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ARTIFICIAL INTELLIGENCE

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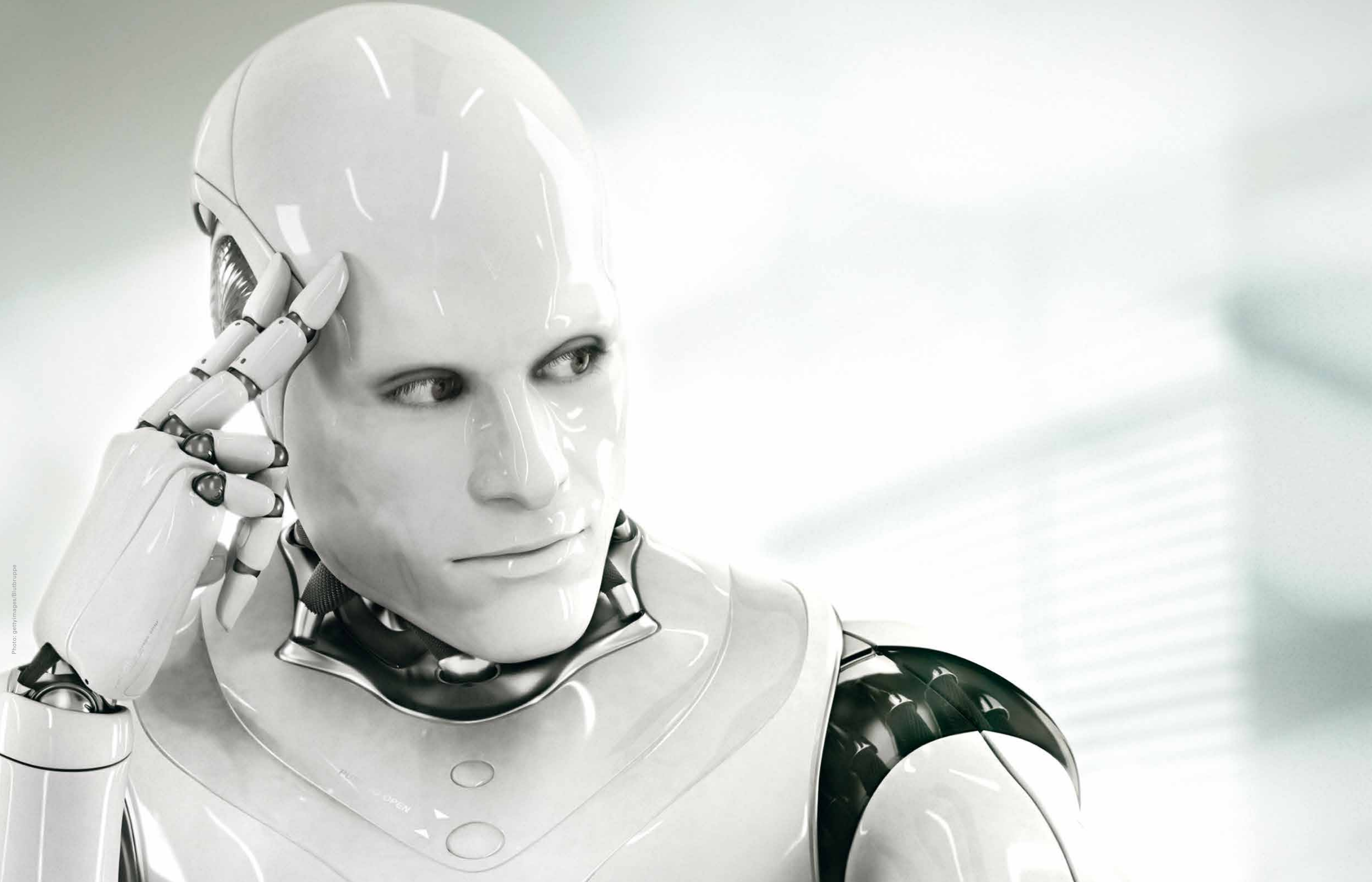
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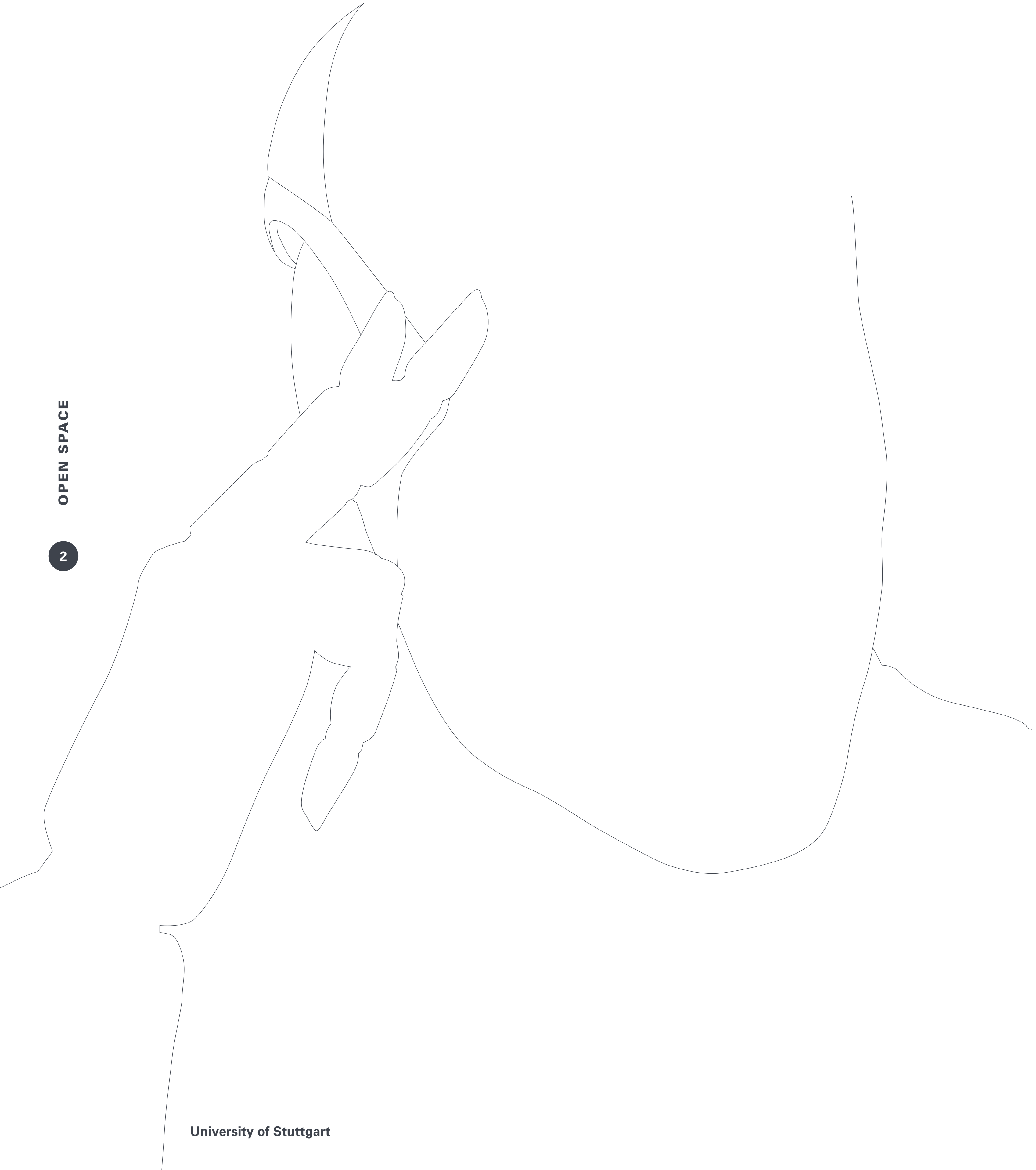

Dear Readers,

Whether it's a satnav system in the car or Siri on the cell phone: artificial intelligence has long since found its way into people's everyday lives and is regarded as the fuel for Germany and Europe's ability to compete. The German government decreed an artificial intelligence strategy last year and the Baden-Württemberg state government is investing around one billion euro towards become the leading digital region in the current legislative period. Winfried Kretschmann Minister President of Baden-Württemberg and guest author in this issue of FORSCHUNG LEBEN, sees the universities in particular as a source of inspiration.
Artificial intelligence plays a central role at the University of Stuttgart in the implementation of its vision of “Intelligent Systems for a Sustainable Society” and is involved in the interdisciplinary collaboration between multiple disciplines. We would like to give you some insights into these activities in the current issue of FORSCHUNG LEBEN.
Read how robots will use a cognitive production approach to train themselves in the future and how new production systems will be ready for operation in just a few days. Learn about how the interplay of artificial intelligence and biological design is inspiring machine learning. Discover how artificial intelligence will fundamentally change many other areas, from telecommunications to power supplies to our clothing. And in the series “Im Bilde” we'll show you what lies behind the potential field of “Autonomous Systems” at the University of Stuttgart and what role the Baden-Württemberg Cyber Valley will play in this.

I wish you an “intelligent” read
Best regards,

Wolfram Ressel

Photo: University of Stuttgart/M. Kovalenko

“Artificial intelligence plays a central role at the University of Stuttgart in the implementation of its vision of ‘Intelligent Systems for a Sustainable Society’”

Wolfram Ressel
Rector of the University of Stuttgart

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... News flash!

Unique pavilions at the BUGA

Rethinking architecture - two unique pavilions of the University of Stuttgart, which can be seen at the Federal Horticultural Show (BUGA) in Heilbronn, show what fascinating results this leads to. They were realized by the University of Stuttgart Institute of Building Structures and Structural Design (ITKE, Prof. Jan Knippers) and for Computer-Based Design and Construction (ICD, Prof. Achim Menges).

Photo: University of Stuttgart/ ICD/ITKE

One of the pavilions is built of indigenous wood species, and stands seven meters high and has a diameter of around 30 meters. Its structure rests on three points and spans a surface area of around 500 m² without supports. This is made possible by biological plate structures that are characterized by particularly high performance and material efficiency. The shell support structure consists of 376 hollow wooden cassettes, which are produced in a particularly material-efficient manner in a fully automated robotic prefabrication process.
The support structure of the second pavilion with a diameter of 23 meters and a height of seven meters consists exclusively of fiber composite components (glass fibers and carbon fibers), which were manufactured in a so-called additive, robotic manufacturing process. This made it possible to adapt the 60 components to the respective requirements without the need for special molds or waste. The resulting structures are many times lighter than all conventional building designs.

Intelligent systems at the Hannover Messe

This year, the University of Stuttgart once again put in an appearance at the world's most important industrial trade fair in Hanover, presenting visionary products and applications in the crowd-pleasing "Research & Technology for Research, Development and Technology Transfer" sector. Cutting-edge research from the two clusters of excellence, "Data-integrated Simulation Science" and "Integrative Computer-Based Design and Construction for Architecture" was on display. In addition, there were forward-looking exhibits from the Autonomous Systems, Biomedical Systems, Sealing Technology of the Future and mobility concepts from the ARENA2036 research factory.

Photo: ARENA2036

Photo: University of Stuttgart/SimTech

Magne Espedal Professor

Prof. Rainer Helmig from the Institute for Modelling Hydraulic and Environmental Systems (IWS) at the University of Stuttgart was awarded the “Magne Espedal” honorary professorship at the University of Bergen (Norway)
for his internationally recognized research in the field of porous media. Magne S. Espedal, a world-renowned professor at the University of Bergen, was the first researcher to combine the fields of applied mathematics and porous media, thus creating a new field of research. The University of Stuttgart has been collaborating on joint projects and doctoral dissertations with the University of Bergen for over 20 years, initially with Magne S. Espedal in particular.

EXCELLENCE

Emmett N. Leith Medal

The Optical Society (OSA) has awarded the Emmett N. Leith Medal 2019 to Prof. Wolfgang Osten, former director of the Institute of Applied Optics (ITO) at the University of Stuttgart. Osten received the award for extending the limits of optical metrology by integrating digital image processing. His research focuses on new concepts for industrial monitoring and metrology by combining modern principles of optical metrology, sensor technology and digital image processing. He is particularly interested in the development of digital optical technologies such as digital holography as well as to resolution enhanced technologies for the investigation of micro- and nanostructures.

Science Data Center for Born-digitals

Modern formats such as blogs slip through the general literature supply net. In addition to the lack of availability, the mass and diversity of digital literary formats requires new digital archiving methods. The aim of a new Science Data Center set up by the German Literature Archive in Marbach in collaboration with the High Performance Computing Center in Stuttgart and the University of Stuttgart’s Institute for Natural Language Processing (IMS) and the Digital Humanities Department is to collect and permanently preserve 'Born-digital' literary materials, i.e. materials originating in digital form. New digital methods will also be developed for researching this heterogeneous, innovative material. The state of Baden-Württemberg is funding the project with almost two million euro.

Terra incognita

According to its vision “Intelligent Systems for a Sustainable Society”, the University of Stuttgart wants to identify promising research fields of the future and position itself as a center of innovation. This is to be achieved, among other things, through the new “Terra incognita” research funding program, which is designed to encourage scientists to dare to develop risky original project ideas and to arrive at new research results via as yet unknown routes.

“Terra incognita” differs from existing funding opportunities in the field of high-risk research in that it is specifically intended to inspire research in completely new trans- and interdisciplinary fields and topics. The funding amounts to up to 50,000 euro.

Thinking ahead in the video

The University of Stuttgart’s new video picks up the university’s motto “Vordenken für die Themen der Zukunft” (Thinking ahead for the topics of the future). The clip visualizes the spirit of a visionary research culture that can be felt throughout the university campus with scenes showing the complexity and excellence of the University of Stuttgart’s research achievements. The faces of scientists from all over the world reflect the fascination with the topics of the future. The clip is highly dynamic and its accelerating visual language, the short image sequences and rapid pace rhythm culminate in a final intensification, which refers to the forward-looking approach of intelligent systems at the University of Stuttgart.

https://www.youtube.com/watch?v=kgaELc5zrHs&feature=youtu.be

Photo: University of Stuttgart

First Professorship in Corporate History

The Ferry Porsche Foundation finances the first professorship in Germany dedicated exclusively to the topic of corporate history. The endowed chair is intended to help companies to analyze their history in a way which is scientifically independent, and to better understand their economic and industrial achievements in a historical and social context. The individual achievements of business personalities will also be examined. The starting point for the initiative for this chair was the sports car manufacturer Porsche's intensive preoccupation with its own history. Prof. Wolfram Pyta from the University of Stuttgart’s Institute of History (HI) had presented a comprehensive analysis of the company's early years - from the creation of the Volkswagen to the role of vehicle designer Ferdinand Porsche in National Socialism and war production to his death in 1951. In the context of the study results, Porsche AG expanded the permanent exhibition in its museum to include content from this period and installed a commemorative plaque for the forced laborers employed at the main plant.

Photo: University of Stuttgart/M. Künzler

Flying, but cost effectively

The student group Akaflieg at the University of Stuttgart has built a glider that can save a lot of money. What is special about the aircraft, which bears the name “harpy eagle” after a type of bird of prey is that it has a comparatively powerful engine and can thus tow other gliders, but legally falls into the category of a glider, because the students have reduced the weight of the aircraft to that of a glider through the use of drastic lightweight construction methods. In addition, the pilots do not need a costly pilots license for powered aircraft for this class of aircraft, which is why the new plane is also interesting for clubs.

Designing the new
A unique ecosystem for artificial intelligence is emerging in Baden-Württemberg

Artificial intelligence (AI) is the driver for drastic changes. Its potential is enormous and competition for the commercialization of innovative applications has already begun. In addition to financial support and targeted research, ethical issues and the involvement of society as a whole are of great importance. In his guest article for FORSCHUNG LEBEN Winfried Kretschmann, Minister President of Baden-Württemberg, explains how Baden-Württemberg can succeed in establishing itself as a leading digital region.

Certain inventions and radical innovations such as printing, the steam engine and electricity have shaped entire epochs. In this context, economists speak of basic technologies that gradually penetrate all areas of life and fundamentally change the direction of economic, social and political development. The most important basic technology of our time is artificial intelligence (AI). Its field is digitization. Its food is data.

Even though the foundations of AI were laid long ago, its “childhood phase” has only just begun; a childhood in which machines are learning to see, speak and read. We have to distinguish between two phases: an initial growth spurt when increasingly powerful chips and memories made it possible to analyze and evaluate huge amounts of data (“old AI”). And a second phase in which AI is developing from a data assembly line worker to a dynamic problem solver that experiments for itself, generates data and learns (“new AI”).

It is crucial for our future to focus fully on the new AI, on machine learning and deep neural networks. Its potential is far greater than that of the old AI and its influence will soon be felt everywhere, especially in the industries that shape Baden-Württemberg, the “three Ms”: mobility, mechanical engineering, medicine. This is not just about increasing productivity, but about a new way of thinking, new business models and restructured markets. We in Baden-Württemberg want to exploit the opportunities offered by this development and minimize its risks.

On the way to becoming a digital lead region

The state government is investing around one billion euro during the current legislative period to achieve this goal. We want to become a digital lead region, for example to detect diseases even earlier and to combat them more specifically, to invent a completely new, more intelligent form of mobility and to protect our natural resources more effectively.

The universities play a decisive role in this context as drivers of innovation, users and critical promoters of digitization and artificial intelligence and also as an investor in our country's most important resource: people's minds.

The foundations of the new AI were laid primarily in Europe. Pattern recognition, the all-purpose computer and deep learning are European inventions. The notion that we have been left behind in this development is a marketing fairy tale. It is true that we are facing tough international competition and that the USA and China, in particular, are devoting considerable resources to advance the commercialization of innovative applications. We will only be able to maintain our economic clout in the future if we keep up with them, and we will only be able to have a say in the ethical standards that will apply in the future by taking the lead. This is why the state government has developed an interdepartmental strategy for artificial intelligence. We want to exploit Baden-Württemberg's strengths: a strong economy, excellent science and good connections and communications between these two areas. On this basis, we want to develop a unique ecosystem for Artificial Intelligence.

Photo: State Ministry of Baden-Württemberg

One central concern in this context is also to involve ordinary people in shaping digital change and to reflect upon the ethical aspects of the digital transition. For the same reason, we are advancing transdisciplinary collaboration between the humanities and social sciences as well as the technical sciences, and in July 2018 we launched the “Society in Digital Transition” research network. This is about ethical orientation, changes in the world of work and questions of sustainable development. It is not just about going faster, higher, further, but also about the conscious handling of AI with regard to its consequences for humans and nature.

> “The universities are playing a decisive role: as drivers of innovation, users and critical promotors of digitization and AI.”
>
> **Winfried Kretschmann**
> **Minister President of the State of Baden-Württemberg**

Cyber Valley as a magnet for early career researchers

At the same time, we are in the process of establishing AI research in Baden-Württemberg at the highest level and offering top talents from all over the world a home here. Only a location of this type will be attractive enough to inspire researchers and business enterprises and to bind them for the long term, which is why we founded the “Cyber Valley” in 2016 together with the Max Planck Society, the universities of Stuttgart and Tübingen and strong companies.

It has already become a beacon of the scientific landscape of our country and belongs to the top 10 centers worldwide for machine learning as well as being a magnet for leading scientists, for young people from all over the world who want to do research here or try their hand as creative entrepreneurs.

Other activities have been added, such as the establishment of endowed chairs and large third-party funded projects such as the Clusters of Excellence “Data Integrated Simulation Sciences” and “Machine Learning - New Perspectives for Science” at the Universities of Stuttgart and Tübingen and the “Machine Learning” Competence Center at the University of Tübingen and the Max Planck Institute for Intelligent Systems Tübingen/Stuttgart. According to the plans of the federal government, the Competence Centre is to become a component of the German AI network - and thus probably also part of a Franco-German AI network.

Networking European research

We have already taken the first steps and our investments are beginning to bear fruit. Nevertheless, we still have a lot of work to do. The federal and state governments must develop a common strategy and coordinate it at the European level to join forces. Countries such as Canada with its three AI centers (including the Vector Institute) are demonstrating that we can achieve a tremendous amount in a very short time as long as everyone pulls in the


Photo: State Ministry of Baden-Württemberg

Visit to the Cyber Valley: Minister President Winfried Kretschmann and the Austrian Federal President Dr. Alexander Van der Bellen (r.) with robot Apollo, which was developed at the Max Planck Institute for Intelligent Systems.

same direction. The state government is making an important contribution to this and is supporting this development with considerable funds. We want the Cyber Valley to grow rapidly, become more structured and create links to the first-rate AI being carried out in other places within the state such as Karlsruhe and Freiburg. We also want to make the Cyber Valley an important element of a networked European AI research environment. Only if we concentrate our forces throughout Europe will be able to form a counterweight to the USA and China.

We therefore welcome the European Union's AI strategy and support the ELLIS initiative of leading European AI researchers to establish a European AI Institute modelled on the European Molecular Biology Laboratory (EMBL). We need a common approach and the courage to think bigger! We also welcome the German government's idea of building application hubs. There are numerous strong institutions throughout the country that can provide a long-term impetus for application with new knowledge, for example in the fields of medicine and cyber security.

But public funding cannot solve everything. We also need a rethink in business, society and politics. We have played a decisive role in shaping the end of the industrial era, but we must not rest on our laurels. Instead, our goal must be to play a decisive role in shaping the digital era that is just beginning, and to develop new visions for the world of data. A seat of learning such the University of Stuttgart is an excellent partner for this.

Best regards,
Winfried Kretschmann
Minister President of the State of
Baden-Württemberg

Winfried Kretschmann trained as a teacher of biology and chemistry in Hohenheim and also taught in Stuttgart. He has been politically active since his university studies and co-founded the party "Die Grünen" in Baden-Württemberg. Starting as a keynote speaker in the Green Ministry of the Environment, Kretschmann was parliamentary party leader of his party from 2002 to 2011. He has been Minister President of Baden-Württemberg since the 12th of May 2011.

Self-optimization in the production hall
Machines are training themselves in cognitive production systemsin an automated and rapid manner

Machines that virtually program themselves will make production faster, more flexible, more forward looking and more economical in the future. Such a "learning factory" is still a vision of the future and the challenges are great. Scientists at the University of Stuttgart and the ARENA2036 research factory are working on the realization of the project.

Fishing out a screw from a tool box and feeding it into the production system seems to be quite a simple task at first glance. But behind the process lies a multitude of partial steps: to recognize the screw among the jumble of parts, to grip it in the right place, to control the workpiece, to turn the screw in the right place and in the right direction - humans intuitively grasp such processes. A traditional production robot, on the other hand, must be programmed by an expert for each individual step. "It takes a long time for the robot to function reliably, and the personnel-intensive programming is expensive," explains Prof. Marco Huber, head of the Cognitive Production Systems department at the University of Stuttgart's Institute of Industrial Manufacturing and Management (IFF). In a cognitive production system, such programming takes place without human intervention. The robot learns autonomously, for example in a simulated environment or by imitation, which steps it has to carry out. From this it generates its own program and finally executes it. The idea of machines that can actually program themselves is still a dream of the future, "but in some areas, such as object recognition, this works very well, at least under laboratory conditions," explains Huber. "We now want to put this into practice," adds the scientist, who also heads the Center for Cyber Cognitive Intelligence (CCI) at the Fraunhofer IPA, which provides support for medium-sized companies in particular, with machine learning for production issues.

