digital transformation of businesses; and Digitalisation of public services. The proposed investments are meant to help maximise the full potential of digital tools and data-enabled research and innovation in healthcare, media, cultural heritage and creative economy, energy, mobility and food production, supporting the modernisation of industrial models and fostering European industrial leadership.

Investments of around 1.9 billion euros are directed towards helping repair the immediate economic and social damage brought about by the coronavirus pandemic. The funding will contribute to building a post-coronavirus Europe that is not only greener and more digital but also more resilient for current and future challenges. This includes topics that aim to modernise health systems and contribute to research capacities, in particular for vaccine development.

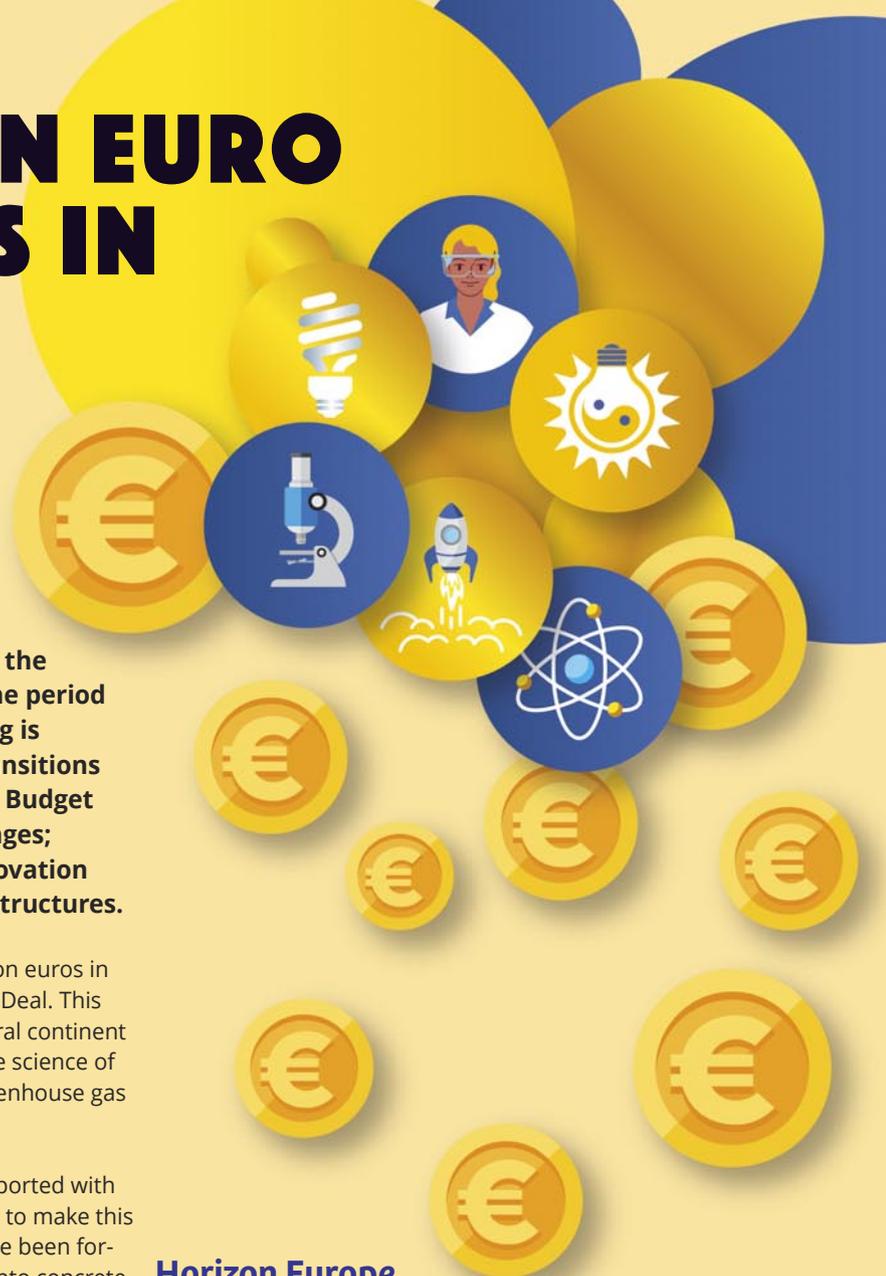
The work programme of Horizon Europe for 2021-2022 also includes dedicated actions to support and strengthen cooperation through multilateral initiatives in areas such as biodiversity and climate protection, environmental observations, ocean research or global health. It also includes targeted actions with key non-EU partners, including the first ever ambitious and comprehensive 'Africa Initiative'.

