Universität Stuttgart

# forschung leben

March
2021

# Responsibility

**Reconsidering intelligent systems**


**Ethics label**
Classifying Artificial Intelligence

**Nuclear waste repositories**
Assessing future security

**Genome editing**
Enabling public participation

**Prof. Wolfram Ressel**

“One of the basic guiding principles of our vision for ‘intelligent systems for a sustainable society’ is to consider the ethical, moral, social, ecological, and economic implications of research.”

# Dear Reader,

Photo: Matthias Schmiedel

**Prof. Wolfram Ressel**
**Rector of the University of Stuttgart**

When the Stuttgart Institute of Technology reopened 75 years ago, on February the 23rd 1946, a ceremony was held at which the then Rector Richard Grammel made the following statements concerning the university's role under National Socialism: "Based on their internal structures, institutes of technology are completely apolitical bodies." The actions of engineers and natural scientists, he continuted, are guided only by the perpetual, eternal laws of nature, which transcend all human quarrels. According to Grammel, it would have been impossible for any obligation towards dictatorship and injustice to have arisen at all.

Unfortunately, this post-war German narrative has not only been a recurring theme in academia. Words, such as quarrel put into perspective the fact that the historical achievements of humanity and civilization were shattered to the core precisely through technology.

Since then, we have established a different tradition at the University of Stuttgart. One of the basic guiding principles of our vision for intelligent systems for a sustainable society is to consider the ethical, moral, social, ecological, and economic implications of research, which is why we have dedicated this issue of *forschung leben* to the topic of responsibility. In this issue, you'll discover, among other things, how the University of Stuttgart is taking responsibility through our "Interchange Forum for Reflecting on Intelligent Systems" (IRIS) as well as diverse approaches to dealing with CRISPR-Cas gene editing technology, and through an interdisciplinary project aimed at drastically reducing animal experiments.

Yours sincerely,

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## EXPERIENCE RESEARCH

**CRISPR - gene editing is accelerating research**

Photos: pp.1 and 84 Getty Images/Sefa Ozel, p.4 Max Kovalenko, p.5 Sven Cichowicz

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## WORLDVIEW

**Into the belly of the wave**

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## VISIONARY

**Smart digital education**

# NOTEPAD

## AWARDS

### THREE POSTDOCS IN THE ELITE PROGRAM

Three young researchers from the University of Stuttgart have been accepted into the Baden-Württemberg Foundation's elite postdoctoral researchers program, which will enable them to take important steps towards becoming professors. **Dr. Nina Engelhardt** of the Institute of Literary Studies is working on her project on literature and tolerance during the Victorian period, in which she examines the role of literary fiction in the propagation of the concept of tolerance. Her objective is to investigate the subject of tolerance in literature and the literary strategies used in visualizing the emotional, cognitive and physically limiting suffering in the process of tolerance, as well as to define the role of literature in tolerance-related discourse. Her research is focused on British 19th-century literature.

Dr. Serena Gambarelli of the Materials Testing Institute is researching the computational mechanics of building materials and building methods, for which she is developing digital tools for analyzing deterioration processes. Gambarelli is interested in modelling and gaining a better understanding of the complex hygro-thermo-mechanical behavior of wood, with a view to preserving structures, historic buildings and artifacts. To this end, she is building upon and further developing a 3D hygro-thermo-mechanical model for concrete with reference to continuum mechanics and using the finite element method for timber.

A project currently being conducted by Dr. Linus Stegbauer of the University of Stuttgart's Institute of Interfacial Process Engineering and Plasma Technology (IGVP) is focused on the development of bio-intelligent façade elements for the construction industry. These elements are fitted with a special biofilm which contains living microalgae, single-cell plants that can store moisture thus producing a cooling effect, as well as absorbing, breaking down and exploiting airborne pollutants. When used in building façades they can make a valuable contribution towards improving the urban climate, and as an indirect consequence, towards the ambient conditions within the building.

## THE DECHEMA MEDAL

Prof. Elias Klemm, Head of the University of Stuttgart's Institute of Technical Chemistry, has been awarded with the 2020 DECHEMA Medal. In presenting the award to Prof. Klemm, DECHEMA, the German Society for Chemical Apparatus (Gesellschaft für Chemische Technik und Biotechnologie) wanted to honor his special achievements in the field of reaction technology, in which he has played a particularly active role both by sitting on various committees as well as by participating in various events. Elias Klemm has been involved with DECHEMA for many years. He played a leading role in combining the Technical Reactions working group and the Reactions Technology specialist group, and closely collaborated in the further development of the recently established specialist group.

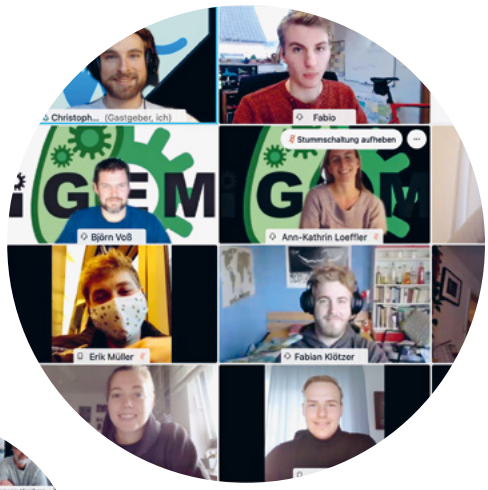
## THE HENRIETTE HERZ "RESEARCH WITH US" AWARD

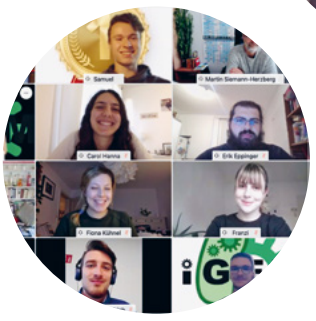
The University of Stuttgart was presented with the Henriette Herz Award by the Alexander von Humboldt Foundation for its "Research with US" concept. This award of 125,000 euro promotes the strategically oriented recruitment and retention of highly qualified young researchers from around the world. The "Research with US" global talent initiative pilot project will make a strong contribution towards the University of Stuttgart's research and internationalization strategies. The specific objectives include actively scouting and recruiting leading researchers from around the world, strengthening global networks, and increasing diversity and intercultural understanding among professors. The starting point for this pilot project is the Data-Integrated Simulation Science Cluster of Excellence (EXC SimTech).

The first stage of the initiative involves actively scouting for talent ("Scout for US"), whereby those researchers at EXC SimTech, who have close ties with other researchers around the world, personally contact outstanding candidates under professional supervision. An initial introduction to the University of Stuttgart as a research site is followed by interactive online events ("Meet US"). Subsequent events, such as scientific symposia, which are held in Stuttgart, then fascilitate the recruiting process ("Stay with *US*"). Over and above the funded project, the "Search for US" initiative supports promising early-career doctoral and postdoctoral projects.

## DETAIL PRIZE AWARDED FOR RESEARCH PAVILION

The Institute for Computational Design and Construction (ICD) and the Institute of Building Structures and Structural Design (ITKE) were awarded the prestigious 2020 DETAIL Prize in the "Students and Universities" category for their fiber pavilion at the German Federal Garden Show (Bundesgartenschau) in Heilbronn. The architecture magazine DETAIL recognized the willingness to experiment, use innovative processes, and technical details which are all evident in the building in an outstanding overall design. The jury concluded that "this pavilion demonstrates the importance of the role universities can play in architecture in an impressive manner" and went on to say that "This structure was created in a close, interdisciplinary collaboration between architects, structural engineers, and several private companies using advanced material technologies and digital manufacturing methods." They also drew particular attention to the elegance and lightness of the building.



## GOLD FOR IGEM TEAM

During the international iGEM competition, students from the University of Stuttgart developed water filters to address the problem of medicine residues in waste water. The international iGEM jury in Boston awarded the team the gold medal for their "Lac-Man" research project. To make the filter, the students produced silicate foam with laccases, enzymes that can neutralize harmful substances in the water, enclosed in its tiny pores. The idea for the project emerged during a visit to a sewage treatment plant, but the project itself was largely completed online due to the Covid-19 pandemic.

# 3 QUESTIONS FOR

## JUN.-PROF. HANAA DAHY

**When architect Hanaa Dahy, a junior professor at the University of Stuttgart, was confronted with the consequences of climate change in Egypt, her country of origin, over 15 years ago, sustainable building became her main focus, whereby she uses nature as a model. She and her students conduct research into components for resource-efficient and intelligent buildings at the University of Stuttgart's BioMat Department (Biobased Materials and Materials Cycles in Architecture).**

Photo: Uli Regenscheit

**What is your particular research focus?**

I focus on sustainable and intelligent approaches in architecture, one of which is the use of bio-based materials and renewable raw materials such as straw. As an architect, I'm looking for aesthetic concepts based on these materials and draw inspiration from them. Within the BioMat department our strategiies include function-oriented design methods, spatial configurations and bionically inspired structural forms, a specialized knowledge of materials, digital fabrication and processing techniques, as well as collaboration with industry.

**What natural inventions do you admire the most?**

Many: one of the concepts I have been working on with my students involves diatoms, small microorganisms that live underwater. They have a great plug-in system, which we copied to construct a shell-like structure. It's a great example of how to minimize the use of resources. You don't even need adhesives for the joints.

**Which of the buildings in Stuttgart do you particularly admire?**

The main one for me is the delicate lightweight structure of Jörg Schlaich's observation tower in the grounds of the Killesberg Höhenpark, which was built in 2001, but had already been planned in the 1980s. The tower showcased a minimal use of materials within a beautiful structural concept at a very early stage. But both the Mercedes-Benz Museum and the City Library are also outstanding examples of architecture.

**The video of the brief interview "Three Questions for Hanaa Dahy" is also available on YouTube.**

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# PRECAUTIONARY CHECK FOR THE SOFIA TELESCOPE

The Stratospheric Observatory for Infrared Astronomy (SOFIA) was given a complete overhaul during the so-called C-Check at Hamburg Airport this winter. The experts from the German SOFIA Institute at the University of Stuttgart also took advantage of the aircraft's maintenance break, setting their sights on the telescope, the heart of SOFIA, to prepare it for new and spectacular discoveries. The work included such things as the visual inspection of components, cleaning and lubricating the moving parts and replacing consumables, such as the enormous seals that separate the pressurized section of the aircraft from the non pressurized section. This also includes the "Vibration Isolation System" components, which isolate the telescope from the vibrations of the jumbo jet.

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## HAWK SUPERCOMPUTER TO BE ENHANCED

The University of Stuttgart's High Performance Computing Center of the (HLRS) is enhancing its Hawk supercomputer, one of the fastest supercomputers in the world, by adding a number of NVIDIA graphics processors, thereby transforming the architecture of the HLRS supercomputer from a dedicated central computer technology to a hybrid platform. This process will optimize the HLRS computer's capability in the field of Artificial Intelligence, particularly for deep learning applications. It will also enable novel workflows that combine high-performance computing simulations with Big Data approaches.

## 4 X 10 PRIZES FOR OUTSTANDING PUBLICATIONS

For the 4th year in a row, the University of Stuttgart has awarded publication prizes, each worth 2500 euro, for outstanding publications from each of its ten faculties. Because it was not possible to hold the award ceremony and for the authors to present their publications during the university's Research Day this year due to the Covid-19 pandemic, the researchers presented their work via the Internet in their online profiles and videos. The topics covered range from bionic construction and photonic structural elements to turbulence simulations and novel approaches in the field of medicinal pain therapy to folk plays and trend analyses using data from the PISA study.

**All presentations are available online at the University of Stuttgart website.**

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# SMART EDUCATION DIGITAL

**TEXT**: Jutta Witte
**PHOTOS**: Sven Cichowicz

**Educational expert Jun.-Prof. Maria Wirzberger is using creative methods and cross-discipline research to prepare teachers for digitalization.**

Digital systems such as virtual classrooms, target group-oriented learning portals and mobile apps, are opening up great opportunities to optimize support for all students and help them to develop their potential. Yet, in practice, there is still a dearth of appropriate concepts for the integration of the numerous technical innovations in everyday education. "There is a lot going on," says Maria Wirzberger, "but unfortunately a lot of it misses the mark." The pedagogical expert wants to introduce intelligent educational technologies that could later be used in a targeted manner, to which end her research is focused on multidisciplinary networks. In terms of her approach to teaching, she agrees with Socrates: "My starting assumption is that learners already have quite a lot of knowledge and that my job is to bring it out."

Wirzberger heads up the "Department of Teaching and Learning with Intelligent Systems" (LLiS) at the University of Stuttgart's Institute of Educational Science and, along with her team, forms part of Cyber Valley, one of the largest AI research collaborations in Europe. →

Versatile and open: Jun.-Prof. Maria Wirzberger believes in computer-based technologies.

→ Accepting the junior professorship was just another step for her in an eclectic career. "My career profile is pretty colorful," she says. She studied therapeutic pedagogy, psychology and human factors and trained as a personal coach. She is as well versed in infant and adult education as she is in computer-based cognitive models, digitalization and software development, the "common thread" of which is education. To discover how people teach and learn, she analyzes such things as how learners draw upon their cognitive resources. She also uses computer models to simulate cognitive processes and compares the model data with human imaging data. To develop tools, such as AI-based training for attention monitoring and testing which she tries out in various educational contexts, she pools her pedagogical knowledge and methods as well as drawing upon psychology and information technology.

## APP-BASED DIGITAL TEACHING

When it comes to training future teachers, she focuses on interactivity and the students' own activities in addition to this interdisciplinary approach. For example, she incorporates "active breaks" into her introductory lecture on educational psychology. She uses lego in her seminars to help people visualize novel ideas and concepts. "It's good for the students to see what can be achieved beyond the traditional didactic methods," she says. She also transfers her philosophy to the digital space, for example, with the aid of intellectual games, short experiments and embedded quiz questions. Yet her real objective is to combine analogue and digital systems and to utilize the best of both worlds. As she explains: "We don't have to make a choice. Even when we're giving digital lessons, we're still moving about in our own physical world." Looking at her recently launched "BeeLife" project demonstrates what she means by this.

This project involves a collaboration with researchers at the Chemnitz University of Technology aimed at developing a mobile teaching app primarily aimed at younger pupils. It's purpose is to make fifth and sixth graders aware of what they themselves can do in their everyday lives to protect the environment and endangered wild bee species, which is why the use of the app is an integral part of school project workshops. The project is specifically aimed at protecting the natural habitats of wild bees thus preserving biodiversity. When the app is launched, a virtual wild bee hatches, which the children care for like a pet thereby developing a bond with it over time. The objective is to create favorable living conditions for their own particular wild bee by acting in an ecologically responsible manner. During the course of this interaction, the children learn such things as which flowers or herbs their wild bee needs to feed on. If these plants are then planted in the school garden as part of a project workshop the app will show how the insect is gradually faring better. Wirzberger is confident that "experiences of success such as these boost motivation and ultimately also learning efficiency."

## INTRODUCE STUDENT TEACHERS TO REFLECTIVE PRACTICE

Methods, such as those used in BeeLife, can also be applied to other subjects. The interdisciplinary scientist always considers it important to create low-threshold access to intelligent learning systems, to create transparency concerning the use of data and, above all, to enable teachers to use the new tools in a confident manner and in a spirit of reflection. "If we wish to implement digitalization in schools in a sustainable manner," she emphasizes, "we have to begin with student teachers." She believes that this also includes discussing the potential impact of AI-driven systems on society, such as when algorithms evoke unconscious prejudices. Wirzberger likes to refer to the "racist soap dispenser" that went viral on social media for only dispensing soap to people with light skin because infrared technology had not previously been trained to recognize dark-skinned hands. →

**Interactive: Lego is sometimes used to explain novel concepts in a visual manner.**

Jun.-Prof. Maria Wirzberger

## "It's good for the students to see what can be achieved beyond the traditional didactic methods."

→ "This raises questions that affect all of us in our everyday lives," she says. One of the objectives of the "Reflecting on Intelligent Systems in the Next Generation" (RISING) teaching forum is to sensitize students to these issues at an early stage and in different contexts. RISING is being developed in the context of the University of Stuttgart's new Interchange Forum for Reflecting on Intelligent Systems (IRIS) of which Maria Wirzberger is the spokesperson together with Steffen Staab. The University's purpose for RISING is to anchor the concept of "AI and society" directly in teaching across all disciplines, for example via key qualification modules or as part of introductory lectures. An overarching teaching forum will be created to this end, which will initially bundle existing course content, but will also provide new formats and methods over time. Wirzberger and her team are currently expanding the teaching courses on offer in conjunction with all stakeholders. The crucial thing, she explains, is to clarify what teachers need to trigger a process of reflection among their students, and to discover the main issues that concerned them. "Our teaching forum represents a generic framework into which we can integrate a wide variety of content going forward."

The first reflection modules are scheduled to be launched as early as 2021 at the University of Stuttgart. Wirzberger has already made a start by including the subject of "unconscious stereotypes and prejudices in (digital) teaching materials" in her own lecture on educational psychology, which is one of numerous building blocks with which she prepares prospective teachers for digitalization and promotes a teaching and research culture aimed at exploting the "potential of the information age for a better and smarter educational environment". →|

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# Reconsidering Artificial Intelligence

TEXT: Carina Lindig

**Researchers at the University of Stuttgart's new Interchange Forum for Reflecting on Intelligent Systems (IRIS) are thinking about how intelligent systems are affecting society.**

Can an inanimate object be racist? Some time ago a video of a soap dispenser systematically denying soap to dark-skinned people went viral on social media. The soap dispenser reacted this way because standard infrared technology was developed by fair-skinned people and tested exclusively on their hands. This is not an isolated case. Another example occurred at the Südkreuz train station in Berlin, where a facial recognition software pilot project involving 300 test subjects was carried out in 2017. The study results showed that the system was flagging too many people as suspects that it was not even looking for. Once again, people of color and women were particularly affected.

Can technological discrimination be blamed on algorithms? According to Jun.-Prof. Maria Wirzberger of the "Department of Teaching and Learning with Intelligent Systems" (LLiS) and spokesperson for the new Interchange Forum for Reflecting on Intelligent Systems (IRIS) research group: "The answer is no because, in simple terms, algorithms work like drawers. they are based on standards which were set by human beings as a result of which they may well reflect their stereotypes. These stereotypes are often unconscious and are therefore incorporated unconsciously into technological developments."

## ANTI UNFAIRNESS

Researchers from all disciplines now wish to collaborate at the IRIS to investigate such developments. "Over the past few years we've learned how the naive use of Artificial Intelligence for automated decision-making can lead to unfair discrimination," says Prof. Steffen Staab of the University of Stuttgart's Institute for Parallel and Distributed Systems and co-spokesperson of the IRIS: "Which is why we are developing new methods to avoid, detect and explain unfairness." Through the IRIS network, researchers intend to critically reflect on the foundations, mechanisms, implications and effects of intelligent systems in research and teaching as well as with regard to society as a whole. The IRIS is funded by the German Research Foundation (DFG) as part of the German federal and state governments's Excellence Strategy as well as by the University's research fund. →

Prof. Steffen Staab

**"Human decisions are often based on unconscious prejudices."**

→ The IRIS's tasks and course offerings are not limited to the field of research, but also create interchange opportunities both within and outside the University to discuss current ethical and social challenges with partners from public society and the business sector ranging from data ethics to informational self-determination and reliable AI. The focus is also on teaching: the "Reflecting on Intelligent Systems in the Next Generation" (RISING) teaching forum, which is headed up by Maria Wirzberger, teaches students of all subjects how to critically reflect on intelligent systems by offering courses on such things as "cultural bias" and "open science". Teachers can further their own training by applying reflective teaching methods.

