A Marvel of Nature
A tiny enzyme could replace gas, oil, and coal in the future and provide climate-neutral energy

Fair Mobility
Researchers are working with society to develop a vision for the future of transport in Berlin

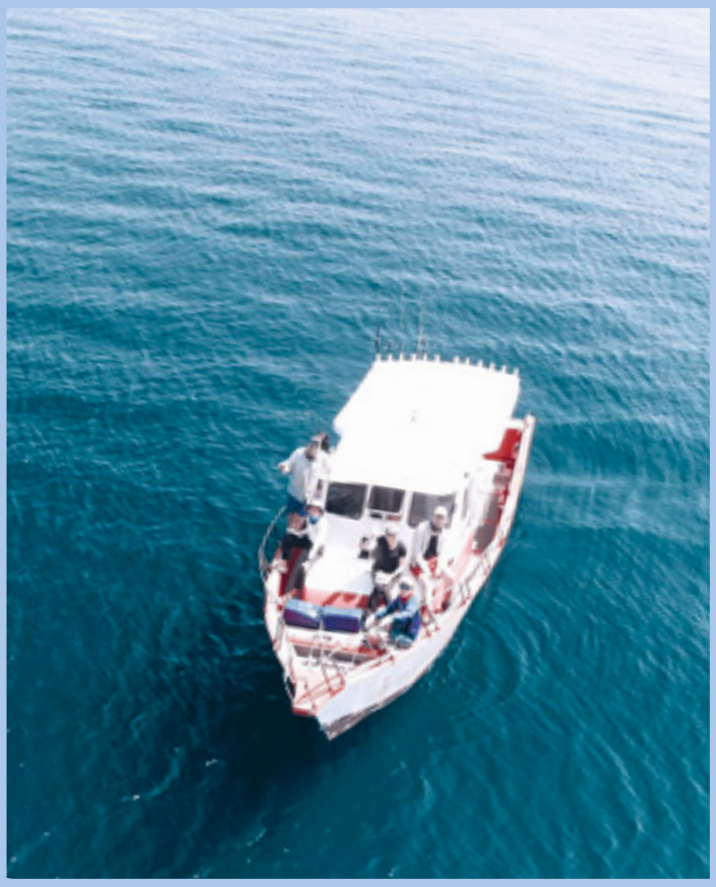
Open Science
Seven ambassadors are promoting transparent research practices at the University

TECHNISCHE UNIVERSITÄT BERLIN

We/Four

Technische Universität Berlin in the Berlin University Alliance

Clusters of Excellence Edition



Light Strips

The striped marlin (front cover) is one of the fastest and largest fish in the ocean. Striped marlins have to work together to hunt sardines, but they are also competing with each other for food. If two of them attack at the same time, they could seriously injure each other with their sharp, spear-like snouts.
Researchers from the Science of Intelligence Cluster of Excellence (SCIoI), for which TU Berlin is an applicant university, used drones to follow the marlins on their hunt off the Pacific Coast of Mexico in order to investigate predator-prey interactions (see p. 24). What they observed was that the marlins' stripes light up when they attack – presumably by exposing certain skin cells that reflect light. The stripes signal to the other marlins that they intend to attack. Without being aware of it, the fish is saying: “Now it's my turn, get out of my way!”

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We/Four Magazine:
Technische Universität Berlin
in the Berlin University Alliance

Berlin University Alliance

We/Four

CONTENTS

This issue of our magazine focuses on the three Clusters of Excellence for which TU Berlin is an applicant university. Since the start of their funding in 2019 as part of the Excellence Strategy of the German federal and state governments, these Clusters of Excellence have collectively published more than 1,800 scientific works. The positive effects of this are evident both for our university and for Berlin as a science hub, as our data evaluations show. The MATH+ Cluster of Excellence, which includes FU Berlin, HU Berlin, and TU Berlin as well as the Weierstrass Institute and the Zuse Institute Berlin, is a beacon for the capital region for its position as a leading center for mathematics. In 2023, TU Berlin, as a partner of MATH+, published the highest number of research results in Germany in the field of applied mathematics.