Horizon Europe

Horizon Europe, the successor of Horizon 2020, is the EU's 95.5 billion euros research and innovation programme for 2021-2027. The recently published Horizon Europe work programme is based on Horizon Europe's Strategic Plan, which sets the EU's research and innovation priorities for 2021-2024. Most of the funding is allocated based on competitive calls for proposals, which are set out in work programmes.

Horizon Europe comprises several new elements when compared to its predecessor. A newly established European Innovation Council provides support for innovations that may be too risky for private investors. Five main missions have been defined to achieve bold, inspirational and measurable goals within a set timeframe. Open access is now mandatory to publications and open science principles are applied throughout the programme. And the EU adopted a new approach to partnerships with industry in support of EU policy objectives.

More information on the latest calls and funding opportunities: ec.europa.eu/info/funding-tenders/



TAKE-OFF COMMIT2DATA

In the spring 2021 round of Take-off, 33 feasibility studies were given the green light. New this year was the Take-off phase 1 cluster Commit2Data, for which three feasibility studies around big data and data analytics were awarded funding. Academic and innovative start-ups will study the feasibility and commercial application of innovative ideas and the start of business based on knowledge innovations from knowledge institutions.

The granted proposals in the Commit2Data cluster are:

- Power Swing Detection and Prevention in Future Networks with High Penetration of Renewable Energy – Dr Marjan Popov, TU Delft
- Implementation of Exercise is Medicine: valorisation of a phased exercise plan for the prescription of Movement as a Medicine in hospital care – Adrie Bouma, University Medical Center Groningen
- ECiDA: Evolutionary changes in data analysis - MVP – Prof. Alexander Lazovik, University of Groningen

NOMINATE CANDIDATES FOR ICT PRIZE

The Netherlands Prize for ICT Research is awarded annually by the ICT Research Platform Netherlands (IPN), in collaboration with the Dutch Research Council (NWO), to recognise outstanding research in computer science. Anyone active in this field can nominate candidates for the award, which consists of €50,000 euros to spend freely on ICT research plus a certificate and a sculpture. The winner will receive this award during the next edition of ICT.OPEN on 6-7 April 2022.

The Netherlands Prize for ICT Research is administered by the Royal Holland Society of Sciences and Humanities (KHMW). All the information needed to submit a nomination can be found on the KHMW website.



ICT WITH INDUSTRY 2022



ICT with Industry 2022 will be held from 17 to 21 January in the Lorentz Center in Leiden, in cooperation with NWO. During five days, a group of about 50 IT and Computer Science researchers from a wide range of universities will extensively collaborate on challenging problems proposed by companies.

The ICT with Industry workshop brings together scientists, in particular (junior) research staff and PhD students, and professionals from industry and governments. The workshop revolves around several case studies, which are subject to an intense week of analysing, discussing, and modelling solutions.

More information:
ict-research.nl/ict-with-industry

TEK NOW LOGY - NWO INNOVATION FESTIVAL

TEK NOW LOGY is the Dutch festival where technology, science, innovation and valorisation meet. At TEK NOW LOGY, visitors are shown the technical innovations of the future and how Dutch science is prepared for these. The next edition will be held both live on location at DeFabrique in Maarsssen and online on 16 November 2021. Admission is free, and the festival is held in English.



HELP BASE DECISIONS ON DATA

By Leendert van der Ent
Images iStock, Quo Mare

Technological transitions such as the energy transition cause variations in a multitude of parameters. So many, in fact, that these cannot be overseen by humans. In such a complex situation, which technology should be chosen? When should investments be made? And which location is best? Quo Mare in Gouda builds and operates decision support models to help out.



'We make more and more use of decision support tools in our projects', says Programme Manager Geoffrey Schouten of the Institute for Sustainable Process Technology in Amersfoort. The Steel2Chemicals (S2C) project is an example. 'It is about converting large quantities of CO₂ and CO-rich blast furnace gases from the steel industry into chemical building blocks for the chemical industry. We use Quo Mare's data-driven Techno-Economic Analysis of Complex Option Spaces model (TEACOS) to support in making the right choices.'

The S2C project, aimed at minimising total CO₂ emissions by 2050, confronted the parties involved with a myriad of options. Schouten sums up: 'You can make naphtha, methanol, ethanol or hydrogen from steel gases – or combinations of these. The optimal choice depends on available technologies, developing infrastructure and cost curves of equipment and emission tax over time. All in all, there are just too many options to oversee without decision support.'