## RAISING AWARENESS

So how does IRIS help to work against stereotyping in such fields as technology development? "What's so good about IRIS," Wirzberger explains, "is that it raises student awareness of this issue before they enter the workplace, which will prevent such developments on this scale." Even in terms of language, because, as Wirzberger explains: "language is also an intelligent system. "Anyone who fails to use language in a sensitive manner may exclude entire deomgraphic groups. Topics such as these should be firmly anchored in the way we think and act. We wish to create an awareness of just how colorful and diverse our society is." On the other hand, the intention is to boost the University's networking activities at the international level. The benefit of bringing different people together, the researcher explains, is that good ideas emerge and there is a lively exchange of ideas.

Steffen Staab emphasizes the fact that people also learn something about themselves in the process: "Human decisions are often based on unconscious prejudices. Digitizing our decisions, makes the results transparent and verifiable. Increasingly, we are now seeing how we have unfairly discriminated against others in the past. In future, AI will hopefully enable us to better scrutinize our own decisions and make fairer judgments."

Reflecting upon intelligent systems is already firmly anchored in several areas within the University of Stuttgart, such as the "Platform of Reflection" within the "Stuttgart Center for Simulation Science" (SimTech) Cluster of Excellence, in one of the thematic foci of the International Center for Cultural and Technological Studies (IZKT) and in the Center for Interdisciplinary Risk and Innovation Studies (ZIRIUS). The IRIS addresses all disciplines, from technology and engineering to the humanities, social sciences and economics, and unites all the various competencies. ↠

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# INTO THE FUTURE WITH FICTION

**TEXT**: Carina Lindig

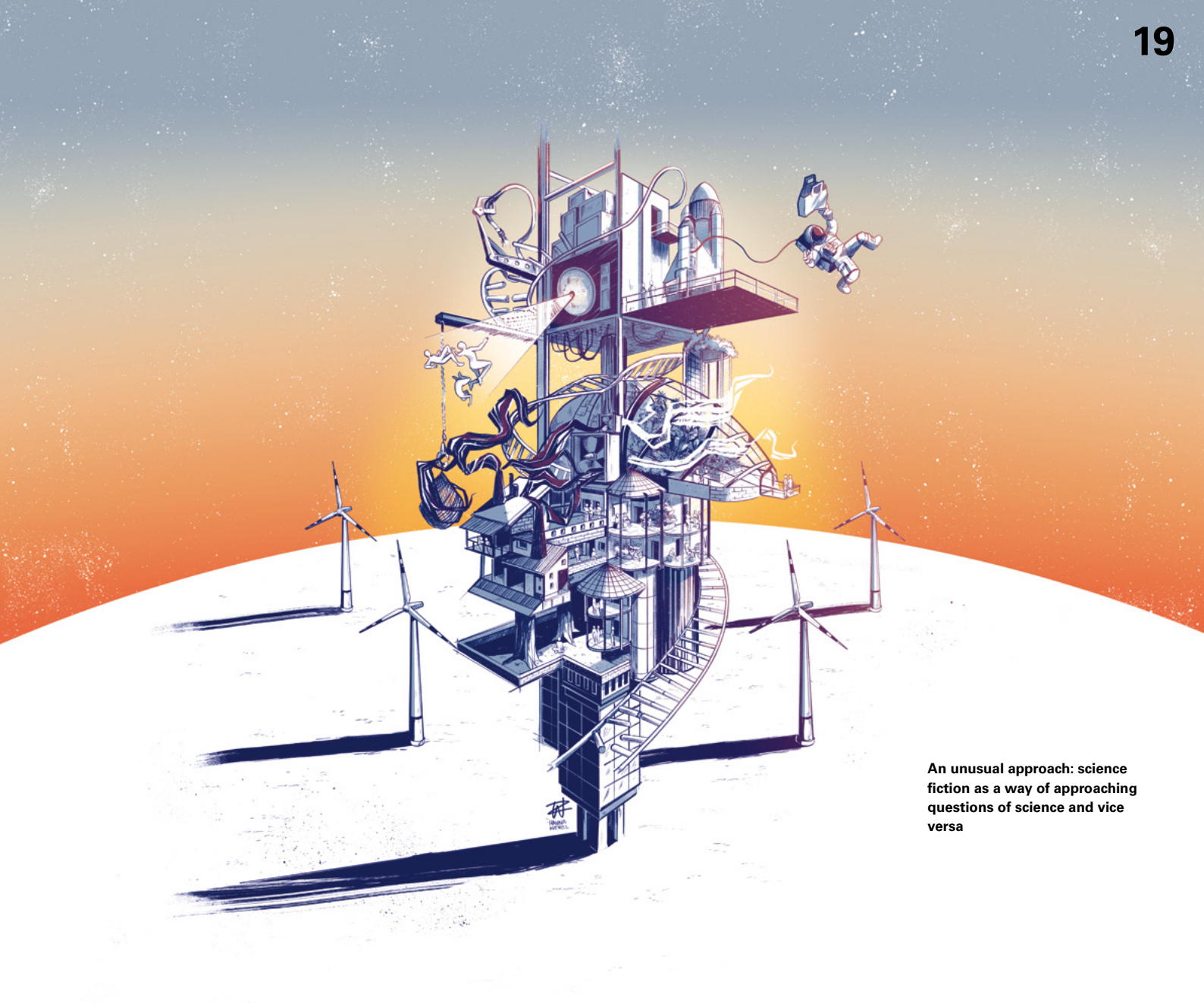
**Researchers meet science fiction authors and interested citizens at the "Next Frontiers" conference. The new event format is bringing science to the public.**

MIRI crouches mute on the stage during the future conference, its face glowing red. Its arm reaches for one of the wooden blocks piled in a tower in front of it, but the girl-shaped robot cannot move the blocks. Its just a prop; a placeholder for the new possibilities represented by Artificial Intelligence, Future Food, Bitcoin and simulations that predict reality. What is our current take on ubiquitous technology? And what future is it leading us towards? "Next Frontiers" provides a forum for researchers from the fields of computing, geobiology, social, media and cultural studies and renowned journalists, such as Eva Wolfangel and Alexander Mäder, as well as science fiction writers such as Emma Braslavsky and Tad Williams, in which they discuss their areas of specialization and the question of science fiction as a technology assessment.

Tobias Wengert is the organizer and brains behind the event. "A few years ago," he says, "I attended the 'South by Southwest' conference in Austin, Texas. It's one of the biggest events for music, film and interactive media." It was there that the idea of linking literary themes with science first took shape. "I wanted to create something new and experiment with various formats," says Wengert, a full-time event designer at the Library of Stuttgart. Collaboration partners of the conference include the University of Stuttgart, the Stuttgart Region Economic Development Corporation (WRS) and the MFG Media and Film Society Baden-Württemberg mbH.

## INSPIRATION THROUGH AN EXCHANGE OF IDEAS

What is the connection between science fiction and science? "It's two-way inspiration," says Wengert, who can cite many examples: Author Arthur C. Clarke anticipated the geostationary news satellite system, and the communicator from the early Star Trek series already defined the main characteristics of the mobile phone – small and mobile. Wengert's favorite litarary example is the notion of blasting people into space in cannonballs. The physicist Hermann Oberth, a great fan of science fiction, did the calculations on this and found that a human being would not survive it. As a result, it is said, he came up with the idea of designing rockets. What makes this conference so special for Wengert is the interdisciplinary exchange between the participants: →



**An unusual approach: science fiction as a way of approaching questions of science and vice versa**

→ "When we organized the event for the first time in 2019," Mr. Wengert recalls, "the most wonderful experience for me was that various researchers approached me to say that we would have to do this again. And the conversations were really enriching for me."

The event is co-organized by the University of Stuttgart's International Center for Cultural and Technological Studies (IZKT) . The IZKT staff were involved in the conceptual planning and it was they who invited and looked after the visiting researchers. "It is more important than ever for science to enter into a dialogue with the public," says Dr. Elke Uhl, Managing Director of the IZKT, pointing out that in these days of "fake news" the mistrust of much of the public towards experts is increasing. This, she says, can be countered through communicating science and knowledge transfer to the public, which raises the question of how the University can live up to its special responsibilities in times of social transformation. According to Uhl, "we're facing a huge bouquet of challenges." Some of the major issues of the future include climate change and the Covid-19 pandemic, digitalization, the global food supply system, biodiversity and Artificial Intelligence. On the one hand, the task for researchers is to develop solutions and technical innovations in their particular fields of research. Yet it will also be necessary to present holistic plans for the future. "What we need," Uhl emphasizes, "are both evidence-based answers and solutions to very specific questions, but also the courage to play a role in shaping the future."

Communicating science is increasingly become a matter of interface management, the idea being to increasingly bring together different forms and sources of knowledge. And the "Next Frontiers" future conference is situated precisely at the interface between fiction and science. "The conference is a fantastic, →


**Robot Girl MIRI: the prop is on display at the future conference as a placeholder for the new possibilities represented by Artificial Intelligence, Future Food, Bitcoin.**

**Video footage and images of the "Next Frontiers" event in September 2020 as well as additional information are available at: https://www.next-frontiers.de/de/gaeste/**

→ innovative format, as it brings together representatives of fields who do not normally meet. It is a powerful indication that the University of Stuttgart is taking its responsibility seriously," says Uhl. Responsibilty, in the opintion of the cultural researcher, involves adopting a future-based approach, contributing to the solution of socially relevant problems, and combining this with a reflective attutude towards one's own actions.

## REFLECTIONS ON THE POST-FOSSIL-FUEL CITY

The post-fossil-fuel city was at the core of last autumn's conference as well as how it may be possible to produce food in a test tube in the future, and the concept of robots learning like children. Whilst enthusiasts and thinkers are imagining life in a distant future, many people can not even think a single generation into the future Nevertheless, Tobias Wengert is hoping that the event will have a longer-term impact on society. But, he says, to find that out, you'd have to travel ten years into the future and then look back. Elke Uhl also says that success cannot be captured in simple numbers or through quantitative methods: instead, it is about long-term processes. Patterns of thought, she says, need to be dismantled →

→ and imagination and creativity should be encouraged. However, she points out, the conference already demonstrated that technological innovations must be considered along with social innovations. One example she cites is climate change: "Fantastic technological innovations, for example, could well reduce $CO_2$ emissions. Yet people's behavior could cancel out these positive reduction effects. This is referred to as the rebound effect." Conferences such as the "Next Frontiers" event at which literature, art and science are brought together make for a direct exchange of information, which in turn provide stimuli for one's own work." The next future congress is already scheduled for this September. ⇥

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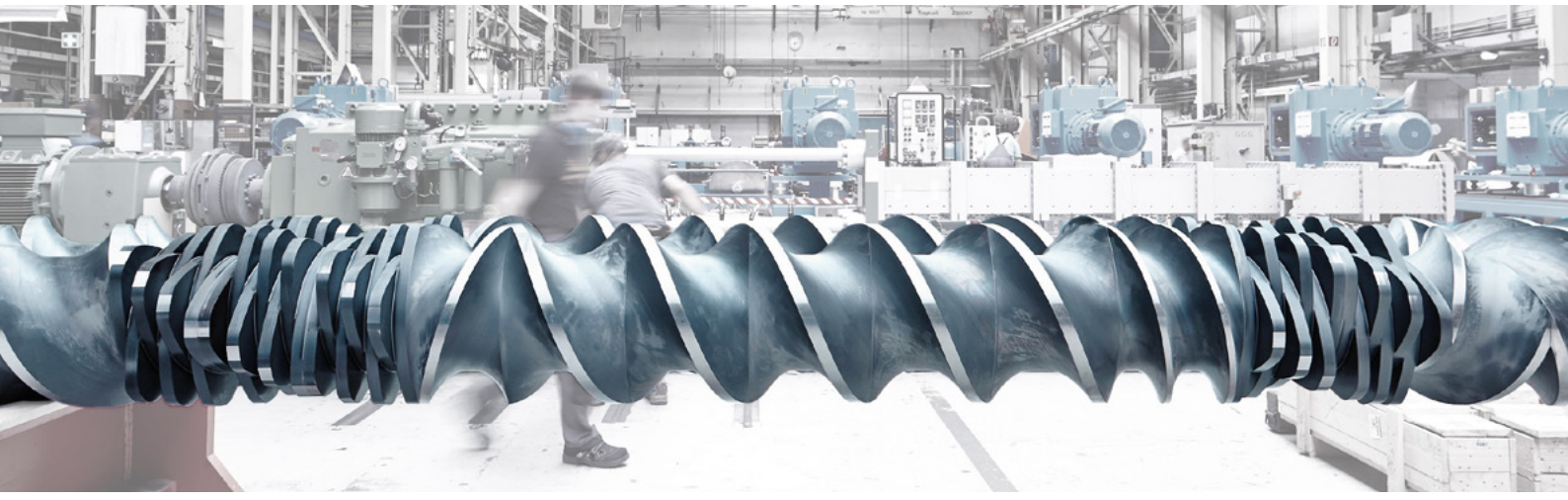

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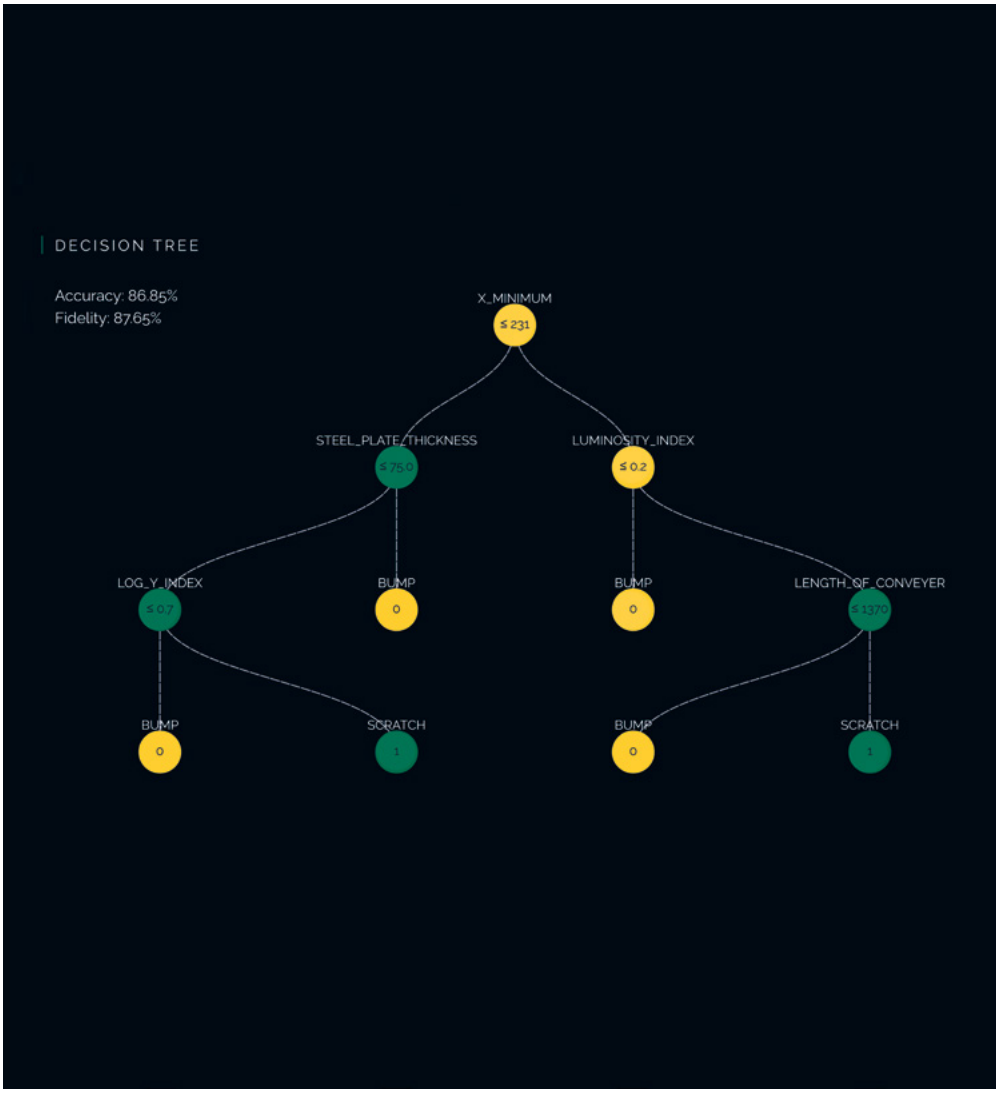
# PEERING INTO THE BLACK BOX




**This decision tree shows the decision making process of the neural network depicted on p. 24. It's all about classification: bump or scratch? The yellow nodes represent a decision in favor of a bump whilst the green ones correspond to a decision in favor of a scratch.**

**TEXT**: Michael Vogel

**AI algorithms are increasingly taking decisions that have a direct impact on humans. But greater transparency into how such decisions are reached is required.**

As an employer, Amazon is much in demand and the company receives a flood of applications. Little wonder, therefore that they are seeking ways to automate the pre-selection process, which is why the company developed an algorithm to filter out the most promising applications. This AI algorithm was trained using employee data sets to enable it to learn who would be a good fit for the company. However, the algorithm systematically disadvantaged women. Because more men had been recruited in the past, far more of the training data sets related to men than women, as a result of which the algorithm identified gender as a knockout criterion. Amazon finally abandoned the system when it was found that this bias could not be reliably ruled out despite adjustments to the algorithm.

This example shows how quickly someone could be placed at a disadvantage in a world of algorithms, without ever knowing why, and often without even knowing it. "Should this happen with automated music recommendations or machine translation, it may not be critical," says Marco Huber, "yet it is a completely different matter when it comes to legally and medically relevant issues or in safety-critical industrial applications." Huber is a Professor of Cognitive Production Systems at the University of Stuttgart's Institute of Industrial Manufacturing and Management (IFF) and also heads the Center for Cyber Cognitive Intelligence (CCI) at the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA).

Those AI algorithms that achieve a high prediction quality are often the ones whose decision-making processes are particularly opaque. "Neural networks are the best-known example," says Huber: "They are essentially black boxes because it is not possible to retrace the data, parameters, and computational steps involved." Fortunately, there are also AI processes whose decisions are traceable and Huber's team is now trying to shed light on neuronal networks with their aid. The idea is to make the black box transparent (or "white").