Similar success has been achieved by the Science of Intelligence Cluster of Excellence (SCIoI), which was applied for by HU Berlin and TU Berlin and investigates the principles of intelligent behavior. Between 2019 and 2024, SCIoI collected around 50 percent more citations per publication than the average in Germany in this field of research – thus strengthening Berlin's position as a focal point for artificial intelligence. Finally, the UniSysCat Cluster of Excellence for Catalysis Research, which was initiated solely by TU Berlin, has expanded our university's scientific network in the field of catalysis by a factor of four since the launch of its predecessor UniCat in 2007. In addition, an entire ecosystem for green chemistry consisting of startups and major companies such as BASF is now growing around this cluster.

Read about selected projects at the Clusters of Excellence starting on page 20!

Professor Dr.-Ing. habil. Stephan Völker
Vice President for Research and Appointments at TU Berlin and member of the Executive Board of the Berlin University Alliance

Responsibility

The Berlin University Alliance's third NEXT GRAND CHALLENGE is on "Responsible Innovation in Times of Transformation." The BUA is supporting three projects that develop and promote responsible and innovative solutions for upcoming societal changes. Under the initiative, scientists and researchers work closely with representatives from civil society. TU Berlin is involved in all the projects, which will receive initial funding of 1.4 million euros over two years. The three projects are presented on the following three pages.

TEXTS Barbara Halstenberg

Fair Mobility

First the vision, then the technical innovation: Researchers and civil society actors are working together on the urban transportation of the future.

PHOTO Oana Popa-Costea / AI-generated using CapCut with help from Janine Rühlicke-Ahrens and Anna Groh

On the once busy traffic circle at Ernst-Reuter-Platz, students and residents now sit on benches, children play nearby, and birdsong has replaced the noise of cars. Wide cyclepaths and footpaths surround the green square, while autonomous electric vehicles whir quietly past. Numerous bicycles are parked in front of the TU Berlin buildings, trees provide shade, and evaporation beds cool the air on hot days.

This vision of the future, developed by an interdisciplinary team at TU Berlin as part of the PureMobility initiative, puts technological innovation at the service of sustainable mobility. The scientists and researchers are taking an unusual approach: Technology innovation is guided by a vision of the future centered around fair mobility which was developed with stakeholders from civil society.

Before and after: Cars will feature less prominently on Ernst-Reuter-Platz in future.

The resulting concept aims to fundamentally transform urban traffic – and, at the same time, represents a major shift in the technical development process. Technological progress is no longer the driver here; for the first time, the project is trialing a shift from "technology push" to "vision pull" in technical innovation.

Paring it down to the essentials

"PureMobility is about stripping everything down to the essentials in order to develop sustainable and human-centered mobility. We aim to largely eliminate private car use in cities and replace them with small, autonomous electric vehicles that are constantly on the move and can be booked via an app," says Dr.-Ing. Steffen Müller, professor of automotive engineering. "These vehicles complement local public transport and take up significantly less space," adds Professor Dr.-Ing. Utz von Wagner. Professor Dr.-Ing. Frank Rackwitz is working on resource-efficient "pure mobility roads" that are water-permeable and thinner than current roads. All three professors are researchers at TU Berlin. "The new vehicles are also creating a fairer mobility system that puts pedestrians and cyclists at less risk and shifts the focus away from cars," stresses Professor Dr. Sabine Ammon, a technology philosopher at TU Berlin. In collaboration with civil society organizations such as the ADFC (the German cyclists' association), Changing Cities e. V., and Paper Planes e. V., she wants to flesh out the PureMobility vision in future workshops and explore what we understand by good and fair mobility, including in the context of climate change. Along with other scientists, she is receiving funding from the BUA for the project PureMobility – A Human-Centered Turn to Responsible Urban Mobility by Transformative Vision Design.

TU Berlin transport planner Professor Dr. Christine Ahrend brings her expertise in future studies to the project and complements the assessment of technological impacts. Geoinformatics expert Professor Dr. Tobia Lakes from FU Berlin is exploring the question of equitable space distribution, while psychiatrist Professor Dr. Gunter Schumann from Charité – Universitätsmedizin Berlin is investigating how urban and traffic design affect mental health. Dr.-Ing. Kerstin Kracht from TU Berlin is coordinating the complex interdisciplinary and transdisciplinary research process.