ITERATIONS

Quo Mare calculates an optimised pathway towards a desired goal with the optimised investment choices, moments and locations based on the inputs in their support model TEACOS. Associate at Quo Mare Nort Thijssen: 'Generic deployment of TEACOS offers a proof of concept. The first phase shows parties what additional information they would want to have in the sequel.'

Schouten: 'These first insights can then be used for targeted iterations and tweaks. This allows the parties involved to get a grip on options related to uncertainties, of which the price development of CO₂ emissions over time is just one.' At present, the project is in this iteration phase, says Thijssen: 'In this stage, we carry out specific studies with individual parties.'

TEACOS consists of logic modelled in algebraic formulas, based on physical and chemical parameters', says Thijssen. 'The logic behind the model is well described. Processes such as the mass balances and energy balances as well as econometric relationships included are based on first principles.'

The under-the-bonnet mathematics of TEACOS involves Mixed Integer Programming (MIP), Thijssen explains: 'Decisions can only be made in whole numbers, as you simply cannot build

1.5 factories in year X at location A and 0.5 factories 3 years later at location B. You have to choose between 0, 1 or 2, which complicates things considerably. It means that the data on all of the many decisions taken into account are at least squared, leading to an exponential demand for computing power. The approach therefore demands the use of advanced methods.'

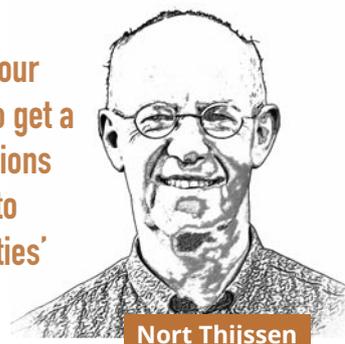
INCLUDED MODULES

Quo Mare's proprietary TEACOS model integrates two third party modules. The first is the Advanced Interactive Multidimensional Modeling System (AIMMS) developed by the Dutch company AIMMS. Thijssen: 'When you enter the capital expenditure timing formula, for instance, AIMMS runs the scenario a large number of times to get to the outcome. So the basis is not historical data – which might be biased by coincidence. It is the large number of samples fed to the scenario that guarantees that all possible variations are covered.' The second module incorporated is the IBM CPLEX optimiser module with, according to IBM, robust algorithms to solve large, real-world optimisation problems.

Output can be visualised via Excel, databases, PowerBI and/or Google Charts. Thijssen: 'The important factor is that the output doesn't emerge from a black box. All intermediary steps and decisions leading to the conclusion can be traced back to find out what influenced it. If necessary, you can change intermediary outcomes that have changed over time to see what they do to the outcome.'

What's also important, Thijssen stresses, is that each use case improves the model. 'The generic model works hand in glove with specific client use cases such as hydrogen decarbonisation, plastics recycling, water re-use/recycling and heat network modelling. All these diverse use cases are elaborated and tested, resulting in improved functionality and performance.'

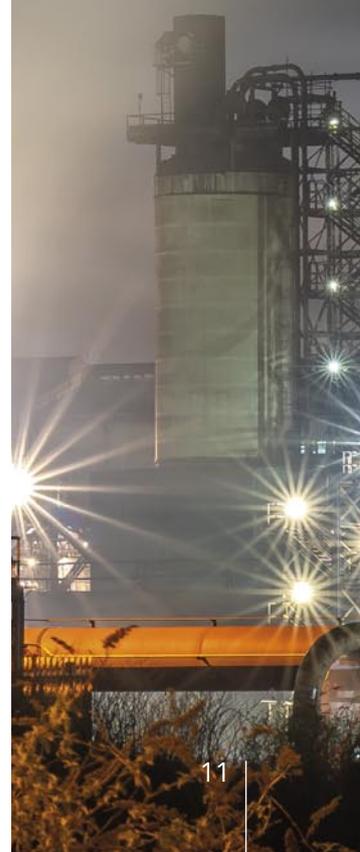
'We allow our customers to get a grip on options related to uncertainties'



Nort Thijssen

COVID vaccination planner

Quo Mare deployed its model for the municipal health services (GGDs) to optimise COVID vaccination planning, to understand when peak periods will occur at specific vaccination locations, and to prepare for the right up- and downscaling of vaccination locations over time. Note that this scenario involves similar parameters as the Steel2Chemicals challenge: locations, constraints, timelapse, capacities and economics.