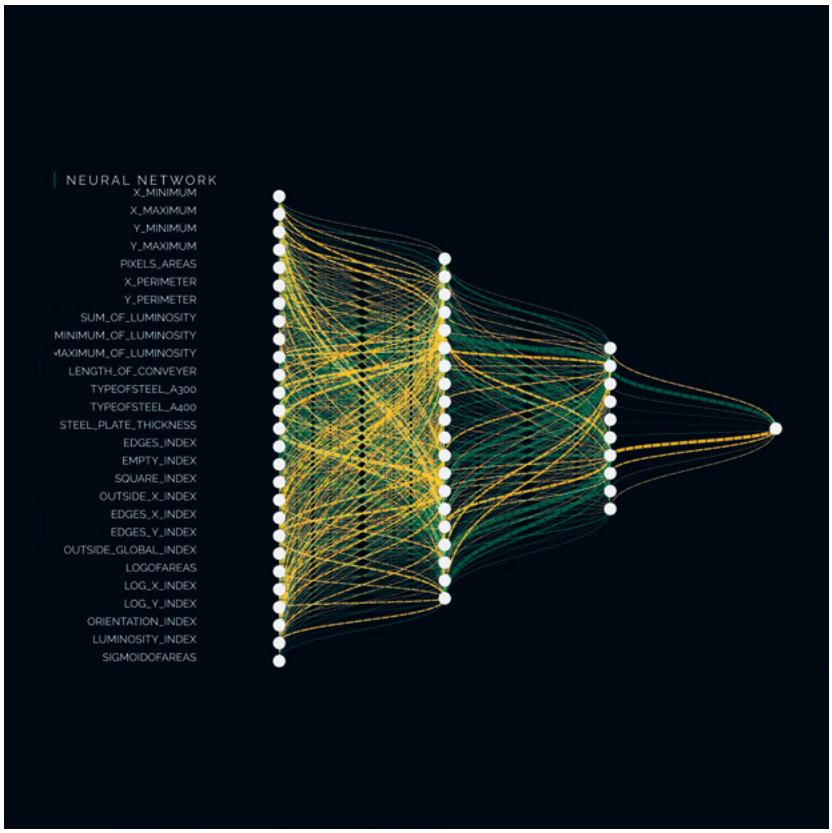
## MAKING THE BOX WHITE THROUGH SIMPLE YES-NO QUESTIONS

One approach involves decision tree algorithms, which present a series of structured yes-no (binary) questions. These are even familiar from school: whoever has been asked to graph all possible combinations of heads and tails when flipping a coin multiple times will have drawn a decision tree. Of course, the decision trees Huber's team uses are more complex.

"Neural networks need to be trained with data before they can even come up with reasonable solutions," he explains, whereby "solution" means that the network makes meaningful predictions. The training represents an optimization problem to different solutions are possible, which in addition to the input data, also depend on boundary conditions, which is where decision trees come in. "We apply a mathematical constraint to the training to ensure that the smallest possible decision tree can be extracted from the neural network," Huber explains. And because the decision tree renders the forecasts comprehensible, the network (black box) is rendered "white". "We nudge it to adopt a specific solution from among the many potential solutions," says the computer scientist: "probably not the optimal solution, but one that we can retrace and understand."

**The neural networks used in Artificial Intelligence (AI) algorithms are modeled on the human brain, whereby the artificial neurons can receive and process information and communicate with one another.**

There are other ways of making neural network decisions comprehensible. "One way that is easier for lay people to understand than a decision tree in terms of its explicatory power," Huber explains, "is the counterfactual explanation." For example: when a bank rejects a loan request based on an algorithm, the →




**The neural network: the white dots in the left column represent the input data whilst the single white dot on the right represents the output result. What happens in between remains mostly obscure.**

**Bottom: Accoring to Prof. Marco Huber, the comprehensible solution is sometimes more important than the optimal solution.**

→ applicant could ask what would have to change in the application data for the loan to be approved. It would then quickly become apparent whether someone was being disadvantaged systematically or whether it was really not possible based on their credit rating.

Many youngsters in Britain might have wished for a counterfactual explanation of that kind this year. Final exams were cancelled due to the Covid-19 pandemic, after which the Ministry of Education then decided to use an algorithm to generate final grades. The result was that some students were given grades that were well below what they expected to receive, which resulted in an outcry throughout the country. The algorithm took account of two main aspects: an assessment of individual's general performance and exam results at the respective school from previous years. As such, the algorithm reinforced existing inequalities: a gifted student automatically fared worse in an at-risk school than in a prestigious school.

## IDENTIFYING RISKS AND SIDE EFFECTS

In Sarah Oppold's opinion, this is an example of an algorithm implemented in an inadequate manner. "The input data was unsuitable and the problem to be solved was poorly formulated," says the computer scientist, who is currently completing her doctoral studies at the University of Stuttgart's Institute of Parallel and Distributed Systems (IPVS), where she is researching how best to design AI algorithms in a transparent manner. "Whilst many research groups are primarily focusing on the model underlying the algorithm," Oppold explains, "we are attempting to cover the entire chain, from the collection and pre-processing of the →

→ data through the development and parameterization of the AI method to the visualization of the results." Thus, the objective in this case is not to produce a white box for individual AI applications, but rather to represent the entire life cycle of the algorithm in a transparent and traceable manner.

The result is a kind of regulatory framework. In the same way that a digital image contains metadata, such as exposure time, camera type and location, the framework would insert explanatory notes to an algorithm – for example, that the training data refers to Germany and that the results, therefore, are not transferable to other countries. "You could think of it like a drug," says Oppold: "It has a specific medical application and a specific dosage, but there are also associated risks and side effects. Based on that information, the health care provider will decide which patients the drug is appropriate for."

The framework has not yet been developed to the point where it can perform comparable tasks for an algorithm. "It currently only takes tabular data into account," Oppold explains: "We now want to expand it to take in imaging and streaming data." A practical framework would also need to incorporate interdisciplinary expertise, for example from AI developers, the social sciences and lawyers. "As soon as the framework reaches a certain level of maturity," the computer scientist explains, "it would make sense to collaborate with the industrial sector to develop it further and make the algorithms used in industry more transparent ." →|

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Photos: University of Stuttgart / IFF

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# AN ETHICS LABEL FOR AI

**The question as to whether a given algorithm respects certain values, such as transparency, privacy, justice, should be answerable in future.**

**TEXT:** Michael Vogel

**Artificial Intelligence has to be ethically assessable; a group of researchers, with the involvement of the University of Stuttgart, has now developed a practical proposal for this.**

Whenever you purchase an LED light, a freezer,or even a car, you will almost inevitably come across an energy efficiency label, an intuitive indication of power consumption that has been mandatory for an increasing number of products within the EU for over a decade. As it can be "optimized", this label is far from perfect. Nevertheless, it is now well established among consumers and often serves as an orientation guide.

The energy label also served – at least in part – as the inspiration for a new form of label, which states whether a given AI algorithm compies with ethical principles. "Whenever algorithms such as these make decisions, that have consequences"→

→ for people," says Andreas Kaminski, "then" the way in which the decision was arrived at must be comprehensible for both ethical and legal reasons." Kaminski, a doctor of philosophy, heads up the "Philosophy of Science & Technology of Computer Simulation" working group at the High Performance Computing Center, Stuttgart (HLRS).

There are two main approaches to designing such a classification structure, one being a set of ethical rules and is integrated into the AI models, the other being the certification of AI procedures based on ethical criteria. "When it comes to practical implementation," says Kaminski, "both approaches are beset with fundamental problems. "In the first approach, it is not possible to take account of implicit rules." For example, the road traffic regulations do not specify how to merge in heavy traffic, which is often only possible without waiting in compliance with the rules. "The second approach invites the exploitation of gray areas, and the identity of the ultimate decisionmaker often remains unclear."

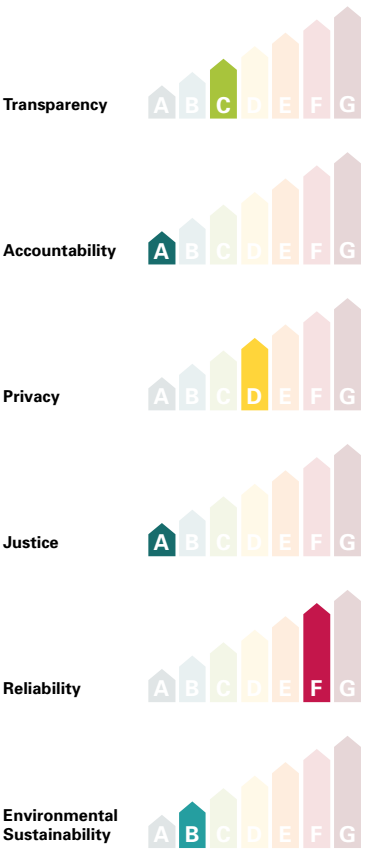
Kaminski is a member of the AI Ethics Impact Group, a consortium jointly initiated by the VDE technology concern and the Bertelsmann Stiftung. This interdisciplinary group combines expertise from the fields of computer science, philosophy, technology assessment, engineering, and the social sciences. "We have developed a practical, applicable concept for AI ethics that meets three criteria," Kaminski explains: "First, it can be applied with pluralistic values, i.e., in different societies. Second, it always evaluates an AI application in its specific context. Third, one can understand how the valuation is arrived at."

## MAKING ETHICAL VALUES MEASURABLE

In visual terms, these results are presented in a similar manner to the energy label, as an AI ethics label so to speak. "Our concept is appropriate for very different groups such as consumers, stakeholders, decision-makers, and buyers," Kaminski explains. "If necessary, they can learn more than what is indicated on the visual display, which creates incentives for companies to actually adapt their algorithms accordingly."

Rather than being based solely on the AI Ethics Label, which places values such as transparency, liability, privacy, equity, reliability, and sustainability in categories ranging from A to G, two additional elements are included, one of which is a model developed by the philosopher Christoph Hubig, which makes the aforementioned criteria measurable. Kaminski's team also worked on this. "We defined criteria for each value and identified the metrics that contribute towards those criteria," Kaminski explains: "This enables one to take account of value conflicts and dependencies. We take a differentiated view of the relevant values, which don't have to be determined in absolute terms." This leaves room for the evaluation of an AI aglorithm in the specific application context. "Not everything needs to be subject to exactly the same ethical regulations," Kaminski explains. "After all, it makes a difference whether an AI algorithm makes a recommendation for an item of clothing based on previous purchasing behavior or makes a medical diagnosis." This approach addresses this aspect through the inclusion of a third element, a risk matrix. "This contrasts the magnitude of the potential harm a given AI algorithm could do with the degree of reliance on the relevant algorithm in decision making," Kaminski explains. "Risk classes can then be derived from this."

The AI Ethics Impact Group's proposal is generating interest. The EU Parliament, for example, has been looking into it, as has the High-Level Expert Group on AI, an EU advisory body. The concept has also been discussed by the German Ethics Committee and the IEEE engineering association. The German Ministries of Justice and Labour are currently working on a project to assess how the concept could be implemented in an employment and administrative context. ⇥




**The Artificial Intelligence Ethics Label, which was developed by the Artificial Intelligence Ethics Impact Group, is a way of rating algorithms.**

**Philosopher Dr. Andreas Kaminski of the High Performance Computing Center, Stuttgart and his team have developed a concept for evaluating the ethics of AI algorithms.**

Photos: AIEI Group, GettyImages, private

# A CALL TO

**TEXT:** Melina Danieli

**An international research team has analyzed the ways in which the Internet is challenging our society. Prof. Steffen Staab of the University of Stuttgart and initiator of "Web Futures: Inclusive, Intelligent, Sustainable – The 2020 Manifesto for Web Science," is convinced that its further development should be shaped consciously.**

What would happen if the power were to go off for a day? The traffic system would collapse, we would be unable to make phone calls, and we would neither be able to shop nor work. What would happen if the Internet and the World Wide Web, which is inextricably linked to it, were to go down for a day? The scenario would be similarly dramatic: a large part of the traffic system would collapse, we would be unable to make phone calls or pay for groceries, and most people would be temporarily cut off from their jobs.

The Internet and the Web have become the nervous system of our planet – just as crucial as electricity from the wall outlet. They enable people to share more information more rapidly, and to work, communicate and interact with one another more easily. In the midst of all of this, the Covid-19 pandemic is acting as a accelerator for digitalization. But in addition to the benefits, the Internet and the Web are also leading to new structures of domination: previously unknown levels of surveillance, invasions of privacy, targeted disinformation and election manipulation, for example, are becoming increasingly possible. A great deal of data is held by just a few private companies, and the use of Artificial Intelligence (AI) further increases the new opportunities and risks.

An international and interdisciplinary team has developed a number of potential scenarios for the Internet of the future in the "Web Futures: Inclusive, Intelligent, Sustainable – The 2020 Manifesto for Web Science," manifesto. It is the result of the "10 Years of Web Science" Perspectives Workshop, which was held at Schloss Dagstuhl in Saarland in June 2018. The publication primarily focuses on the question of Internet opportunities and risks, especially in light of the increasing importance of AI. The participating researchers, from a range of disciplines including sociology, computer science, and philosophy, presented the content at the Association for Computing Machinery (ACM) International Conference on Web Science in July 2020.

Among other things, the authors argue for an expansion of interdisciplinary collaboration, their objective being an inclusive, intelligent and sustainable Internet for all. "For the future of our society," says Prof. Steffen Staab, a researcher at the University of Stuttgart's "Simulation Technology (SimTech) Cluster of Excellence" and in the Cyber Valley research network, as well as being the initiator of the manifesto, "we need to think about how our potential futures may be intertwined with the future of the web. The science of the World Wide Web is not just for researchers, but for everyone."

The manifesto also sheds light on the ambivalence produced within the web: freedom of information versus poor quality information, personalization opportunities versus privacy issues, participation of the many versus manipulation of the many, inclusion and fairness versus exploitation, and sustainability versus growth. It also provides a vivid illustration of the challenges that lie ahead in terms of the future organization, use and development of the Web and identifies the regulations needed to make it fair and inclusive.

For many people, the World Wide Web has today become something taken for granted to which individuals give little thought. Yet, it has an enormous impact on all of our lives. Staab is convinced about the fact that it still remains uncertain how the web will change in response to the increasing influence of AI and how that will influence our everyday lives: "The only certain thing is that the change itself will happen. We now have the opportunity to think about how we want to deal with it."⇥

**Prof. Steffen Staab is the initiator of the Web Futures Manifesto.**

Photos: University of Stuttgart / Max Kovalenko

# ARMS

## RECOMMENDED ACTIONS FOR AN INCLUSIVE, INTELLIGENT AND SUSTAINABLE WEB

### RESEARCHERS

Researchers should collaborate with researchers from other disciplines. Questions relating to the impact of the digital world on the environment and climate should be on the shared agenda. We also need an AI review board to provide clear guidelines.

### BUSINESS ORGANIZATIONS

Networking is also becoming increasingly important for busnesses. Collaboration with the public, academia and non-governmental organizations could increase efficiency, innovation and confidence in the business sector.

### ACADEMIC INSTITUTIONS

Both academic institutions and funding bodies should be taking a broader approach towards promoting interdisciplinary research as well as sustainability research. The uncertainties associated with the Web could be addressed in a continuous dialogue. Support should also be provided for diversity programs.

### POLITICS

Politicians should establish research areas in which education, innovation and environmental policy are considered holistically. Inclusion laws should be revised with a view to assessing them relative to various criteria.

### TEACHERS

Teachers of all disciplines ought to be encouraging civilized interactions on and with the Web and instilling values of mutual understanding and respect. People could also be instructed in the proper use of the web in specially developed educational programs.

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# A CODE OF CONDUCT FOR PROGRAMMERS

**GUEST ARTICLE**: Jörg Dräger

**Increasingly, our decisions are being influenced by Artificial Intelligence (AI) and algorithmic systems. Programers ought to be mindful of this responsibility, whereby an established set of values could provide them with the necessary orientation. Jörg Dräger, director of the Bertelsmann Stiftung, sets out the route to such an ethics of the profession.**

Algorithms are having an ever greater influence on our lives and actions without the majority of us even being aware of it, whether it be in investments, insurance, job hunting, policing, Internet shopping or online dating. Yet algorithm-based systems do not simply fall from the sky; their objectives and the ways in which they work are determined and implemented by people. Algorithm designers ought, therefore, to draft a professional code of ethics. Many professions already have such guidelines, above all medical doctors in the form of the Hippocratic Oath. Others have established appeal bodies. The German Press Council (Presserat), for example, has the power to issue public reprimands if journalists violate the press code. The field of algorithm development also involves a high level of social responsibility and ought to have a particular committment to ethical integrity.

Ethical rules for algorithmic systems design cannot and ought not to define in detail what constitutes a good or bad algorithm. Instead, it is about establishing quality criteria both for the development process and for the use of algorithms, which should include such principles as transparency, traceability, controllability, and clearly defined responsibilities. No such model will prevent algorithmic systems from occasionally being maliciously manipulated,→

**Dr. Jörg Dräger**

# “Everyone, including leaders and practitioners, needs to collaborate on a professional code of ethics to ensure a wide acceptance of the relevant moral standards.”

**Jörg Dräger holds a doctorate in physics and was Senator for Science and Research at the Senate of Hamburg between 2001 and 2008. He has been a member of the Bertelsmann Stiftung Executive Board since 2008, where he is responsible for education, integration and digitalization.**

→ but, if sufficiently well-known, will remind algorithm developers of their responsibility and provide them with the confidence to take action. In the event of conflicts with superiors or employers, employees would be able to refer to a professional code of conduct such as this.

## DIVERSITY AND COMMITMENT

The development, institutionalization and dissemination of a professional code of ethics is a lengthy process involving many stakeholders, because the heterogeneous professional field of algorithm development involves more than just traditional computer scientists. It is often data scientists who decide which data to use to train learning systems and which evaluation and prediction methods to use in the search for patterns. They come from a very diverse range of professional backgrounds including, in addition to computer science, mathematics and physics, lateral entrants from completely different professional fields, all of whom, including leaders and practitioners, need to collaborate on a professional code of ethics to ensure a wide acceptance of the relevant moral standards. A sufficient level of commitment will only be brought about through a continuous exchange between science and practice, long-term promotion of the guidelines and their consistent integration into training and advanced education courses.

Although a professional code of conduct is currently lacking, there is a growing awareness among people within the industry of their ethical responsibility and the social ramifications of their actions. Google employees involved in the Dragonfly project, for example, protested when they discovered that they were in fact working on a censored search engine for the Chinese market. And hundreds of students from elite U.S. universities declared in June 2018 they would turn down job interviews with Google if the corporation were to continue working on the Maven AI project for the U.S. Department of Defense. Thousands of employees also demanded that their employer should not participate in such technology of war. The protests were successful: Google allowed its contract with the Pentagon expire in the spring of 2019.

## RESPONSIBILITY HALLMARK

Ethical guidelines should not only provide guideance for algorithm developers, but also for the decisionmakers and professional system users, such as managers who commission algorithmic systems, or the police officer who has to deal with them on a daily basis. Many companies are currently developing their own Corporate Digital Responsibility (CDR) strategies, based on the established Corporate Social Responsibility (CSR) strategy, which set out a voluntary commitment for managing digital technologies. This provides an opportunity to commit to a code of ethics for algorithms. As such, and even in the absence of direct sanctions, a CDR supplements legal requirements, such as those pertaining to data management, with ethical considerations and in-house values.