Greater complexity through Deep Learning

Deep Learning, a sub-field of machine learning based on neural networks is a central factor for these developments. The concept goes back to its beginnings in the 1940s and is based on the functioning of the neurons in the human brain, which record information via synapses and "fire" when a critical value is reached. The American psychologist and computer scientist Frank Rosenblatt derived the so-called perceptron (a word derived from "perception") from this process. Perceptrons convert an input vector into an output vector and thus represent a simple memory whose contents can be accessed associatively. Neural networks arrange a large number of perceptrons in layers, thus enabling the representation of non-linear mathematical functions.

"The more layers such a network has, the more complex the problems it is able to solve," explains Huber. At least in theory. Because, for a long time, this thing that is actually essential, the training of neuronal nets, has presented a major challenge. The training relies on adjusting the weightings for the connections between the neurons - an enormous effort with several 100,000 or even millions of potential weightings. The first solution emerged in the 1980s with a core algorithm that made automated weighting possible. The name "backpropagation" of the algorithm suggests the basic principle: deviations between the prediction made by the system and the actual data set are fed back into the net "from back to front", which enables the system to adapt gradually until the errors are minimized. Mathematically, this is the well-known principle of gradient descent, a method used in numerics to solve general optimization problems.

Driver of the breakthrough

The actual breakthrough for Deep Learning came with three developments in recent years: "By using graphics cards, we now have computing power that allows us to speed up the training effort. Secondly, the Internet provides us with a mass of data, and thirdly, there are high-quality software packages, some of which are inexpensive or even open source," says Huber, describing the drivers of progress.

Nevertheless, the remaining challenges are considerable. One is called Sim-to-Real Transfer and describes the transfer from a computer simulation, for example, to a real robot. The problem with this is that there is no perfect simulation - so there can be no perfect training. Another difficulty is that machine learning requires a lot of high-quality data. In fact, there are also masses of data generated during production, but its quality often leaves much to be desired. Sensor data is noisy, sometimes complete data fields are missing or the data has different time stamps because it is generated by machines whose clocks tick slightly differently. "Data is the key to machine learning," says Huber, "and the well-known principle of 'garbage in, garbage out' applies here."

Until a machine can make decisions as complex as a human being's, more research will need to be carried out into learning methods. One promising approach to planning actions involves so-called reinforcement learning. A robot, for example, learns its job like a child through trial and error and receives a reward if it is successful: if it places its workpiece in the right position, it gains a point, but gets minus points for droppings it - which continues until it has mastered its job.

Another research topic is "transfer learning", i.e., transferring something that has already been learned to another task. Whilst humans can draw on their wealth of experience when dealing with similar problems, until now it has been necessary to start from the beginning every time a machine is programmed. Closely related to this is "meta-learning", i.e. learning how to learn. At the moment, machine learning still involves a lot of trial and error. How many layers does a neural network need, what does each layer do, how many neurons does each layer need? "It would be good to have an algorithm that could determine the appropriate architecture for the neural network by itself," hopes Huber.

Bringing light into the black box

Last but not least, neural networks currently resemble a kind of black box. What happens in it and why

Machines that learn independently and program themselves - this already works in some areas and under laboratory conditions. Prof. Marco Huber and his team want to make them fit for use in practical situations.

Photo: University of Stuttgart/M. Regenscheit;

a neural network makes a certain decision remains in the dark. This becomes or will become critical, for example, in the clarification of questions of guilt in accidents involving autonomous driving, in the financial sector when a customer wants to know why he or she has been turned down for a loan, or in medicine when an operating robot takes the decision as to whether or not to remove a tumor. According to the General Data Protection Regulation, humans have a right to an explanation of any automated decision. The black box can, therefore, prevent the application of something that is technically feasible in borderline cases.

Scientists are therefore trying to extract decision rules for neural networks and turn the black box into a white box. Unfortunately, that is an endless task, says Huber. “With complex systems, more and more rules are added over time, some of which are even contradictory. Then, at some point, the control system itself becomes a black box.”

Nevertheless, the triumph of Deep Learning is unstoppable. The range of possible applications today extends from all phases of production through autonomous driving to chatbots such as Alexa and Siri as well as DeepL, the online translation engine. Quality assurance is a classic aspect in production where artificial intelligence is already being used intensively, especially during final inspection. In the past, and sometimes still today, a workpiece would be inspected by a human being, for example, to check that it had a perfect surface finish. The results are subjective and the task tiresome. Today such inspections are usually camera-based, but the image processing function has to be parameterized very elaborately. By combining the camera images with neural networks, the system can detect errors much more reliably and the risk of false alarms is reduced. In addition, the systems are becoming more robust, so that fluctuations in lighting, for example, have less of an effect.

Artificial intelligence can also be used to solve problems of predictive maintenance, a core component of industry 4.0. Condition data from machines is used to predict when a part will fail and to plan the optimum maintenance time. In this context, neural networks can, for example, improve the forecast models for determining the remaining running time of a machine.

Agile production facilities

What is already possible in individual production areas will soon also apply to complete production lines. Dr. Matthias Reichenbach, head of the FutureTec team at Daimler AG, is working on this project at the University of Stuttgart’s ARENA2036 research factory. The construction of such systems currently takes several months from planning to programming to commissioning. One only knows whether the process works in the end and what quality the products will have when the system is in operation.

Dr. Matthias Reichenbach's area of research are robot assistants that can be programmed to perform routine tasks easily and without IT knowledge.

Photo: University of Stuttgart/M. Cichowicz

To make things faster and more agile in the future, the group is focusing on simplifying its systems, on intuition - and on its production staff. “The people at the assembly line know the production processes best and have the 'screwing skills'. We want to make their work easier, inspire them emotionally and unleash their creativity,” says Reichenbach, describing the objective. “Man should enjoy technology and use it for more than its original purpose.”

A very practical example are small robot assistants that can be easily programmed by anyone without IT knowledge. The employee simply shows the robot what to do. This then imitates the motion sequence - man and machine can work hand in hand. Technology supports people in their daily work in the way that is best for them individually. This is made possible by torque sensors originally developed at the German Aerospace Center (DLR) for the International Space Station (ISS). “The robot feels what it's doing,” explains Reichenbach. After just ten minutes, the sequence is already in place and the robot can, for example, screw in screws or install a battery pack and check that it is in the correct position.

As part of the “FluPro” (Fluid Production) project, in which a total of 18 partners are involved under the leadership of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, the easy-to-reconfigure and easy-to-program production modules are now to be linked step by step to form a complete assembly line for electromobility. In ARENA2036, the researchers are relying on the principle of swarm intelligence: rather than planning the system as a whole, each expert optimizes his or her specific area, which is then integrated into the overall system. The prototype should be ready by the end of 2019. However, it will be some time before a production system can be programmed in real life in just two days. “We need completely different levels of stability and process reliability for continuous operations. We will be working on this together with our partners at ARENA2036 or even in a real factory,” says Reichenbach confidently.

Further potential for AI

But self-training systems are not only of interest in production environments. Predictive maintenance, for example, is also an issue in the construction industry, since there is a lot of integrated technology in industrial buildings and a lot of money can be saved through predictive maintenance.

There is also enormous potential for artificial intelligence in the life sciences. Research into new drugs, for example, currently takes between seven and eight years on average, as countless databases have to be searched manually to find an active substance. In this context, artificial intelligence could automate the search process and make it more accurate, which could significantly reduce development times as well as the financial risks.

Biological transformation is the buzzword of the future. It refers to the convergence of technical and biological processes, which is intended to bring about greater sustainability in a wide variety of areas such as production or the housing sector. As with the digital transformation, information technologies such as AI play an essential role in achieving a high degree of automation or even autonomy. A Bio-Intelligence Competence Centre is currently being established with the participation of the Stuttgart Fraunhofer Institutes and the Universities of Stuttgart and Hohenheim. There, the development and use of bio-intelligent systems in different fields of application will be investigated.

Andrea Mayer-Grenu

New thinking
Achim Menges sees the potential for the architecture of the future in digital co-design

The famous Stuttgart architect Frei Otto once revolutionized the design process of buildings with his principle of finding forms. Now another revolutionary innovation from Stuttgart is set to emerge: co-design, the digital networking of planning, building processes and building systems. One of the progenitors of this method is Professor of Architecture Achim Menges. Together with more than 100 scientists at the "Integrative Computional Design and Construction for Architecture" Cluster of Excellence, he wants to make the predigital building industry fit for the future.

A certain dissatisfaction with the state of affairs is often the beginning of new progress. Achim Menges already felt this dissatisfaction in the 1990s: When the current professor and director of the Institute for Computational Design (ICD) at the University of Stuttgart studied at the TU Darmstadt and later at the Architectural Association in London, "blob architecture" or "free-form architecture" with its seemingly organic forms was regarded as forward-looking, as it had only just become possible with the advent of computer-based planning (CAD). "I was irritated by the fact that although the buildings looked different, the planning methods were relatively conventional," recalls Menges. "I was particularly surprised by the fact that the ambitions were always related only to design and planning and that there was a discontinuity when it came to materials usage and construction."
The construction process was essentially the same as before, but with digital support. Menges, on the other hand, was interested in the question of how digital technologies could be used to combine planning and construction to derive a completely new form of architecture. Today, 20 years later, the 43-year-old has made good progress along this path, which is evident in two pavilions on display at the Federal Horticultural Show (BUGA) 2019 in Heilbronn. Menges and his team designed and built them together with the Institute of Building Structures and Structural Design (ITKE) under the supervision of civil engineer Prof. Jan Knippers. They are the latest in a series of visionary works that the interdisciplinary team sets up year after year in Stuttgart's Stadtgarten. It is important for Menges to emphasize that building and architecture are never about the performance of a single individual.

Analogously quite impossible
Like many of the researchers in Stuttgart, he regards Frei Otto as one of his influences. The current research generation around Menges and Knippers has transferred his form finding process, which he developed in Stuttgart, into the digital age. While the architect, who died in 2015, still covered simple wire models with soap film to find the perfect shape for the tent roof of the Munich Olympic Stadium, scientists today use digital techniques. Among other things, they use them to translate nature's complex construction principles into lightweight structures that would not otherwise be possible in the same way: a spider was the inspiration for one of the former pavilions made of fiber composite materials. The wooden forest pavilion built for the Landesgartenschau Schwäbisch Gmünd 2014 was modelled on the shell of a sea urchin, the sand dollar.

The principle of co-design
Computers are now bridging the discontinuity that disturbed Menges in the late 1990s by introducing feedback loops: "We try to think holistically and to create digital feedback loops between design and planning methods, manufacturing and construction processes as well as material and construction systems from the very beginning. We ask ourselves:

"It's about genuinely next-generation digital building systems. And thus also about a new kind of construction work that will change architecture".

Achim Menges

Photo: University of Stuttgart/M. Regenscheit.

Planning, manufacturing and assembly in co-design: The geometrically different hollow cassettes created by robots for the timber pavilion for the BUGA 2019 could be assembled like a 3D puzzle.

Photo: University of Stuttgart/ ICD/ITKE

what new building systems and construction methods can emerge that are genuinely digital?" Menges calls this principle co-design. The researchers developed a fully automated production system For the timber pavilion for BUGA 2019 at the same time as creating the design methods. Two robots produced 376 geometrically different hollow cassettes from veneer layer boards. One robot takes a thin wooden plate and places it on a holder. The second applies glue all around. The first machine then places a ring beam along the edges, the second nails it with wooden nails. Then the surface panel is applied following the same principle. Finally, the robots cut box joints along the sides, which enable the pavilion to be pieced together like a 3D puzzle. In the same way that planning, material and production interlock, the computer had previously calculated the geometry of the plates itself by, among other things, reconciling the dimensions of the structure with the limits of the robotic arms and the mechanical properties and dimensions of the beech wood, always under the proviso that as few panels as possible were to be produced and that they should be as lightweight as possible.

Menges explains that the declared goal was to surpass Schwäbisch Gmünd's own pavilion. The new one is three times as large without increasing the base weight of 42 kilograms per square meter. "This was only possible because we were no longer building with solid panels, but with hollow cassettes." Without an automated system, such a construction method would not be manageable - at least not economically and within twelve months. The concrete planning began only one year before the completion of the pavilion for the opening of the Federal Horticultural Show. The principle of co-design is even more obvious in the fiber pavilion on display at BUGA 2019. The 60 individual elements of this exhibition piece were created practically in open space. A robot wrapped the glass and carbon fibers around two distantly spaced frames. The synthetic resin on the fibers hardened enabling the resulting element to be removed from the holder and installed. Each has a different shape, geometry and fiber arrangement depending on the prevailing forces and architectural requirements. This enables a surface weight of just 7.6 kilograms per square meter of load-bearing fiber construction for 400 square meters of spanned area. A transparent ETFE film makes the pavilion weatherproof. Both constructions meet all German building standards and structural requirements. "The pavilions provide a glimpse into the future of construction. The technology is ready," says Menges.

Cluster of Excellence for Civil Engineering 4.0

According to Menges the goal of the Integrative Computational Design and Construction for Architecture Cluster of Excellence of which he is the spokesman, is "to further develop this technology for the broad mass of building applications". From 2019 to 2025, the University of Stuttgart will receive funding of several million euro per year from the German Research Foundation (DFG). More than 100 scientists from seven faculties and from the Max Planck Institute for Intelligent Systems now want to transfer co-design to the building industry. In addition to architecture and civil engineering, other disciplines involved include construction physics, engineering geodesy, production and systems engineering, computer science and robotics, as well as the social scientists and humanities. The researchers will develop digital and at least partially autonomous construction processes in three networks: for multistory construction, for existing buildings and for wide-span buildings. "It is about research into integrative, computer-based design and planning methods, about new manufacturing and construction processes, about genuinely digital building systems of the next generation. And thus also about a new kind of construction work that will change architecture," says Menges.

In just three years, each of the three networks will have realized a first prototype building, with a second following in 2025. Because time is of the essence: "Our current construction methods place a massive burden on the planet," he says. They consume 40 percent of global resources and energy. What's more, they generate 50 percent of the world's waste. At the same time, the number of buildings worldwide will have to double by 2050 - not only due to population growth, but also because of global urbanization. In view of these prospects, the visionary speaks into the conscience of his guild: "Neither our methods nor our construction processes or styles are suitable for this." In terms of digitization, the construction industry currently occupies the last place of all branches of industry - behind forestry or fishing. Productivity has even fallen recently. It is high time for real progress in construction. And once again it should start in Stuttgart.

Daniel Völpel

Cutting-edge AI Research and Entrepreneurship

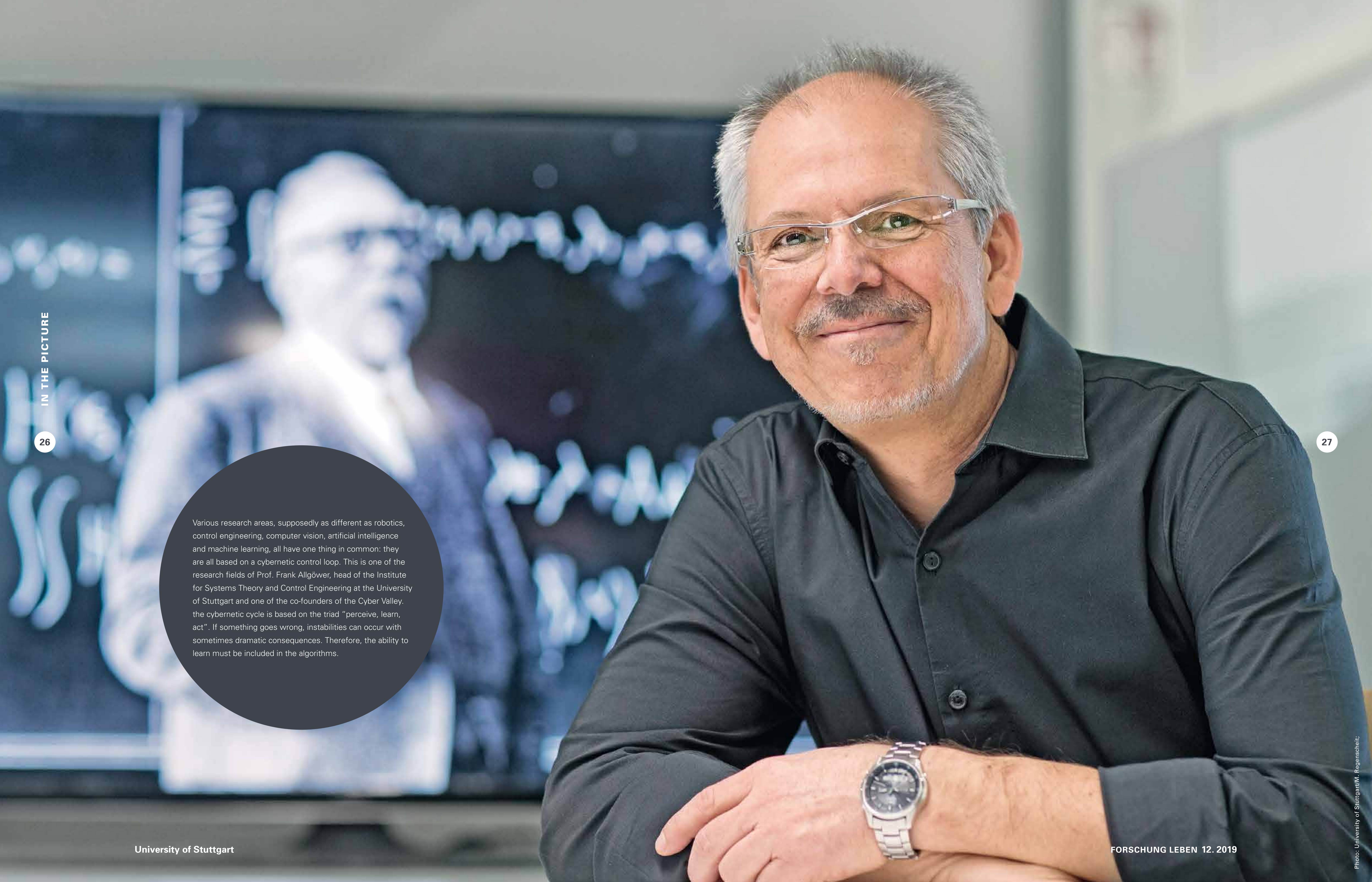
From autonomous vehicles and aircraft through automated production to assistance robots and intelligent medical devices: intelligent systems for a sustainable society are the overarching vision of the University of Stuttgart. Autonomous systems are one of the research fields with enormous future potential.

The Cyber Valley innovation campus is one of the largest research collaborations in Europe in the field of Artificial Intelligence (AI) and has become an international flagship. The Max Planck Institute for Intelligent Systems, the universities of Stuttgart and Tübingen, the companies Amazon, BMW, Daimler, the automotive engineering service provider IAV, Porsche, Bosch and ZF Friedrichshafen are all participating in the initiative, which is sponsored by the state of Baden-Württemberg.

The research focuses on machine learning, robotics and computer vision. Ten new research groups and three university chairs have already been set up under the Cyber Valley program, and seven more have been put out to tender. The Cyber Valley is also home to the International Max Planck Research School for Intelligent Systems (IMPRS-IS), a postgraduate school for doctoral candidates. Last, but not least, the Cyber Valley provides an ideal environment for start-ups, breaking down the barriers between industrial research and basic research driven by pure curiosity.

Researchers at the Cyber Valley are conducting cutting-edge research in their respective fields. They were recruited from all over the world in a targeted selection process to advance their research in the Stuttgart-Tübingen region. To provide some examples, we introduce a selection of them on the following pages.

Photo: MPI-IS/W. Disc



Various research areas, supposedly as different as robotics, control engineering, computer vision, artificial intelligence and machine learning, all have one thing in common: they are all based on a cybernetic control loop. This is one of the research fields of Prof. Frank Allgöwer, head of the Institute for Systems Theory and Control Engineering at the University of Stuttgart and one of the co-founders of the Cyber Valley. the cybernetic cycle is based on the triad "perceive, learn, act". If something goes wrong, instabilities can occur with sometimes dramatic consequences. Therefore, the ability to learn must be included in the algorithms.

Photo: University of Stuttgart/M. Regenscheit;

With the help of the vacuum system visible in the background and a vapor deposition process developed by Prof. Peer Fischer's team at the University of Stuttgart's Institute of Physical Chemistry (IPC) and at the Max Planck Institute for Intelligent Systems, it is possible to produce hundreds of billions of custom-made nanostructures ranging in size from 20 nm to 1 micrometer on a wafer in just a few hours. The computer-controlled growth process allows control over the three-dimensional shape and material composition. In this way, the scientists produce nano-propellers that they can move through tissue, among other things.

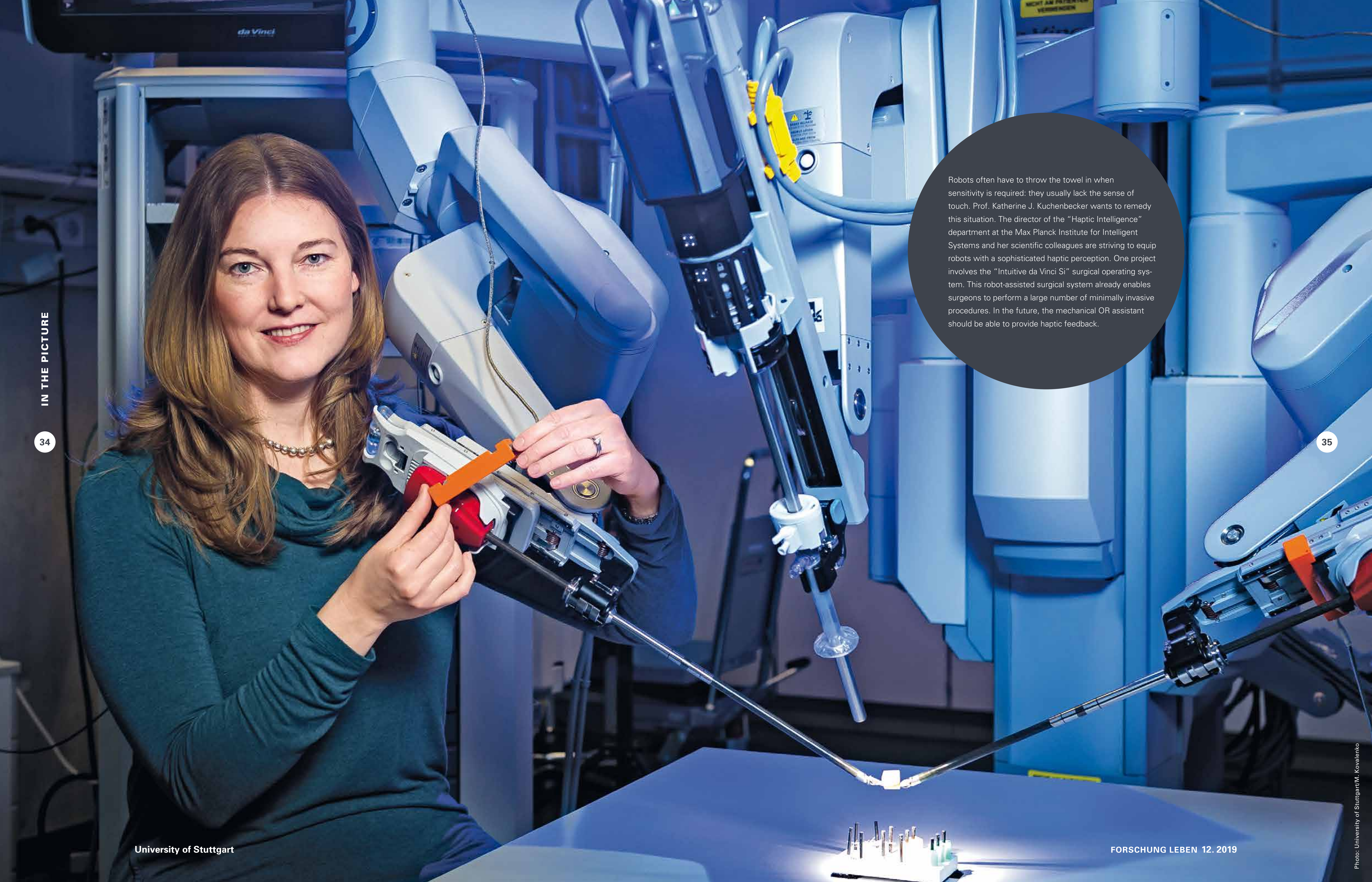
Photo: University of Stuttgart/M. Kovalenko

How can exciting scientific phenomena be viewed in virtual worlds and changed interactively and in real time? How can we humans influence the method of presentation or the visible data? This is what Michael Sedlmair, Junior Professor for Augmented and Virtual Reality at the University of Stuttgart's Visualization Institute, wants to find out with his research. Together with students, he develops ideas and suitable algorithms that could enable such solutions and facilitate interactions between humans and data. One of the biggest challenges is to find out how complex data can be displayed in a real context and which new interaction possibilities are suitable for AR and VR technologies.