Efficiency and security

By Bennie Mols Images Ivar Pel



GROUP PASSPORT

RESEARCH FIELD

applied cryptography, data security, high-performance computing, large-scale computing infrastructure, embedded & real-time computing, cyber security

INSTITUTION

Leiden Institute of Advanced Computer Science (LIACS) at Leiden University

FACILITIES

Edge & Cloud lab, under construction

EMPLOYEES

2 professors, 1 associate professor, 3 assistant professors, 1 post-doc, 14 PhD students

WEBSITES

LIACS Systems and Security:
www.universiteitleiden.nl/en/science/computer-science/systems-and-security

Nele Mentens:
www.universiteitleiden.nl/en/staffmembers/nele-mentens

Recently awarded PROACT project:
www.universiteitleiden.nl/en/news/2021/05/proact-project-improves-security-of-internet-of-things-devices

The Advanced Computing and Systems group at the Leiden Institute of Advanced Computer Science builds tools and techniques to improve the efficiency and security of advanced computing systems.



Last May, NWO awarded 1.8 million euros to the PROACT project, in which a consortium of researchers from various universities and companies is going to investigate how to improve the security of electronic and mobile devices connected to the Internet of Things. The consortium's coordinator is Nele Mentens, Professor of Applied Cryptography & Data Security at the Leiden Institute of Advanced Computer Science (LIACS) of Leiden University.

In 2020, Mentens started her job at the Advanced Computing and Systems group, which is formally led by her colleague professor Harry Wijshoff. The group's focus in research and education lies in the design and security of advanced computing systems, she explains. 'On the one hand, we study distributed and cloud computing systems, with the goal of speeding up applications. On the other hand, we investigate embedded and edge computing systems, mainly with the goal to improve their energy efficiency. A third theme of the research in the group is data security, which runs from the lowest hardware level to the highest software level. The PROACT research is part of the second and third theme: it concentrates on securing energy-efficient embedded systems at the hardware level.'

Nele Mentens



A specific characteristic of the Advanced Computing and Systems group is that it builds tools and techniques to automatically analyse and improve advanced computing systems, for example by exploring a system's energy efficiency or computational delay. 'In Leiden, our group comes closest to what technical universities do', says Mentens. 'Whereas the rest of LIACS mainly uses computing systems as tools for specific algorithms or specific applications, we are passionate about designing, understanding and developing the details of advanced computing systems.'

The group's research also comes pretty close to real-world applications such as home appliances, biomedical and automotive systems, and consumer electronics. The group is constructing an Edge & Cloud Lab at LIACS in order to perform the necessary experiments. Mentens: 'It will be a lab suited for experiments covering all kinds of devices, from low power to high power, from small embedded systems and devices connected in an Internet of Things to high-performance cloud servers. With all the new experiments we design, we keep in mind that they have to fit in the new lab.'



Alexandru Uta

Beyond theory

Alexandru Uta is an assistant professor in the Advanced Computing and Systems group. He specialises in large-scale computing systems like the Cloud, or the internet. 'I evaluate their efficiency and performance', says Uta. 'Many researchers in this field neglect the reproducibility of experiments, whereas I put a strong emphasis on creating reproducible experimentation. One of the biggest challenges is to reproduce experiments in large-scale systems. That is very difficult because the performance of different infrastructures often varies quite a bit and their properties can change over time, which might alter the final outcomes.'

Uta has just started his research on reproducibility for which he received an NWO Veni grant in 2020. In order to experiment with large-scale systems, he cooperates with other Dutch universities and with SURF so that he can run experiments over hundreds or thousands of CPUs and come close to what happens in real large-scale systems. 'This type of cooperation between a cluster of institutes through infrastructure like the DAS-6 is quite unique for the Netherlands', he says.

Uta: 'What I like in our group is that we are all very much interested in going beyond the theory, in analysing what makes a system functional and efficient, and ultimately in building systems that work. I also like the fact that we have many young people and that LIACS, in general, has a focus on interdisciplinarity.'



Olga Gadyatskaya

Freedom of choice

Olga Gadyatskaya is another assistant professor in the Advanced Computing and Systems group. She specialises in cyber security. 'On the one hand, I develop formal models to understand and tackle cyber security threats', explains Gadyatskaya. 'On the other hand, I investigate the cyber security of mobile applications. Many consumers are much more relaxed when they use their mobile phone compared to using their laptop. We are developing new ways to analyse which security problems might arise by using a third-party app, like a game, for example.'

Gadyatskaya was educated in Russia and subsequently did research in Italy and Luxemburg, so she is in a good position to make comparisons. 'What I like in our Leiden group is that there is a lot of knowledge about advanced distributed systems and that everybody is free to pursue his or her own directions and ambitions. My ambition is to establish my own group focusing on the intersection of software security and models to analyse cyber threats.'