A public that communicates its expectations clearly, rewards ethical behavior and sanctions unethical practices, can also exert considerable pressure. Companies can certainly gain a competitive advantage through the appropriate use of algorithms, as exemplified, by fairly produced fashion or fair trade food. Whilst the USA and China are the pioneers of AI technoloy, Germany and Europe could develop the social and ethical aspects for algorithmic systems as unique selling points. Whereas "Made in Germany" has always stood for reliable quality, "AI made in Europe" should become the hallmark of responsibility and innovation in the future. →|

This article is based on an abridged and adapted excerpt of the chapter "Wissen wirkt Wunder" from the book "Wir und die intelligenten Maschinen - Wie Algorithmen unser Leben bestimmen und wir sie für uns nutzen können" (DVA 2019, 272 pages) by Jörg Dräger and Ralph Müller-Eiselt.

Photo: Besim Mazhiqi

# C R I S P R

## Genetic engineering is accelerating research

A nutrient solution in a cell culture bottle

Tiny samples are extracted in pipettes.

**TEXT**: Helmine Braitmaier
**PHOTOS**: Max Kovalenko

**Precise, cost effective, and rapid: CRISPR-Cas9 gene scissors can be used to target and modify DNA. Emmanuelle Charpentier and Jennifer Doudna were awarded the 2020 Nobel Prize in Chemistry for developing the method. Researchers at the University of Stuttgart are using the technology in a number of different ways.**

CRISPR-Cas9 gene scissors can be used to cut the DNA of plants, animals and microorganisms with pinpoint accuracy, after which individual DNA building blocks can be exchanged, or entire gene segments can be inserted at the intersection as required. Hopes are hight that this will pave the way to such things as the development of fungus-resistant corn, pigs with greater muscle mass or new cancer therapies. Eventually, it may also be possible to cure hereditary diseases.

Ever since the 1970s, methods of altering genetic material have existed but all of which have been too imprecise, time-consuming and expensive until recently. For example scientists exploited the fact that the cellular apparatus sometimes incorporates inserted genes rather than an existing gene variant. It was usually necessary to carry out crossbreeding experiments for many years until animals were produced with the new genes in all of their body cells. Gene therapy trials have often involved the use of attenuated viruses able to insert any piece of DNA into the genome, but in an uncontrolled manner and at random locations, which could result in the unintentional interruption of important genes, such as those that protect against cancer.

The first gene scissors, such as zinc-finger nucleases and later TALENs sent the research community into a state of euphoria at the turn of the millennium, because these were the first ever precise surgical gene tools. However they were never widely used: “These DNA-cutting enzymes have to be redesigned for each gene locus at which →

→ they are targetted, which is no trivial matter," Prof. Albert Jeltsch explains. Jeltsch, who heads up the the Department of Biochemistry at the University of Stuttgart's Institute of Biochemistry and Technical Biochemistry (IBTB) has been experimenting with gene scissors since their infancy.

## THE RESEARCH FIELD IS EXPLODING

The CRISPR-Cas9 method, by contrast, requires no complex protein design: all it needs is a short snippet of RNA containing the transcript of the target section of DNA to direct the DNA-cutting enzyme Cas9 to where it is required. "The sequence of this RNA probe then spits out a piece of online software for me," Dr. Cathrin Hagenlocher of the Institute of Cell Biology and Immunology (IZI) explains, "which I can then purchase for less than 10 euros."

Hagenlocher was working on her doctoral thesis when Charpentier and Doudna published the method in 2012. "I grasped the theory back then and thought, I want to use this technique too," the cell biologist explains. Four years later, she immersed herself in the reams of protocols already available on the Internet at the time and established the new technique within her own working group.

One of her students was looking into a signaling pathway in colon cancer cells that can force them into programmed cell death, but does not always respond to incoming self-destruct signals on the surface of the cell. "We wanted to find out why some cancer cells are resistant in order that we might eventually be able to trigger the cell death of tumor cells in a targeted manner as part of our cancer therapy," says Hagenlocher, who goes on to say that the Institute is now able to produce gene knockout cell lines in which CRISPR gene scissors are used to destroy certain genes. →

**In the Petri plate: bacteria with recently cloned DNA**

## WHAT IS THE ORIGEN OF CRISPR-CAS?

CRISPR-Cas is how bacteria defend themselves against viruses, CRISPR being the name of certain sections of the bacterial genome, in which the bacterium incorporates and stores specific sections of viral DNA from viruses that have infected it. In the event of a reinfection by the same virus, the bacterial enzyme Cas uses the selected section to recognize the genetic material of the hostile virus and then cuts the viral material at the exact site it has "memorized", thus rendering the virus harmless. The bacterial system can easily be hijacked in the laboratory to perform targeted genetic modifications in all kinds of organisms.

**Dr. Cathrin Hagenlocher**

"We wanted to find out why some cancer cells are resistant in order that we might eventually be able to trigger the cell death of tumor cells as part of our cancer therapy."

Dr. Cathrin Hagenlocher has established the use of CRISPR-Cas9 in her research group.

Human cancer cells in nutrient solution ready for the next experiment

→ "It is more complicated to insert something into the genome." This is done by, for example, introducing the desired piece of DNA into the cell and allowing the cell's own repair system to insert it at the fracture point. Some members of the Institute have already successfully inserted known cancer mutations into cellular genetic material so that they can analyse them with greater precision. "The field is just exploding and there is an amazing number of modified forms of the original CRISPR-Cas9 technique," says Hagenlocher.

### SURPRISING FINDINGS THANKS TO CRISPR

The method can also be used for such things as delivering markers or proteins to specific gene locations, by deactivating the Cas9 enzyme to prevent it from cutting the DNA. Another research group led by Prof. Jörn Lausen, head of the Institute of Industrial Genetics, uses specific RNA probes to target Cas9 enzymes, for example, genes which usually control cell division and differentiation but which become misregulated in cancer. "Our goal is to identify the proteins that bind to the gene in which we are interested," Lausen explains. These could be transcription factors needed to read genes. Yet so-called epigenetic enzymes also bind to them, which add or remove methyl groups from DNA, thereby switching certain genes on or off.

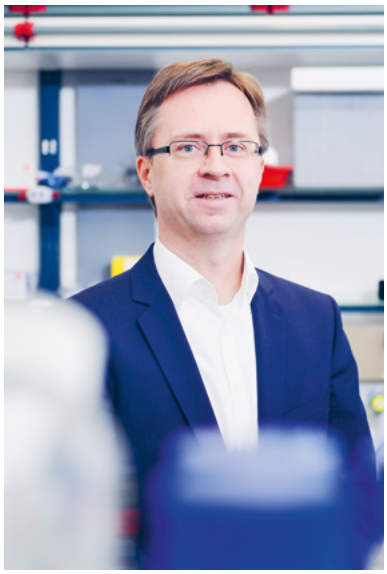
The scientists first slice up the complete genetic material of cancer cells to detect these proteins. They then fish out only those bits of DNA marked with the Cas9 enzyme from this DNA soup together with the proteins that bind to them. "If, for example, we find an epigenetic enzyme bound to a tumor suppressor gene, we could use inhibitors to reactivate the gene and inhibit the enzyme thereby forcing the cancer cell to self destruct. Inhibitors of this kind are currently being developed for clinical application around the world," Lausen explains. Basic researchers had only been able to confirm their hypothesis that protein X binds to gene Y using previous methods. "But with the →

**Prof. Albert Jeltsch**

"The benefit is that only the epigenetic markers but not the genetic material is changed."

**Prof. Albert Jeltsch has been working with gene scissors since their invention at the turn of the millennium.**

**Right: Genetically modified cell clones are isolated.**



**Prof. Jörn Lausen**

"With the CRISPR method, I can just see whatever I find."

**Prof. Jörn Lausen uses the gene scissors on cancer cells, among other things.**

→ CRISPR method," the professor of genetics explains enthusiastically, "I can just see what I can find, which is usually something I never would have expected."

Albert Jeltsch is also working on epigenetic gene regulation at the IBTB. For the first time, the biochemist now hopes to directly couple a deactivated Cas9 enzyme with an epigenetic enzyme and test it in rats in a project for which he and another Tübingen-based researcher have applied. Their objective is to target and methylate, thereby switching off, a gene that is mutated or overactive in certain patients suffering from Parkinson's disease. "The benefit," as Jeltsch explains, "is that only the epigenetic markers but not the genetic material is changed." The gene would be irretrievably destroyed using the basic CRISPR-Cas9 method and the DNA damage could even cause cell death in some cases.

### THE LEGO PRINCIPLE: COMBINE WHICHEVER BUILDING BLOCKS YOU LIKE

Fundamentally, inactive gene scissors can be used to combine any amount of building blocks, just like a set of Lego and assemble them to form completely new tools. Jeltsch and his colleague Dr. Pavel Bashtrykov, for example, have developed and patented a methylation sensor that enables the first live microscopic observations of how genes are switched on or off in individual cells during the cell division process. To achieve this, a component of a fluorescent dye is coupled with inactive gene scissors – currently the CRISPR- Cas gene scissors – and transported to the target gene site. The other half of the dye is coupled with a protein domain that is able to recognize methylation sites. Whenever the two dye components are in close proximity, they glow thus proving that a specific gene has been switched off. →

## WHERE IS CRISPR TECHNOLOGY BEING USED?

This technology has already been used in the lab to produce numerous useful plants and animals with new properties None of these organisms is currently on the market. They are also considered to be "genetically modified" within the EU and have to go through an elaborate approval process. Clinical trials are currently being conducted in humans to test CRISPR therapies for cancer, HIV, inherited blood disorders as well as for a rare congenital blindness condition. In the majority of countries, genetic modifications in germline cells that are passed on to offspring are prohibited, but a set of twins, who were genetically engineered using CRISPR-Cas were born in China in 2018, for which scientist He Jiankui and two of his colleagues received jail sentences and heavy fines.

→ Given the many possibilities, a debate on medical ethics has been raging in scientific circles for a while now. In particular, any intervention in the germline is considered to be controversial whereas gene therapies for adults for severe or previously incurable diseases are viewed in a less critical light because, as Jeltsch explains, "an unborn child cannot comment on the question whereas an adult can."

However, CRISPR technology is also raising concerns among the public: "These concerns," as Jörn Lausen reports following a panel discussion, "extend to suggesting that it might be possible to breed super soldiers who could take over the world." As co-inventor Jennifer Doudna wrote in Nature in February 2020, there are still many unanswered questions about the long-term efficiency and safety of the CRISPR process in humans. Even though the precision tool sometimes makes a cut at the wrong position, the technology is constantly being improved.

"For us as basic researchers," says Prof. Dr. Markus Morrison, director of the Stuttgart Research Center Systems Biology and head of University of Stuttgart's Institute of Cell Biology and Immunology, "this type of ethical question does not arise, as we don't cure patients or intervene in the germline of human embryos." Nevertheless, he continues, anyone who genetically modifies cell lines and animals used as model systems in research carries a certain responsibility. "Every genetically modified cell line or animal experiment requires a risk assessment and a decision by an independent ethics committee," Morrison stresses.

Whatever the outcome of the debate about the use of gene scissors on humans, Morrison is convinced that: "CRISPR-Cas is accelerating research at a tremendous rate and is set to become the next standard in molecular biology." →|

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**Prof. Jörn Lausen presents various research projects relating to stem cell biology, epigenetics and cancer research in this video.**

Prof. Markus Morrison

**"CRISPR-Cas is accelerating research at a tremendous rate and is set to become the next standard in molecular biology."**

**Top: a sugar molecule model next to a Petri plate**

**Left: Prof. Markus Morrison is responsible for the coordination of CRISPR research at the University of Stuttgart.**

# Genome editing: a voice for all

**INTERVIEW:** Helmine Braitmaier

**Curing serious diseases or creating designer babies? Social scientist André Bächtiger explains in this interview why decisions about what will be possible in future is not only a matter for experts and politicians.**

**Prof. Dr. André Bächtiger holds the professorship for Political Theory and Empirical Democracy Research at the University of Stuttgart's Institute for Social Sciences, where he is Vice Dean of the Faculty of Economics and Social Sciences and Co-Director of the Center for Interdisciplinary Risk and Innovation Studies (ZIRIUS).**

**Professor Bächtiger, as co-author of an article published in "Science", you are calling on citizens around the world to get involved in the debate on genome editing. Why is that important?**
**PROF. DR. ANDRÉ BÄCHTIGER (AB)** Stakeholders often have a limited point of view, and it is quite amazing how differently the broader masses see the world, often holding views that are inaccessible to experts because we all live in a bubble. But we can discuss the subject, which is the more democratic way to deal with such issues.

**The first global citizens' forum on genome editing is scheduled to begin shortly under Australian auspices. What is the plan for that?**
**AB** National citizen forums on genome editing already exist. The current idea is to find a minimum of 24 citizens from around the world to ensure that all perspectives on genome editing, all levels of education, religions and genders are represented. The participants will be provided with detailed information and then take part in guided discussions. The final result will be a report containing recommendations for the global public.

**How could a debate between passionate supporters and opponents of genetic engineering be successful?**
**AB** Taking the Covid-19 pandemic as an example, we were able to demonstrate in a "terra incognita project" at the University of Stuttgart that we need a mixture of views. On the one hand, it's useful to use avowed "devil's advocates" who confront one with counterarguments, which will reveal any inconsistencies in your reasoning. This is often the first step. On the other hand, you try to move people towards the center ground by using sympathetic questioning techniques such as by saying: "You all have your prejudices, all of which are perfectly legitimate, but put yourself in the other side's shoes."

**What do you think constitutes a good discussion?**
**AB** We've recently started using computer-based analysis tools to study citizens' forum discussions at the University of Stuttgart's Center for Interdisciplinary Risk and Innovation Studies (ZIRIUS),. A minimum criterion is to justify one's position, which doesn't have to be rational – a personal anecdote will do. Another necessary criterion is to listen, which entails paying close attention to the other person and engaging with their contrasting point of view. The point of a citizens' forum is not to solicit opinions, but rather to reflect upon and publicly debate them.

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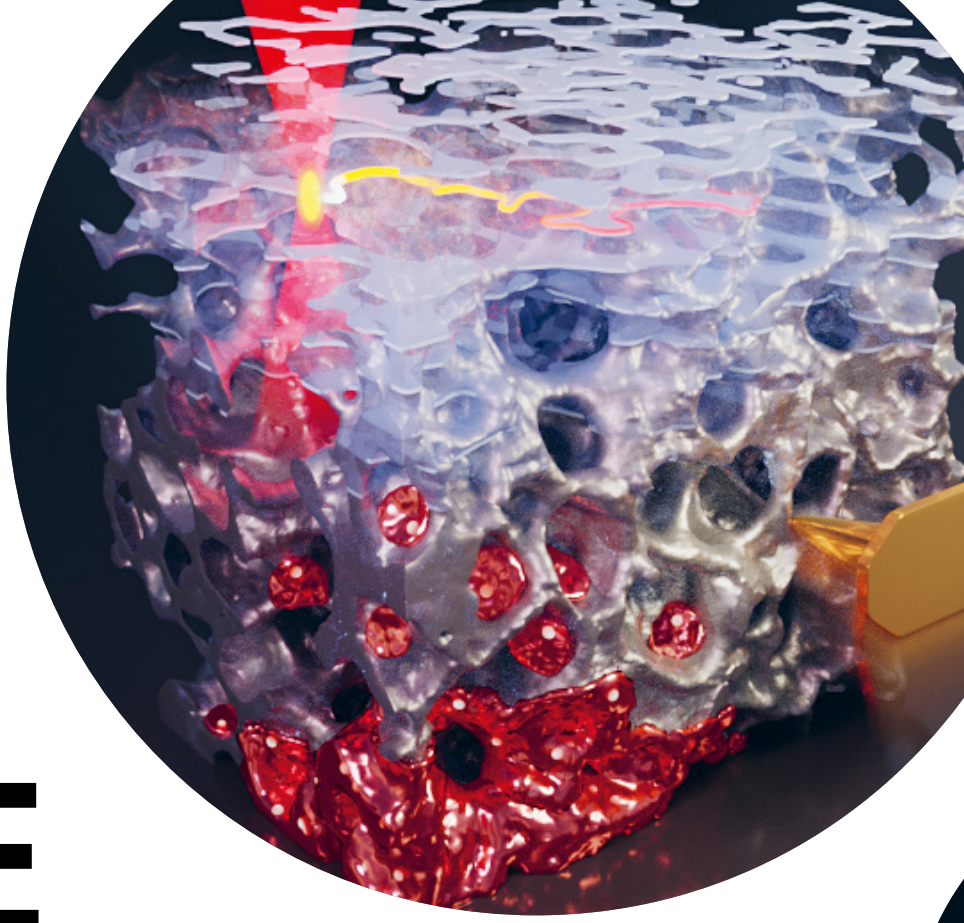

# LESS IS MORE

**TEXT:** Jutta Witte

**Experiments on animals is a controversial subject. An interdisciplinary project team at the University of Stuttgart now wants to "drastically" reduce them and render them superfluous over the long term.**

"When it comes to animal experiments, all researchers and those that commission them bear a huge responsibility," says Prof. Roland Kontermann, deputy director of the Institute of Cell Biology and Immunology (IZI). According to the German Federal Ministry of Food and Agriculture (BMEL), some two million laboratory animals were used in Germany in 2019, partly for basic research, but many of them also for preclinical drugs and compatibility testing. Binding guidelines for approving animal experiments are set out in the EU Animal Experiments Directive and the German Animal Experiments Act, based on the concept of "Replacement, Reduction, and Refinement (3R)" which puts the onus on researchers to replace animal experiments with alternative methods wherever possible, to reduce the number of animals used in experiments and to keep their stress levels as low as possible.

In the "3R-US" project, which is coordinated by Prof. Monilola Olayioye of the University of Stuttgart's Institute of Cell Biology and Immunology (IZI), various teams at the IZI as well as researchers from the Institute of Biomaterials and Biomolecular Systems (IBBS) and oncologists from the Robert-Bosch-Hospital (RBK) wish to promote these standards. Their objective is to establish a platform for cancer research under the auspices of the Baden-Württemberg 3R Initiative with a view to making technology and analytical methods based on primary tumor tissue of human beings available, which will gradually replace animal tests. A glance at Olayioye's work shows how full of preconditions these new instruments are. Her group is therefore conducting research into the complex interactions between the signaling networks of oncogenes, which promote the growth of tumors, and tumor suppressors, which inhibit it. These and other kinds of biophysical and biochemical mechanisms ensure that cancer cells cannot proliferate out of control. So it is necessary to find suitable →

**High-precision 3D printing can be used to create complex support structures (grey) and fill them with cells (red). The microstructure depicted here has about the same width as a human hair. This objective is to use this technology to reproduce tumor tissues in detail.**

**The goal, which is to render animal testing completely obsolete, is in sight**

→ areas of attack to which new active substances, which can override the relevant mechanisms and thus arrest the growth of the tumor or destroy it completely, can dock.

"If," says Olayioye, refering to the challenge with which she is faced, "we wish to test substances such as these whilst carrying out as little animal testing as possible or at some point even none at all, we will have to model the complex organism of a tumor in as realistic a manner as possible." Previous methods have only managed this to a very limited extent. The potential substance is fed directly into the cells during tests carried out in petri dishes with isolated cancer cells in a nutrient solution. This does not correspond to the normal distribution processes within the body, but, there are also limits to testing systems in which tumor cells or human tumor tissue are implanted into mice which lack an immune system where they continue to grow, as they do not represent the communication paths between cancer cells and immune cells in humans.