Photo: University of Stuttgart/M. Kovalenko

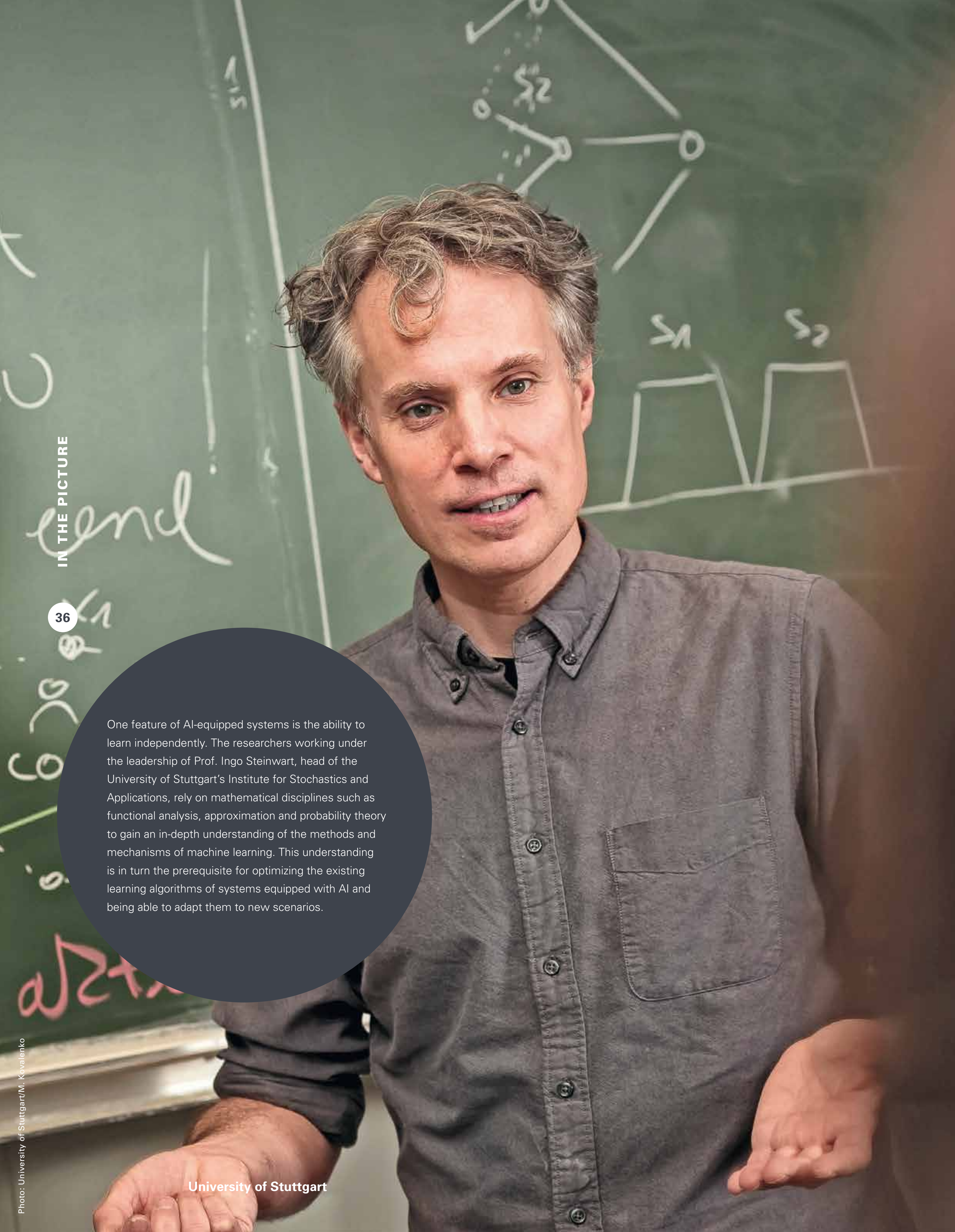
Prof. Marc Toussaint, head of the Machine Learning and Robotics group at the University of Stuttgart's Institute of Parallel and Distributed Systems (IPVS) and a Fellow at the Max Planck Institute for Intelligent Systems, conducts research at the interfaces between artificial intelligence, robotics and machine learning. As part of the Cyber Valley project, he is working on how robots can manipulate and understand their physical environment to learn.

Photo: University of Stuttgart/M. Kovalenko



Robots often have to throw the towel in when sensitivity is required: they usually lack the sense of touch. Prof. Katherine J. Kuchenbecker wants to remedy this situation. The director of the "Haptic Intelligence" department at the Max Planck Institute for Intelligent Systems and her scientific colleagues are striving to equip robots with a sophisticated haptic perception. One project involves the "Intuitive da Vinci Si" surgical operating system. This robot-assisted surgical system already enables surgeons to perform a large number of minimally invasive procedures. In the future, the mechanical OR assistant should be able to provide haptic feedback.

Photo: University of Stuttgart/M. Kovalenko



One feature of AI-equipped systems is the ability to learn independently. The researchers working under the leadership of Prof. Ingo Steinwart, head of the University of Stuttgart's Institute for Stochastics and Applications, rely on mathematical disciplines such as functional analysis, approximation and probability theory to gain an in-depth understanding of the methods and mechanisms of machine learning. This understanding is in turn the prerequisite for optimizing the existing learning algorithms of systems equipped with AI and being able to adapt them to new scenarios.

Photo: University of Stuttgart/M. Kovalenko

Industry 4.0 en miniature: the test and model plant for clocked production scenarios at the Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) is the model of a modern factory with digitally closed, flexible process chains. The plant, which was developed under the direction of Prof. Oliver Riedel, the head of the "Production Engineering Information Technologies" chair, does not only have actuators, sensors and control engineering at its disposal. An example: during operations, the workpiece carriers independently record measurement data, which are transmitted to a server with the aid of data analysis and AI preprocessing algorithms, where they are further evaluated. This allows production facilities to be monitored in real time, problems to be detected early on and workflows to be optimized - in the best case fully automatically.

Photo: University of Stuttgart/M. Kovalenko

Cyber-physical systems are becoming increasingly pervasive in automation technology. In this context, the Institute of Industrial Automation and Software Engineering (IAS) at the University of Stuttgart is working in collaboration with Siemens Corporate Technology in Munich, on digital twins as a virtual image of a physical system. The team, which is led by Prof. Michael Weyrich, concentrates on possible benefits of the use of digital twins in different application scenarios and created the demonstrator shown here for this purpose. Various aspects of the digital twin are made tangible using an illustrative example from the field of logistics. In the context of technology transfer, abstract concepts should thus find easier entry into industrial practice.

Photo: University of Stuttgart/M. Regenscheit

Perceiving, deciding and acting: For intelligent machines, this triad is the basis for being able to act independently in the physical world. The machines record the state of the environment via sensors, decide - based on this data - which action is to be carried out next and then convert it into an action. At the same time, they should learn from the data independently - for example, to become faster or better. Learning and decision-making abilities must be built into robots in the form of algorithms. Dr. Sebastian Trimpe, Cyber Valley research group leader at the Max Planck Institute for Intelligent Systems and guest scientist at the University of Stuttgart's Institute for Systems Theory and Automatic Control (IST), and his team are conducting research in this field.

Photo: University of Stuttgart/M. Kovalenko

Machines with morals

Philosophers are developing ethical principles for a successful collaboration between man and machine

Warrior robots that could kill on their own volition - without doubt one of the horror scenarios of applied artificial intelligence (AI). But the question also arises for their use in smartphones, cars, the world of work and in building technology: How should AI applications be designed to benefit human beings and respect our right to self-determination rather than harming us? Scientists at the University of Stuttgart's Institute of Philosophy (PHILO) are trying to provide answers to these questions.

Patients diagnosed with dementia are quite capable of living an independent life in the initial phase of the disease. The aim of assistance systems in the residential environment is to maintain independence for as long as possible in the further course of the disease. Together with external partners, researchers at the University of Stuttgart, have developed prototypes for such intelligent home technology in the "Design Adaptive Ambient Notification Environments" (DAAN) project. In addition to engineers, the team also included philosophers, who designed a moral framework for DAAN, because technology should not patronize or dominate people, but should instead respect their personal preferences and independent day-to-day decisions. To do this, the system must learn to respond to the user. "Biography work and memory care techniques are already used by nursing professionals," explains Hauke Behrendt, a researcher at the Institute of Philosophy. "But automating and digitizing this is new: self-learning systems that automatically adapt to the interests and needs of users."

The central task of the philosophers was to find a basis for deciding with what level of urgency DAAN reminds the patient of various activities. "If he or she forgets to water the flowers, it is less bad than if they forget to drink," says Behrendt by way of example. The water glass on the table could vibrate as a reminder. Which follow-up actions would be taken, if this were also ignored, for example as of when DAAN should notify relatives, can be defined. "But how much autonomy is given up in this scenario? How much manipulation is in play? To take account of philosophical aspects to find answers to questions such as these is very beneficial for further developments," says Behrendt. "At the same time, certain values that are close to our hearts must be taken into account." This raises questions of data ethics, such as who owns the data recorded by the assistance systems or who is allowed to use it. Not least of the concerns is the classic conflict between autonomy and well-being: "Should the system remind drinkers that they have not yet reached their alcohol limit?," asks Behrendt. In any event, DAAN should only point out possibilities, but leave the decision to the user. "Provided that these possibilities rule out overtly self-damaging behavior."

Ethical AI as a unique selling point

AI was also the focus of the interdisciplinary "motionEAP" project. Watched by a camera with motion detection, fitters assemble components, for example in workshops for the disabled. If they make a mistake or are unsure of how to proceed, the system projects the relevant information directly onto the work surface. This posed related questions to the developers: To what extent should the system be allowed to monitor the worker, and what level of intervention should be permitted? Who has access to the data? As was the case with DAAN, the philosophers involved in this project collaborated with the Institute for Visualization and Interactive Systems (VIS). "The German government takes the topic of digitization very seriously and allocates a great deal of research funding to this area," says Behrendt: "however, always under the proviso that project

Tool of oppression and control or useful aid? The system projects instructions directly onto the work surface at the personalized Future Work Lab assembly workstation at the Fraunhofer IAO.

Photo: Ludmilla Parsyak/Fraunhofer IAO

partners take an active part in ethical reflections." He is convinced that a unique selling proposition could emerge in this regard: "In countries such as China, ethical reflection is not currently as important as it is in Germany."

The philosophers make use of so-called reflexive circles to arrive at their decisions, which involves deriving specific instructions for action from moral principles, which they then weigh up against intuition and other judgements, which in turn could lead them to modify the principles. To check whether their thought processes are comprehensible, consistent and conclusive, they exchange ideas with colleagues, users and affected persons from other disciplines and present their ideas for discussion in colloquia.

In addition to applied ethics in connection with specific projects, they also consider fundamental questions relating to digitization. "Natural resources are running out, climate change is looming, the surplus value produced is being distributed more and more unequally: will digitization exacerbate these developments?" Behrendt wonders: "It is necessary to think about what form of economic activity, social participation and coexistence is needed to shape the digital transformation in a sustainable way." Like the earlier industrial revolutions, digitization could lead to disaster for many people. Behrendt, on the other hand, stresses the opportunities: "If we reflect upon that and have the will to actively shape the process, then we could make huge gains in terms of knowledge and self-empowerment." Rather than emphasizing the antagonism between man and machine, the philosopher argues in favor of uniting the best of both worlds: "Algorithms can already detect cancer much better than experienced chief physicians. However, armed with this technology, a chief physician is even more competent in his or her judgement. My hope would be that we would forego certain efficiency gains and equip people with the technology." Then nobody would have to fear losing their jobs to a robot – or even being shot by one!

Daniel Völpel

A question of trust
The Germans and their acceptance of intelligent systems

The car searches independently for a parking space, a robot takes care of the grandmother's day-to-day well-being: technically, this will soon be possible. But what do people think of the potential benefits of artificial intelligence (AI)? Researchers at the University of Stuttgart have conducted a representative survey to determine how Germans rate the use of intelligent systems in road traffic and nursing.

You lose concentration for a single moment and plough right into the braking car in front. At present, 90 percent of traffic accidents are caused by human error. A fully automated vehicle could prevent this accident. There is also hope that intelligent technology could prevent tailbacks and facilitate parking management. It could also increase mobility for the disabled or senior citizens. Together with the German Academy of Engineering Sciences (acatech) and the Körber Foundation, Professors Cordula Kropp, Michael Zwick and Jürgen Hampel from the Institute of Social Sciences (SOWI) at the University of Stuttgart, conducted surveys to determine whether digitization is accepted in view of such technical possibilities. They have published their results in “TechnikRadar”*, which examines what Germans think about technology in general and about fully autonomous driving in particular, “Dr. Google” or nursing robotics.
The Germans are critical of fully autonomous driving, which would involve vehicles driving independently on interstate highways, country roads or in the city and looking for a parking space with no driver input. Overall, only around 16 percent of German motorists are prepared to hand over responsibility to a fully automated vehicle. Almost two thirds (would tend to) reject this. “The population feels very much at the mercy of intelligent systems and political decisions, but has little confidence in their credibility and ability to provide solutions,” says Kropp. Recent data scandals and attacks from the Internet, are also largely to blame for this: In 2017, for example, Deutsche Bahn was affected by the worldwide Trojan attack “WannaCry” and the hackers used the display panels in train stations to demand ransom money.

Fears of data misuse

The Germans are most disturbed by the fact that these vehicles collect and record a lot of personal data, and are worried that this data could be misused and sold, for example to insurance companies, vehicle manufacturers or the advertising industry. “The population is sick of advertising,” says Zwick. In addition, they fear that computer breakdowns could cause traffic chaos or result in Internet attacks. “Imagine criminals blackmailing a driver in his or her car: If they don't pay, their car will be driven into the next best bridge pillar.” Continuing the horror scenario, entire cities could be threatened with the complete shutdown of their traffic systems, which would also affect all emergency services such as police and fire brigades.
Not all European countries are as skeptical about fully automated vehicles as the Germans. The Scandinavian population, for example, is more positive about digital technologies. Zwick suspects that this could be due to greater trust in manufacturers and operators, but above all in political figures and institutions, compared with Germany. Administration services In Sweden have long been completely digitalized due to the sparse population and long distances – and it works. “That's why the Swedes are more familiar with digital progress than the Germans. They don't assume that someone's out to get them.”

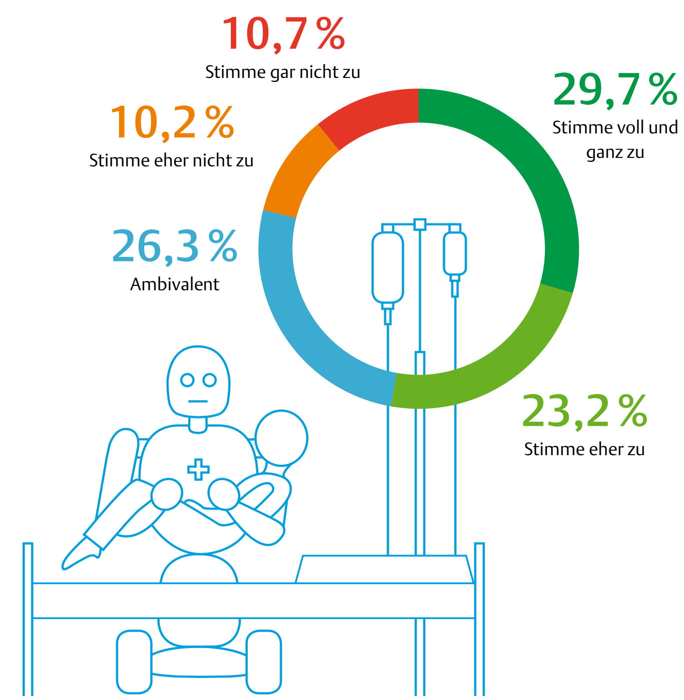
Disagreement about nursing robots

Another area of application for digital technology is in the nursing and care professions, which are coming under increasing pressure due to demographic change and the increasing shortage of skilled workers. One possible solution under consideration within the sector would be to use robots. This prompted Cordula Kropp's research group to ask German citizens how they felt about the use of robots in nursing. The result: opinions vary widely. 40 percent of nursing staff rate robots positively, 32 percent reject them and around 28 percent are undecided about the subject. More precisely, however, 81 percent fear that the use of robots will dehumanize nursing practice, and more than half think that only the wealthy will be able to afford care services provided by actual humans in future. “The approval or rejection of care robots will depend to a large extent on whether they are intended to relieve the burden on caregivers or replace them,” observes Zwick.
While business and politics - driven by the demands of global competition - are calling for progress at any price, the Germans only accept uninhibited digitization to a limited extent. According to the research team, this is also due to the lack of involvement of the population in political decision making. “The Germans should not feel that they are doomed to be at the mercy of technical progress, but should be involved in its design,” Kropp insists. “It’s up to the politicians and technology operators to gain the confidence of the consumers, and so far that hasn't happened!”

Bettina Künzler

Roboter in der Pflege

Menschliche Zuwendung als »Luxus«?



»Der Robotereinsatz führt dazu, dass am Ende nur noch die Wohlhabenden durch Menschen gepflegt werden.«

Image: acatech, Munich/Körber Foundation, Hamburg

Poems at the touch of a button
Tracing the history of information aesthetics and the origins of "digital literature”

Claus-Michael Schlesinger, a cultural scientist and research assistant with the Digital Humanities Department at the University of Stuttgart’s Institute of Literatures (ILW), is researching the history of information aesthetics and also deals with the question of whether computers will write novels one day.

Literature or texts that provide information on several levels are assumed to fall into the exclusive preserve of the intellectual capacities of the human brain. However, Schlesinger would only agree with this assumption to a limited extent: he knows that computers are more than capable of writing meaningful texts. Moreover, such texts are not even an innovation of our time, in which artificial intelligence is playing an increasingly dominant role in our everyday lives. Stuttgart, for instance, was not only a center of technical development in the early days of the computer, but was also at the forefront of the astonishing use of computer technology in the arts.

First attempts

“NOT EVERY GLANCE IS NEAR AND NO VILLAGE IS LATE”. This sentence was output at the University of Stuttgart in 1959 by a Zuse Z22 computer system, which was one of the first serially produced vacuum tube computers in Germany. A native of Esslingen, Theo Lutz, s computer scientist and long-time professor at the Esslingen University of Applied Sciences, had written an algorithm and fed the computer with 16 subjects and predicates each from Franz Kafka's “The Castle” in addition to certain logical constants and operators. The results were the first attempts at literature with the aid of a computer in the form of several million possible pairs of sentences like the one cited above.

The idea that his Zuse computer systems would one day be used to create art would certainly not have occurred to their inventor Konrad Zuse in his wildest dreams.

Photo: ZKM Karlsruhe

“Lutz used so-called combinatorial text generators,” Claus-Michael Schlesinger explains. In another experiment, the program generated random mathematical propositions, which Lutz checked against a “truth matrix”, the idea being that the more detailed the matrix, the better it would be able to judge for itself which sentence is actually true. “That was a very early proposal for what is now called artificial intelligence,” said Schlesinger. Although this idea was developed almost 60 years ago, primarily as a theoretical concept, and has not yet been put into practice, there is, nevertheless, a direct line to be drawn between Lutz's approaches and artificial intelligence as we currently know it.

Schlesinger joined the Digital Humanities Department as a postdoc in 2016 to continue his work on the history of information aesthetics. “It's a great pleasure for me to work here because Stuttgart was a hotspot in the interplay between cybernetics and the humanities.” Among other things, Schlesinger's work involves not only evaluating texts created at that time, but even, to some extent, rediscovering them because in many cases these pioneering literary efforts are only preserved as paper printouts. Schlesinger received a box with previously unpublished texts from the long-time director of the Institute for German Language in Mannheim. Among them was the program code that Stickel had written in the 1960s as a research assistant at the German Computer Centre in Darmstadt to create his “autopoems” on an IBM 7090 machine.