The visions for effective and equitable mobility developed in collaboration with civil society as part of the BUA project will subsequently be integrated into the technological development of the PureMobility initiative. The team will develop transition scenarios for bringing the vision of equitable mobility to life.

Are you interested in contributing to the vision of fair mobility?
Write to info@transform-mobility.de

Little Digital Helpers

Researchers are exploring how everyone – from care recipients to medical professionals – can benefit from a digital care ecosystem.

Retired teacher Selma Stein lives in a nursing home in Berlin. The digital services available in the facility help her stay connected to the world. Once a week, she meets online with other former teachers, and on two evenings Selma goes on trips to faraway places with her travel group, an online community of people with care needs. Thanks to a virtual reality headset, she can indulge her love of travel despite her limited mobility.

New opportunities for travel in nursing homes

PHOTO istock/PeopleImages

This is the vision that Professor Dr. Nancy Wünderlich and Dr. Julia Rötzmeier-Keuper will be pursuing over the next two years as part of the BUA-funded project Digital Care in Aging Societies: Designing Responsible Care Ecosystems (CaringS). Working with an interdisciplinary team, they aim to explore how digital technologies can be interconnected and effectively implemented in the care context to the benefit of everyone involved – care recipients, families, care staff, and doctors. "A responsible care ecosystem takes into account the needs of these different groups and connects them with the various technologies," says business economist Nancy Wünderlich. "I want to promote sustainable social innovations for society that will ultimately affect all of us at some point – when we become old, dependent on care, or ill."

For Wünderlich, innovations in the care sector must be practicable and free up time for care staff. Due to heavy workloads caused by staff shortages, interaction with care recipients often falls short, she says.

Selma Stein's smart care bed can monitor her vital signs and detect health issues early, enabling quick responses. Networked robots can also recognize social isolation and alert care staff and family members, ensuring Selma Stein receives visitors.

Reducing burnout

"Our aim is to integrate technologies in a way that improves care conditions, relieves the burden on caregivers, and allows them to spend more time with those in need of care," says Julia Rötzmeier-Keuper. This also reduces the risk of burnout.

Over the next two years, the team plans to explore what a responsible digital care system could look like. What technologies are needed and how should they be interconnected? How can data security and privacy be guaranteed?

Expertise in information systems is provided by Professor Dr. Martin Gersch from FU Berlin, while Professor Dr. Claudia Spies from Charité provides the medical perspective. Philosophers, ethicists, and lawyers may also contribute their knowledge as the project progresses. Pflegewerk Berlin GmbH is already ensuring that real-world care perspectives are incorporated into the project.

Wünderlich and Rötzmeier-Keuper's research interest lies in the digitalization of markets, with a focus on marginalized customer groups. Most recently, they have been researching the identity processes of older people in care facilities. The lack of opportunities to maintain social connections and establish new ones is a recurring problem, as is the meaningful involvement of family members. "Sometimes relatives bring food that is hard to digest, or they administer medication without informing staff. All of this could be recorded in an intelligent system, minimizing potential conflicts with family members," says Wünderlich. It is also important to combat the stereotype that old people and technology do not go together.

Green Food Revolution

Alternative sources of protein aim to secure the global food supply while reducing emissions. Researchers are investigating how responsible innovations in the protein transformation are.

PHOTO Philipp Arnoldt

Plants, algae, insects, and fungi are all considered alternatives to animal protein sources and are expected to secure the food supply of the world's population in the future. They hold the potential to significantly contribute to climate change mitigation, biodiversity, and healthy diets. That is why the focus is now shifting to technologies that process protein-rich plants into alternative products or, in future, produce cultured meat. For 2024, the German government has earmarked 38 million euros for investments in the transition to plant-based and other alternative protein sources. However, whether or not the associated innovations will be truly sustainable remains uncertain.