This is why researchers are looking for more ambitious systems, in which tumor cells can grow in three dimensions and can interact with other types of cells. 3R-US is based on three approaches: ex vivo, de novo and in silico. Ex vivo refers to a process whereby substances outside the organism are tested on tissue samples instead of individual cells. To obtain the different cell types and understand the ways in which they interact in the tissue, the team led by Prof. Walter Aulitzky at the RBK as well as experts from the affiliated Institute of Clinical Pharmacology has developed technology which enables human tissue samples, the so-called "slice cultures", to be supplied with nutrients in a continuous and controlled manner.

## TISSUE-LIKE STRUCTURES MADE FROM BIO-COMPATIBLE MATERIALS

However, because it is only possible to use this tissue once, the 3R-US team focuses on reproducing it using so-called de-novo technology, to which end they use 3D printing techniques to fabricate structures similar to the tissue made from biomaterials and cells and cultivate them in a microfluidic system – tiny chambers which enable the gradual infeed of active substances. As Michael Heymann, a junior professor at the University of Stuttgart's IIBBS explains: "using microsystem technologies such as these enables us to assemble different biological structures to model the relevant tumor as if we were using Lego blocks." The data which results from the ex-vivo and de-novo tests should also feed into creating and validating in-silico models. As a third component, it should be possible to collaborate with simulation experts to create more realistic forecasts of the dissemination of the substance.

"Filtering out the best drug candidates from ex-vivo culture systems at an early stage," Kontermann explains, "will enable us to significantly reduce the number of test animals used in the final preclinical tests." In his opinion, the use of de novo and in silico models offers a great potential for completely replacing animal experiments in the future. The scientists want to share their insights into alternative test models with other partners in the 3R Initiative. A 3R-US network spanning different institutions is set to be created over the next five years which should combine the knowledge of the university and the clinic, create synergies between expertise in biotechnology and medicine technology, and create a concept which can also be used to make students familiar with the topic at an early stage.

Whether and when animal experiments will no longer be needed, i.e. when alternative methods for testing new active substances and anti cancer drugs will be recognized as equivalent standards, is something that researchers cannot yet predict. "But," as Kontermann explains, "every step we take in projects such as this one will bring us a bit closer to our goal." ↠

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Photos: Florian Sterl/Sterltech Optics/University of Stuttgart/IBBS, GettyImages

# WORKS OF LITERATURE FOR

**TEXT:** Daniel Völpel

**Several institutes at the University of Stuttgart and the German Literature Archive (DLA) Marbach are collaborating to find ways to make literary research and web-based literature permanently usable on a digital basis.**

The task only sounds underwhelming at first glance: A team consisting of members of the University of Stuttgart's departments of literary studies, computational linguistics and computer science is planning to set up a database known as the Science Data Center for Literature (SDC4Lit) for literary studies, which researchers believe will be useful for their future work: "The great thing is that it is an attempt to think about and combine research and infrastructure," explains Sandra Richter, director of the DLA and professor of modern German literature at the University of Stuttgart. "The main question concerns the data and format in which literature should be recorded to make it useable. And this question is not new. In light of digitalization, it is now possible to answer it in a very specific way."

Because works of literature are now created on computers and published on digital platforms, the objective of the SDC4Lit is to provide a platform on which they can be researched. It first has to record and archive the texts in question, which researchers will then be able to evaluate using intelligent, digital tools. The results are to be made available to researchers and the public via the SDC4Lit. The state of Baden-Württemberg is funding the project with 1.8 million euro.

"Ideally, we will store text documents in a fully searchable format. The question is what data does one record to do this?" explains Richter. This goes far beyond the place and year of publication and the name of the author. When it comes to authors in exile for example one might wish to know about the history of the text, where it came from, or how much it sold for at auction? More such text-related metadata can be archived in digital format than used to be possible in library index cards. "The relevant data could be continuously expanded for researchers to work on and generate their own analyses based on the metadata," Richter explains. For example: "What is known about the provenance of a given text? What about similar texts? Could more general conclusions be drawn from this?" The larger the corpus, the broader such questions could be.

The relevant software and storage systems have already been chosen, says the researcher about the status of the SDC4Lit, which was launched in 2019. "We can now start to upload the texts." The objective is to establish concepts for working with the texts by the end of the project in 2023. "In doing so we are working in completely unchartered waters," says Prof. Michael Resch, head of the University of Stuttgart's High Performance Computing Center (HLRS) and the University's Institute for High Performance Computing. This is because the metadata pertaining to literature differs from the technical data with which the HLRS usually works. →

# VIRTUAL ETERNITY

**Prof. Sandra Richter is Director of the DLA Marbach and Professor of Modern German Literature at the University of Stuttgart.**

**Prof. Michael Resch is head of the High Performance Computing Center, Stuttgart (HLRS) as well as the University of Stuttgart's Institute for High Performance Computing.**

→"When I refer to a flow simulation or something of that nature, it usually involves technical parameters that have been standardized within the research community for many years," Resch explains. "When it comes to pure library research, it would be similar in literature. But, rather than digitizing books, what we want to do is to map a creative process that doesn't follow standardized norms." Resch's team provides the means to store digital data for the next 20, 30 or 40 years, as well as the information management know-how.

To explain the features of this terra incognita, Resch uses the origins of literature as an example: "For example," he says, "one can view the original manuscripts of Franz Kafka at the DLA. One can see that he's crossed out a word and replaced it with another." In the case of digital literature, one is faced with an infinite process of change; the author can modify the text every day. "It's about recording a creative process and deriving something from it that I can use in the following creative process."

## PERFECTLY MATCHED PARTNERS

As Richter explains, the fact that DLA and HLRS are partners within the SDC4Lit is extremely beneficial: "Both institutions have the capacity to host infrastructures such as these on a long-term basis and make the data available to the research community, which will then be able to use it." Something similar, he adds, is planned in projects being run by the German National Research Data Infrastructure (NFDI), which is planning is to make all German humanities data accessible, networked and permanently utilizable. It will initially provide funding for these projects, but the plan is for them to continue independently over the long term. The major German humanities institutes are currently applying for this funding as part of the "Text+" consortium and plan to digitize language and text data from various collections, editions and lexical resources. "I could imagine the SDC4Lit participating in this," says Richter. The DLA, which maintains one of the most important libraries for German-language literature and literary studies, could eventually upload its holdings to the NFDI project. If the development of the digital sphere continues at an extremely fast pace and partly replaces analogue resources, we will have to provide whatever resources we can provide. Our resources are finite of course, but our core mission encompasses this very area and therefore everything that is created in the digital space." ↠

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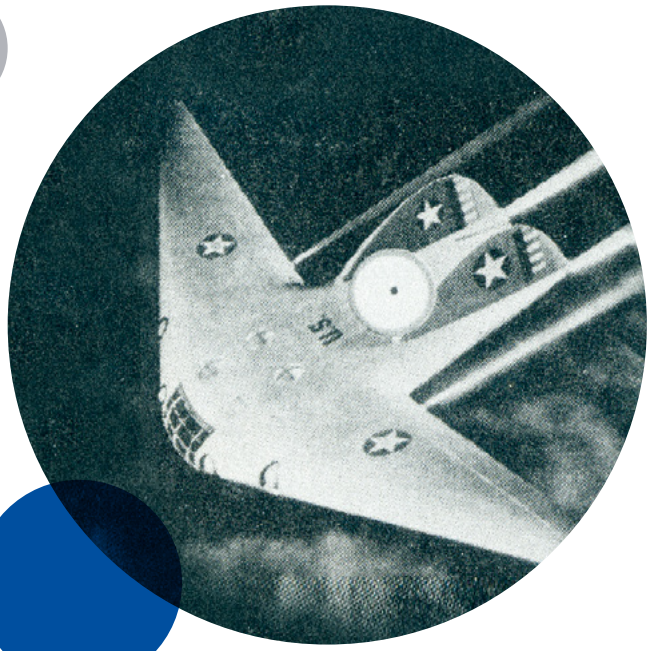
Photos: David Aussenhofer, University of Stuttgart/Uli Regenscheit



Top: Excerpt from the Lehrbuch der Technischen Kernphysik (Textbook of Technical Nuclear Physics) by Hugo Watzlawek, which he completed in late 1943

Right: Even after atomic bombs had been dropped, people were still dreaming of the many potential applications of nuclear energy, for example, as aircraft engines, as seen here in a 1945 edition of Newsweek magazine.

# Nuclear physicists under National socialism

**TEXT:** Michael Vogel

**A recently discovered document from 1944 reveals the mindset of a nuclear physicist scientist who failed to reflect upon the responsibility of his actions.**

It was a matter of pure chance when Prof. Klaus Hentschel of the University of Stuttgart was looking through a cache of bequeathed documents in 2019 and came across a typewitten document entitled “Interatomic Energy,” written by Hugo Watzlawek in 1944. “The document provides an unfiltered, amazingly knowledgeable, but in many ways also frightening insight into the technocratic conceptual world, knowledge level and the horizons of application of a Third Reich 'technical nuclear physicist',” says Hentschel, who heads up the History of Science & Technology at the University of Stuttgart’s Institute of History. Half a year before the end of the war, Watzlawek had still been sending emphatic requests for “further funding for nuclear research and for the development of nuclear weapons.” His request was rejected. →

→ Experts have long debated the ability of Hitler's Germany to build an atomic bomb. What is certain is that when Hiroshima was bombed in 1945 key figures in the Uranverein, which was founded in Berlin in 1939, had no idea how such a bomb could be made. "Yet, Watzlawek's remarks contradict the myth of a conscious reluctance on the part of German nuclear scientists to use nuclear energy for military purposes that took hold after 1945," says Hentschel, who goes on to say that Watzlawek's type-written text demonstrates an astonishing amount of detailed knowledge of physics and technology.

## THE SEARCH FOR FUEL FOR A LONG-RANGE BOMBER

He knew, for example, that reflector walls in a bomb are required to keep the critical mass, i.e., the minimum mass above which a chain reaction will start, low. He also gave a clear description of the Allies chosen method of bouncing two halves of the bomb off one another to prevent it from reaching critical mass until detonation. Whist Watzlawek failed to provide any quantitative data on the subject, the applications in aircraft engines and rocket warheads to which he referred demonstrate that he expected a few kilograms rather than tons. "By that time," as the historian explains, "he had already been involved in the search for a nuclear fuel for long-range bombers for a number of years, and had been carrying out research at the Henschel Flugzeug-Werke since 1940." "In his document, Watzlawek listed countless applications for nuclear energy, the majority of which were military, which he almost appeared to be longing for, than civilian."

He was born in Austria in 1912: his father was the manager of a grinding plant close to Innsbruck. He graduated from high school with honors in 1930 and went on to study "Technical Physics" at the Vienna University of Technology, graduating five years later with a degree in engineering. He had already taken an interest in nuclear physics before the outbreak of the war and, whilst not being ideologically close to National Socialism, was a national conservative. His application to the US Army Ballistic Missile Agency was turned down in 1957 although the vetting report stated that he was "neither a war criminal, nor an enthusiastic Nazi."

## SCIENCE WITHOUT ACCOUNTABILITY

Watzlawek published his Lehrbuch der Technischen Kernphysik (Textbook of Technical Nuclear Physics), which he had already written during the war, in 1948. "Neither in this work nor in his Darstellung des Lebenswerks (My Life's work), which he published as part of his doctoral dissertation in 1950, does one sense in any sense of remorse, reflectiveness, or doubt about his own actions before 1945," Hentschel reports. "He is an example of an attitude that was widespread at the time that one only wanted to further technology or simply carry out science without being disturbed." Those that held this view either did not notice or did not want to notice that their actions were supporting a criminal system. "Even his 1948 textbook," says Hentschel "inlcudes a statement to the effect that whoever solves the problem of nuclear energy will be master of the world."

Although he tried several times, Watzlawek never worked in nuclear physics again after the war but continued lecturering at the Bundesgewerbeschule Innsbruck (now known as the HTL construction and design or HTL Bau und Design Innsbruck) until he retired. He died in 1995.

"What his document shows is that there was more than just the Uranverein in applied nuclear physics in Hitler's Germany," Hentschel explains. "Watzlawek maintained a very different network of contacts to the aviation industry, the German Ministry of Aviation, and the Berlin, Munich, and Vienna Universities of Applied Sciences." It was this distance to the Uranverein that accounts for the few blind spots in his manuscrpt. "On the other hand," Hentschel explains, "Watzlawek's document covers quite a few points that were either inadequately considered, or not considered at all, in the work of the Uranverein." ↠

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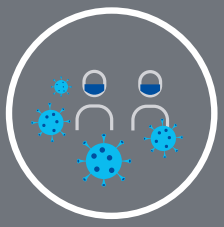
Photos: Deutsches Museum, München, Archive, FA-002-752_0008, Newsweek

# RESPONSIBILITY IN STATISTICS

"Not only does the University turn students into outstanding experts in their specific fields of study, it also molds them into responsible citizens who think on a global level with an inclusive attitude towards science, society, and business." This statement is included in the University of Stuttgart's mission statement. This mission not only forms a core aspect of the research and teaching carried out at the University, but also in the administration and numerous departments, initiatives and groups involved in University life as well as in wider society. It provides support for families, refugees and victims of the Covid-19 pandemic, as well as providing young people with a professional future, ensuring diversity and taking an active part in sports, music, culture and more. The following are just a few examples:

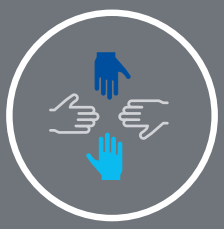
## The stuvus student council includes over 300 Covid-19 helpers



who are providing support for people in need during the pandemic. In collaboration with the Arena2036 research campus, they have produced protective visors and are playing an active role in the German Red Cross, the Stuttgarter Tafel and in public health departments as well as providing care to students in quarantine.

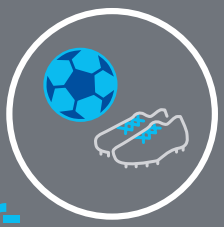
## 91 University groups are currently

are taking part in debates, providing development aid, making music, promoting protection for the environment, exchanging ideas with students from around the world, and helping to shape university policy ... All of this and much more is being done by the 91 University of Stuttgart groups.



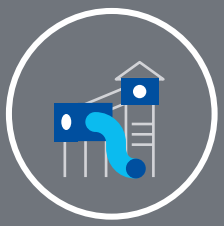
## 7 diversity foci

Work at the University of Stuttgart is characterized by equal opportunities, equal rights and diversity. Our diversity concept covers gender, life style, age, health, social origin, nationality & culture as well as professional focus.



## The University Sports Department

offers around 200 sports courses, including everything from gymnastics and yoga to underwater rugby, Frisbee and the recently developed Jugger. every semester for both students and employees.



## 124 day nursery places

for babies and kindergarten children are available to University of Stuttgart students in addition to 32 places for the children of employees.

## 60 trainees

The University of Stuttgart also takes responsibility for the professional development of young people following their studies: There were 60 trainees in 14 apprenticeships at the end of 2020.

# WE NEED TO TALK

**TEXT:** Jens Eber

**Construction techniques have to become more sustainable and cost effective in the future. To fully exploit these goals in its research activities, the University of Stuttgart's Integrative Computational Design and Construction for Architecture Center of Excellence (IntCDC) is using a novel interdisciplinary method known as socio-technical research integration.**

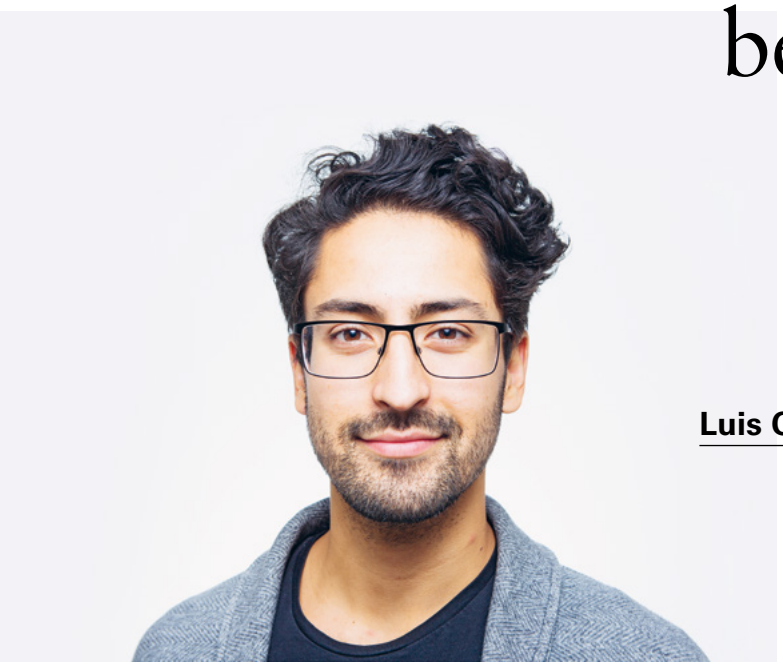
Like few others, architecture is a discipline whose results remain visible to the public throughout many generations. It can foster a sense of identification or friction, but barely leaves anyone unmoved. With this in mind, the IntCDC, in which 120 scientists from the University of Stuttgart and the Max Planck Institute for Intelligent Systems are collaborating in various research projects, is taking an interdisciplinary reflection approach. The objective of the "socio-technical integration research" project STIR) is to help make the building of the future ecologically, economically and socially sustainable, even during the research phase. The fact that friction also arises in the course of this is definitely desirable.

Luis Orozco, a doctoral student at the Institute for Computational Design and Construction (ICD), is currently working on novel approaches to timber construction with a view to being able to prefabricate multi-story buildings in a modular fashion. During his work over the past few months, the architect has not only met professional colleagues and researchers from computer science and engineering, but has also met with Deniz Hos of University of Stuttgart's Institute for Social Sciences once a week. He and Orozco are looking into individual research stages in terms of their ethical, legal, social and even ecological consequences.

"Architecture and construction have a bearing on many different aspects of life as well as people," Orozco says. Through the STIR process it is becoming possible to bring the view of the different perspectives and ramifications into focus, for example in terms of the concerns of workers within the construction industry.

During the STIR project, Hos and Orozco met up almost every week throughout a three-month period, during which time they talked about the assumptions upon which Orozco's research was based and existing connections to the major social challenges of today. The aim of such a process is to identify possible consequences of technological development - both desirable and undesirable - at an early stage and to compare them with societal expectations. Hos emphasizes the fact that socio-technical integration is not only an accompanying factor of the respective research but rather helps shape →

# “Knowledge transfer can be difficult.”



**Luis Orozco**

Architect Luis Orozco is currently completing doctoral studies at the Institute for Computer Design and Construction (ICD).

**Deniz Hos**

“If we didn't clash, we wouldn’t be able to move forward, so friction is built in.”

Deniz Hos is a research associate at the University of Stuttgart’s Chair of Sociology of Technology, Risk and Environment.