Compared to the countries where she previously worked, the Netherlands has a strong ecosystem, she states: 'Everybody knows everybody, and it is not difficult to start a new collaboration.'

A specific tradition cherished by the Advanced Computing and Systems group is a regular outdoor meeting in Katwijk aan Zee, Gadyatskaya says. 'We go for a walk in the dunes and along the beach and we end our group meeting with eating 'kibbeling' (fried fish), some of the best in the country I've heard. Even during the pandemic, we could go for these walks, talk with each other and still stay at a safe distance.'



Ilyaz Nasrullah is a digital strategist. After obtaining his master's degree in Media & Knowledge Engineering from TU Delft in 2009, Nasrullah worked as a software developer, portfolio and program manager, start-up mentor and digital innovation consultant for various enterprises and governmental organisations. Since April 2021, he has been writing about the societal impact of digital technology for the Dutch newspaper Trouw.

EDUCATE THE PUBLIC

'We need more IT experts to engage in the societal debate and educate the public about the opportunities and threats that come with digitalisation.' With his biweekly columns in the Dutch newspaper Trouw, digital strategist Ilyaz Nasrullah wants to play his part in achieving this.

By Sonja Knols

Image Elodie Burrillon

How does someone become a digital strategist?

'I studied Computer Science and Media & Knowledge Engineering at TU Delft. My educational programme comprised topics like user experience engineering, machine learning, computer graphics and cryptography. After my graduation, I started working as a software engineer. Then I was offered the opportunity to work for a start-up company called Riscure. That's where I got involved in strategic product development and innovation management, and I decided I wanted to develop further in that direction.'

Now you are a self-employed consultant. What does your work entail?

'In general, I help organisations in developing digital innovation strategies. A nice example is a recent assignment I've done on behalf of the municipality of Rotterdam. I was asked to found the Port and Maritime working group of the Netherlands AI Coalition (NL AIC). Traditionally, the Dutch maritime sector has been highly fragmented. With partners from the maritime and IT industries we published a joint vision document on what AI could mean for this sector, and what would be needed in the short and long term to successfully implement these innovations.'

What do you hope to achieve with your columns in Trouw?

'In popular media, digitalisation is a niche subject. Everyone thinks it's too hard. It is up to us as experts to explain recent and future develop-

ments, because otherwise they will not be discussed at all. And then things will just happen outside of the public's control. What's worse, American big tech companies like Google and Facebook are now at the helm. I am a strong advocate for more independent, publicly funded IT specialists in the public debate.'

With the term publicly funded experts you refer to academics?

'Indeed. Scientists who receive public funding also have a duty towards the public. Unfortunately the current way of funding research at Dutch universities has done huge damage to their independence. Nowadays researchers must deal with commercial interests of private parties that are (co-)funding their projects. As a result scientists have lost the public's trust in societal debates. But we need them to provide society with facts, to interpret those facts, and to base well-founded opinions on them.'

What kinds of topics should researchers publicly address?

'Society isn't aware of the possible consequences of certain technological developments. Take AI, which makes many new applications possible. But it also creates problems by taking humans out of the loop. Problems we then want to solve with "human-centred AI". Scientists should take a holistic view on such technologies and initiate the societal debate on what we deem desirable. We shouldn't leave it to the commercial companies to decide for us what our future will look like.'

COOPERATING SELFISH ROBOTS

Ming Cao likes to break down the boundaries between engineering on the one hand and biology and sociology on the other. His experiments with robotic fish teach us how multi-agent systems evolve cooperative strategies over time.

By Bennie Mols

Images WAT ontwerpers

In the middle of a small tank filled with water stands an obstacle. On the left side of the obstacle, a handful of autonomous robotic fish are swimming around. Each robotic fish has the selfish intention to swim to the right side of the tank where food is supposed to be. However, a single fish doesn't have enough power to push the obstacle away and it needs to cooperate with other fish. The fish also don't know how many of them are sufficient to push the obstacle aside, they can't communicate, and they can only observe the behaviour of the other fish.