This is where the Responsible Innovation and Protein Transition (RI-ProT) project aims to provide clarity. "We're looking at what raw materials, products, and technologies are currently available on the market, but also at what problems exist and where solutions still need to be found in the future," explains Dr. Cornelia Rauh, professor of food biotechnology and food process engineering. By the end of the project, the aim is to develop an innovation radar to assist stakeholders in industry and policy in assessing whether an innovation in the alternative protein sector is responsible and sustainable.

The RI-ProT team wants to understand what motivates industry to drive innovation, the problems it faces, and what it hopes for. On the consumer side, focus groups will be used to assess knowledge about what fears or prejudices exist, and what potential is seen in the new protein sources. "The desire for a healthier, more natural, and additive-free diet is growing among many people," says Professor Dr. Martina Schäfer. Ethical issues, such as livestock treatment, are also increasingly being discussed in the Global North.

Alternative source of protein: ground soybeans can be processed into meat substitutes using extrusion technology.

Schäfer, a sustainability researcher, is also responsible for promoting interdisciplinary and transdisciplinary collaboration in the project, which also involves innovation systems researcher Dr. Dagmara Weckowska from Freie Universität Berlin and political scientist Professor Dr. Peter Feindt from Humboldt-Universität zu Berlin. Regular meetings with associations from the food industry, agriculture, and consumer protection, who are also partnering in the project, are part of the process. "It's essential to think in advance about how to provide methodological support for an exchange among a range of very different partners," explains Martina Schäfer.

Good old pea soup

For the plant breeders' association involved in the project, the question is which regional plants, such as field beans and lupines, could be cultivated as sources of protein in Germany. Companies, in turn, are considering how they could offer protein crops, such as peas and lupines, to consumers: naturally or processed into a patty or cutlet?

A specialist from Charité will look into how healthy such a processed product is. "Maybe in the end, good old pea soup is the healthiest option," laughs Cornelia Rauh. What Rauh and Schäfer appreciate about the Berlin University Alliance is that it brings together academics and scientists from all of Berlin's universities and a wide range of disciplines to work together on one project.

Rooted in the Real World

Whether it's the question of how to provide healthy meals for students in schools, how to build ecologically sustainable roads, or how artificial intelligence can be integrated into the artistic creative process – scientists are always concerned with addressing real-life issues that are relevant for society. This involves engaging with stakeholders outside universities and takes the form of transdisciplinary research. The TD-Lab – Laboratory for Transdisciplinary Research is run by the Science & Society Unit at TU Berlin and focuses on research carried out in collaboration with civil society.

PHOTOS:
Kevin Fuchs

PRODUCTION:
Sybille Nitsche

Vision of ecological mobility

Today's transportation systems consume an enormous amount of space, energy, and resources. PureMobility is a network of scientists and researchers who are developing a new vision for the future of mobility. Their approach centers on public mobility services using small, lightweight electric vehicles integrated with streets designed to enhance urban life. Kerstin Kracht is part of the team; working with her colleague Frank Rackwitz at the Chair of Soil Mechanics and Geotechnical Engineering, she is researching the static and dynamic properties of the urban roads of the future. These roads are designed to have a small spatial footprint, high water permeability, and minimal heat retention. Ethicists, social scientists, ecologists, and health experts are collaborating with stakeholders from civil society to define the parameters for a livable city. The aim of TD-Labs is to translate scientific findings into real-world societal contexts.

Fresh impetus

The TD-Lab – Laboratory for Transdisciplinary Research is being set up for the BUA as a central contact point for researchers at all career levels. The lab is based in the Science & Society Unit at TU Berlin. The team develops innovative formats, methods, and training opportunities to foster new collaborations and networks, and it supports scientists, researchers, and social actors in transdisciplinary projects. Creative approaches like incorporating elements of improvisation strengthen dialog between practitioners and researchers, helping them engage on an equal footing, and bringing fresh impetus to collaborative research. One example is the Transimpro workshop format, which promotes dynamic collaboration and is available for booking by interested consortia. Pictured (clockwise): Dr. Audrey Podann (olive green cardigan), Dr. Melanie Kryst, Dr. Ina Opitz, Nadin Gaasch, Sorka Tzschabran, during an improvisation exercise on climate adaptation and sponge cities.