**Prof. Cordula Kropp**

# “We ask a lot of critical questions, which the subjects try to answer.”

→ it. Social issues and concerns are therefore a component of scientific and technical endeavors right from the start.

“Our assumption,” explains Prof. Cordula Kropp of the Chair of Sociology at the Institute of Social Sciences, whose main research focus is on risk and technology, “is that rather than being predetermined, here is room for decision-making in respect of technological developments at many points along the way.” However, she continues, this leeway is often only used unconsciously or with a view to achieving the most cost-effective outcome, as a result of which, opportunities for shaping future developments in a more sustainable and responsible manner are neglected. The discussion protocols developed as part of the STIR process, not only make such options evident, but also exploitable.

Prof. Achim Menges of the ICD is also convinced of the benefits of this approach: “As far as the Cluster of Excellence is concerned,” he says, “raising awareness of the multiple aspects that need to be integrated is the most important thing .” STIR, he goes on to say, clarifies how broad or narrow the view of the individual researcher has been thus far and what other perspectives could be taken into account, which, according to Menges, “is a very valuable contribution.”

## THE VIEW BEYOND SCIENCE

Menges believes that the IntCDC Cluster of Excellence’s decision to adopt an approach based on interdisciplinary discussion protocols is a very good one: the cluster includes researchers working in everything from architectural history, materials science and civil engineering to robotics and the social sciences. On the one hand, he continues, the socio-scientific approach to socio-technical research integration could sensitize those concerned to the priorities of certain topics in specific phases. On the other, it may be possible to look beyond science and to recognize the consequences of research decisions that are otherwise taken without much thought. →

→ "One of our issues," Luis Orozco explains, "has been that the subject matter is so complex that even within the same field of research, knowledge transfer from one working group to the next can be difficult." He was able to test the transfer of knowledge within two groups of master students via STIR: "Our goal was to communicate the timber construction system we are developing in as simple a manner as possible to enable us to transfer the knowledge in the optimum way."

The STIR processes approach is fundamentally open-ended as Prof. Cordula Kropp emphasizes: "We ask a lot of critical questions, which the subjects try to answer. Yet, it is not possible to for any given discipline to lay down the rules for another."

Nevertheless, as Deniz Hos adds, a certain level of conflict is definitely desirable as part of the discussion process: "If we didn't clash, we wouldn't be able to move forward, so friction is built in." In the two projects in which Hos has been involved, he says, the level of communication was so good that he was able to ask pointed questions without being met with any personal resentment. "I was also able to actively follow up whilst still always feeling as if I was adding value in doing so."

Friction, he goes on to explain by way of example, arose when it came to certain aspects, such as ethical issues or access to building materials, which did not have the highest priority from an expert perspective in terms of technical development. "The reason the IntCDC project seemed appropriate for us," says Cordula Kropp, "was because it is such a radical, disruptive innovation that could fundamentally change traditional construction approaches."

It's about changing architecture, which involves more than just architects," Achim Menges agrees. In his opinion, everyone and everything, such as social science issues or historical reflection involved in the complex creation of buildings such as these should be taken into account. According to Menges, it is still too early to draw any final conclusions from the process, although he hopes that the STIR process will be used on an even broader scale within the Cluster of Excellence. ↠

**Prof. Achim Menges**

"It's about changing architecture, which involves more than just architects."

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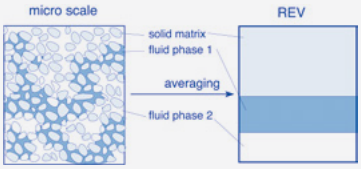
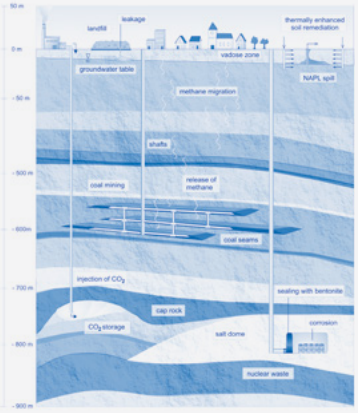
Photos: p. 51 University of Stuttgart, pp. 52-53 Uli Regenscheit

# THE BENEFIT TRANSPARENT MODELS

**TEXT:** Jens Eber

**Where science and politics meet: three researchers have shown just what models and simulations can achieve in an interdisciplinary study.**




**Top: Calculating the average – the transition between microscale and REV scalants**

**Below: schematic representation of selected subsurface gas-liquid flow problems**

As well as being a researcher at the Stuttgart Centre for Simulation Science (SimTech) Cluster of Excellence, engineer Holger Class is a professor at the University of Stuttgart's Institute for Modelling Hydraulic and Environmental Systems (IWS). However, to exemplify his reasons for believing that excellent computational models and simulations are important, he first points out the example of the Covid-19 pandemic. Ever since the virus started spreading out of control, German politicians have largely based their decisions on the opinion of scientific experts. What troubles Class, however, is that there are no reliable models for this specific pandemic. "If we knew the relationship between the relevant factors," he explains, "we'd be able to get through the pandemic in a much smarter way."

Class' work at the IWS and beyond is based on precise, scientifically sound computational models and simulations that are based on them. He, Prof. Bernd Flemisch another SimTech researcher, and Dr. Dirk Scheer co-authored the book "Subsurface Environmental Modelling Between Science and Policy", which was published in 2020. The book addresses the interface between science and policy from a bedrock modeling perspective.

A lot of basic research is carried out in this field of science on such things as the impact of fracking on bedrock and how to remove carbon dioxide from the atmosphere and sequester it underground. The elaborate experiments and complex computational models involved are usually carried out in scientific seclusion. In this case, however, there was a lot of public attention on the task, as fracking and $CO_2$ storage were the subject of intense public debate within Germany.

## A CONTRIBUTION TO DECISION MAKING

However, even when it comes to these politically sensitive topics, he goes on to say, science had not been influenced from the outside. "I've never felt like I had to deliver what people wanted to hear." Researchers could have contributed to the decision-making process instead. According to Class, the problem is more about the fact that political decision-makers barely have the time to read the results of what is often many years of research thoroughly.

Bernd Flemisch's main focus is on the development of computational models at the IWS. While co-authoring a book with his colleagues Class and Scheer, however, he also put a lot of thought into how to improve the interfaces between science, society and politics. "To make a difference, we would ideally need →

# FOR OF SOCIETY

Prof. Holger Class, Prof. Bernd Flemisch and Dr. Dirk Scheer (from top to bottom) have been collaborating on a joint research project on the interface between science and politics based on modeling bedrock and have published a book on the subject.

→ complete transparency," he says. What this means in his own field of research is that software programs and other data would have be freely available and reusable. "Research processes that are not comprehensible don't really function as a font of knowledge."

## SIMULATIONS AS A BASIS FOR PUBLIC DISCOURSE

In his capacity as a social scientist, Dirk Scheer has been involved in environmental and sustainability research for some 20 years. He has been in contact with researchers at the IWS since 2008. In their book, Class, Flemisch and Scheer discuss the detail of how knowledge is processed by politicians and administrators. "Research has its own logic; it has to do with the attempt to generate knowledge even about things we don't know about," says Scheer, a researcher at the Institute for Technology Assessment and Systems Analysis (KIT). Yet, it is precisely the understanding of knowledge gapst that politics finds difficult to deal with, although it is also important for researchers to put more thought into crossing disciplinary boundaries. "It's about gaining a better understanding of others without having to follow them," as Scheer explains.

During their background research, Class and Flemisch, both whom work together at the Interface-Driven Multi-Field Processes in Porous Media – Flow, Transport and Deformation Collaborative Research Center (SFB 1313), have come to recognize the added value of high-quality simulations. "The great thing is that simulations can help to make a distinction between important and unimportant things," Class explains. On the other hand, he goes on to say, this is the least that a simulation model must be capable of. However, he adds, everyone involved should also recognize what models can actually achieve as well as the purposes for which simulations can be used. In his contribution to the book, Scheer works on the assumption that models and simulations are suitable for two purposes: to make tangible something as abstract as future developments, and to form the basis for public discourse. ↠

**"Research processes that are not comprehensible don't really function as a font of knowledge."**

**PROF. BERND FLEMISCH**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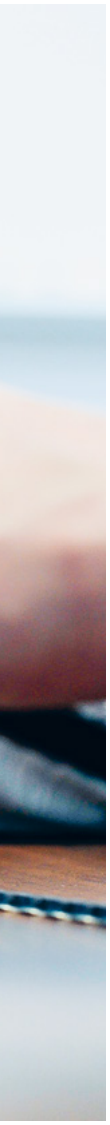
Photos: University of Stuttgart/SFB 131, University of Stuttgartt/SimTech, Barbara Lubienski
Graphics: Scheer/Class/Flemisch: Subsurface Environmental Modelling Between Science and Policy

# Increasing security by pointing out insecurities

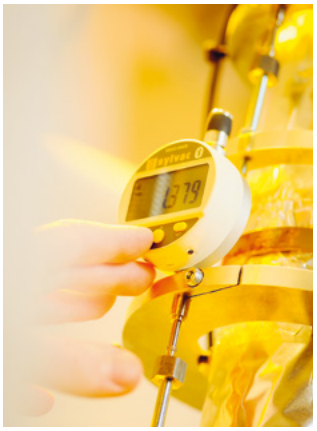
**TEXT:** Sabine Sämisch / Andrea Mayer-Grenu
**PHOTOS:** Max Kovalenko

**It is extremely difficult to forecast the very distant future such as a million years from now. Yet this is exactly what the long-term safety analyses for nuclear waste repositories requires.**



**Left: Concrete, plastic and more – the material models used in the project can describe a wide variety of substances.**

**Below: a radio-signal-controlled gauge on the test bench**



Dr. André Schmidt

**"Generally speaking, this branch of science is not well known."**

A million years – that's the period of time that underground radioactive waste repositories are supposed to be safe for according to the German Repository Site Selection Act (StandAG). Those areas in Germany that may be used as nuclear waste repositories were made public in the autumn of 2020: there are 90 locations, including salt mines, clay layers or granite, that are suitable in principle from a geological perspective. The first radioactive waste containers are to be deposited starting in 2050, but how can these storage sites really be hermetically sealed over such a long period of time

when even the most suitable geological formations, in which the underground repositories will one day be placed, contain cavities. The idea based on current state of technology is to use concrete closure systems – so-called dams and plugs – to seal them off once the nuclear waste has been deposited. However concrete is a new material that has only been around since the 19th century; nobody knows if it is really suitable for sealing mineshafts or how it will behave throughout a million years. Will the concrete remain stable? And what impact will geological effects and other influences have?

To answer these questions, the University of Stuttgart's Institute for Nonlinear Mechanics (INM), Materials Testing Institute and the Gesellschaft für Numerische Simulation (GNS mbH) have joined forces in the collaborative ProVerB research project. "Predictive tools for the mechanical behavior of concrete over long periods of time for the safety analysis of closure systems for nuclear waste repositories" (ProVerB) research project. This project, which has been approved by the German Federal Ministry of Education and Research (BMBF), is receiving close collaboration from the German Federal Company for Radioactive Waste Disposal (BGE). The core competencies of the applicants include conceptual, mathematical and numerical material modelling with a focus on models with so-called "fractional coefficients" for viscoelastic materials. "Generally speaking, this branch of science is not well known," as project leader Dr. André Schmidt from the INM explains: "Using fractional coefficients to describe long-term deformation behavior opens up new function classes that are particularly well suited to long-term modeling."

## TRADITIONAL METHODS OF ESTIMATION DO NOT WORK

The currently expected service life for conventional concrete structures is 30 to 50 years. Empirical criteria and, where appropriate, regular inspections are used for verification purposes. "However," as Prof. Kai Diethelm explains, "traditional approaches cannot be applied to the temporal scale that needs to be taken into account to estimate the long-term safety of nuclear waste repositories. new methods need to be developed." In addition to his work for the GNS, Diethelm holds the professorship for mathematics and applied computer science at the University of Applied Sciences Würzburg-Schweinfurt, which is also participating in the project.

The researchers are developing a simulation technique based on the finite element method within the context of the ProVerB project, which will then be able to be used to simulate any scenario providing that the behavior of the material in question can be measured, described, and numerically mapped. Certain clearly defined assumptions have to be made to demonstrate the long-term safety required by law. "One first has to consider non reinforced concrete," says Schmidt explaining the scenario established for the prediction: "so not reinforced with steel, in a static mineshaft, i.e., assumed to be invariable over time. Under these conditions, we study the behavior of the sealing structure over long periods of time."

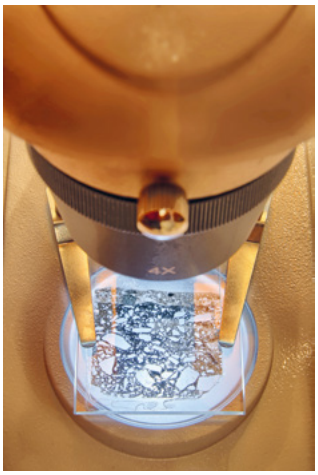
This is where the question arises as to the certainty with which statements can be made about whether the nuclear repository will remain sealed or not. Schmidt puts it more precisely: "The broader question is what knowledge would one need to rule out failure with a reasonable degree of certainty under the given assumptions?"

To answer this question, the project partners also called on the expertise of a team led by Prof. Wolfgang Nowak Director of the Institute for Modelling Hydraulic and Environmental Systems (IWS). and Head of Research at the Simulation Technology (SimTech) Cluster of Excellence, who also holds the Chair of Stochastic Simulation →

# The end goal of this interdisciplinary project is to have a flexibly applicable simulation tool for use in long-term analyses.

**Left: Project manager Matthias Hinze explains how the test stand, with its integrated concrete test specimens, works.**

**Right: The ProVerB project is headed up by Dr. André Schmidt of the Institute for Nonlinear Mechanic.**



**Peering into the interior of the material under examination**

→ and Hydrosystem Safety Studies. Nowak specializes in data-integrated simulation, uncertainty and reliability analyses, and optimized experimentation design. Uncertainty analyses are required for the prediction of the complex long-term behavior of concrete. To date, simulation models have been used in the evaluation of long-term experiments lasting up to three years, but this approach is far too uncertain for predictions of periods of thousands of years. "This is why we record the tiniest uncertainties when analyzing the experiments to enable us to quantify the remaining uncertainties within the prediction mode in an extremely precise manner," Nowak explains. The question then focuses on the size of these uncertainties: what level of certainty (i.e., probabilities converging 100 percent) could be achieved by tripling or quadrupling the safety factor? And could long-term experiments of five to ten years reduce the uncertainties and the associated risks?

## BIG GUNS

"The good thing is that most simulations are one- or two-dimensional," Nowak explains: "this provides optimal conditions for the calculations, simulations and uncertainty analyses, because the individual calculations can be carried out extremely rapidly in just milliseconds to a few seconds, at least for the very simple cases." This enables the researchers to use elaborate methods that would otherwise not be feasible because they would require months, if not years, of computing time. Normally, a model reduction always has to be made for tasks such as this. "But in this case," Nowak explains "we can bring out the big guns, in other words statistical methods that require millions of simulation runs, and with no upstream model reduction, which means that we can use rapid models to test out all the things we're researching in SimTech and other projects for slower, larger simulations."

The end goal of this interdisciplinary project is to have a flexibly applicable simulation tool combined with a methodology for measuring uncertainties for use in long-term analyses and from which recommendations could be derived for such things as the duration of long-term experiments to exclude any potential failure of the closure system with a sufficient degree of certainty. →|

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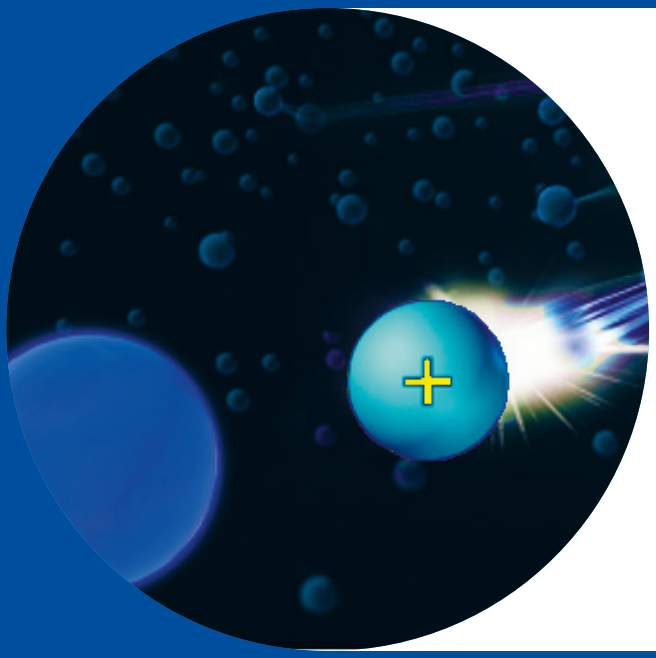
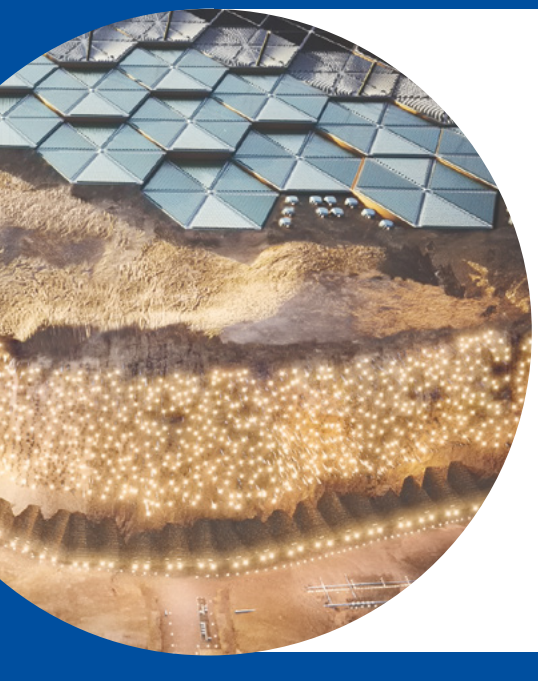
Photo: S.59 University of Stuttgart / INM

# NOTEPAD





## SELF-SUFFICIENT LIFE ON MARS

A team of experts known as “SONet” (Sustainable Offworld Network), which includes Dr. Gisela Detrell of the University of Stuttgart’s Institute of Space Systems is currently looking into how humans could survive on Mars. The life support system for the city “Nüwa”, which she designed, is intended to support a million people at some point in the future.

The concept study for Nüwa was based on a city that is not only sustainable, but would also be able to expand and grow with no support from distant Earth,. whereby the life support system is a key element. The main food source of Nüwa would include agricultural modules in which plants and microalgae would be cultivated in addition to insects and meat from cell cultures. Plants and algae would also ensure that the air would be recycled, by using the carbon dioxide produced by humans and producing oxygen through photosynthesis. Just as on Earth, plants would need light for this, which on Mars, which is very distant from the sun, would comes from energy-efficient LEDs.