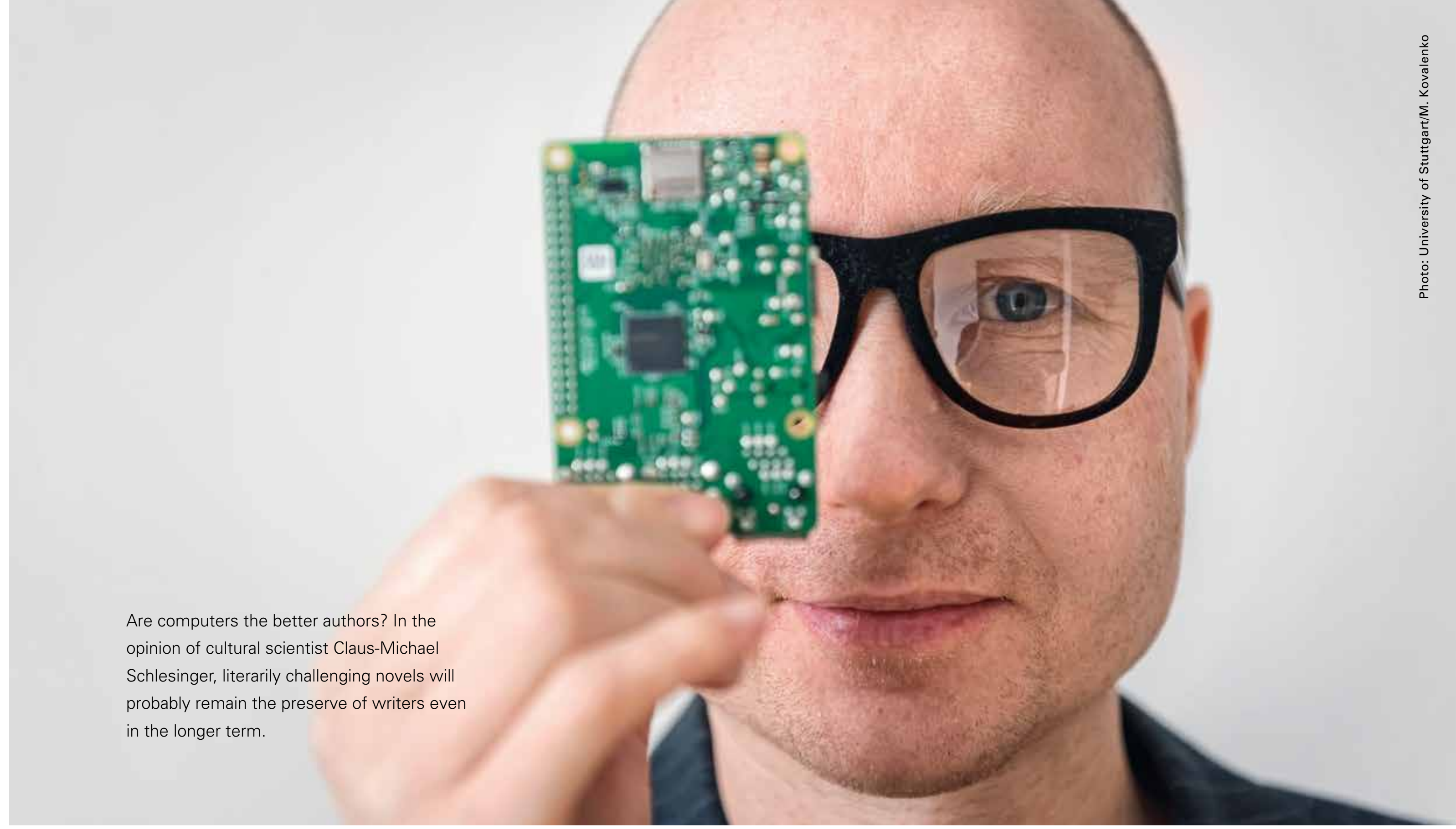


Photo: University of Stuttgart/M. Kovalenko

Are computers the better authors? In the opinion of cultural scientist Claus-Michael Schlesinger, literarily challenging novels will probably remain the preserve of writers even in the longer term.

In the beginning was the mainframe computer

The concept of information aesthetics was coined by the philosopher Max Bense, who taught at the University of Stuttgart from 1949. Bense's approach was to use the tools of information-theory and the mainframe computers available at the time to find aesthetic forms of expression. This may seem to be an outmoded concept these days when computers are often inseparably involved in the creation of music or visual art. But, according to Schlesinger, “the humanities in the 1960s were completely different and had nothing to do with information theory and cybernetics, and was primarily driven by interpretations based on the intrinsic qualities of a given work.” The information aesthetics approach, on the other hand, was far ahead of its time, as Schlesinger confirms.

Schlesinger refutes the concern that computers might one day be able to independently write literarily challenging novels. Grammatically correct sentences are relatively easy to learn, but when it comes to semantics, which works at the content level of a text, computers are largely clueless. “You'd have to feed them extremely large amounts of text for them learn semantics.” And even then the actual literary level, the poetics of the text, would still be missing.

So much experimentation was carried out in Bense and Lutz’ day that texts of literary quality were actually created. However, it is mainly the theoretical foundations that have survived to this day. The fact that aesthetic questions began to play a role in the development of complex systems also led to today's machines that write social media commentaries as bots or reformulate sports and stock market results to produce journalistic reports.

“My impression is that a lot is happening with regard to such utility texts because of the potential industrial applications,” says Schlesinger. Once again, he goes on to say, much experimentation is currently being done on “digital literature”, whereby a small community of fans of the so-called uncanny-effect, i.e., the somewhat uncanny and mysterious computer-generated literature, certainly exists.

Jens Eber

Photo: University of Stuttgart/M. Kovalenko

Google Maps for indoors

The indoor navigation system NaiSE, which is currently being developed by the eponymous start-up of the University of Stuttgart is similar to Google Maps, but works inside buildings and is much more accurate: NaiSE pinpoints and controls motorized robots, people and vehicles such as forklifts and enables all participants to communicate with one another. The objective is to connect robots and humans flexibly on a surface to ensure an optimal collaboration. "We do autonomous intralogistics," explain the NaiSe founders Jens Heinrich (l) and Kai Przybysz-Herz (r). Particular attention is paid to safety in this context. For example, if someone were to have a fall in the production hall and remain lying on the floor, the sensor would detect this and send an instant message to the screens of nearby colleagues.

Driverless sport cars

In addition to its electric sports car, the University of Stuttgart's GreenTeam has developed the first ever autonomous racing car, with which it will compete in the Formula Student design competition in 2019. The car works on the "see, think, act" principle: it perceives the data, processes it and reacts accordingly. To achieve this, a lidar, a very accurate laser scanner, scans the surroundings while driving, recognizes objects and calculates their distance. Also, two to four cameras on the vehicle record the color and size of the traffic cones which mark out the route. Additional sensors measure the acceleration and speed of the vehicle, among other things.

Photo: GreenTeam Driverless

Animal-like walking robots

Prof. David Remy at the Institute for Nonlinear Mechanics (INM) at the University of Stuttgart is hoping to develop robots that will either operate independently or be used as training systems in rehabilitation to assist in patient recovery or else take over certain functions completely. Remy also analyses the biomechanical effects involved in the movement patterns of animals with a view to reducing the power consumption of walking robots. The results of these motion studies can be transferred to robots. Algorithms can be used to calculate which type of movement is most energy-efficient for robots at a given speed, and the results can be used to formulate guidelines for robot construction which, for example, provide information on whether or not it would be worthwhile to install a spring in the spine of a given robot.

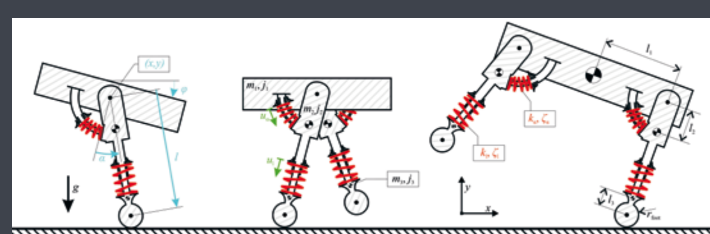


Image: David Remy/University of Michigan, Ann Arbor

Image: Fraport/Volocopter

Safety for flying taxis

From the city to the airport by air taxi: no longer a concept from the realms of fiction. Both the airport operator Fraport and Volocopter, a start-up based in Bruchsal, Germany, are looking into the integration of autonomous airport taxis at Frankfurt Airport, The safety and reliability of the new aircraft is ensured by control software whose algorithms were developed in collaboration with the University of Stuttgart's Institute of Flight Mechanics and Control (IFR).

Volocopters are emission-free multirotor helicopters powered by 18 electric motors and based on drone technology. Unlike airplanes, which are stabilized by wing and tail aerodynamics, volocopters are stabilized by the torque properties of the individual propellers. At the same time, the power reserves of manned multi-copters are considerably lower than those of conventional drones due to their large payload; manned flight also involves additional demands in terms of handling and comfort. For these reasons, suitable flight control and regulation algorithms are key to the realization of flight taxis.

Three birds with one stone

In the future, quantum computers will be able to solve certain computing problems much faster than a classical computer. One of the most promising approaches is based on the use of single photons for the transmission and processing of quantum information. Scientists at the Institute of Semiconductor Optics and Functional Interfaces (IHFG) at the University of Stuttgart and the Karlsruhe Institute of Technology (KIT) have succeeded for the first time in integrating three necessary main components (single photon sources, beam splitters and single photon detectors) on a single chip and operating it at the level of individual photons. The experiment shows the potential of fully integrated photonic circuits with all major components on a single chip. The scientists are hoping to be able to increase the complexity of the chip in the near future.

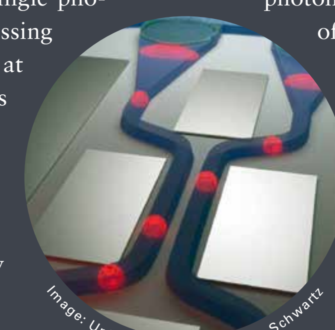


Image: University of Stuttgart/M. Schwartz

Humanoid muscleman
Scientists teach a robotic arm how to learn movement sequences

The hope is that, in the future, robots will be able to learn autonomously to execute a multitude of different movements, which is something we humans can do without giving it a second thought: . But do we actually need the complicated human musculoskeletal system or are muscles more of an evolutionary happenstance? Researchers led by Professors Marc Toussaint and Syn Schmitt are investigating whether an intelligent robotic arm can learn movements faster and easier with the aid of artificial muscles.

Reach for a glass, write a letter, throw and catch the ball, walk, hop or balance: man is undoubtedly an all-rounder. Robots that have mastered individual movements, such as baking pancakes, unscrewing a bottle or jumping, impressively well already exist. However, there is currently not a single robot in existence that could balance on a slackline, for example, or that would have the necessary sensitivity to swipe a smartphone screen with its finger. “That sounds trivial, but such movements are not so easy to control,” says Marc Toussaint, head of the Machine Learning and Robotics group at the Institute of Parallel and Distributed Systems (IPVS) at the University of Stuttgart. When swiping, for example, the finger must detect the surface and keep in constant contact with it. “The robot finger would quickly press too hard and then more or less stumble,” explains the expert for artificial intelligence, imitating the forwards-tapping movement of the robot finger with his finger.

In the “Deep Control” project, which is coordinated by Toussaint, physicists, computer scientists and control engineers are investigating whether muscles could help to better control the movements of robots to enable them to perform complicated movements one day. The test objects are computer simulations and a muscle-bound robotic arm that is designed to learn autonomously to point in any given direction. The Baden-Württemberg Foundation has been funding the project for a total of three years since the spring of 2017 as part of its Neurorobotics research program. Both physicists are also active in Baden-Württemberg’s “Cyber Valley” initiative, the objective of which is to promote research into artificial intelligence.

Until now, the limbs of humanoid robots have usually been rotated and flexed directly by electric motors, based on industrial robot models. Although today's robots can already point in any direction with extreme precision, the effort involved is high. “To move a robotic arm from one point to the next, the controller must send new signals to the motor every millisecond,” says Toussaint. Parallel sensors continuously monitor the arm’s current location. The human brain has it easier in this respect: All it takes, Toussaint explains, is for a nerve impulse to be sent to the arm muscles, whereupon the muscles contract and the arm automatically executes the movement.

Unpredictable muscle play

If robots are equipped with artificial muscles in the hope that they will be able to carry out more difficult movements in the future, they will first have to learn the relevant movements, just as humans do. Human movements involve a complex interplay between different brain regions, different muscle groups that relax or contract in a precisely coordinated manner, and tendons, which transfer muscle power to the bones. “The control algorithms of muscle-driven robots have no other choice than to learn the requirement movement,” says Toussaint. “If I use motors to control the joints directly, I can then use the joint angles to calculate where the finger is and then use an algorithm to bring the finger into a desired position; that's simple mathematics,” says Toussaint. But, he continues, if one wants to introduce muscles as a further level of regulation, there will be no mathematics. It is no coincidence that the name of the project is “Deep Control”, which means nothing other than deep control of the movement across several hierarchical levels.

Photo: University of Stuttgart/M. Kovalenko

“The control algorithms of muscle-driven robots have no other choice than to learn the requirement movement,” says Toussaint.
Prof. Marc Toussaint

Two master’s students of computer science from Toussaint's research group have recentlly programmed the “brain” for a robotic arm, an intelligent control algorithm based on machine learning. Syn Schmitt's recently renamed “Computational Biophysics and Biorobotics” research group has, so to speak, contributed the artificial muscles, tendons and bones. On the one hand, the robotic arm exists purely virtually as a simulation model on the computer. In addition, Schmitt, co-director of the new Institute for Modelling and Simulation of Biomechanical Systems, has had a real life-size torso with a single right arm built.

The metal robotic arm can be moved via a shoulder and elbow joint and terminates in a rigid hand with an outstretched index finger. The “arm muscles” are actually cylinders made of a pressure-tight rubber hosing with an internal yarn lining, and are operated pneumatically: as soon as a compressor pumps compressed air into the hose, it expands and becomes thicker and shorter like a natural muscle, i.e., it contracts. A total of five of these artificial muscles enable the robotic arm to move up and down as well as backwards and forwards on a single plane.

The muscles interact in a similar way to their human models: a “biceps” muscle on the upper side of the upper arm attaches to the elbow joint and bends the arm, its opponent, the “triceps” muscle on the back of the upper arm, stretches the arm again. Two antagonistic muscles in the torso move the shoulder joint based on the same principle. Another muscle in the torso can both move the arm forward and bend it at the shoulder joint. In addition, Schmitt's employees have installed finger-thick springs as tendons that protrude from the top of the shoulder joint, as well as various sensors that measure the force exerted by and length of the artificial muscles as well as the angle of the joint and transmit them to the computer.

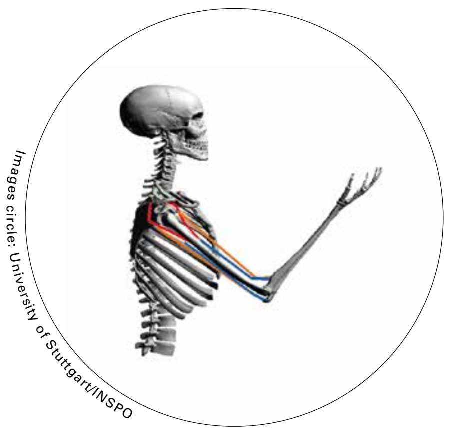
Robot learns from experience like a baby

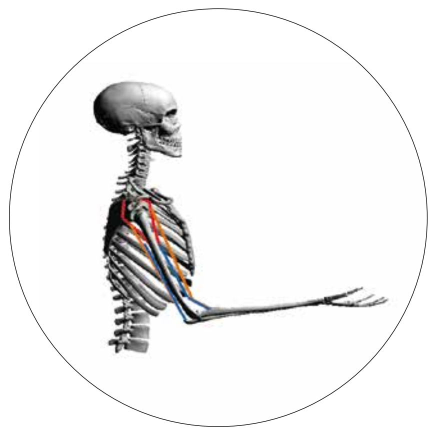
But how does the robot’s artificial intelligence, or more precisely the control algorithm behind it, learn to let the arm point in a particular direction? To put it simply, it learns like a human baby that initially fidgets around in an uncoordinated manner and eventually moves on to more coordinated

Digital research in analogue form: Instead of a skeleton model, Syn Schmitt's research group uses information from relevant specialist literature to understand what makes human motion possible.

Photo: University of Stuttgart/M. Regenscheit;

movements based on its experiences. "Initially, the algorithm has no idea what signals it needs to send to the muscle to move the arm to a certain point," Toussaint explains. So it sends any random signal, and the arm might move down. It then saves this



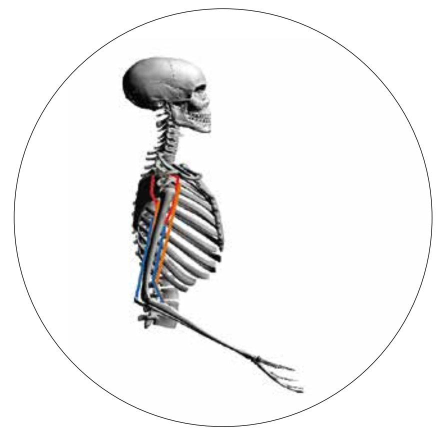


Images circle: University of Stuttgart/INSPO

experience as a data point. From this first data point it generates a rough model of how to move the arm up or down. Back in the starting position, the next thing it might do could be to send a signal in the opposite direction and, sure enough, the arm does actually move in the opposite direction. This is the second data point. "That won't yet get the arm to the right destination, but it may well get a lot closer," says Toussaint. And so the artificial neural network is trained incrementally and the model it constructs through the learning experience becomes more and more accurate: up to 700 times, in the simulation even more than 1,000 times, always a new pointing movement. The virtual "map" is gradually filled up with data points and the necessary muscle signal is assigned to every possible target that the arm has aimed at. "If the arm wants to go down in the future, it will know how to do so because it has already experienced 'down'," Toussaint explains.

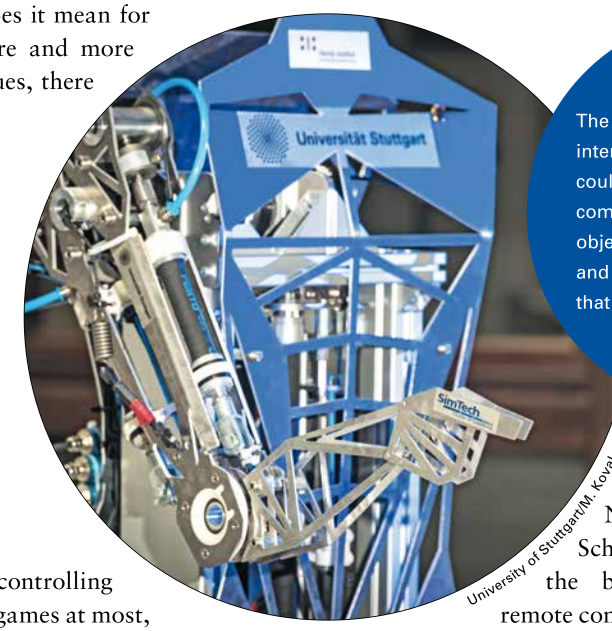
This learning method is based on so-called deep learning, which has been used for years in image recognition and in the speech recognition module used by Siri, the digital assistant on the iPhone. This involves arranging a network of nodes corresponding to the neurons in the brain into levels that use increasingly complex features to recognize something such as a face. For example, the first layer will only identify the brightness values of pixels. The second layer would register that some pixels are associated with edges. The next one would distinguish between horizontal and vertical lines, until at some point a level is reached on which the system learns which shapes are suitable for face recognition. In Reinforcement learning, connections between the nodes are either reinforced or weakened according to the carrot and stick principle, depending on the experiences made after each training round.

"We asked ourselves what the analogue of this idea of signal processing is when it comes to controlling a system," says Toussaint, "What does it mean for a control problem to introduce more and more hierarchical levels? So far, he continues, there



are hardly any concepts available for controlling robot movements, only for computer games at most, in which a game character learns to walk through a labyrinth or carry out certain actions. As a major innovation, Toussaint's researchers have also equipped the robot's "brain" with an exploration strategy so that the robotic arm systematically explores its entire range of motion during training. "If the algorithm next selects a target that is very distant from all previous targets, it will learn just as little from the data as if it were to move towards the same destination umpteen times," explains Toussaint. The program code that the researchers have installed, on the other hand, stipulates that the robotic arm always selects targets between the two extremes - distant from previous experience, but not too far away. "This guarantees that the algorithm learns the most from the experience it has gained," says Toussaint.

"From an engineer's point of view, absolute nonsense."



University of Stuttgart/M. Kovalenko

The "Deep Control" project is intended to show whether muscles could also help robots to perform complicated movements. The test objects are computer simulations and a muscle-bound robotic arm that is designed to learn auton-

Now, if Schmitt presses the button of a remote control at his institute, the robotic arm moves purposefully in the desired position, albeit swaying slightly. "The deviation for a target point is about eight millimeters, and in the simulation it is even less than two millimeters," he reports and hopes that a corrective camera could increase precision even further. But what drives the biophysicist most is the question of why biology has produced such complicated things as muscles. Was the human mus-

culoskeletal system driven by evolution, or simply by the fact that there are no other building materials available? “From an engineering perspective,” Schmitt goes on, “it's absolute nonsense to install two motors around a joint , i.e. antagonistic artificial muscles, rather than a single electric motor that can rotate in both directions”.
The team have now answered this question themselves by first having the robotic arm learn the pointing movement once using muscle power and once using direct joint control via an electric motor and comparing the results. In fact, muscles and tendons make it easier to regulate the movement. “Easier means easier to understand and faster to learn, which means that the algorithm needs significantly fewer data points for training. It also means less computing effort, i.e. smaller processors, resulting in increased energy efficiency,” Schmitt concludes.
In a computer simulation of a jumping robot , a former doctoral research student of Schmitt’s had previously found that much less information needs to be exchanged between the sensors, the control algorithm and the drive system, and computed, when the robot is driven by muscles. He devised the metric used to measure the control effort required for movements specially for this purpose. In the current project, however, the researchers also tested what happens when the arm's movement is disturbed by someone pressing against it: Will the robotic arm still be able to steer towards its target with precision after that? “We can clearly see that what was learned at the muscle level is much more robust than what was learned directly at the joint level,” Toussaint reports.
The next objective is for the robot to learn to master a really difficult task, i.e., swiping a finger across a surface. However, Toussaint and Schmitt point out that there is still a long way to go before their research results will be ready for use in a marketable robot. “Many challenges still remain” says Schmitt: “there’s the limited installation space in which many mechanical parts have to be accommodated; the pneumatic muscles that need a giant compressor; the robustness of the drive system. “Basically, we would now have to test which muscle models work particularly well,” adds Toussaint. It is possible that after optimization “the muscles” would then no longer resemble real muscles at all.

Side by side with the robot of the future

In the future, the muscle-bound, autonomously learning robot could be used when natural, varied movements are required, or when the robot has to adapt the force with which it executes the movement to unforeseen events. Collaborative workplaces in which robots and humans work side by side could be one such area, for example. If a human and robot were to accidentally collide, the robot would give way and take evasive action, which is something an industrial robot cannot do. “I am convinced that a muscle-driven robot can carry out such evasive actions much more easily,” says Schmitt. More natural exoskeletons are also conceivable, giving workers “super powers”, for example for overhead installations or lifting heavy loads. In rehabilitation, they could help stroke patients or paraplegics learn to walk again. “The exoskeleton would learn, together with the carrier, to execute the movement in an adequate manner,” says Schmitt. Humans are still far superior to robots. The next step towards the intelligent robots of tomorrow that Toussaint wants to climb in the coming years entails “physical thinking”. For example, a robot that is supposed to grab a wooden block but can't reach it might try to throw a ball that was within its reach against the wall so that it bounces at the right angle needed to move the wooden block within reach of the robot. To loosely quote Neil Armstrong, this task is one small step for a man, one giant leap for robotics.

Michael Vogel

The capacity creators
On the potential of Artificial Intelligence in processing and administration

It's the same every day: the working life of many clerks is determined by routine. According to Helmut Zaiser and Tobias Müller from the University of Stuttgart's Institute of Human Factors and Technology Management (IAT), there is an urgent need to investigate the extent to which Artificial Intelligence (AI) can be employed beneficially in this area, which is the starting point of the "SmartAIwork" project.