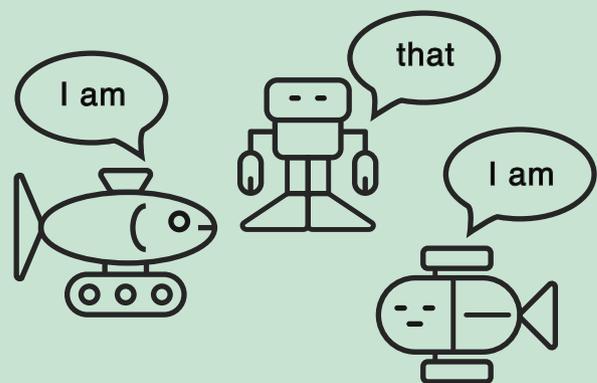
This elegant experiment is designed by professor Ming Cao and his collaborators at the University of Groningen. Cao is a control theorist and electrical engineer, specialising in networks and robotics. He takes inspiration from both biology and sociology, looking at how animals and humans cooperate. Cao: 'The challenge for our robotic multi-agent system is to find out how many fish are needed to push the obstacle away and collectively move to the other side. How much selfishness must each fish give up in order to gain as a fish collective?'

Multi-agent systems

The experiment was part of the research Cao conducted with the NWO Vidi grant that he received in 2015. Cao essentially wants to know how multi-agent systems, such as a group of robots, can be coordinated. How should the agents communicate? Should there be a leader in the group? How to resolve conflicting interests?

'During my Vidi research, which just ended in December 2020, I focused on modelling the selfish behaviour of the fish', says Cao. 'I used evolutionary game theory as a model. This theory

is inspired by biological evolution and predicts how decision-making strategies evolve over time. However, because real robots never meet all the simplifying assumptions of a game-theoretical model, I also study robotic fish in a real-world setting. From the experiments, I want to learn how we can compensate our models for the deviations from the real world. The most important outcome from the Vidi research was that I managed to show that evolutionary game theory can work for a multi-robot system.'



'I managed to show that evolutionary game theory can work for a multi-robot system'

In 2017, Cao received a two million euro ERC Consolidator Grant for new research that he started in 2018 and that will end in 2023. 'The ERC-research is more about control in the sense of taking action to make changes in a multi-agent system. Imagine a system of electric cars driving on a highway. We can change the electricity price depending on the traffic conditions. If there is a traffic jam, we lower the electricity price and expect more cars to turn away from the highway to recharge for a low price. Such pricing mechanisms are very useful for controlling multi-agent systems.'

Many systems in society can be modelled as networks of agents making self-interested decisions that often conflict with group objectives. Cao is therefore exploring various potential applications of his research: 'Concretely, I am talking with Dutch water management companies to see whether we can use robotic fish for sampling the water quality. And we are also doing simulations for a piece of highway between The Hague and Rotterdam to study whether a pricing mechanism can resolve traffic jams.'

FROM TALLY TO FORETELLING

The exact prediction of time, date and location of future fire incidents will remain beyond the reach of ICT. But the project Data-Driven Risk Management for Fire Services intends to inch closer to that situation. For example, the indication of the seasonal incidence of chimney fires in 1930s neighbourhoods has become within reach. This allows fire services to optimise their capacity deployment and address prevention activities.

By **Leendert van der Ent**
Images WAT ontwerpers



'Timely, measured response based on expectancy will go hand in hand with effective prevention'



Data science student Tineke School dedicated her master's thesis to the prediction of chimney fires in the operational territory of Brandweer Twente (Twente Fire Service). Ron de Wit, deputy commander at Brandweer Twente: 'The result was a successful web application. The topic became quite a hit in regional media.' It also gave rise to a sequel; the data allow for further elaboration. The fourteen municipalities of Twente have kept records on categorised fire incidents since 2004. De Wit: 'This database is now proving its value. Scientific analysis also lays bare some flaws. This new project allows us to underline the need for high-quality registration and enriched data. Once you know what the data can bring you, awareness grows about the importance of correctness and completeness.'

The leader of the present project is Marie-Colette van Lieshout, Professor of Spatial Stochastics at the University of Twente and staff member at Centrum voor Wiskunde & Informatica (CWI) in Amsterdam. The research is done by a PhD Student under the operational supervision of associate professor Maurits de Graaf from Mathematics of Operations Research at University of Twente and who is also active for Thales Nederland. Van Lieshout: 'Can the data support preliminary assumptions? Analysis will tell. This asks for the handling of unstructured, complex data. That is where machine learning comes in. And when it comes to interpreting underlying mechanisms, stochastic statistical models are used. The most important aspect is the integration of both technologies.'

Scientific challenge

The project's biggest scientific challenge is finding patterns in space and time without inappropriate stationary assumptions, says Van Lieshout. 'The data consist of a single realisation of a point process. Classic spatial stochastics relies on certain assumptions that do not hold for our data, as information from long ago and far away does not tell as much about the risk of a chimney fire as data from here and now. In these cases, classic assumptions do not lead to valid outcomes.'