For more information and a video please visit: https://www.uni-stuttgart.de/universitaet/aktuelles/presseinfo/Nachhaltig-bauen-auf-dem-Mars/

## USING LASERS TO CREATE ANTIBACTERIAL SURFACES

Deposits in the filling systems used in the food industry or in household appliances, such as washing machines and dishwashers, cause damage and can even lead to ill health. This problem can be addressed through the use of ultra-short laser pulses during the production stage, which have an antibacterial effect on the surfaces in question. This is the finding of TresClean, a three-year EU research project, in which the University of Stuttgart’s Institut für Strahlwerkzeuge (IFSW), the University of Parma and five other European research institutes and industrial partners participated. The University of Stuttgart was tasked with using lasers to increase the productivity of surface structuring to the point that it can be integrated into the industrial manufacturing processes of the relevant components.

Photos: ABIBOO Studio/SONet, University of Stuttgart (ITFT, IKTD, PI 5/Celina Brandes)

## THROUGH THE PARTICLE CLOUD WITH A POSITIVE CHARGE

There are still many unsolved mysteries surrounding the transport processes in matter A research team led by Florian Meinert at the University of Stuttgart's 5th Institute of Physics has developed a new method which for the first time, enables the observation a single charged particle as it moves through a dense cloud of quantum particles. The results were published in the renowned journals Physical Review Letters and Physics.

The team used a so-called Bose-Einstein condensate (BEC) to achieve their results in which they used sophisticated laser technology to prepare a single Rydberg atom. The outermost electron in this large atom is only weakly bound to the nucleus, which meant that the researchers were able to capture it from the atom using a special sequence of electric field pulses, thereby transforming the previously neutral atom into a positively charged ion, which is then pulled through the BEC'S dense atomic cloud in a controlled manner using electric fields. The ion accelerates during the process colliding with other atoms along the way, before being slowed down and reaccelerated by the electric field. The scientists were able to use this interplay between acceleration and deceleration to move the ion through the BEC in a constant motion in a targeted manner.

## AUTONOMOUS DRIVING COMFORT

Reading or even sleeping whilst driving in a car but still being ready to take control of the wheel in an emergency – the possibilities and requirements for drivers and passengers will change as soon as highly automated vehicles first appear on the road. The Institute of Engineering and Industrial Design is carrying out a number of projects to investigate what the vehicle interior of the future will have to look like if it is to continue to guarantee comfort and safety. Under the auspices of the RUMBA consortium, the Faculty of Industrial Design Engineering, for example, is developing new concepts for car and truck interiors with such things as seating groups and office workstations. The researchers are also looking into how to adapt vehicle dynamics, for example to prevent passengers from spilling their coffee whilst accelerating. Using Ingolstadt as an example, the Faculty of Interior Design Engineering is collaborating in the SAVeNoW consortium and is using a digital model of urban traffic to simulate how the design of the vehicle interior might influence traffic behavior.

## NODES MODELED ON NATURE

Buildings with a support structure of branched columns are creating light open spaces. This method is mainly used for representative buildings such as halls, but also for bridges in which slender ramified load-bearing elements are enabling aesthetic constructions that conserve resources and bear enormous loads. The technical challenge involved in columns of this type is the structural node between the straight bars as this is subject to complex forces.

To overcome the limitations of earlier steel construction methods, an interdisciplinary research team from the University of Stuttgart and the German Institutes of Textile and Fiber Research has developed a new structural node and the corresponding manufacturing process, which consists of a composite component comprising a shell of fiber-reinforced plastic and a concrete core. The component was developed at the DFG-funded TRR-141 Biological Design and Integrative Structures Collaborative Research Center in collaboration with the University of Freiburg.

# Smart cable assembly

Hope for automation: the prototype produced by fhe "DataCon" project, which was funded by the DGF is intended to demonstrate the potential of data-integrated simulations based on the example of cable loom assembly.

**TEXT:** Jutta Witte

**The task of IC SimTech is to introduce complex manufacturing processes developed by theData-Integrated Simulation Science (SimTech) Cluster of Excellence (SimTech) to industry: this industrial consortium sees itself as a bridge between basic research and industry:**

Prof. Alexander Verl is head of the Institute for Control Engineering of Machine Tools and Manufacturing Units.

Markus Wnuk is a researcher at the Institute for Control Engineering of Machine Tools and Manufacturing Units.

A glance inside a car's chassis will reveal a disorganized collection of long cables. As Markus Wnuk, a scientist at the University of Stuttgart's Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW), puts it: "What we see here is a very unstructured scenario, which is a bad starting point for automation." That is why, even now in the Industry 4.0 era, cable looms are still laid out and fitted within the vehicle entirely by hand from unpacking the bag in which they are delivered to the final fitting. "What makes automation difficult," the expert explains, "is the huge number of variants, as no cable loom is manufactured twice."

This is due to the enormous number of components and assembly operations, the very small contact systems, but above all the material. Cables are flexible and easily deformed; they get twisted up, form loops and change shape whenever they are touched. To be able to automatically assemble components such as these in spite of all this, researchers at the ISW are collaborating with scientists from the SimTech Cluster of Excellence to develop new approaches, which will make it possible to combine existing sensor data and new simulation technologies, the aim being to integrate the real-time simulation of a machine and its control system thereby optimizing production processes as they happen.

## MONITORING DEMAND

Their research is being received with open arms within the industry. Programming a mobile robot to perform complex manufacturing processes autonomously is a challenge, particularly as production environments are becoming more dynamica and products increasingly customized. "The psychological pressure is high," says Prof. Alexander Verl Director of the ISW. As head of the "IC SimTech" industrial consortium, a spin off from the cluster, Verl is committed to the transfer of new know-how to industry and to close collaboration with potential users. Data-integrated simulation science, he says, is booming. The evaluation, automation, optimization and visualization of manufacturing processes based on data produced by the machines themselves are all high on the agenda of research funding bodies and industry stakeholders,

which makes it all the more important to ensure that developments meet demand. As a bridge between basic research and practical application, the "IC SimTech" not only wants to provide information about the new methods and models, but also to actively promote their application in industrial practice. Among other things, the consortium organizes bilateral projects with regional, national and international industrial partners, and provides support for PhD students and postdocs in collaborating with industrial partners and encourages them to use their ideas for start-ups.

## DISCUSSING CURRENT RESEARCH TOPICS

"We want to keep companies updated on our research, but we also need their feedback to ensure that our research assumptions are realistic," Wnuk explains. As a member of the "DataCon" project, which was launched in 2020 and is funded by the German Research Foundation (DFG), the engineer is currently working on another important building block for the transfer of knowledge, a prototype, whose first use case, specifically addresses the assembly of cable harnesses, to demonstrate the →

# The completion date for the prototype is 2023 and it will be used at trade fairs and other events.

**It looks easier than it is: the robot is supposed to learn to accurately locate a deformable object, such as a cable, and then to grasp it with the aid of control software.**

→ potential of data-integrated simulations and to boost SimTech's profile among the manufacturing industries. This will cater to the needs of interested companies, especially in the automotive industry.

The objective for the production model is to demonstrate how data from the simulation, which is continuously updated in the manufacturing process, can be combined with the recorded data from the machine to control an industrial cable assembly robot as precisely as possible. During the development of the relevant control software, the experts at SimTech are moving from one subproblem to the next in collaboration with their partners in industry. The goal for the initial stage is for the robot to use the merged data to learn how to correctly locate a deformable object such as a cable. →

→ This primarily involves recognizing the respective grip point before positioning the object in the correct end location. The completion date for the prototype is 2023 and it will be used at trade fairs and other events.

"What we want is for our inventions to play a useful role in industry," says Verl. There is still a long way to go before it will be possible to manufacture a production model of the new assembly system. But for the head of the ISW, the value of transfer-oriented research projects is not only about the saleable end product; he is also interested in what his students, the vast majority of whom go on to work in industry, learn along the way. "I also want something to stick in people's minds." ⇥

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Photos: University of Stuttgart / ISW

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# Stronger together

**TEXT:** MICHAEL VOGEL

**The purpose of data cooperatives is toenablesmall and medium-sizedenterprises to better exploitthe potential of digitalization. One research team is currently looking into what they can achieve.**

Hitherto unprecedented volumes of data are currently being stored in gigantic data centers around the world.

Data is considered to be the oil of the 21st century because of its importance for opening up new areas for business and growth. The significance of this can be illustrated by the ten most valuable companies in the world, which included seven Internet platform operators in 2019, including Alphabet (Google), Amazon, Apple, Facebook, and Microsoft. Online platforms provide digital marketplaces in which many players can participate with their products and services, but in which the operator has a great deal of power. "This creates completely new problems for small and medium-sized enterprises," says Dr. Henning Baars, senior academic councilor at the at the University of Stuttgart's Faculty of General Business Administration and Information Systems 1 "Due to the limited size of their business, they are often unable even to create the relevant database by themselves that would be needed to offer innovative AI services," says the business information scientist. "Yet, if they participate in a digital marketplace with partners of very different sizes, they could come to depend on the platform."

That is why Baars and his colleagues are researching a different approach, which they are currently implementing in a data cooperatives project. Data cooperatives are business networks through which the joint collection and analysis of data are institutionalized under the legal form of a cooperative. "Whereby," Baars, one of the junior project managers, explains, "we deal exclusively with status data relating to machinery or goods, rather than with personal data or research and development data." The project, which was launched in June 2010 and is scheduled to run to the end of 2021, will receive around EUR 1.4 million of funding from the Baden-Württemberg Ministry of Economic Affairs over a five-year period. Collaborating in the project are two chairs at the University of Stuttgart, the Ferdinand-Steinbeis-Institut (FSTI) and the Baden-Württembergische Genossenschaftsverband (BWGV).

## OLD MODEL IN A NEW CONTEXT

"Cooperatives are an old, tried and trusted model that is in certain respects more agile than alternative legal forms," says Dr. Ann Tank, who is currently completing her habilitation at the University of Stuttgart's Faculty of Management Accounting and Control and is also leading one of the subprojects. "For example, members can join or leave a cooperative without notarial certification." This is a benefit, particularly in light of such dynamic developments as digitalization. There is also something inherent in cooperatives that involves sharing and having a common interest in something. And many small businesses already have some experience with cooperatives. "The technical implementation of an Internet platform is one thing," says Tank: "but the main question will be about how to establish trust between partners in a data cooperative." One of the important things in this context concerns charging for data-based services. "What we plan to do is to develop a concept that is transparent for the members of the cooperatives," the economist explains. "This concept will consist of various modules that can be combined and adapted depending on the context."

## HOW CAN ONE SHARE DATA?

"We have already shown in preliminary practical studies that, in principle, small businesses benefit from new data-based networks," says Patrick Weber, a research associate at the Steinbeis-Zentrum who is also one of the subproject leaders. One of these networks, for example, consisted of a sawmill and three other partners, whereby the primary objective was to prevent fires and optimize maintenance times by actively monitoring machinery and buildings.

During the data cooperatives project, Baars, Tank, Weber and their teams initially interviewed 15 experts to gain a better understanding of how cooperatives work. "This involved such things as success factors, service charges and roles," Weber explains. They then interviewed experts on the Internet of Things, data sharing and Artificial Intelligence to learn about suitable network architectures, how to share data, and how to create a spirit of acceptance among the partners. "We have derived a concept based on the results, →

→ which we are now evaluating in collaboration with various cooperatives," says Weber. The end goal is to set up three data cooperatives with the help of the BWGV, one in the small trade sector, one in the production sector and in one with close links to an existing cooperative. "We will make use of existing infrastructures and focus on the functional business side," the economist explains. The plan is to produce a practical guideline for setting up cooperatives by the end of the project. ⇥

**Dr. Henning Baars**

"The main question will be about how to establish trust between partners in a data cooperative."

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Photo: GettyImages

# ENHANCED PER

Evelyn Hoffarth testing the augmented reality app.

**TEXT:** Daniel Völpel

**The use of augmented reality (AR) applications could help vocational school teachers to convey their teaching content in a more playful way. The interdisciplinary "Teacher Training at Vocational Schools 2" research project at the University of Stuttgart is currently researching and developing such novel teaching formats.**

What is the best way for undergraduates, vocational school students and their teachers to learn to operate or service an Index-R200 turning-milling machine in an advanced training session? This was the starting question for a bachelor thesis by mechanical engineering student Alfonso Terrasi. To answer it, Terrasi developed a modern teaching format based on an augmented reality app. His work is part of the "Teacher Training at Vocational Schools 2" (LEBUS2) project at the University of Stuttgart' at the Institute for Machine Tools (IfW) and Institute of Educational Science (IfE), which is will receive funding from the German Federal Ministry of Education and Research until 2023. The project focus is on consolidating professional teaching in industrial-technical vocational schools with a view to inspiring more young people to study technical education and to choose a career in vocational school teaching.

One of the objectives of this interdisciplinary project is to develop a concept for a course on Machine tool mechatronics, which will cover new teaching tools such as virtual reality (VR) and augmented reality," explains Walther Maier, Group Leader of Machine Design at the IfW. The engineers and teachers complement each other very well with their respective expertise: "Our technology education students add a technical and didactic component, whilst the mechanical engineering students bring in the technical knowledge," says Evelyn Hoffarth, a Research Assistant at the IfE.

According to Hoffarth, the IfE has been working with VR learning environments for a considerable time. In addition to smartphones and tablets, he adds, the IfW has recently started using a range of AR goggles, whose use is currently being tested and for which applications are being developed. What this involved for Terrasi, for example, was to apply stickers containing AR markers, which the camera of the tablet, smartphone or AR goggles recognizes, to the lathe-milling machine for each process step, which his app uses to direct students to the various control elements of the machine. When one holds a device over it, all the necessary information about →

# SPECTIVE

→ the machine operations to be carried out will be displayed on the screen with images, text and videos. In some cases 3D animations are even used to demonstrate what has to be done. "For example, you'll see a key turning to the right to unlock the machine," Hoffarth explains.

The research group is currently looking into which digital support system is best suited for what teaching content and whether it would be better to use a smartphone or AR goggles. "The good thing about cell phones is that two people can look at the same thing at the same time," says Maier: "However, you always have something in your hand, which limits what you can do. AR goggles, on the other hand, leave both hands free." Whilst most school children and undergraduates will probably enjoy learning through AR apps and VR goggles, the researchers are giving careful consideration to when it makes sense to use them. "One always has to consider the added value compared to a well-made 3D instructional video," Hoffarth explains. "Because just being able to rotate an object on a tablet screen often improves one's spatial perception after which one can focus on any specific component."

## APPS ARE STILL RARELY USED IN SCHOOLS

Despite the fact that teachers are open to digital programs and AR apps, they are still rarely used in schools. For one thing, as Maier explains, the cost and effort involved in creating an AR app is immense and close to impossible for individual teachers. "Currently," he adds: "teachers will rarely find ready-modeled 3D objects that would be ideal for creating their own teaching apps. But taking on the task of modeling them and, where necessary, animating them or even optimizing the app for various, rapidly changing end devices is extremely time-consuming and one would need programming skills to do so." What the researchers have seen though is that providers of teaching and instructional materials have as yet failed to adopt such apps to any great extent. Existing digital support services usually have to be paid for on a call-by-call basis, which schools cannot afford. "Often," says Hoffarth, "the quicker approach is to teach the relevant skills on the machine itself, even if this may lessen the motivation of pupils and undergraduates."

In Maier's estimation, it will not be long before this market niche is recognized: "Not all teachers find preparing for asynchronous teaching approaches an easy thing to do, which is why I believe that more and more companies will start to offer digital teaching aids." However, he adds, AR goggles still take some getting used to, which makes them difficult to use. And purchasing enough of them for an entire would also be costly. The use of AR and VR apps will therefore probably continue to be a niche application at best, at least for now. →|

**App users can unlock the machine using the virtual key on the screen.**

**An video on how to operate a lathe-milling machine via an AR app is available here.**


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Photos: University of Stuttgart/IfW

# Between artistic


Moved online with no great fanfare: the "Architecture and Responsibility" series of public lectures was presented online in the 2020/21 winter semester.

Scientific Director Prof. Christine Hannemann in conversation with Prof. José Luis Moro

**TEXT:** Daniel Völpel
**PHOTOS:** Uli Regenscheit

**The University of Stuttgart's "Architecture and Responsibility" series of public lectures presents a comprehensive overview of architecture and urban planning. The researchers involved wish to address the question of what guiding principles their profession ought to adhere to in future.**

# and social aspirations

The inspiration for the "Architecture and Responsibility" series of public lectures was a book, or rather numerous copies of a book: "The Physicists" by Friedrich Dürrenmatt. The reason for this was that the University of Stuttgart chose this work about the ethics of science and the notion that discoveries, once made, cannot be reversed as its contribution to the "One University - One Book" campaign in 2019, the objective of which is to get as many people as possible involved in discussions on a given topic at universities throughout Germany. This was achieved in a special way at the University of Stuttgart's Faculty I Architecture and Urban Planning in the winter of 2019/20: an entire series of public lectures was created, which was continued into the winter semester of 2020/21. In the course of this series of public lectures, the various professors who took part explored the question of what responsibility means to them in their specific fields of expertise. Landscape planner Prof. Leonie Fischer, for example, raised the question as to whether people or nature should be prioritized in urban green spaces. Prof. Laura Calbet i Elias, Director of the Instiute of Urban Planning and Design (SI), addressed the question of responsibility in residential building policy.

"When we heard that the University had won the bid," says Prof. Christine Hannemann, Head of the Faculty of Architektur- und Wohnsoziologie (the sociology of architecture and housing) at the Institute of Housing and Design (IWE), "my colleague at the Instiute of Urban Planning and Design, Prof. Astrid Ley, suggested that we should also focus the series of public lectures on the dilemma raised in the book about the responsibility of scientists for their inventions. She took on the academic directorship for the series of public lectures, which was launched in 2019. The colloquium itself has been around for a few years longer. The professors orginally talked about their specific fields of study there. The "Architecture and Responsibility" series met with such a great and positive response in the 2019/20 winter semester that the faculty continued the theme this winter. For many years, says Vera Krimmert who is studying architecture, sudents have lacked any interdisciplinary exchange. "This series of public lectures is now exploring a given topic from all perspectives. That never happened in this form before."

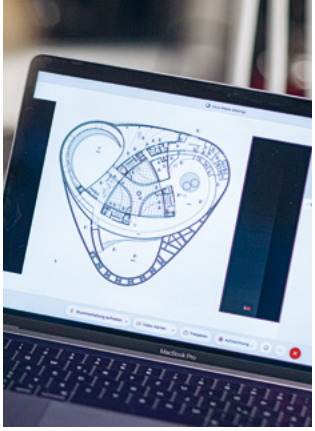
## A FOCUS ON CLIMATE CHANGE

Dürrenmatt's physicists have three clashing points of view. The first declares that science is science and that society is responsible for the consequences, not science. The second is of the opinion that science is always carried out in the service of one power or another. The third rejects science and wants to retract certain findings and evades responsibility by taking refuge in an insane asylum. "By contrast," as Hannemann stresses, "architects and urban planners always bear responsibility." The architectural sociologist says that her colleagues now perceive her in different light because of the response to the series of public lectures: "There was one clear focus during the discussions following each lecture: climate change, a subject that really moves the students, because it is an area in which architects and urban planners have a specific responsibility." Krimmer takes the same view: "So far," she says, "the climate issue has only played a peripheral role in introductory courses. Later it is possible to address it appropriately but the choice is very limited and the seminars are over-subscribed." Particularly when it comes to questions relating to the responsible use of construction materials and the goals of architecture, she goes on to say, students really need information and discussions, whereas the subject is already covered in broader terms in urban planning courses.