Together with the Fraunhofer Institute for Industrial Engineering IAO and seven other partner organizations, the two IAT scientists Helmut Zaiser and Tobias Müller are investigating the meaningful use of AI in processing and administration. They are investigating how AI-supported work can be made more productive and human-friendly, challenging but not overly strenuous. "SmartAIwork" is a joint project funded by the Federal Ministry of Education and Research (BMBF) under the "Innovations for Tomorrow's Production, Work and Services" program.

In the first step of the three-year project, the scientists analyzed the effects of the use of AI in processing and administration tasks and created studies. They will then implement the knowledge gained in pilot projects in three project partner companies. In the final step, Zaiser and Müller's team will create action and orientation aids for the future use of AI, and develop research and development recommendations for politics, research and practice.

AI in public transport complaints management

Zaiser and Müller have already described a concrete idea for the use of AI for one of their project partners, which involves complaints management at a local public transport company (ÖPNV). Many customers complain every day about unpunctual buses, lack of cleanliness at bus stops or the driving style. The clerk first has to sort the topics and forward them to the relevant department. "A program could take over this categorization task thus lessening the workload," says Müller. And, thinking ahead, the AI system could also pre-formulate a suitable response to the customer and suggest it to the employees. Routine queries could be answered more quickly, leaving staff with more time for more demanding tasks, such as dealing with more research-intensive queries. "That's our vision for using AI as a support system."

But before it gets to this stage, Zaiser and Müller are still facing a major challenge: in small and medium-sized enterprises, they say, the digitization of work steps has often been lacking so far. "The range of tasks still performed by hand, even when the technical means of digital processing already exist is really quite shocking," says Müller. "AI engines are fueled by data, so the basic digitalization of processing tasks is a prerequisite - yet this has not yet happened."

AI has the potential to automate knowledge sector tasks. However, it can also be used to support work that promotes innovation and competence. "AI is not intended to replace clerks, but to support them and relieve them in their day-to-day work routines," says Zaiser. The use of AI should serve to modify jobs in these sectors such that the work becomes more productive and innovative. "Man and machine go hand in hand", is how Müller sums up AI's objective in processing and administration.

Bettina Künzler

Photo: Universität Stuttgart/U. Regenscheit

Breaking the routine: Tobias Müller (left) and Helmut Zaiser from the IAT are working on using AI to create more freedom for clerical staff to perform non-routine tasks.

Photo: Stock/krass99

Further information about the project is available at: www.smart-ai-work.de

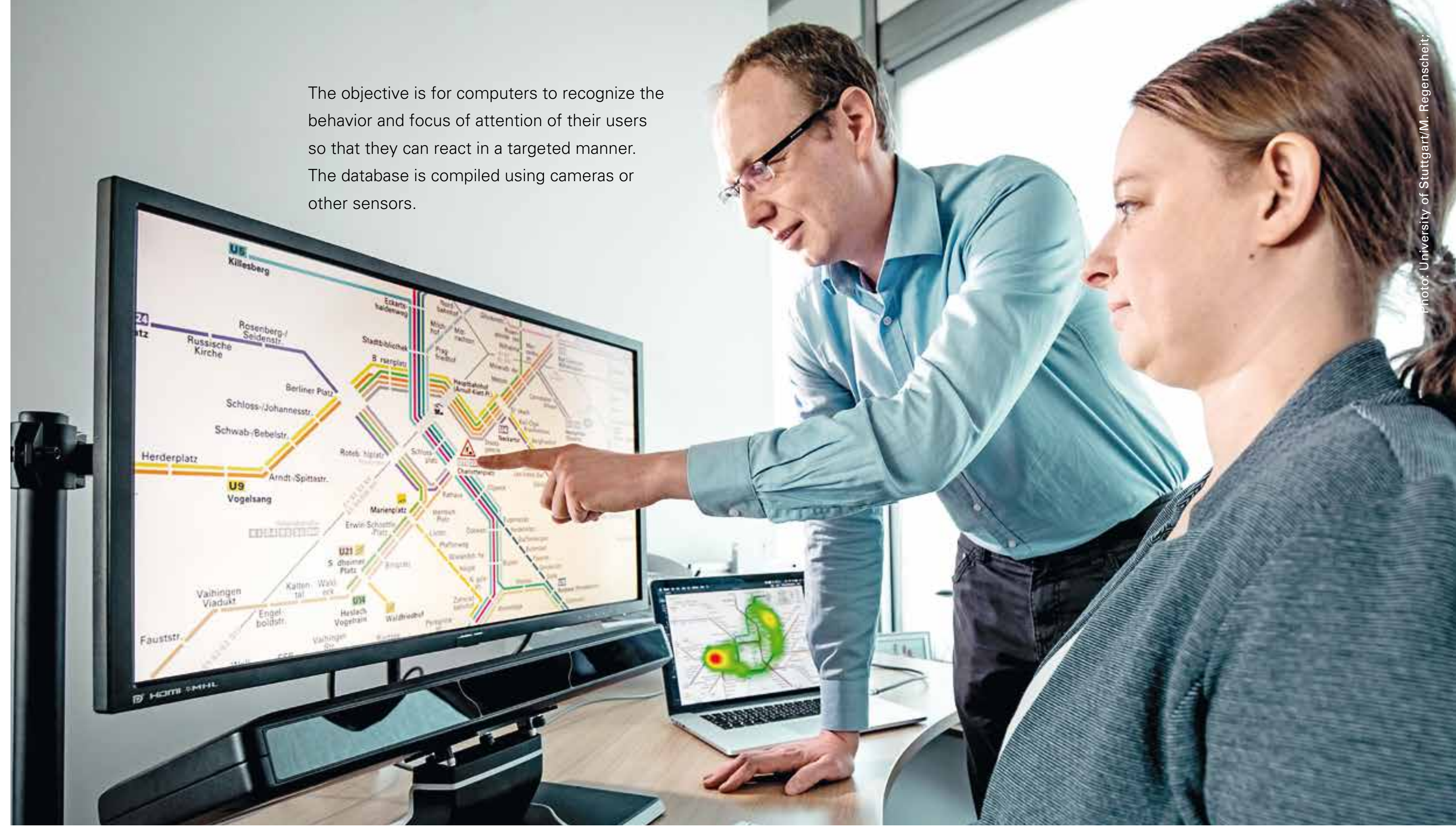
The intention is clear...
Intelligent user interfaces turn computers into attentive companions

How can computers react better to their users in the future? How could they determine what their attention is focused on and what they intend to do next? This is to be achieved in the future through the use of intelligent user interfaces such as those developed by the Institute for Visualization and Interactive Systems (VIS) at the University of Stuttgart.

In computer science, the term “user interface” to describe the point at whcih a person comes into contact with a computer and performs an action. This applies to all operations involving the keyboard, screen or mouse as well as to other forms of program control, whether graphical, textual, auditory or otherwise. Equipping these interfaces with Artificial Intelligence (AI) and extending them with competences similar to human perception, makes computers better able to understand their users and interact with them in a human-like way. As attentive helpers, they could help people to better control their situation and avoid mistakes. Intelligent user interfaces are already being used in the automotive industry to detect driver drowsiness and remind them to take a break in good time. But even in the office or in everyday activities, computers will soon know where their users' attention is focused, what they need help with, or what they intend to do next.
What distinguishes human beings is their ability to put themselves in the shoes of others and, for example, to assess their emotional state, intentions or focus of attention based their body language. For computers to be able to do this in the future, they will need intelligent user interfaces to precisely measure and interpret users' intentions or attention. Machine learning and computer vision methods are used and are continuing to be developed for this purpose.

New generation of interfaces
Prof. Andreas Bulling, head of the Department of Human-Computer Interaction and Cognitive Systems at the Institute for Visualization and Interactive Systems (VIS) at the University of Stuttgart, is currently developing such intelligent user interfaces. The aim of his research is to develop a new generation of intelligent user interfaces that are closely oriented on interpersonal interactions. The rapid developments in computer technology over the past few years have also opened up many new possibilities for the design of human-computer interfaces. It benefits, for example, from very high computing power used in super computing and exploits the revolutionary developments in the field of AI.

Recognizing user behavior
For computers to be able to recognize the behavior and focus of attention of their users, they need as broad a data basis as possible. The data is recorded by cameras or other sensors, automatically analyzed and interpreted. The better the computer is able to understand how attentive the user is, the better it can react to them.
Machine Learning is used to evaluate these vast data volumes: intensive training enables computers to process hundreds of thousands of data sets on powerful graphics architectures and to make increasingly better predictions based on recurring patterns.
One method for the computer to learn how to correctly classify the behavior and attention state of users uses the gaze estimation approach, in the development of which Andreas Bulling's faculty is playing a leading role. The computer uses cameras to measure the viewing direction and movements of users' eyes. The eye movements are recorded either by permanently installed or mobile cameras on the computer or integrated into laptops or mobile devices.
“The gaze estimation allows us to measure, for example, how often someone looks away from the



The objective is for computers to recognize the behavior and focus of attention of their users so that they can react in a targeted manner. The database is compiled using cameras or other sensors.

Photo: University of Stuttgart/M. Regenscheit

screen during work, is distracted by a notification, or makes eye contact during a conversation. This gives us important clues about a person’s ability to concentrate, how well a person gets on with their conversation partners or even what personal attitudes they hold,” explains Andreas Bulling. Maintaining eye contact for a long time during a conversation signals interest or understanding to the other.

Sensitive like a human
The next important step on the path to intelligent user interfaces is that they must also be able to recognize the user's intentions, especially in everyday situations. Computers should be able to put themselves in the user's shoes and know what he or she intends to do or needs next. Again the model for this is the human being. Our ability to make assumptions about the thought processes of others by analyzing where they focus their attention and their intentions, i.e., to form a “theory of mind”, is fundamental to interpersonal interactions.
Andreas Bulling is pursuing this goal in his new project, “Anticipate: Anticipatory Human-Computer Interaction”, for which he received an ERC-Starting Grant at the same time as he started at the University of Stuttgart , which is one of the highest researcher awards in Europe. The European Research Council will be providing a total of 1.5 million euro in funding the project over a five-year period. A project is also being prepared within the framework of the “Simulation Technology” Cluster of Excellence (SimTech) at the University of Stuttgart, the object of which is to simulate human thought and perception processes using computers and to further improve the accuracy of predictions using deep learning architectures.

Petra Enderle

On the up draught
Machine learning in aviation is improving flying

Using gliding as an example, the researchers at the Institute of Flight Mechanics and Control (IFR) at the University of Stuttgart hope to gain insights into how air traffic can be made more eco-efficient going forward.

The potential of artificial intelligence (AI) is extending the spectrum of methods everywhere, including the field of flight control. “We critically examine these new methods, but without simply following the popular wave blindly. Instead, we try to place AI within the classical systems theoretical context,” explains Prof. Walter Fichter, head of the IFR. His team includes Pascal Groß and Stefan Notter, two scientists who are working on this aspect as part of the TakEOF research project, which stands for “Tactical Energy Optimized Flying”. A higher degree of automation up to autonomous flying should contribute to the goal of more environmentally friendly aviation below the cloud ceiling.

Currently, contributions on automation are coming from two different fields: systems theory and computer science. “We belong to the first group, but are actually users,” says Fichter. Specifically, algorithms are being developed at the Institute for 'Urban Air Mobility Vehicles' - better known as air taxis - such as the Volocopter and City Airbus. According to Fichter, the questions and problems are similar, whether below the cloud ceiling or in space. There are good reasons why gliding was chosen in the end: this kind of flying is multi-layered, requires a careful consideration of the available options, experience and feeling. Everything revolves around thermals and their intelligent use. “Pilots have to perform at a high level. But gliding is even more demanding than motorized flight,” says Fichter. “This is why we reached the conclusion that the relevant parameters would serve as a suitable benchmark across the board,” report Pascal Groß and Stefan Notter, who designed and worked on the project, which was funded by the Federal Ministry of Economics and Energy (BMWI) for two years.

Methods find their niches

As always with new methods, the question as to where AI fits in also arises for flight mechanics. “We are currently investigating how classical control systems engineering can be usefully combined with methods from the field of artificial intelligence - in particular machine learning,” says Notter. Fichter emphasizes the necessary openness in the result. As he knows from experience: “control systems engineering originated in the 1940s and has subsequently been subject to many waves of new methods. At first, these were always viewed critically, but over time they have always found their appropriate applications and niches.” Of course, the IFR hopes to be able to successfully fill such a niche with these new methods, especially since initial results are available that look promising, at least within a certain circumscribed field of application. “We find it exciting to automate the competitive gliding scenario, which in some aspects resembles a board game, using methods of machine learning,” says Notter. “We are cautiously optimistic that this process will achieve what a good human pilot is capable of.”

Even approaching the mathematical optimum, he goes on, presents a real challenge. “Using classical methods, we can calculate optimal behavior in a scenario in which we know all the boundary conditions and have all the information, with difficulty for sure, but also very well, because we know how a plane behaves in calm air conditions.” However, if there are additional environmental factors, for example in the form of an updraft distribution, which are not known at first, one can still approach an optimal solution using Reinforcement Learning (RL), a form of machine learning. Notter explains: “This optimal solution is based on the fact that we know exactly what the environment looks like beforehand. And although our agent, which has been trained using RL, does not know this, it is still able to move intelligently within this environment, which is initially unknown to him, based on its total collected experiences.” The scientists at the IFR consider this form of AI to be a suitable method “because we are dealing with an unknown airspace, which we can hardly model beforehand”.

Mass data reconciliation

Huge amounts of data is required to be able to predict under which conditions updrafts will occur. Because glider pilots record all their cross-country flights and the data is accessible, Notter and Groß are able evaluate over 26,000 glider flights with over 110 million positional measurements: “The aircraft’s precise position is measured every few seconds.” In addition to this data, the scientists also have access the data of the German Weather Service, which is often received on an hourly basis. “That alone amounts to several gigabytes a day.” These data sets, which often refer to different coordinate systems, must be reconciled with each other by software programs. A tricky business. But that is precisely what the Institute does best: “We are very algorithm-oriented, but we do not only design the algorithms. It's about implementing them so we can test them.” An application has already been submitted for a follow-up project, which involves direct practical implementation: Particularly in disaster operations, such as forest fires, an aircraft’s energy balance is important for keeping the aircraft in the air for as long as possible. “The trick is that several unmanned aerial vehicles should complement each other,” says Notter. It is already clear that using updrafts saves a lot of fuel. “So the unmanned system can carry much more payload - or fly much longer.”

Susanne Röder

Photos: University Stuttgart/IFB/IFR (glider pilots), Stock/metamorworks (background), Sock/chesky (second plane)

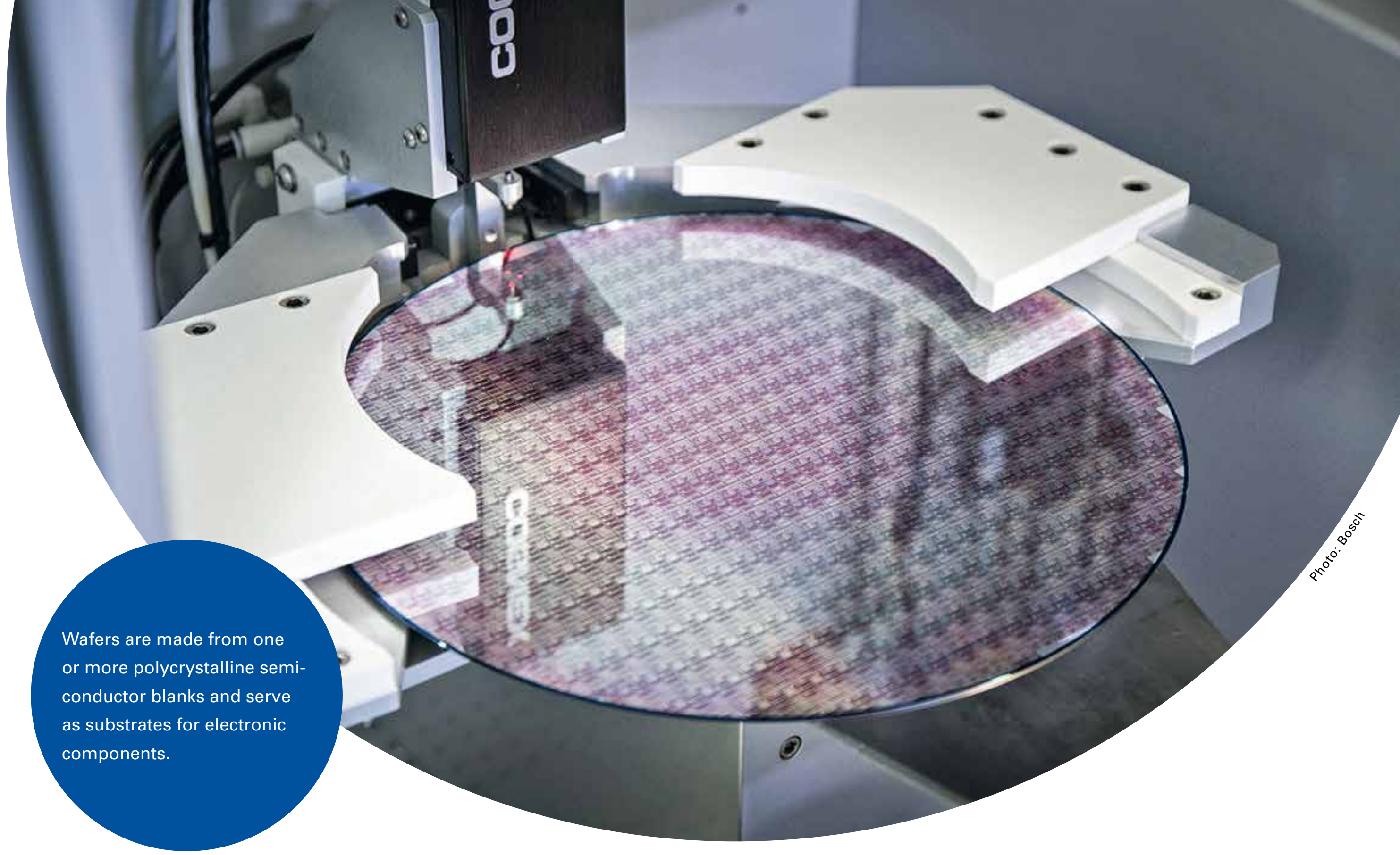
Chips on the test bench
New testing methods and Artificial Intelligence are improving semiconductor manufacturing

Internet, payments, electricity, traffic: nothing can dispense with integrated circuits these days. Due to the omnipresence of chips and computers, semiconductor tests are also becoming increasingly important. The University of Stuttgart is establishing a graduate school in close collaboration with Advantest to promote early career researchers and research in this field.

The products of the 480 billion US dollar semiconductor industry are paving the way for new or improved functions in more and more everyday products. “In fact, contemporary societies depend on chips functioning reliably and securely,” says Prof. Hans-Joachim Wunderlich, head of the Chair of Computer Architecture at the Institute of Computer Architecture and Computer Engineering (ITI) at the University of Stuttgart. “Without regular checks, the reliability and security of the chips cannot be guaranteed,” says Wunderlich. “This is why the tests also cover the entire life cycle of an integrated circuit from development to production to operational monitoring.”

Early detection reduces costs
Developers who design a new chip can use increasingly precise mathematical models for this purpose. But at the same time, the miniaturization of structures and the increase in complexity are progressing equally rapidly. By itself, the order of magnitude involved, which is in the range of a few nanometers, makes it difficult to accurately predict the behavior of the new chip. “Tests on prototypes therefore already contribute to better development results in this early phase,” says Wunderlich. When the chip goes into production, the manufacturing process is successively optimized. The result is that at the beginning of the process, many chips land in the wafer reject bin, i.e., don’t meet the strict requirements specified for them. Therefore, the initial yield is often only a few percent. “The purpose of test runs performed here is, on the one hand, to separate the wheat from the chaff and, on the other hand, to derive important findings from the measurement data which could improve the production process,” explains Wunderlich. “In this way, the manufacturer gradually manages to increase the yield per wafer thus reducing unit costs.” Manufacturers are aiming for mass production yields of 99 percent for memory chips, such as those found in every PC and smartphone.
But even when an integrated circuit has left the factory and is working in a computer system, no matter which kind, testing continues to play a role. “Instruments are integrated on the chip that monitor the work of the other circuits,” says Wunderlich. “On the basis of the test data obtained, the manufacturer can analyze a return after a failure in order, at best, to adapt the development or manufacturing process accordingly.” And so to avoid the problem in the future.

Experts wanted
What sounds very complicated to the layman represents a veritable pool of options for experts. “When testing chips, you acquire data about how several hundred parameters change over time, many of which are interdependent,” says Wunderlich, outlining the challenge. Such parameters could include such things as temperatures, voltages, currents or the susceptibility of a signal to interference. “This data is difficult to interpret,” says the scientist, because it is often the case that only a handful of the parameters play a role in the effect under investigation. Finding them is like the infamous search for a needle in a haystack, a search that also requires a great deal of expertise. The University of Stuttgart’s Faculty Five is, therefore, planning to conduct research into such issues in the new graduate school in collaboration with Advantest, a Tokyo-based company, whose second largest site is located in Böblingen and is one of the leading suppliers of automated test solutions and measuring instruments for the semiconductor industry. They will be providing the funding for equipment, jobs and the qualification program and providing each doctoral student with a mentor. A stay abroad is also planned.



Wafers are made from one or more polycrystalline semiconductor blanks and serve as substrates for electronic components.

Photo: Bosch

Research using real data
“We have been working with Professor Wunderlich’s team and other university teams on a case-by-case basis for decades,” says Klaus Siegert, Vice President of Research & Development at Advantest in Böblingen. “But the graduate school is a new dimension.” The company's medium-term strategy is to build a cloud-based test infrastructure for its own customers based on data and artificial intelligence. Collaborations, such as those with the University of Stuttgart, will also contribute to this. “The German site is the first to have initiated such a close collaboration,” says Siegert. The collaboration is initially scheduled to run for six years, but an extension is not excluded.
Neither partner will apply for patents for anything based on their joint research. In this way, they will ensure that neither publications nor the commercialization of results will be prevented. “The graduate school offers the opportunity to work with real data on something that will meet with great interest in industry,” promises Siegert, who studied electrical engineering at the University of Stuttgart 28 years ago.

AI on the testbench
Artificial Intelligence (AI) will also be important for the work carried out by the Research Training Group, partly in connection with the methodologies used to deal with specific questions, but also for when it comes to identifying the correct parameters for a given problem. “It is important to note that - unlike in many other industries in which AI methods are used - semiconductor testing does not depend solely on classification,” Wunderlich emphasizes. “Instead, it's always about understanding why certain interdependencies occur.” The relevant development and manufacturing process or operation cannot be optimized without this understanding.
In addition to the search for causes of design and product issues, the scientist sees four further fields

Prof. Hans-Joachim Wunderlich (left) at the collaboration partner Advantest in Böblingen at one of the testers with the aid of which semiconductors can be tested over their entire life cycle.