Creative drawing with an AI robot

This AI-powered robot is able to learn new drawing techniques from humans. In this learning process, based on "reinforcement learning," it continuously adapts and optimizes its strategies. At the same time, the interaction with the robot inspires humans to take new creative approaches. As part of this reciprocal process, both parties must continually analyze and interpret each other's actions in order to build upon and expand the drawing ideas.

The robot was developed by Alessandro Mac-Nelly (left) and Pietro Lugaro (right) together with Albert Lang, head of the Design and Computation master's program. It is an example of how AI can be integrated into the creative drawing process of humans. The robot is the product of transdisciplinary research supported by the TD-Labs and was awarded the Grand Prize at the Ars Electronica Campus Awards 2024.

Sustainable and healthy school meals

Children and young people often do not have a very healthy and sustainable diet. In addition, the number of households affected by food poverty is on the rise. Quality school meals can provide this age group with affordable access to healthy food, while also increasing demand for organic products.

Dr. Benjamin Hennchen has helped establish a TD-Lab as part of the project "Social Cohesion, Food, and Health. Inclusive Food System Transitions," which looks at meal provision in Berlin's secondary schools. The lab piloted various event formats and works with stakeholders involved in school meal provision.

Findings revealed that alongside cooperation among relevant actors, greater opportunities for student participation are needed. Overall, the topic needs to be integrated more deeply into daily school life.

PHOTOS Berlin University Alliance

A Space for Exchange

The BUA Open Space salon series provides a dynamic platform for representatives from academia, industry, policymaking, and urban civil society to regularly come together and discuss the big questions of our time. The salons address scientific topics in a way that is accessible to everyone, while providing a platform for open exchange.

They offer exciting insights into current research approaches relating to pressing societal transformations and invite participants to discuss these issues together.

Topics at previous salons have included "Democracy under pressure," "Artificial intelligence & ethics," and "Trust in science and research."

By providing a range of perspectives, the series opens up space for reflection and uncovers new insights. The interactive format encourages attendees to actively participate in the conversations and share their viewpoints. (JS)

BUA OPEN SPACE #4

Cities of the Future
The next BUA Open Space in February 2025 will focus on the future of urban living and construction.

Find out more about Open Space:

A Digital Research Space for the Alliance

In the Berlin University Alliance, the institutions have so far collected their research data on their own digital document servers – referred to as repositories. It is also common to have subject-specific infrastructures in place. Researchers can save their own data permanently in these data repositories and others can access it at the same time. Researchers at TU Berlin and FU Berlin, led by Professor Dr. Sonja Schimmler, have been investigating how data can be made digitally usable within the Alliance. Schimmler is a visiting professor at the Research Data Infrastructure Group at TU Berlin and research group leader of Digital Public Services at Fraunhofer FOKUS.

INTERVIEW Julie Spielmann

Ms. Schimmler, the aim of your project was to develop a digital research space for the BUA. What was the initial situation?

Research data and other digital artifacts, such as articles and scripts/code, are usually archived digitally in repositories. The three Berlin universities also have such document servers, although each university uses its own technological solution. In addition, there are subject- and domain-specific infrastructures that exist at various faculties. All of these systems contain information that can be used for research. Our aim was to create a shared digital research space – a central point from which the data can be accessed.

That sounds like a mammoth task. What was your approach?

First, we analyzed which data the three institutional repositories in the Alliance contain. Then we got an overview of additional subject-specific infrastructures. These can simply be datasets that are available on a website. And next we spoke to researchers who regularly work with data themselves. That was important in order to gain an understanding of what data is available within the BUA.

The project also included "co-creation workshops" in which the requirements for the platform were developed with the parties involved. Who did you talk to and what was the outcome?

The co-creation workshops were a central component of our project. They were conducted by our colleagues at FU Berlin. The participants included experts in research data management and infrastructures and researchers who work a lot with data. The aim was to define the requirements for the digital research space more clearly. The challenge was that each expert had their own preferred technical solution in mind.