De Graaf: 'Working with the arithmetic mean is not an option with the datasets. In order to predict the confidence interval, you have to model the uncertainty. Bayesian inversion is the way to go.' Alternatives have to be carefully weighed and combined. Van Lieshout: 'You need to deploy Bayesian hierarchical models, alongside Monte-Carlo simulation-based statistical inference.'

Bayesian mathematics turn out to be an important ingredient in the project approach. Van Lieshout explains: 'Risk is something you cannot observe. Datasets contain information on incidents that did actually happen. Bayesian statistics can be used for inversion because it is able to translate observed incidents reliably into unobserved risks.'

The risks depend on sometimes quite logical and, in other instances, more surprising explanatory variables. Variables such as "the house has a chimney" and "it's autumn" can be expected to heighten the incidence of chimney fires. 'But the fact that houses from 1920 to 1945 ran a higher risk of chimney fires was quite surprising. We don't have an explanation yet, but we will look into it. Could it be the construction of the chimney?', De Wit wonders.

There are all kinds of variables: the weather, the type of house (detached, semi-detached), the building period and more. Machine learning techniques will bring unclear explanatory variables to the surface and Bayesian statistics will quantify the risk.

Clear benefits

With the project a year underway now, De Wit can already highlight practical benefits from predictions. 'We now have the same capacity stand-by at all times: 24/7, the whole year long. That is because we cannot match capacity to risk yet. The operational guarantees are the same at all times and locations, but the idea is that this could be differentiated in accordance with the predicted risk. Once we have a careful, elaborate and accurate expectancy of incidents over time and space, we will be able to adjust preparation of capacity of staff and equipment to actual risk.'

That means more capacity will be available when it is really needed. De Wit: 'Once we know what a "code yellow storm" means in terms of specific capacity demand, we will be able to scale up beforehand. Of course, we were always able to act on the basis of educated guesses. But now, for the first time, we will be able to anticipate on a scientific basis. That makes a big difference. Being able to turn intuitive knowledge into a rock solid assessment is a relief.'

There is a second important benefit, De Wit emphasises. 'The project will show us patterns. It will hand us the required insights to approach specific target groups in our prevention policy. Timely, measured response based on expectancy will go hand in hand with effective prevention. A targeted message to owners of specific risks connected to specific types of houses works far better than a generic message to all.'

It is clear that the project benefits are not limited to fire services, nor to Twente. De Graaf: 'Police forces, which are included in the user group, can equally benefit from the approach, as could other first responders.' De Wit: 'With Twente, we now get a risk profile of one safety region. This approach can be easily scaled up to all 25 safety regions - hence the participation of Brandweer Nederland [Dutch Fire Service].'

'We cannot match capacity to risk yet'

DATA-DRIVEN RISK MANAGEMENT FOR FIRE SERVICES

Project duration:
1 September 2020 to 1 September 2024

Budget:
400,000 euros

Knowledge institutions:
CWI and University of Twente

Partners:
Amsterdam-Amstelland Fire Service, Dutch Fire Service, Twente Fire Service, Datacadabra, Institute for Safety, Amsterdam Police, Enschede Police, Thales



BANISHING BATTERIES FROM COMPUTING SYSTEMS

By Sonja Knols

With a tsunami of smart sensors and devices coming our way, it is vital that we eradicate batteries from this so-called Internet of Things. The research required for this in the field of battery-free computing is slowly but surely making progress. Associate professor at TU Delft Przemyslaw Pawelczak explains what is needed to reduce the environmental impact of ubiquitous computing.

It made the headlines, when researchers from TU Delft together with colleagues from Northwestern University presented a battery-less and failure-resilient clone of the 8-bit Nintendo Game Boy last autumn. This specific Game Boy generates its own power from solar panels attached to the front, and harvests some additional energy from the user's actions. 'The main challenge for these types of self-sufficient systems is to ensure proper operation despite frequent power failures caused by intermittent energy harvesting', explains Przemyslaw Pawelczak, one of the inventors of the battery-less remake of the historical gaming device.

Pawelczak is an expert in intermittent computing, which enables computer programs to be executed continuously and flawlessly despite frequent short

power failures. 'We want to develop small-scale computing systems that harvest all the energy they need from their surroundings, for example by capturing solar energy or by making use of temperature differences or vibrations. This energy is then converted into electricity used to power the device.' Instead of batteries, small capacitors are used for a rudimentary form of energy storage.