Photo: University of Stuttgart/M. Regenscheit

in which AI could be useful in testing, for example, in connection with methods that help to better understand confusing test data, and for configuring the best working states of a particular chip. “Predicting lifetime and maintenance requirements is also a task that could be handled by AI,” says Wunderlich. And finally, AI will help with designing tests as efficiently and effectively as possible. “Adaptive tests - those that learn from their own results - are our vision.”

Michael Vogel

Photo: Stock/I. Traimak

Agents know what to do

More efficient construction and production planning with the aid of AI

Individualized mass production is increasingly becoming a reality. However, design and production planning can become a bottleneck if engineers do not have enough work capacity. The Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) at the University of Stuttgart is investigating how artificial intelligence (AI) can relieve the strain on engineers.

Automobile production is highly automated. It would not otherwise be possible to manufacture a product as complex as a vehicle in the required quality and speed, let alone at an affordable price. It is a mass production process, but one that allows for a lot of variations: the range of chassis, seat covers, paintwork, infotainment equipment and assistance systems is so wide that the possible combinations for a vehicle model can be several hundred million. This is why automotive production today is already more a customer-specific process than a classic mass production process and this is made possible by automation. Now there is talk within the industry of batch sizes of 1, whereby vehicles are manufactured for each customer individually without incurring uneconomically high production costs. This highly automated manufacturing process is no longer just the vision of the automotive industry, but also everywhere where large quantities are produced on an industrial scale.

Independent production is state of the art Technology

“In the past, a manufacturer planned once and manufactured several times, but with batch sizes of 1 he has to plan once to manufacture once,” says Akos Csiszar, explaining the consequences of this trend. Csiszar is a scientist at the ISW of the University of Stuttgart, which is headed by Prof. Alexander

“Planning once, manufacturing several times” is the current norm thanks to CNC machine tools. Akos Csiszar of the University of Stuttgart wants to use AI to make the programs of computer-controlled machines automatically adaptable.

Photo: University of Stuttgart/M. Cichowicz

Verl and Prof. Oliver Riedel. “Planning once, manufacturing several times” is common practice in production today: CNC machine tools, i.e. computer-controlled machines, are standard. “One operator can operate several of these CNC machines simultaneously,” says Csiszar. “He doesn't have to give his full attention to any one of them as long as it is running smoothly and completes its task.” The situation is different in the preceding stages of the production chain: whilst workpieces can be designed and planned with the aid of computers, the software used for this can only perform very rudimentary tasks without the constant intervention of the designer. “Each step must be defined manually,” clarifies Csiszar and adds with a wink: “with these software solutions, engineers work more than computers.” While a single operator can support three to five CNC machines in parallel, software-supported design and production planning require constant intervention.

This way of working is similar to driving a car today: the available software tools are the maps. They show all possibilities, but the immediate attention of the driver is permanently required to stay on the right track. In an autonomous vehicle, on the other hand, the driver's attention is only required in certain situations; for the rest of the time he can devote himself to other things. “In a figurative sense, one would also need a highly automated car that relieves one of standard tasks during construction,” says the ISW scientist. And as with the mobility of the future, AI is also considered to be the hope for automated construction.

AI agents take on subtasks

“We want to use existing AI algorithms, many of which are even freely available as open source software, for computer-aided production planning” says Csiszar. “The difficulty is to formulate typical production engineering problems in such a way that they can be processed with the AI algorithms.” The following example shows that this is less trivial than it sounds: The aim of milling is to produce a workpiece with the desired geometry and surface accuracy as quickly as possible - for example from a metal block. If the engineers plan this machining process on the computer, they have many variants to choose from, such as whether the milling head moves back and forth along parallel strips or always only in the same direction, where the milling head starts and at what feed rate it advances. All of this has an influence on the accuracy and the time required. “In our AI approach, engineers would no longer have to go through all the settings in the program,” explains Csiszar. “Instead, they would have a small utility, a so-called agent, as an aid. This in turn would commission other subordinate agents with special tasks, such as drilling holes or removing material as quickly as possible.” To ensure that the final result meets the requirements, the agent system learns using realistic simulations with the aid of AI, and acts independently in accordance with the objectives set. This leaves the engineers plenty of time to deal with other things until the results are available, without having to go through the optimization process themselves.

“We have already used simulation methods at the ISW to explore how AI agents could be trained,” said Csiszar. “A further step will be to catalogue existing methods and formalisms for problem description to assess which of these AI approaches are best suited to our questions.” This preliminary work is necessary for a research project that the ISW is currently preparing: together with international scientific institutions and medium-sized companies, the ISW team want to create the basis for the ability to automate tools for computer-aided production planning in the future. The project starts this year.

Michael Vogel

Intelligent impulse generators
From classical signal processing to message transmission with neural networks

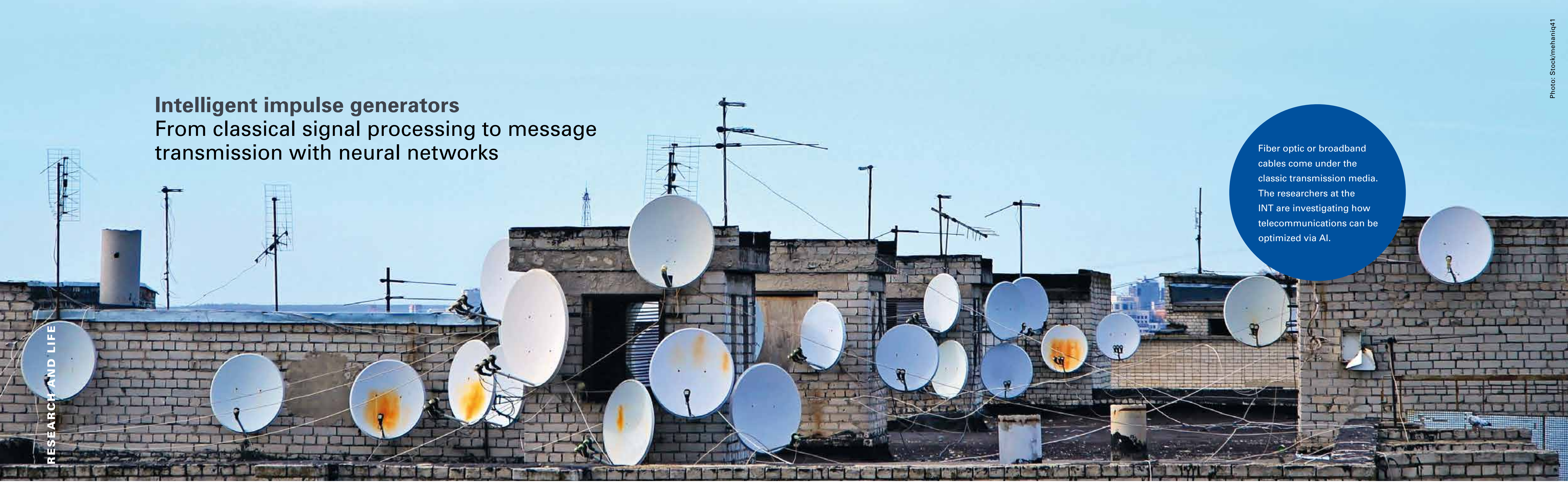


Photo: Stock/mehaniq41

Fiber optic or broadband cables come under the classic transmission media. The researchers at the INT are investigating how telecommunications can be optimized via AI.

Prof. Stephan ten Brink, head of the Institute of Electrical and Optical Communication Engineering (INT) at the University of Stuttgart, and his team of 15 researchers are investigating how artificial intelligence can be used productively in communications technology. He relies on a clever mix of classical mathematics and self-learning methods.

Whether it's a radio channel, fiber optics or broadband cable network as used by the Internet or cable television, contemporary telecommunications systems all work with classical signal processing methods. "We don't care much about the transmission medium as long as it's suitable," says Stephan ten Brink, head of INT. "We're developing methods to make the most of this medium." Beyond traditional methods, ten Brink and his team are working with artificial intelligence (AI), which makes the Institute one of the few research institutes in Germany and Europe working in the field of AI processes for the physical transfer layer. The aim of the engineers is to find out where the advantages lie compared to classical, mathematically model-based methods.

Because the physical transmission layer determines the specific conditions of the transmission medium, it is necessary to clarify questions such as: Which disruptions or interferences there are on a specific radio channel? What are the propagation conditions? Which echoes, reflections or diffractions occur? Which variations over time are measurable in the short and long term? "The overall aim is to identify the physical phenomena inherent in each channel. The signal shaping or 'packaging' of the information to be transmitted can then take place using either classical signal processing and coding or with new AI procedures," says ten Brink, describing the procedure at the Institute. "The bit transmission layer is about error protection and particularly good detection in noise, i.e. noise robustness." His institute is currently working on developing particularly good transmission methods and is therefore doing important basic work to provide the best possible foundation for scheduling, which involves allocating frequency channels and time resources.

Although the Institute also has expertise in scheduling, it focuses on the underlying physical conditions. "The bit transmission layer is about error protection and particularly good detection in noise, i.e. noise robustness.

Exchanging the transmission medium, e.g., by replacing the radio channel with a fiber-optic or cable channel, hardly changes the routing or scheduling in the upper layers," explains the INT manager. "The bit-transmission layer, our sphere of action, is completely different because the physical phenomena are completely different." For example, dispersion phenomena can be observed with glass fibers, while completely different noise phenomena can be observed with cables.

Counteracting the flow of impulses

In the chromatic dispersion of the glass fiber, for example, the digital light pulses at the beginning of the fiber can be clearly seen. After 80 kilometers, however, these pulses dissolve, resulting in dispersion or scattering. This happens because the refractive index depends on the wavelength. The various signal components in the optical fiber therefore run at different speeds, which is why they arrive at the receiver at different speeds - the pulse has faded away. As the signal technicians know the properties of the glass fiber very well, they can model a suitable signal processing function according to the known non-linear Schrödinger equation using classical mathematics. Put more simply: they can mathematically determine what they have to do at the receiver to back calculate the dispersion.

This is exactly where AI methods can be used. "These methods are much more generally applicable. They learn the channel, so I no longer have to abstract an exact model, I can just transmit the signal. Together the receiver and transmitter learn what the channel looks like without having an exact model, and can even transmit the signal better," explains ten Brink. The reason is that "the mathematical model fails to consider many effects that may only occur in the real channel."

Better performance thanks to AI

His team has set up a radio link at the institute. "We first applied classical signal processing to it and transmitted signals across it. Then we set up neural networks at the transmitter and receiver. It turned out that they could make the transmission quality

even better." Many effects arise that cannot be mapped in the model, but are implicitly exploited. However, it is "not so easy to know exactly what additional structure the neural network has detected via AI," says ten Brink. In short: scientists at the Institute have so far been able to observe that performance has improved thanks to AI. The disadvantage of this method is, however, that it is currently almost impossible to derive simple rules from the trained net to better understand how exactly the robustness was increased.
But the disadvantage of AI is also an advantage. "The method is particularly interesting for channels with properties that are difficult to model." In addition, ten Brink provides an idea of where and how AI could be used in the future: "We radio technicians are always concerned with electromagnetic waves - and that is physics. In molecule-based transfer, chemical substances are involved as information carriers and the transfer is much slower." Sometimes, however, there are combinations of both, for example in nerve pathways. So there are transmission channels that are extremely difficult to model mathematically and therefore difficult to manage using traditional approaches. There might also be a way to make progress with these using AI procedures." So far, however, it has not been clearly clarified that AI is always better he points out.

Susanne Röder

The INT under the direction of Prof. Stephan ten Brink (left) is one of the few research institutes in Germany and Europe working in the field of AI processes for the physical transfer layer.

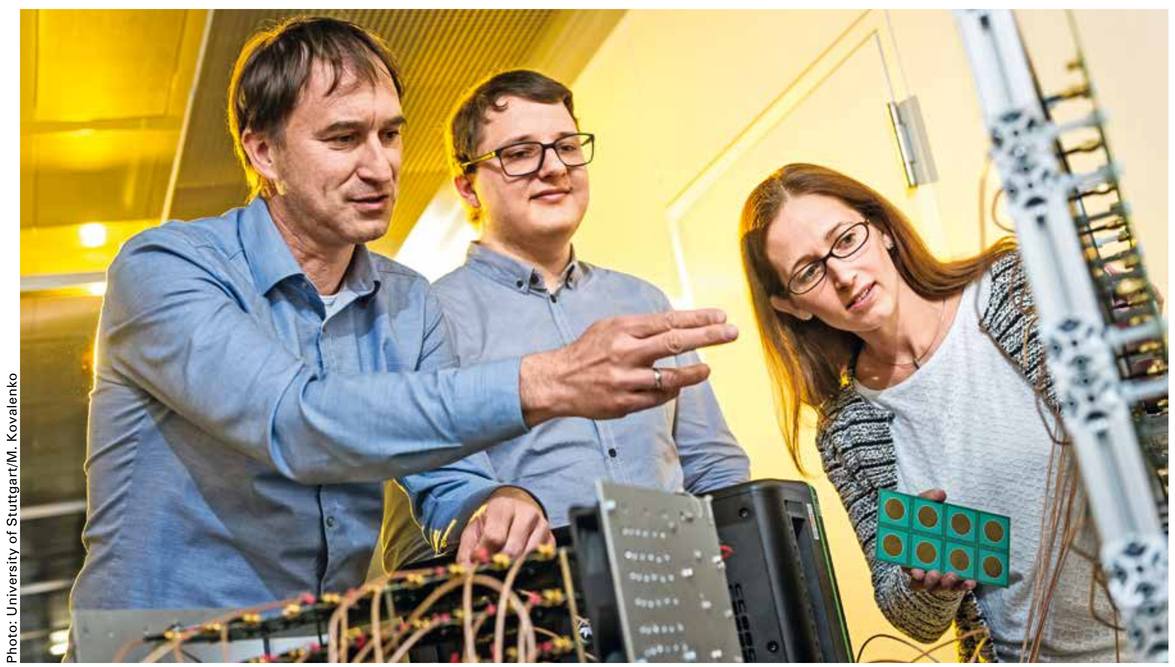


Photo: University of Stuttgart/M. Kovalenko

Photo: Stock/C. Camus

Smart drills
Machine learning in machining and cutting technology

One production step follows the other, the different manufacturing processes interlock smoothly: What looks so simple in industrial production today takes enormous effort and a lot of experience. This is the only reason why mass-produced products can be manufactured economically today with zero or almost no defects. Developers and operators have an important role to play in this context. The University of Stuttgart's Institute for Machine Tools (IFW) is looking how machining manufacturing systems could be made to optimize themselves.

Yes, a drilled hole is a drilled hole, but that is only superficially true. In fact, they can be quite different even if they were made by the same drill on the same machine. The drillings could be slightly elliptical or the roughness of their inner surfaces might differ. Even if the deviations are only in the range of a few thousandths of a millimeter, it could mean the difference between quality products and rejects in everyday industrial life. "The causes for these fluctuations can be manifold," says Rocco Eisseler, Group Leader for Machining Technology at the University of Stuttgart's IfW. "The speed or feed rate of the drill bit plays a role, as does the type of material the workpiece and drill bit are made of, but also factors such as cooling during drilling." However you twist it, no two drilled holes are ever the same. And this also applies to any other machining technology, such as turning or milling.

Working at the limits

"Of course, the people who operate such production machines have the requisite knowledge and experience to produce a workpiece of the required quality within the specified tolerances," says Eisseler. "However, based on the specifications of the tool

Photo: University of Stuttgart/M. Regenscheit;

The team headed up by Rocco Eisseler (left), Group Leader in Machining Technology at the Institute for Machine Tools (IFW), is investigating how machining manufacturing systems can optimize themselves.

manufacturers, it is usually necessary to adapt the machining parameters specifically to the respective machining processes, i.e. to always find the optimum.” For example, when it comes to very complex workpiece requirements or making manufacturing processes as economical as possible. “And there is always the issue that all these influencing variables also influence each other,” says the group leader. The hole may meet the geometric quality specifications at a certain drill speed and feed rate, but the drill bit may wear out relatively quickly. Not only would that necessitate an earlier replacement, but the wear would also lead to a lower quality result in terms of roundness and surface roughness. So everything is connected to everything else. “That’s why we chose drilling as an example for our research into how an expert system could be used to optimize the various demands of the manufacturing process,” says the scientist. This required a lot of drilling. However, the diameter of the drill and the material of the workpiece were always the same. “What varied were quantifiable parameters, such as speed and feed rate,” says Eisseler. It was then necessary to relate these input variables to the output variables of roundness and surface roughness, to which end, the team used a process called a Bayesian network. “Bayesian networks make it possible to establish a connection between cause and effect, even if there are no simple causal relationships,” explains Eisseler. “With them it is also possible to take account of the fact that wear on the drill bit affects both the input and output variables - Bayesian networks function in both directions, so to speak.” This is decisive in so far as, in addition to the correlations, causalities can also be discerned.

Interdisciplinary collaboration

The greater vision behind such research is that of a self-optimizing manufacturing system. IfW Director Prof. Hans-Christian Möhring explains: “Such a system would independently identify the optimization potential of a manufacturing process and initiate the necessary measures to realize this potential.” This could either be done automatically - an area of specialization in the IfW's research - or in interaction with the operator. “Currently, such a system remains aspirational,” says Möhring, “because the trained human operator can permanently record a wide range of information, intuitively anticipate the incipient states and virtually take them into account in real time during process control.” But with the help of machine learning, this will change in the future. “This could involve Bayesian networks, as in the case of the drilling process, but completely different methods, such as deep neural networks, are also conceivable,” says the engineer. The ultimate choice would depend on the specific task. “We work in interdisciplinary collaboration with other faculties within and from outside the university.” Möhring's team takes a holistic approach to the self-optimizing manufacturing system, starting with the definition of the relevant machining process in the CAD/CAM programs and ending with the finished result, the quality of the workpiece and the wear and tear on the tool. “It is always important to trace the knowledge gained back to the process parameters,” emphasizes Möhring. “And that’s not easy, given the multiple, sometimes opposing, interdependencies.”

The whole concept is still in its infancy in industry. “However, the manufacturers and users of the manufacturing systems are very open to the idea,” says Möhring. “Perceptions are changing, not least due to the buzzword ‘industry 4.0’.” Even if the vision of the self-optimizing manufacturing system is much older than the digitization of industrial production processes, he adds. “There are companies that have been collecting manufacturing data for many years. But for many, the question of how they might be able to use this data remains unanswered.” From his point of view, however, there is no single solution here, but only answers to each individual case.

Möhring also believes that there is no simple yes or no when it comes to the question of whether self-optimizing production systems should function automatically in the future or only in interaction with the operator. He illustrates this point with an analogy to autonomous driving: “Would you entrust yourself blindly to an autonomous vehicle at 160 kilometers per hour or would the car at least have to signal to you regularly and comprehensibly that it has everything under control,” he asks - and it sounds rhetorical.

Michael Vogel

The high pressure digitizer
The automation of cleaning tasks is one of the most demanding challenges

At the end of the 1970s, Johanna von Koczian, a pop singer, sang "Das bisschen Haushalt macht sich von allein" (That wee bit of housework will take care of itself), humorously drawing attention to the fact that cleaning, washing and cooking were activities that had to be taken seriously and were physically strenuous due to poorly developed technology. However, much has changed in recent decades: These days, floors really do clean themselves - with the help of robotic vacuum cleaner. One of the first suppliers of automatic household aids was Kärcher, a company that recognized early on the opportunities inherent in digitalization, whereby – as Hartmut Jenner, alumnus of the University of Stuttgart and CEO of Alfred Kärcher SE & Co. KG – is convinced, the opportunities outweigh the risks.

Kärcher produced the first ever robotic vacuum cleaner - what is the current situation regarding autonomous cleaning?

In fact, we were the first supplier worldwide to offer a fully automatic floor cleaning robot for private households. At that time, the device was not only at the cutting edge of technology, but also conceptually years ahead of the competition. The current successor model, the RC 3, is even more intelligent thanks to progress in computing power and sensor technology and includes, for example, a laser navigation system for surveying the room. I can also use an app and a calendar function to define cleaning zones and times according to my own personal needs.
We are also much further ahead in research and development in the commercial sector than just a few years ago. This applies to robots for floor cleaning as well as window cleaning. We invest in start-up companies through Kärcher New Venture GmbH, for example, which are pursuing some very creative approaches in this field.
The one thing you should always keep in mind is that the automation of cleaning tasks is one of the most demanding technical challenges of all and for one simple reason: cleaning is always a downstream process. In terms of complexity, this means, among other things, that the environment in which cleaning takes place is usually pre-defined by someone who is supremely indifferent to how it is subsequently cleaned. In this respect, the same applies to robotics as to conventional cleaning technology: anyone in our industry who fails to understand in detail what the customer actually does and needs every day will not survive in the market for long.

You have been at the head of Kärcher for almost two decades now. How has digitization changed the market for cleaning equipment during this time?

As I've just indicated on the subject of robotics: by themselves, even the most expensive chips and sensors will not lead to success. What makes a difference are clever concepts tailored to the reality of the customers' work and lives that offer them tangible added value here and now. One key word currently used in this context is "networked cleaning services". "Networked" in many ways including the networking of machines and software, of user knowledge and database systems, of customers and service providers and, last but not least, of manufacturers and service providers. With our "Connected Cleaning" system solution, for example, cleaning specialists can be deployed exactly when a requirement for cleaning services arises. In this respect, our industry is undergoing a development comparable to that of telematics in road traffic.

Photo: Kärcher

"Artificial intelligence is a technology that will revolutionize many areas of human life. It is up to us to make something really good out of it for as many people as possible."

Hartmut Jenner, Chief Executive Officer of Alfred Kärcher SE & Co.

How has Kärcher reacted to these challenges and what are the strategies for the future?

We took account of digitization in our strategic planning over a decade ago. This naturally includes our internal processes from the paperless office to industry 4.0, but also completely new, disruptive business models. We are active in the international start-up scene through our subsidiary Kärcher New Venture. In 2017 we founded Zoi TechCon GmbH, our own IT consulting company, which concentrates on the development of digital solutions, cloud transformation and electrical engineering and also offers these services to third parties.

Industry 4.0 also creates new competitive conditions in global markets. Nevertheless, Kärcher deliberately decided against going public. How can the culture and values of a family business be preserved and developed against the background of globalization?

Family businesses and globalization are not mutually exclusive - on the contrary: the value orientation and the strong cohesion of owners, management and staff, which are typical for family businesses, imbue people with the security and self-confidence that are necessary to open up to new and foreign ideas. And in the final analysis, it all comes down to people. The statutory provisions force us to list employees not as assets but as expenses in our accounts. However, it is obvious that a company's real value lies not in machines, buildings or financial means, but in its people, because, without people, machines and buildings are worthless, whereas a person without machines and buildings loses nothing of his or her value. So focusing on people is not just an imperative of common decency, but also a basic prerequisite for sustainable corporate management.

Kärcher also uses its technology for the preservation of cultural monuments, for example in collaboration with the University of Stuttgart's Materials Testing Institute, at Mount Rushmore in the USA. What is the special attraction of such projects?