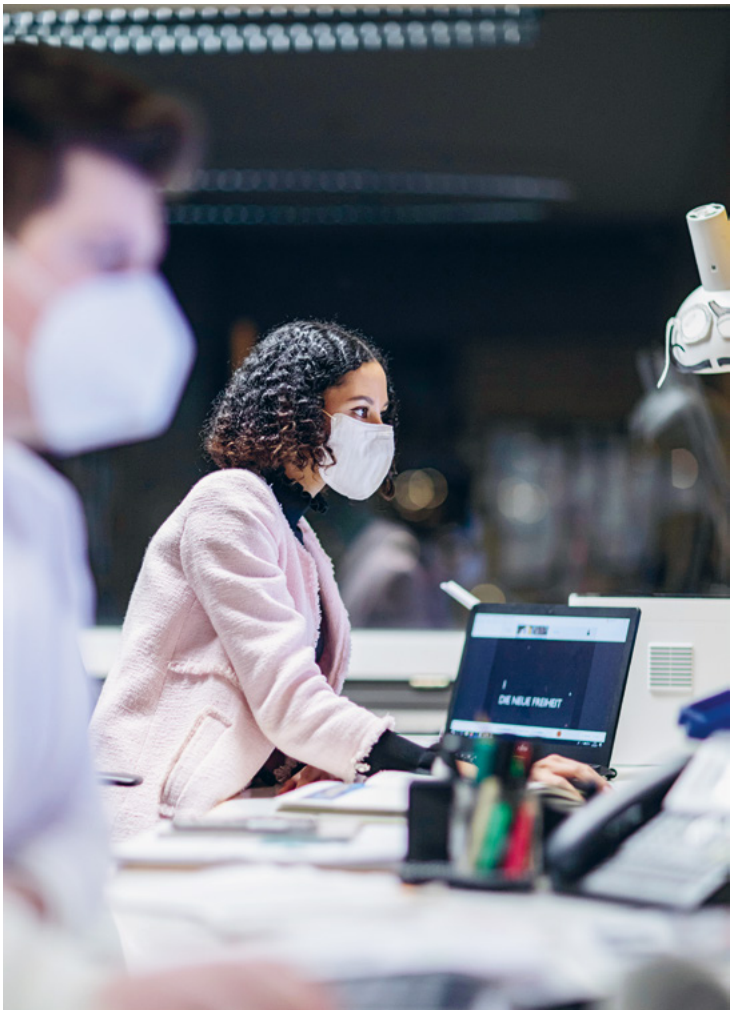
"In my opinion," says Hannemann, "a series of public lectures such as this also serves a cathartic function by pointing out the gaps and dealing with them in a creative manner, whereby we should not only be considering the climate issue, but also the social side, i.e., affordable accommodation. And the trick will be to combine affordable accommodation with climate change mitigation, which I've yet to see any research and studies on." Architects are still fixated on new builds, but purely in terms of square meterage, there is already sufficient housing space to accommodate everyone. Hannemann is therefore convinced that "construction form in the future will be about refurbishing existing buildings. "These tasks need to be tackled and we're using the series of public lectures to discuss ways of initiating that with the faculty."

The professor and the student both confirm that students are insistant about these topics: "From what I see, we have a new generation of students with a social conscience," →

**The responsible use of construction materials: an issue that moves students of architecture such as Vera Krimmer.**



Why not consider new forms? The lecture series creates the space in which to do so.



Many students have accessed this series of public lectures online: they are keen to discuss current housing issues.

Prof. Christine Hannemann

**"From what I see, we have a new generation of students with a social conscience."**

→ Hannemann explains. "I also think that increasing numbers of young people are studying architecture not because of any artistic aspirations, but from a desire to shape society in terms of construction and space usage." Following a neoliberal phase, she explains, ethical-social questions are now increasingly coming to the fore. "The first scholarly, overarching account, the Handbuch Verantwortung, edited by Ludger Heidbrink, Claus Langbehn, and Janina Loh, was published in 2017, and demonstrates that attempts are being made to bring things up to date." And as Krimmer notes: "It seems to me that the generation born after 1995 has become more aware of their social responsibilities than we older students had been. Our main concern was optimizing our own careers, or maybe we didn't have to get so involved with political issues." But now, she says, political questions – such as how to replace concrete, which has a huge $CO_2$ footprint, with timber – are taking priority. "The problem," says Krimmer, "are the DIN standards and the building authorities, neither of which is yet geared up to deal with this." But then she does get political: "Actually, all of this should be regulated by the market but then it would the same as with the internal combustion engine – an outdated design is being kept alive by artificial means."

At the end of his lecture "Creative design process and social responsibility" which he delivered as part of the series of public lectures, Prof. Markus Allmann outlined some better construction methods. His company is currently building a school in Munich for 1000 young people using a completely $CO_2$-neutral timber construction method. As a fundamental principle, he urged, "we have to make a commitment to socially and environmentally responsible construction." Because, he adds, it is already apparent that architecture is falling into disrepute to the same extent as cars. "All the more reason to think about how the benefits of a building could, and maybe even should, outweigh the harm it causes."→

# RESPONSIBILITY

→ The architectural researchers sum up their understanding of responsibility and its significance in a series of short statements. ↠

"In my opinion, responsibility is about using resources in such a way that it will be possible to use them in the future. Architecture has to be flexible and adaptable and capable of reacting to changing conditions. But because I can never be sure that there will always even be a need for adaptable architecture, I not only have to design for its creation but also its disposal."

**Martin Ostermann, Professor at the Chair of Building Technology, Construction and Design**

"In my opinion, responsibility is about providing people with access to nature in the city, which means identifying ways to design urban nature in such a way that everyone can access it and benefit from its positive effects. Urban nature exists in parks and gardens as well as on wild uncultivated land or green roofs, so Land diversity refers to both utilization and natural diversity."

**Prof. Leonie Fischer, Head of the Institute of Landscape Planning and Ecology**

"Being able to take responsibility is a great privilege, because by designing living spaces, we are providing answers to the questions that life throws up. This is the way we'take responsibility for a project. Given the complexity involved, this is an iterative collaborative process that can only be objectified to a limited extent. We're continuously moved by empathy, doubt and a lack of knowledge. Architecture is a journey with no fixed destination."

**Prof. Peter Schürmann, Director of the Institute for Building Materials, Building Physics, Building Systems and Design**

"What responsibility means to me is taking responsibility for the future; a future that will be defined in the cities. Will they continue to be sites of energy and resource consumption and social polarization, or will they become spaces for alternative solutions? Together we can shape city life, but that will require active participation as well as discourse."

**Prof. Astrid Ley, Managing Director of the Instiute of Urban Planning and Design**

"As a teacher and practicing architect, responsibility for me is about the realization that it is perceived in terms of comletely different levels of impact. A simple reference to the golden rule may suffice at the individual level: 'treat others as you would like others to treat you.' The task at the collective level, which it is not possible to realize without internal and external contradictions, is to develop environmentally sustainable and socially equitable residential spaces which are also convincing from a design perspective."

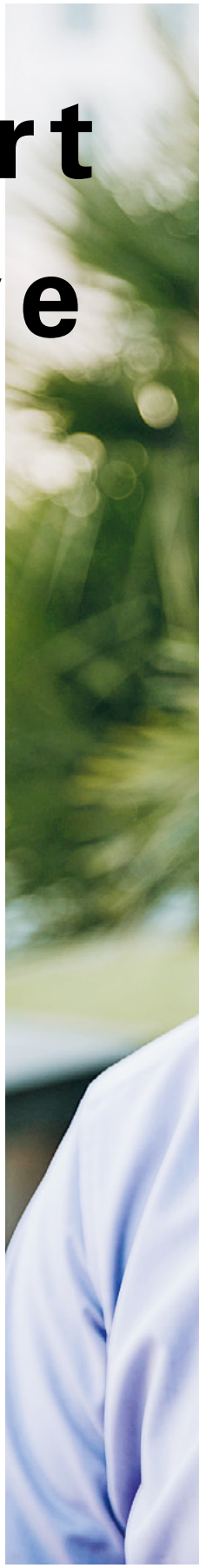
**Prof. Markus Allmann, Director of the Institut für Raumkonzeptionen und Grundlagen des Entwerfens (Institute of Spatial Concepts and Basic Design)**

"Creating art is a basic human need and and should be an integral part of all processes. Art puts things into perspective, overturns them and reemerges. On the other hand, thinking about responsibility raises questions about how to act responsibly. But art is not about lending an artistic veneer to political convictions. Art doesn't impact on anyone, because adopting a side would be too fatuous. Making connections between these things is important in my opinion. So that's the great attraction of discovering the connection between art and responsibility, and deriving a set of socially responsible values from it."

**Prof. Sybil Kohl, Director of the Institute of Arts**

Photos: P.74 Julius Stark pp.76/77 Dietmar Spolert, private, University of Stuttgart/IDG/Pirmin Wollensak, Brigitta Stöckl, Myrzik&Jarisch, private

# Into the heart of the wave



**TEXT**: Andrea Mayer-Grenu
**PHOTOS**: Sven Cichowicz

**Tsunamis such as the one that inundated the coasts of Southeast Asia in 2004 can cost hundreds of thousands of lives and cause extensive damage. Prof. James Foster of the University of Stuttgart wants to improve early warning systems, and his experience from Hawaii, a tsunami hotspot is helping him to achieve this.**

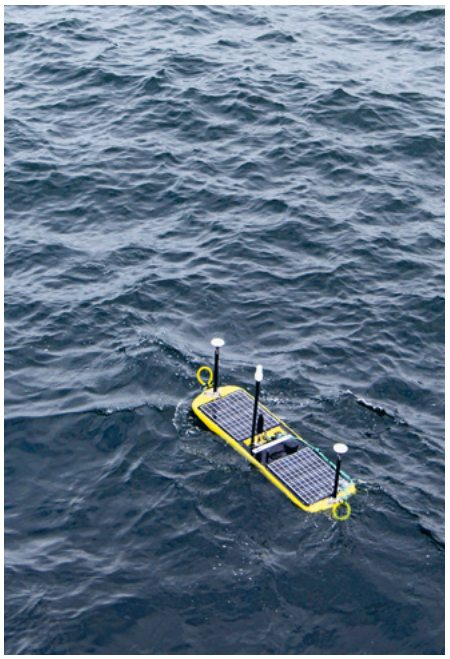
James Henry Foster ends his email with the word "Aloha", and the Hawaiian greeting is no accident. Foster (51), whose father was American but was born in England spent 30 years of his life living on the island in the tropical Pacific. He earned his doctorate in geology and geophysics at the University of Hawaii in Honolulu and carried out his most recent research at the Hawaii Institute of Geophysics and Planetology (HIGP).

Honolulu, where the Pacific Tsunami Warning Center (PTWC) is located, is a center of tsunami research. The PTWC is an international early warning system whose task is to provide early warnings of tsunamis, the focus of Foster's research, to populations throughout the Pacific region. There is a good match between PTWC's and the university professor's research approaches: whilst the early warning system uses seismometers to detect earthquakes that could potentially trigger a tsunami, Foster and his team are trying to develop new ways of improving these forecasts. "My aim," as the geodesist explains, "is to take direct measurements of tsunamis even before the wave reaches its maximum size and hits the coastline.

Even major tsunamis only start off at about ten centimetres to a metre in the open ocean. Only when the wave reaches shallow water does it mount up to form powerful tidal waves that can result in catastrophic devastation in coastal regions." So, there is a gap in tsunami prediction systems that needs to be addressed. The reason for this is that, whilst traditional seismographic recordings provide data on the epicenter and strength of an earthquake, from which it is possible to calculate the likelihood of a tsunami, it takes hours for the actual sea level changes to reach the coast where they can be registered by tidal gauges. →

**The tsunami prophet: Prof. James Foster wants to be able to detect tsunamis before they reach a montrous size.**

**Autonomous sea vessels, so-called wave gliders, form part of tsunami warning systems.**



**Prof. James Foster**

"Today, of course, we are more technically advanced; our methods of detection are developing and the algorithms have also become much faster."

**New location: Foster is currently carrying out research at the University of Stuttgart, which involves excursions like this one to (mount) Rotenberg.**

→ Foster uses ships fitted with GPS sensors to identify low-level tsunamis from the usual ocean wave activity, whereby the different characteristics of both types of waves are exploited. "Normal oceanic waves pass a ship in just 15 seconds, whereas a tsunami wave can take up to half an hour." One can use a GPS to measure these long amplitude shallow wave motions, and the fact that ships are constantly on the move enables a high frequency of measurements, so the GPS-equipped ships deliver data about the tsunami at a very early stage. "What I want to do is to have ten percent of all commercial ships fitted with a GPS," Foster explains. This would provide a headstart that would save lives.

The use of a GPS also makes it easier to determine whether an earthquake will actually trigger a powerful tsunami. The key factors are the strength of the earthquake, the proximity of its epicenter to the water surface and the so-called "push", which is the energy with which one tectonic plate pushes the other upwards. "A land-based GPS records the push very well at first," says Foster. The only problem is that earthquakes that cause tsunamis occur in the ocean floor, and data recorded on land only provides very unclear information about the occurence.

## ENABLING REAL-TIME ALERTS

So, by focusing on marine geodesy, Foster is trying to find ways to make land-based recording methods usable in tsunami research and to measure the events on the actual seabed. One technology for doing so involves pressure sensors that more or less measure the weight of the ocean. The weight of the water changes whenever the seabed rises, thus chaning the pressure registered by the sensor. Another method involves sonic measurements, whereby acoustic signals are transmitted from the surface of the sea to the seabed and the return time is measured. By comparing the return times of these signals one can detect movements of just a few centimeters per year at the fault lines between tectonic plates. →

→ The relevant measurements are taken by so-called wave gliders, i.e., autonomous surface vessels equipped with both GPS and acoustic measuring devices. “Just had a wave glider like that deployed during a seaquake in Alaska, which is already waiting to be redeployed,” Foster happily reports.

Thanks to the integrated accelerometers, even smartphones can be used for early earthquake detection. Accelerometers tell the smartphone whether the user is holding it in a vertical or horizontal position so that the screen layout can adjust accordingly. If one attaches the phone to a wall or floor, the accelerometer will react to the tremors in the event of an earthquake and sound a warning signal, which can give people in a neighboring town 10 to 20 seconds to react before the quake hits. “That's sufficient time for people to get to dive for cover under a table and alert emergency services,” Foster explains. A network collaboration with Costa Rica is already being used to test whether the system can run in a fully automatic and safe manner: the initial results are promising. The system is of particular interest because mobile phones are cheap and mass produced, which means that large numbers of them can be used. “This will enable us to obtain almost real-time alerts,” says the scientist enthusiastically.

The question as to whether his research will help to prevent the consequential damage caused by tsunamis such as the one that hit Southeast Asia in 2004, makes Foster chuckle. “Today, of course, we are more technically advanced; our methods of detection are developing and the algorithms have also become much faster. But it wasn't the natural disaster that was the problem in 2004, it was the people.” There were early indications of an iminent big event but, because no major tsunami had hit the region in the past 100 years, no one was prepared: the countries themselves had no warning systems, there was no one to contact, there were no safeguards in place, and nobody knew what to do in an emergency. “People did see the tide rushing out, but failed to recognize the signs or run to safety. There is always a social dimention to tsunami protection.”

## FROM HONOLULU TO STUTTGART – FOR GOOD REASONS

But what brings a tsunami researcher from Honolulu to Stuttgart, where the most that might happen is that the Neckar River will flood its banks and earthquakes rarely exceed magnitude 4 on the Richter scale? Foster was primarily moved by private reasons: his wife is German and he wants his children to see their grandparents more often. But the research facilities at the University of Stuttgart also appealed to him: “Geodesy studies at the University of Stuttgart are extremely well respected around the world,” he explains: There are also a lot of experts there who are working on technologies, such as low-cost sensors, that are interesting for my own research.”

And finally, contrary to popular belief, he also has a very positive view about research funding in Germany, because in Hawaii – as is the case in many US universities – researchers there first use amy project funding to cover their own personal income as well as contributing some of the funding to the institute. “The upshot is that I have had to put a lot of time into proposals just to support my family.” Funding in Germany, by contrast, tends to be lower, but money for living expenses comes from other sources. “I have to pen funding proposals here, too,” says Foster with a smile, “but at least the funds flow into my research.” ↠

**The autonomous wave gliders are equipped with a GPS and acoustic metering apparatus.**

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Photo: pp.79/81 private

DR. KRISTY PEÑA-MUÑOZ

# PROTECTING THE ENVIRONMENT AND PROMOTING SUTAINABILITY

In Germany it is normal practice to separate glass, plastic and paper when disposing of waste products, but as yet, this practive is not common in Mexico, which is why Kristy Peña-Muñoz is currently working on ideas for waste separation there. “Waste management in Mexico,” she says, “is 20 to 30 years behind Germany.” She is addressing this issue by advising Latin American countries on environment and sustainability issues. Peña-Muñoz is a graduate of the University of Stuttgart’s “Air Quality Control, Solid Waste and Waste Water Process Engineering” (WASTE) master's program, and earned her doctorate in 2014 in the context of the Environment Water, ENWAT international doctoral program. She and her six employees have been working as a project developer for her own company, KFG EnviroSmart Solutions since January 2021, and would like to encourage other companies to separate their waste. Her plan is to produce biogas from organic waste, which, she says, would not only generate renewable energy, but also money.

Peña-Muñoz became aware of the fact that not all conflicts in business have to do with technology; they sometimes arise from communication problems when, for instance, people do not understand another culture. She worked for Daimler in 2008 and 2009, where she spent a year at a plant in Sindelfingen near Stuttgart and another at a plant in Saltillo, northern Mexico. In retrospect, she says, Daimler Germany was different to Daimler Mexico. “Although it was the same company,” she says, “and we had German colleagues in Mexico, the mentalities were different.” “There were also differences in terms of the environment, she says. “Waste products in Sindelfingen were separated into about 200 different components. In Mexico, it was zero.” When Peña-Muñoz arrived in Saltillo, she discovered that, rather then being a technical issue, the lack of waste separation was based in a cultural difference. She managed to convince staff members to at least separate the waste along basic lines. “With the money we earned through the waste separation process, says Peña-Muñoz, “we were able to develop the entire waste separation program.” That was when the need to take account of different mentalities dawned on her. Through her studies and work in various countries, she has learned that it is not possible to iplement certain concepts in the same way everywhere, which is why she wants to use her company to build a bridge between cultures and develop solutions that suit each respective country.

Photo: private

Universität Stuttgart


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**TRANSLATIONS**
Proverb oHG

**ADS**
ALPHA Information Society mbH info@alphapublic.de
www.alphapublic.de

**PRINTING**
W. Kohlhammer Druckerei GmbH & Co. KG

RECYCLED
Papier aus Recyclingmaterial
FSC® C016267

**ONLINE EDITION**
https://www.uni-stuttgart.de/forschung-leben


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70174 Stuttgart
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