Since the energy supply is unstable and intermittent, not only the hardware but also the software for these types of systems needs to be redesigned, Pawelczak says. 'Both need to be energy efficient. On top of this, the software should enable operation in such a way that the end-user notices any power shortages that occur as little as possible.'

Rethink screens

We should reconsider a system's main functionality and adjust our designs in such a way that more features will be realised with less hardware, the Delft researcher thinks. 'Take phones. Researchers from the University of Washington have already managed to produce a battery-free phone, but you can only use it to actually call someone. Developing battery-free alternatives for current smartphones is a major challenge though, unless we reconsider the need for their current enormous screens. They simply consume too much energy.'

In terms of software, intermittent computing requires an additional layer to make sure the program is executed correctly. 'Here the main challenge is how to



‘We need to ensure proper operation despite frequent power failures’

minimise the overhead of the additional protection without compromising the system’s reliability. The easiest solution would be to check after every line of code if the power is still on, then store all data in a non-volatile memory, and go back to that point when the system restarts after a power failure. But that is way too inefficient. So the challenge is to find the optimal number of checks. Use too few of them and you have a large restart penalty. And when you have too many, the system will become too slow and the software will consume too much energy.’

Mitigate consumption

In practice, this quest requires a lot of work in writing code, checking its accuracy, testing it in experiments and optimising it, sometimes even up until the single clock cycle level. After all, since the power can often be lost multiple times per second, every microsecond counts when restoring data. Pawelczak: ‘At the moment, this is only a young field of research. But I am convinced this is a crucial element of the energy transition. We should not only look into solutions to generate more electricity from sustainable sources, or find ways of getting rid of natural gas, but we should definitely also mitigate the energy consumption of our digitising society. Our electronics and computing devices consume vast and ever-increasing amounts of energy. It is our duty as computer scientists to turn this tide.’

ZERO – TOWARDS ENERGY AUTONOMOUS SYSTEMS FOR IoT

The largest research programme in the field of battery-free computing currently being carried out in the Netherlands is the Perceptief programme ZERO, a four-year programme that started in 2017. The three technical universities of Delft, Eindhoven and Twente are collaborating with 13 private partners to create energy-autonomous, ultra-low power devices that scavenge their own energy. In six research lines, the programme covers both hardware and software challenges, ranging from developing energy harvesting and ultra-low-power architectures and circuits to establishing energy-aware algorithms and system integration.

www.zero-program.nl



Ayushi Rastogi is an assistant professor in software engineering at the University of Groningen. Previously, she held postdoc positions at TU Delft and the University of California, Irvine. Rastogi obtained her PhD in Computer Science and Engineering from IIT-Delhi, India.

GROWING TOGETHER

By Sonja Knols Image Bram Saeys

'Understanding social fabric is as important as technical aspects for solving real problems', states Ayushi Rastogi, assistant professor in Software Engineering at the University of Groningen. Her research showcases the relevance and influence of diversity, inclusivity, and multidisciplinary in software development.

'Software is changing every aspect of our lives. When poorly designed, the software can induce and exacerbate discrimination and unfairness, but it is also a powerful tool that can make systems fairer in unprecedented ways. My research is on understanding software development and leveraging its potential in creating better software and society. After working as a postdoc at the University of California and TU Delft, I was looking for a place that harbours the right balance to study software development's social and technical aspects. Groningen offers the possibility of cooperating with psychologists, philosophers, and economists.

I explore socio-technical factors in software engineering to improve individual and team productivity and support diversity and inclusion. When it comes to the latter, most research today focuses on individual factors, predominantly gender diversity, in isolation. In practice, a combination of factors causes unfairness, creating sub-optimal and somewhat counterproductive development environments and processes. For example, one of my projects on the software development activities from seventeen countries showed that the assessment of code contributions differs significantly depending on the developer's country of residence. We found that the chances of a developer's contributions getting accepted are more than twice as high when the developer resides in the Netherlands or Switzerland than in China or Italy. I am exploring the causes for these striking differences.

My motto is 'growing together'. The world is full of exceptional talent, and I believe in making the best of it. In Groningen, I focus on three aspects: what ways are there to improve diversity and inclusion in software development; how to improve developer productivity and make software teams effective; and how software is evolving, pinpointing the opportunities for improvement.

CHALLENGES AHEAD

One of the main challenges with this type of research is finding appropriate signals of unfairness and validating them. Moreover, people's perceptions may not always match reality. People are likely to see bias in the actions of others but not in their own. For my research, I consolidate evidence from multiple sources and perspectives. Further, diversity in the research team and being aware of our own biases help. I firmly believe that responsible development leads to responsible software and innovations, which is crucial in building a responsible society.'