Our commitment to listed properties is unique in the world. None of our competitors has succeeded in copying us in this so far - although this program has existed since 1980. Which sponsor can say that about themselves? We have restoratively cleaned

Cleaning services 4.0: For Kärcher, the combination of innovative technology and clever concepts that take account of the working and living reality of customers and offer them tangible added value is the basis for the effective, intelligent automation of cleaning tasks.

Image: Kärcher

over 140 monuments during the past 40 years. Each project is unique and presents our specialists with new challenges. In addition to the invaluable experience gained by Kärcher, we can demonstrate our technical competence in these initiatives and associate our cleaning products with cultural assets that are among the most valuable that humanity possesses.

? As an alumnus, you are associated with the University of Stuttgart in many ways. What does your commitment involve and what motivates you?

My university studies in business administration and engineering in Stuttgart laid the foundation for my future career. I'm still very grateful for that today. I continue to maintain close contact with the University of Stuttgart, and am frequently involved in lectures and discussions. Our company collaborates with your university and supports events and projects, among other things. And last but not least, I am a member of the Board of Trustees for the University of Stuttgart's Business Management Support Group.

? What will students need to be able cope with the changes brought about by artificial intelligence?

Students will need what their predecessors have always needed since antiquity and in every century: curiosity, taking delight in astonishment, which according to Plato is the beginning of all philosophy, which is to say of all scientific reflection. Curiosity is about being open and questioning the seemingly self-evident; taking pleasure in knowledge and research, combined with the will to get to the bottom of things. Also, the willingness to take responsibility for oneself and society: it will take no more than that to make one's way and succeed even in our time, which is certainly one of upheaval. Of course, no one can say where the journey will lead. But it's always been that way. Whoever invented the wheel was presumably not thinking of Formula 1 at the time. Artificial intelligence is a technology that will revolutionize many areas of human life. It is up to us to make something really good out of it for the benefit of as many people as possible. I actually envy the young people who will have the chance to participate in these developments over the coming decades and drive them forward.

? Against this background, what would you want to see from your Alma Mater?

I'm convinced that digitization will not only pose great challenges for companies, but also for universities, and that it will present opportunities at the same time, more opportunities than risks, in fact. I therefore hope that the University of Stuttgart will assume a pioneering role and also set an example in the field of digitization, and that we in Baden-Württemberg will continue to take control of our technical, scientific and social future in the coming years and help shape it with a plethora of novel ideas.

Questions by Andrea Mayer-Grenu

Image: Kärcher

Business studies and engineering graduate Hartmut Jenner is Chief Executive Officer of Alfred Kärcher SE & Co., where he has worked since 1991. After completing his studies at the University of Stuttgart, he was initially employed as Assistant to the Commercial Director before being promoted to Head of Operational Accounting. He became the Commercial Manager and Deputy Divisional Manager for Systems Engineering in 1994 before taking over as Head of the Home & Garden business unit (consumer products) in 1997. He has been Chief Executive Officer for North America since 1998 and was appointed Managing Director in 2000, and, one year later, Chairman of the Board for the Kärcher Group and Member of the Board at the Alfred Kärcher Foundation.

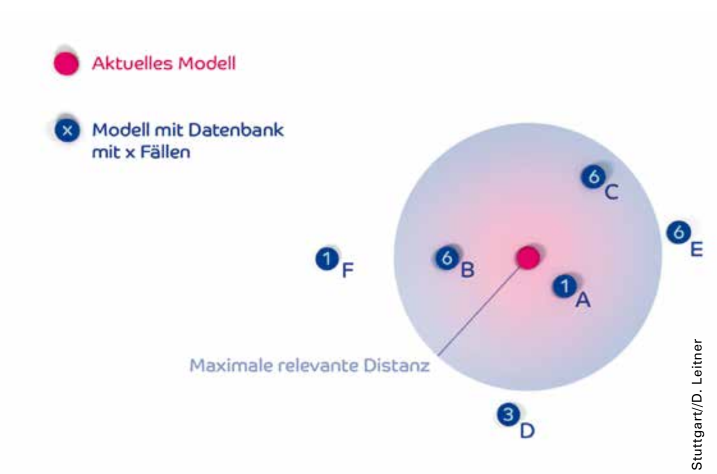
No compromises
Multiphysical investigations to become easier, better and faster

Hardly any technical system today is created without the aid of computer simulations. With their help, developers can assess the success of their previous work more quickly than would be possible through the construction of gradually improved prototypes. However, if a simulation is to take several physical properties into account at the same time, things become complicated and time consuming. A research team at the University of Stuttgart is using artificial intelligence methods to make such multiphysical simulations for electrotechnical problems better and faster.

Companies can use simulations to significantly reduce the product development times. Although the object in question still goes through all the traditional phases of development - from conceptualization, design and detailing to prototype construction, testing and revision - they are all shorter. Using simulated application scenarios helps developers to assess how a product will behave in various, possibly even extreme, situations at a much earlier stage. However, such simulations can become almost arbitrarily complex, both in terms of the computing effort required, which can quickly become enormous, and for the developers, who need to have an extremely precise understanding of all parameters to ensure that the results actually reflect reality. “This becomes particularly evident in multiphysical simulations,” says Prof. Jens Anders, Head of the Institute for Smart Sensors (IIS) at the University of Stuttgart. “These consider several areas of physics simultaneously, such as a system’s thermal and mechanical behavior.” If, for example, a pump moves its piston, it heats up at the same time. Thus, not only does the shape of the magnetic field in which the rotor rotates have a significant bearing on the behavior of an electric motor, but also the temperature the motor reaches during operation. Moreover, there are interdependencies between the various sub-areas. In terms of the motor, for example, this means that increasing electrical currents also generate more heat.

Dark Multiphysics

“For example, to simulate the behavior of such a motor, we would have to calculate the temperature and the magnetic field at many points,” explains Anders. “If an unlimited amount of computing power were available, these points could be placed over the entire model of the engine like a close-meshed network.” But because computing power still has to be used economically today, despite increasingly improving computer technology, this network has to be plotted as coarsely as possible. “Only as accurately as necessary is the rule when simulating,” says Anders. The choice between computing speed and accuracy involves constant compromise - but no important physical effect should be missed.



Is the model similar enough to the current question to be accepted by the user in a simulation? If the blue dots fall within the circle, then yes, it is.

Image: University of Stuttgart/D. Leitner

Prof. Jens Anders (left), Head of the Institute of Smart Sensors (IIS) and Prof. Michael Weyrich of the Institute of Industrial Automation and Software Engineering (IAS)

Photo: University of Stuttgart/M. Regenscheit

The experts know, for example, that they have to plot the mesh nodes very closely to calculate the magnetic field, especially along corners and edges. On the other hand, the calculation points in the metal body of the motor can be spaced further apart. The temperature calculation is different: corners and edges or the air gap of the motor are of very little interest in this context, on the other hand, the metal body dissipates a large part of the generated heat, so that a close-meshed network is required for calculations. “Different networks are needed for each physical sub-area, but they have to be adapted to each other in such a way that the results make sense overall,” says Anders.

Due to this complex starting position, science and industry have not yet fully exploited the potential of multiphysical simulations. This was the reason why the IIS and the Institute of Industrial Automation and Software Engineering (IAS) at the University of Stuttgart launched a joint research project a few years ago with funding from the German Research Foundation (DFG). “Most development engineers not only have to deal with multiphysical simulations but also many other tasks,” says Prof. Michael Weyrich, Head of the IAS. So it can happen that they fail to set up complex multiphysical simulations properly, require many attempts or even need external help from specialists. “This costs at least time and money and, in extreme cases can even leads to the decision to abandon multiphysical simulations altogether,” said Weyrich.

The researchers at both institutes want to eliminate this hurdle. “We have provided the user with an intelligent assistant for multiphysical simulations of electrotechnical systems, which executes various tasks independently, so that the user no longer has to have such a profound knowledge of the topic,” Weyrich explains. “Based on available simulation results that make physical sense, the assistant recommends approaches to existing simulation problems.” The project participants created a database for this purpose in which the assistant can search for similar known cases for a given subproblem of the simulation in hand. “If it finds a corresponding match, it uses it as a basis for proposing solutions to the user for the relavant subproblem,” says Weyrich.

Intelligent assistance for experts

In fact, the structure and operation of this assistant are much more complex than described here. It actually coordinates several subordinate assistants, each of which is responsible for a specific subtask such

Using the example of an injection valve for a natural gas car engine with direct injection, the researchers studied the switching behavior and operational reliability of the valve. The calculation was carried out using traditional techniques, but the complex multiphysical task is also amenable to testing with software agents.

Photo: University of Stuttgart/IIS, IAS

as mechanics or temperature. In addition, there are always various options that the downstream assistants can choose for themselves to select the most resource-efficient assistant for achieving the objective. The project participants trained the assistance system using machine learning methods, prototypically implemented on the simulation of a microwave oven in which a vessel is to be heated with water. The research team played through various cases based on the hundred or so available solution approaches to find the best solution strategy for the simulation. This resulted in a fourfold decrease in computing times. To optimize the computing time, the software can independently distribute the computing load of a simulation to different computers, if one fails. In addition, the assistant is able to optimize the network mesh sizes of the physical subareas.

"For a development engineer to accept such an assistant, the system must of course only identify the appropriate old cases in its database," says Weyrich. To achieve this, the project participants defined a set of metrics. I.e., mathematical measures of how well the old cases in the database fit the current problem. "Then we trained the algorithm by considering how well a suggested case fits the current problem," explains Weyrich. Encouraged by the results, Anders and Weyrich and their teams now want to demonstrate that intelligent assistants are helpful in solving multiphysical simulations in a transfer project using case studies with real data. Warning messages to alert the user to critical points in the simulation and automatic mesh width determination could be the first practical benefits, which could ultimately lead to faster, more reliable results. The two University of Stuttgart Institutes will implement the project in collaboration with Comsol, a Swedish provider of software for multiphysical simulations.

Jens Anders uses a simple numbers game to illustrate the importance of better multiphysical simulations: "Assume 30 variants have to be simulated for the development of a given product. If you only manage to run two simulations a week, you could just as well build a physical prototype and study it in the 15 weeks it would take. If, on the other hand, you could run 15 simulations per week, you would save on prototype construction because the simulations would be completed in just two weeks." Not only would this shorten the overall development process, but certain individual steps could be eliminated entirely, saving time and money. "But for this to succeed beyond those companies that employ their own multiphysical specialists in their development departments," says Weyrich, "concepts such as our intelligent assistant must find their way into mainstream industrial practice."

Michael Vogel

Ultra-fast and consistent

A self-learning program detects whether solar cells are still intact

Several tens of thousands of photovoltaic modules jointly generate electricity in large solar parks. Until now, experts have had to examine photos of each individual solar cell in these modules.to determine whether any of them has been damaged by thunderstorms or aging. Researchers at the University of Stuttgart have now trained a computer program to analyze millions of images reliably and quickly.

The hailstorm has lashed down on the solar panel and entire areas on the photo of a particular photovoltaic module taken by the Solarzentrum Stuttgart (SZS) are black, which means these areas are no longer functioning, because current only flows where the electroluminescence (EL) images are light. The daylight EL (Daylight Luminescence System DaySy) method for the inspection of large solar parks, which is protected by a global patent, was developed by the SZS, a spin-off of the Institute for Photovoltaics (IPV) at the University of Stuttgart, in collaboration with the IPV itself. The scientists and the Insitute of Signal Processing and System Theory (ISS) are now developing a program that will use DaySy EL images of solar parks for automated analysis in a research project entitled "PARK" which is funded by the Federal Ministry of Economics and Technology. "Photovoltaics are making an important contribution to the transition to renewable energies," says Alexander Bartler, a researcher at the ISS, whose master's thesis was about the self-learning artificial analysis eye. Today's large solar parks are already generating one gigawatt and more. "However, this can decrease over time if defects occur in the modules."

Appearances alone do not suffice

More than 86 million images of individual solar cells have to be examined in the DaySy EL process to examine a medium-sized solar park with an output of 300 megawatts for these defects. Put simply, the way the cell works is reversed: normally, radiation hits the silicon cell, which converts it into electrical energy. However, if electricity is sent through the cell instead, it emits infrared radiation - but only where it is intact. "By recording this with a special camera and a special measuring method, it is possible to see which structures within the semiconductor are defective and which are intact, which is not possible with the naked eye," explains Bartler. "Until a year and a half ago, experts had to manually analyze each image," the researcher goes on. Given the large number of pictures involved, this can be an expensive undertaking for the operators of solar parks. According to Michael Reuter, Managing Director of the SZS, it is advisable not only to inspect all modules after delivery, installation and before the warranty expires, but also after every severe storm, which is what spawned the idea of automating the process: "We took cell images from the SZS that had already been evaluated and used them as training data for an artificial neural network," explains Bartler. In the first stage, the program should simply distinguish between "intact" and "defective". "This will save us an enormous amount of time." For a module with 60 cells, the computer needs a maximum of one second. A human being needs about 60 to 120 seconds for this assessment with the same accuracy - but is unable to do this for several hours at a time, as the activity is strenuous and requires concentration. In the first step, the still static software then corrects the perspective of the photographs, which the SZS receives from global measuring campaigns. It then divides the image into individual images of each solar cell. Only in the next step does artificial intelligence take over the work previously done by the photovoltaic experts to examine the individual cells and, in the event of a defect, to classify them as such.

Accuracy training with 1,800,000 images

For their initial experiments, the team used an existing artificial neural network from the Visual Geometry Group (VGG) at the University of Oxford as the initial architecture, which they adapted and re-trained. The researchers recorded 98,000 images on which the SZS experts had marked the visible defects. "We know where the solar cell is located in which module and how the company has classified it. This classification task is now performed by the neuronal network," explains Bartler. It only learns the rules of how to deduce the errors from the cell images. Even with the adapted VGG network, the team achieved an accuracy of 93 percent. "The bigger problem was that the data set was very unevenly distributed: In the data, about 95 percent of the solar cells were intact, but we want to find the other five percent - and we had few examples." The researchers therefore had to adapt the training specifically for this purpose: They used the images of defective cells several times and slightly modified them in terms of their actual appearance in the training.

They are currently using other network architectures that correspond to the current state of the art. "We now need an even larger training dataset that we can use to create the final version," says Bartler. This includes 1,800,000 cell images. Once it has trained with it, the intelligent artificial eye should be ready for use in the first half of 2019. At the same time, the scientists are working on refining the system further: if it detects different types of defects, it could also be used in future to predict exactly how severe the drop in performance of a module will be, Bartle reports. "If it is known that the performance drops by five percent per year with a remaining term of 15 years, one can calculate exactly whether or not it would be worthwhile to replace a given part."

Daniel Völpel

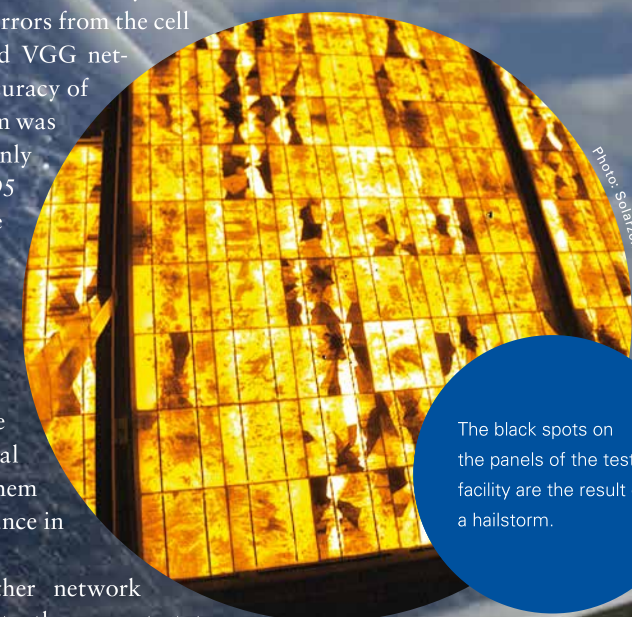


Photo: Solarzentrum Stuttgart

The black spots on the panels of the test facility are the result of a hailstorm.

Photo: Stock/Jenny

Network stability from the boiler room
Intelligent control systems are making renewable energy generation independent of weather conditions

How can we ensure that heat is generated in buildings exactly when it is best for the stability of the electrical system? The Smart Energy Lab planned at the Institute of Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart intends to develop intelligent control systems for this purpose thereby providing an important building block for the energy transition.

The nuclear phase-out is currently ongoing, the coal phase-out is planned for 2038. This represents federal government policy reactions both to safety concerns expressed by many people and to the need to reduce carbon dioxide emissions. However, it is clear that even after 2038, when the last coal-fired power plant in Germany is to be shut down, a sufficient, stable and both economically and environmentally compatible power supply will still be required. In 2018, more than 40 percent of the electricity generated in Germany already came from renewable sources. In all likelihood, this share will continue to rise significantly over the next 20 years. Nevertheless, the energy transition poses certain challenges - in addition to other sectors - in terms of the supply of electricity, because neither wind power nor photovoltaic plants necessarily provide electricity when it is needed. So what can be done when the wind dies away and the sky is clouded over in the middle of a peak demand period?

This is the sort of question that Julia Kumm of the University of Stuttgart's IER deals with. Kumm and her colleagues are setting up the Smart Energy Lab, a test facility for decentralized intelligent energy systems, on the former Telekom site on the University of Stuttgart's Vaihingen campus. The Smart Energy Lab was designed by Prof. Kai Hufendiek, head of the IER. The complex will eventually accommodate seminar rooms, offices for researchers and staff as well as a guest house - usage types that will enable IER scientists to conduct research under real conditions in the future.

Practice room for intelligent interactions

"The Smart Energy Lab will be an experimental space in which we will be able to investigate a wide variety of configurations as flexibly as possible," Kumm explains. The experimental setups for the heating systems of the future are unlikely to be as spectacular as one might think at first glance: "We use the latest standard equipment, of the sort that could be found in any building's boiler room. The exciting thing happens behind the scenes, through the intelligent interaction of the components."

The focus in the Smart Energy Lab is not on further technical development of the individual heating technologies themselves. "Our goal is for heating systems in the future not only to see their own supply function as such, but also to react intelligently to the prevailing situation throughout the entire energy system," says Julia Kumm.

An example: Many contemporary boiler rooms house heat generators that produce hot water on demand. But what if there were an air heating pump and a large hot water tank? The heat pump could generate a lot of hot water on a windy night when there is a lot of electricity in the grid and buffer it in the storage tank. Conversely, this storage facility would also provide heat when less electricity was available. "In theory, any boiler room could take on the tasks required for the flexibility or stabilization of the entire system in this way," says Julia Kumm. "You can use storage to run the generators exactly when it makes sense for the system, regardless of the current heat demand." The most important condition, however, is that the heat supply is secured at all times. And these innovative control systems should not entail any additional expense or loss of comfort for the users. "Nobody would have to change their habits," emphasizes Kumm, who also advocates fair compensation for "participation" in the supply system.

Intelligent heating technologies are the goal of the research group led by Prof. Kai Hufendiek and Julia Kumm of the IER

Photo: University of Stuttgart/M. Regenscheit;

The Smart Energy Lab will serve as a test platform for testing the control algorithms for this complex task for many years. Including heat generators from different manufacturers, as well as different storage systems, building sizes and user habits as well as several control variants in the experimental setup will result in a huge number of possible configurations, which the researchers in Stuttgart want to investigate with regard to their benefit for the overall system under real conditions. The Smart Energy Lab on the Vaihingen campus will supply energy to an area of up to 5,000 square meters during the test periods, supported by a redundant heating system that will take over the supply outside the test time series. Among other things, a heat accumulator with a volume of about 70 cubic meters is planned. The end result should be the most robust, intelligent control systems possible.

"Building-focused" forecasts

The multitude of challenges that researchers have to face during this undertaking only become apparent at second glance. The first requirement for system control are load forecasts for the building. This means that the system needs to get an "idea" of what the heat consumption of the next hours and days will be. In addition, it must estimate how the electricity generation will develop, for example when using a photovoltaic system. And all of this should happen practically on a "building-focused" basis, i.e. not viewed across a region. Therefore, the control systems must be equipped in such a way that they can learn to reconcile individual user behavior and the weather conditions with the needs of the general power grid.

Julia Kumm uses a number of specific figures to counter those who doubt that decentralized heat storage systems can make a significant contribution to the energy transition and grid stabilization: one third of Germany's final energy consumption takes place in the household, commercial, trade and heat generation service sectors. So far, around 80 percent of this demand has been met by conventional energy sources, whereas the German government is aiming for an "almost climate-neutral building stock" by 2050. So there is plenty of scope for AI-based intelligent control systems that can contribute to the energy transition.

"I find the interdisciplinary issues particularly exciting," says Kumm, who has been researching at the IER for around four years, highlighting the appeal of her work. She sees this as a very practical application of AI: the control system "senses" what is happening in the connected house in real time and matches this knowledge with the distributed and highly complex supply grid. The exact launch date of the Smart Energy Lab has not yet been set. However, the first components are to be put into test operation before the end of 2019.

Jens Eber

Image: University of Stuttgart/D. Leitner

The End of Excess
Artificial intelligence is ensuring that clothing fits perfectly

Every human being has an individual shape. In view of the sheer variety of body shapes, it is not always easy to find clothes that are not only fashionable, but also "fit" perfectly. But traditional clothing sizes often reach their limits when it comes to the right fit, which is why experts from the University of Stuttgart and the German Institutes for Textile and Fiber Research Denkendorf (DITF) are using AI to help classify body shapes and to find the right measure.

Off-the-shelf sizes leave plenty of scope for a redesign. The calculation is based on standard tables based on body measurements - usually body size as well as chest and waist circumference, but there is no binding standard and each fashion label has its own contour styling. So the same item of clothing will not necessarily fit two people of the same size and the same individual can rarely wear the same size in all garments. "Simply measuring the body," Prof. Meike Tilebein explains, "does not enable us to completely reproduce the overall body shape, which, for example, is also determined by the relational proportions between individual parts of the body." The cyberneticist heads the Institute for Diversity Studies in Engineering (IDS) at the University of Stuttgart as well as the Center for Management Research at the DITF. She has carried out research into diversity in many of its varied facets and she and her team have analyzed the diversity of body shapes in collaboration with Avalution GmbH, a provider of services and software for fashion and body models. They have now succeeded in improving the fit of clothing on the basis of morphotype classification and with the aid of AI methods.

Morphology matters

A look at the body scans of various people, all of whom take a size 38, but each with a different body shape, shows how wide the range can be. Hollow back or upright posture? Knock-kneed or strong thighs? Square or sloping shoulders? "These and many other morphological features contribute to whether or not clothes fit properly," explains Thomas Fischer, a scientist at the DITF. An analysis of data from the "SizeGermany" series measurement pool compiled by Avalution illustrates the problem: of 455 representative women's bodies, 331 could not be assigned an unambiguous size.

The team initially developed ten basic features for the new classification model, which are subdivided into the entire body and the upper and lower bodies. These include, for example, typical basic shapes such as the "triangle" with narrower shoulders than hips or the "rectangle", in which shoulders and hips have a similar width. Sorting is also done according to the waist shape: is the waist of the clearly pronounced hourglass type or more like the circumference of a sphere? In the case of the lower body, the model also takes account of the leg length, and in the case of the upper body, the ratio between chest circumference and back length.

Four human experts independently compared each of these ten characteristics with the 455 body scans from the "SizeGermany" database. The result is a validated knowledge base that is available to the AI algorithms as a training set and, above all, is scalable. "This offers the possibility of classifying much larger data pools with the help of AI," says Tilebein. A long-established AI sub-area called Case Based Reasoning (CBR) is used for this purpose. This method of machine learning imitates the behavior of human professionals and is based on the principle of similarity, i.e., just like humans, the software learns and works under the premise that similar solutions exist for similar problems.

Photo: University of Stuttgart/M. Kovalenko

There are as many different body shapes as there are people. The scientists Prof. Meike Tilebein and Thomas Fischer are working on classifying them in such a way that manufacturers can produce clothing that fits.

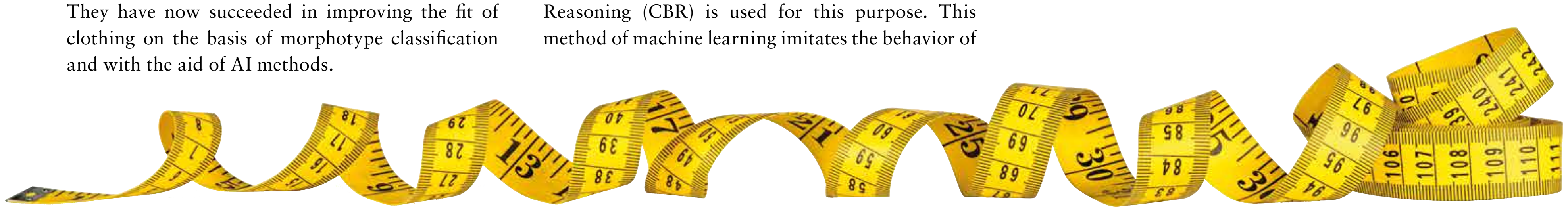
Benefits for manufacturers and customers

Applied to the classification of body shapes, the process works like this: the algorithms developed at the DITF keep the so-called CBR cycle going. If a new person or figure is to be classified, the algorithm uses the "old cases" stored in the case base and searches for the classification that is most similar to the new case. Based on this template, the system develops a classification proposal. This is adjusted as far as possible and then saved as a new classification in the case base. In this way, the AI engine expands its knowledge incrementally.

The CBR method not only allows conclusions to be drawn about the most suitable individual size, but also, for example, about the frequency and distribution of certain morphotypes, which offers enormous benefits both to fashion companies, but also their customers. Companies can better analyze the market and optimize their products by using more precisely fitting ready-made sizes and plan production in a more targeted manner. Particularly in e-commerce, providers can recommend the individually best product in the optimum size and thus minimize unnecessary returns. And the customers should also be satisfied with their new favorite piece for a longer period, if it fits perfectly.

The new technology is now being used successfully in practice. Morphotypes are included in Avalution's analyses and the analyses carried out for special customer groups at the DITF were also successful. Tilebein and her team are currently investigating the application potential in online retailing and are looking into whether and to what extent artificial neural networks are superior to the CBR method. So will AI introduce more affordable individualization to the fashion industry? "We already have the vision of using digital technologies to get as close as possible to the individual 'fit' before we start sewing," says Tilebein. "But whether this will work in mass production scenario remains to be seen."

Dr. Jutta Witte



Assistant physician Dr. AI

Researchers from the fields of medicine and signal processing are using AI for improved diagnostics

A robot that examines humans and makes diagnoses is a scientific and technical dream and will remain so for the time being. However, artificial intelligence is already able to provide support for diagnostics and several relevant research projects are currently underway at the Insitute of Signal Processing and System Theory (ISS, headed by Prof. Bin Yang) at the University of Stuttgart.

Artificial intelligence (AI), which examines images of the human body in search of serious illnesses - for many people this thought is still likely to cause a frisson of discomfort. The knowledge and experience of doctors is too important for most people to leave their health in the hands of a machine, yet it seems as if the use of AI is booming in the medical field.
This is the point at which Annika Liebgott interjects: "I don't think doctors can be completely replaced and nor does anybody want that," she says. Instead, the main goal is to provide physicians with good tools with which to do their work by means of AI. A total of four doctoral researchers and one postdoc are currently working at the interfaces between medicine and information technology at the ISS. The ISS is not only working on several projects in this area of specialization, for which the German Research Foundation (DFG) provides funding, but also maintains close collaborative ties with the Diagnostic and Interventional Radiology Department at the University Hospital of Tübingen.

Mechanization is creating new room for maneuver

From Liebgott's point of view, the interaction of medicine and engineering is extremely fruitful. Methodological studies on signal processing and machine learning are carried out at the ISS, with a particular focus on deep learning and AI in recent years. These methodological findings are subsequently applied to medical questions, which are then dealt with in close collaboration with the experts in Tübingen. "Although we are enthusiastic about the topic, we are not medical doctors," explains the 29-year-old. "But in collaboration with Tübingen, we can always immediately check our results for their medical value."
For example, the ISS is currently working on the detection of motion artifacts, which can be caused when patients inadvertently move during an MRI scan, among other things. One potential model going forward could be to detect disruptive movement artifacts during the scan and to re-record individual body parts. This would save costs and spare patients who would not have to be "popped back in the tube". The ISS is also investigating the automatic correction of unavoidable motion artifacts, such as those caused by heartbeats.
Another project is dealing with immunotherapy for cancer patients. Using images taken before and after the start of treatment, the aim is to estimate how the course of treatment will develop. Annika Liebgott is convinced that "we can save radiologists a lot of time". Whilst there are more images of the human body available today than ever before, it is still necessary to manually check the large number of image layers produced during an MRT scan. Preparing the images for use in relation to certain questions is also unavoidable every now and then. But the doctoral researcher is certain that "doctors have better things to do than to process images." "The manual segmentation of organs, for example, is extremely time-consuming, which is why colleagues at the ISS are researching automated approaches using deep learning." If the medical specialists could be relieved of routine tasks, it would not only reduce costs, but more importantly it would also leave them more time for their actual task, i.e., diagnosing illnesses.

The team led by Annika Liebgott (center) from the ISS at the University of Stuttgart and radiologists from the University Hospital in Tübingen hope to use AI to search for serious diseases in images of the human body.

Photo: University of Stuttgart/M. Regenscheit;

Acceptance increases in line with the benefits

As Liebgott explains, this prospect of being able to concentrate more on one's own core competences was also a decisive factor in bringing about the collaboration with Tübingen. In the beginning, some radiologists were rather skeptical about AI. However, this has changed as a result of what they have experienced during the past few years: more and more often, doctors are approaching the signaling specialists for help with specific questions.
Of course, the question of acceptance is also relevant to the affected patients. How will people react when artificial intelligence penetrates such sensitive areas as the diagnosis of severe diseases? "That will depend on the respective application," says Liebgott adding that hardly anyone would resist a motion correction on the images but the more "machines" are involved in the actual diagnosis, the greater the concerns might be. Yet in this context too, the researchers at the ISS emphasize the supporting function of AI and the realistic potential of the technology. A computer that could produce a complete diagnoses would first need to be trained using enormous amounts of data. However, the available data for rare diseases is much too scant for "training" a computer. It therefore makes much more sense to develop AI to such an extent that it can provide the diagnostician with hints and practical assistance. For example, if a doctor were to specifically examine the lungs of a patient, an algorithm could simultaneously parse the images of other organs and body parts for abnormalities.
In addition to the immunotherapy project, Annika Liebgott is currently investigating whether computer tomography can be used to visualize structures that have hitherto only been visible on positron emission tomography (PET) images. Since the patients have to be given substances labelled as being radioactive for the PET scan, the procedure is relatively stressful and the researcher hopes to be able to reduce the number of examinations that involve the use of such substances.

Jens Eber

At the center of global performance

As the operator of one of the fastest supercomputers in the world, the High Performance Computing Centre Stuttgart (HLRS) has collaboration agreements with numerous internationally leading supercomputing institutions. These collaborations, whose primary benefit is the exchange of knowledge and experience on the latest trends, developments and applications in high-performance computing (HPC), also result in joint research and further training activities.

These international collaboration agreements are dedicated to opportunities and challenges in terms of the continuously increasing performance of hardware, algorithms and software developments in the supercomputing environment and address trend-setting visualization technologies for the analysis of highly complex data sets, and have also provided support for staff exchanges and training measures such as regular workshops and training sessions.

For example, the HLRS and Tohoku University organize an annual Sustained Simulation Performance Workshop. In addition, the HLRS co-organizes an annual German-Russian workshop in which scientists from both countries come together to consider issues from the fields of HPC and applied mathematics. The HLRS and the Korean Institute of Science and Technology Information (KISTI) entered into a partnership agreement in 2018 with the aim of bringing together independently developed software for the visualization of simulation data at the two centers.

On the basis of the various long-term collaborations in which the HLRS is involved, it promotes cross-border collaboration between the University of Stuttgart and other renowned international centers for computer-aided research. *red*

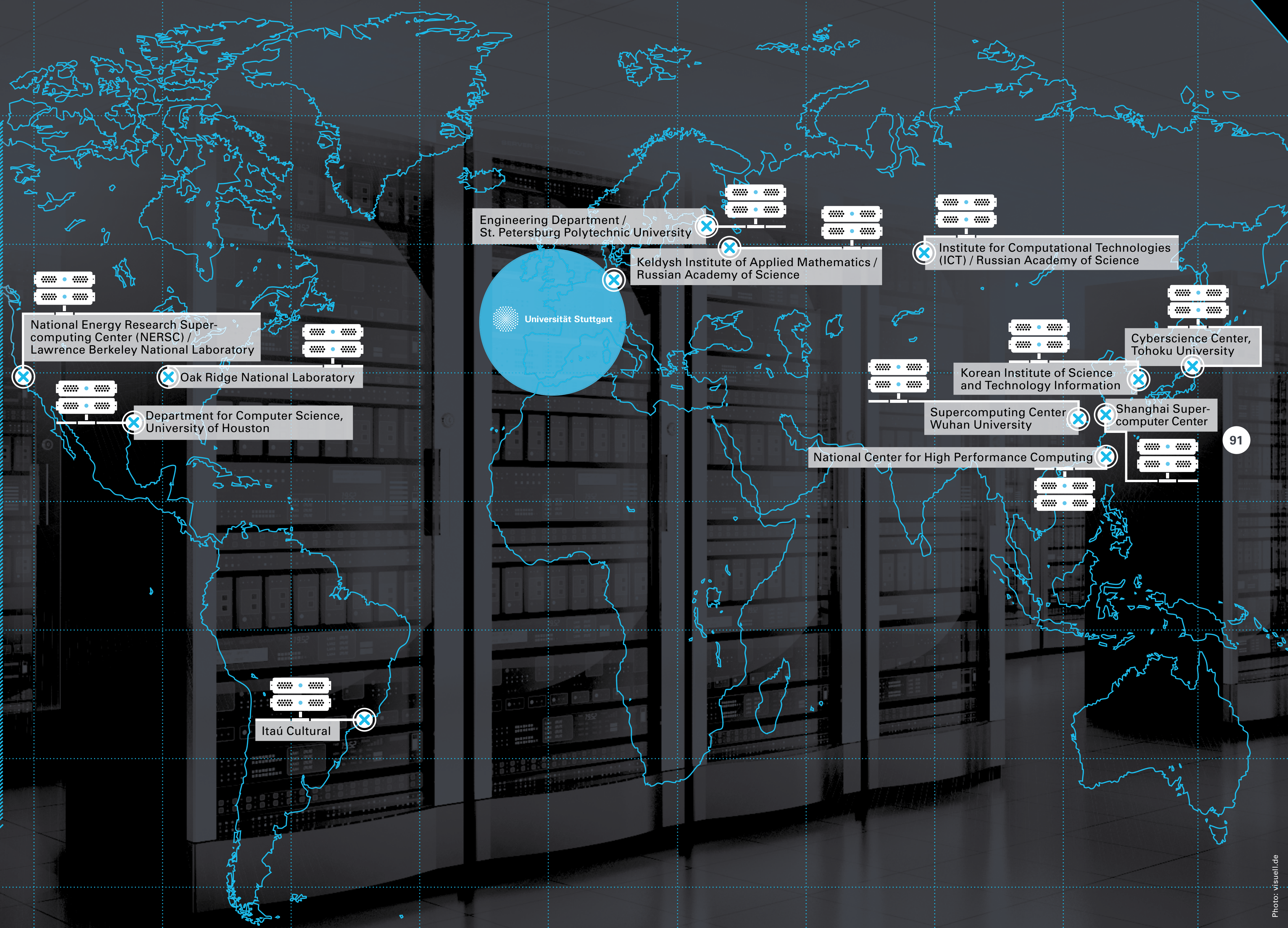


Photo: visuell.de

Form follows material
The Egyptian, Hanaa Dahy, wants to incorporate intelligent materials into architecture

She followed the usual career path of an architect until an event in her home country opened her eyes, from which point on Hanaa Dahy has been interested in sustainable building and has developed a straw composite material which has received several awards. As junior professor and head of the Department of Biomaterials and Material Cycles in Architecture (BioMat) at the University of Stuttgart, she provides students of architecture with the wherewithal to develop sustainable and intelligent building components.

Some of her students have presented sketches of their building concepts on posters in the entrance area of Kollegiengebäude I on the Stadtmitte campus, miniature three-dimensional models of which are placed on small stands in front of the walls, delicately constructed of cardboard, plywood, polystyrene or plastic foil. Dahy's office is four floors above in the Institute of Building Structures and Structural Design (ITKE). The junior professor is calling for a rethink of building planning, and is starting with the students.
"Architects usually produce beautiful designs during their university studies, but they don't necessarily know how the building could be built," says Dahy. For the architect, however, the material and its properties are at the beginning of every concept. Is there a material for the desired purpose? How can the desired material be adapted or created? The 38-year-old can't understand why even in hot countries houses are built in the style of international architecture with large glass fronts that have to be cooled down with air conditioning systems. "The local architecture, which matches the local resources and climate, is almost non-existent," Dahy complains.

Instead of using only proven materials, Dahy gives students the opportunity to develop new materials and experiment with smart systems such as solar cells and sensors. "This enables innovative systems that are truly sustainable and can reduce the enormous energy consumption," Dahy explains. In the "Material Matter Lab", which she set up at the Institute, the prospective architects immerse themselves in materials science, learn the basics of electrical engineering and learn how to program.

Materials inspire design

Among the design models the students subsequently felt inspired to create a façade made of pyramid-shaped elements covered in a light diffusing textile coating, which creates special lighting effects at night. The energy for the LEDs mounted on the back comes from solar cells cleverly integrated into the façade elements. Another of the resulting designs includes undulating timbers that can be moved by electromagnets enabling it to be adapted to different loads whilst simultaneously saving material. This could be used, for example, in chairs or bridges.
Another student developed an intelligent wall that changes color when a person approaches it. "Approaching a wall doesn't normally make you happy," say Dahy, "but this wall interacts with you." There is this trend in architecture, she goes on to say, to also create entertainment spaces: so this wall could become a magnet for visitors to museums or meeting places. In recognition of her teaching concept the Baden-Württemberg Foundation awarded her a senior fellowship for innovations in university teaching in 2016. Coincidentally, this grant also marked the beginning of her junior professorship at the ITKE.
Recently, Dahy's group has also been working on soft, supple robots for the smart building of the future, primarily on the materials needed for their construction. Unlike solid metal robots, these ones can change shape like amoebae and will in future be able to detect damage in the remotest corners of a building in good time to preserve the building for as long as possible. Soft Robotics could also help to anchor mobile, self-erecting wall elements to divide sports halls or other large rooms as required. Jan Petrs, a member of Dahy's staff, is working on robots that would crawl to where they were needed via a pipe system. "Motors or electrical components can make the building extremely expensive," says the architect which, she goes on to say, is what gave rise to the concept of such shared mechatronic components.

Photo: University of Stuttgart/M. Regenscheit;

"The beaches were gone"

Dahy remembers the moment about 15 years ago when she began to take an interest in sustainable building. As an artistically gifted child who had already won many painting competitions, she was the only one of five siblings to follow in the footsteps of her mother, a professor of architecture. During her architectural studies in Cairo, she founded her own architectural office and designed classical buildings. Her first project was two hospitals. But then one day, for the first time in five years, she revisited the beach of her childhood in Alexandria: "The beaches where I used to play were just gone," says Dahy. The water level had risen in a very short time and had flooded the beaches. The shock she felt about the consequences of climate change jolted her out of her slumber, says Dahy. The most obvious countermeasure she could take as an architect was the use of resource-saving materials in construction.
"In Egypt, there are individual researchers and non-governmental organizations dealing with the topic of sustainability and great young architects who take the local climate into account in their designs." Dahy reports: "But, unlike in Germany, there are no statutory regulations that oblige building owners to build energy-efficiently, especially in state buildings." The architect came to Stuttgart in 2009 along with her family and a scholarship from the Egyptian government to begin her doctoral thesis. "One important reason was the great collaboration between industry and research that exists in Stuttgart," said Dahy.
The University of Stuttgart, where many of her Egyptian professors had already completed their doctorates, became a second home to her. Because composite materials are already a major research topic at ITKE, Dahy concentrated on alternatives from renewable raw materials. She has developed flexible and recyclable fiberboards from straw, which is generated as waste during the grain har-

vest, and bioplastics. Whether it's designer furniture, curved partition walls or sandwich elements for thermal insulation, the potential applications are innumerable. The prizes Dahy won for the concept are lined up along the windowsill of her office. Some material samples at the far end of the large table in her office testify to the variety of forms this novel, now patented, composite can take.

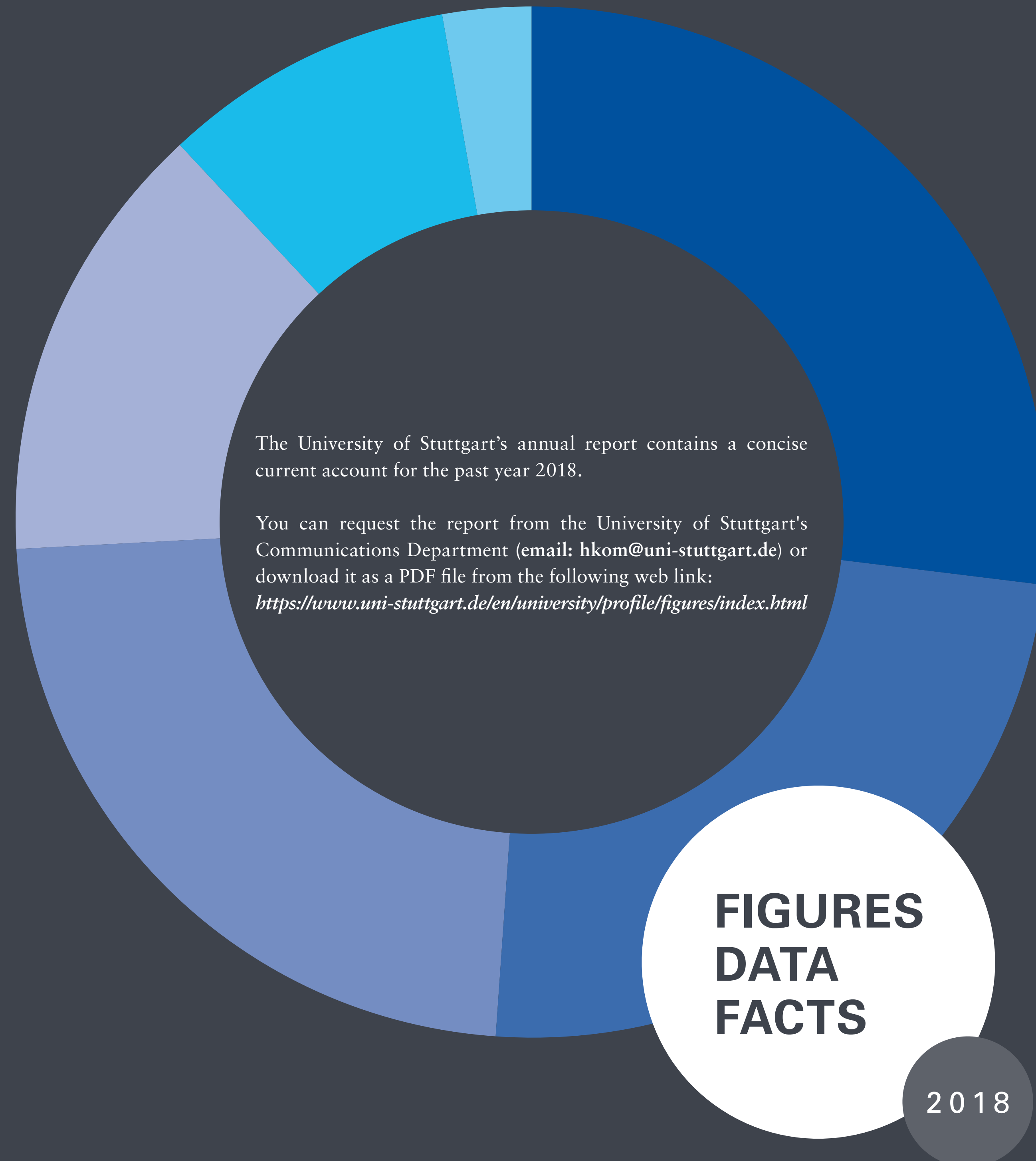
A test for new materials: a research pavilion

From sustainable materials, it was then only the next logical step towards future-oriented architecture to also use components that react intelligently to their environment. In the summer of 2018, Dahy's flexible panels, which she had developed during her doctoral thesis, were used in the construction the BioMat Department's first research pavilion right next to the two college buildings. Around 40 students had previously developed various design proposals over a period of two semesters. Other young architects then analyzed how the curved pavilion elements could be optimally equipped with flexible solar cells for power generation, and how damage-detecting robots could be integrated into the pavilion.
"There is a huge movement towards digitization and smartness in all areas and Germany has always been strong in this field and is one of the leading nations in their development, especially within Europe," Dahy states. She is currently summarizing her experience with bio-based composite materials and ideas for sustainable building in a technical reference book. She would also like to push ahead with the market launch of her product, but, due to her research and teaching commitments and the establishment of the new research group, has simply not had the time as yet even if she were to turn night into day, for example to answer questions from the Chinese Patent Office with a view to extending the patent for her straw-based composite material to China. When it comes to the cause, she's willing to work hard. Even when she had her second child at the halfway point of her doctoral thesis and her husband was working on his own doctoral thesis in Tübingen, she did not take any time off. "At certain times I wasn't so happy with my progress: things weren't moving fast enough for me, but in the end it went quite well," says Dahy and laughs. Her success has proved her right.

Helmine Braitmaier

Photo: University of Stuttgart/ITKE, BioMat

University of Stuttgart Annual Report



The University of Stuttgart's annual report contains a concise current account for the past year 2018.

You can request the report from the University of Stuttgart's Communications Department (**email: hkom@uni-stuttgart.de**) or download it as a PDF file from the following web link:
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