PHOTO Fraunhofer FOKUS

Which rarely results in anything new...

Right, and to circumvent this issue, we worked with metaphors. We described our digital research space in terms of very different things – for example, an airport, delivery service, restaurant, and a map of buried treasure. We ended up working with the metaphors "botanical garden" and "kitchen" and imagined that we weren't working with research data, but with plants or ingredients – and of course with other people. By moving to a different context, it was much easier to develop new ideas about how the digital research space should look and function.

And the findings were then used in developing a prototype?

Correct. The prototype of a metaportal was developed at TU Berlin; it displays the data records and associated metadata from the institutional repositories. The system is already online and enables access to the data of the three institutional repositories of FU, HU, and TU Berlin. We are currently still in the process of integrating some subject-specific infrastructures to serve as examples, since that's also possible.

In addition, we are developing analysis and visualization tools for different types of data such as texts, tables, images, and videos. It's not generally the case that you can directly display text or play audio and video files in repositories. For example, we're working on functions that summarize texts or extract keywords. To do this we're using new technologies such as large language models, among other things.

You're also involved in the National Research Data Infrastructure (NFDI) network, which aims to make research data accessible, cross-linked, and usable at a national level. What findings from the project are you taking with you to the NFDI?

Our project is a blueprint for the NFDI when it comes to testing how to set up metaportals on existing infrastructures and make the data from them available via a central access point. The information can initially be collected at regional level, for example within the BUA, and later aggregated at national and European level, for example as part of the NFDI or the EOSC, the European Open Science Cloud.

Other takeaways from this project are the findings from the test implementation of analysis and visualization tools. They can also be incorporated into the NFDI.

What now? What happens to the prototype?

We now have a stable metaportal with basic functions that can continue to be operated. In the team, we've decided to engage more in dialog and publicize the project over the last few months. However: In order to fully integrate the additional tools that we developed experimentally in the final phase into the metaportal and make them usable, the project would have to be extended. Furthermore, the sustainable operation of the digital research space is not guaranteed at the present time.

In addition to project leader Professor Dr. Sonja Schimmler (photo), the team comprises: Professor Dr. Veronika Weiß and Professor Dr. Claudia Müller-Birn (both FU Berlin) as well as Daniel Conde, Sefika Efeoglu, Dr. Vinicius Woloszyn, and Professor Dr.-Ing. Sebastian Möller from TU Berlin.

Bridge Builders

The BUA's Open Science Ambassador Program is building a bridge to raise awareness of open science at universities. Over the next two years, seven ambassadors at TU Berlin will show researchers, students, and decision-makers how they can benefit from open and transparent research practices and integrate them into everyday life.

"In my academic chair, open science primarily means free access to research results, software, and data. It has a lot to do with reproducibility, in other words, being able to reproduce the results of other researchers. But it's also about fairness: The opportunity to conduct research should depend less on the resources available to you."

Professor Dr. Max Moorkamp
Institute of Applied Geosciences

Dr. Cristina Brischetto
Institute of Biotechnology / Bartfeld Lab

"At my previous university, I often had limited access to research results, which led me to seek contact with international scientists. This experience showed me the enormous importance of free access to knowledge and motivated me to become an ambassador for open science."

"During my master's thesis, I came into close contact with open science and applied the relevant methods in all my projects. I was surprised that much of it was not yet considered standard practice, which is why I would like to promote its implementation."

Marvin Kopka
Institute of Psychology and Ergonomics

PHOTOS Simon Brunel / Atelier LIMO

Niklas von Kalckreuth
Institute of Psychology and Ergonomics

"As an ambassador, I would like to use my time to raise awareness among colleagues at the faculty about the importance of pre-registration and securing the approval of an ethics committee when it comes to studies involving human subjects. My goal is to get these standards firmly rooted – and, first of all, to make them established practice at my institute."

Thies Johannsen
Institute of Machine Design
and System Technology

"I would like to raise awareness, to network, and provide support. Existing offers should be made more visible. I would also like to see a critical discussion of open science. In the current geopolitical situation, it's important to view open science as both an opportunity and a risk. Science is not neutral; a responsible discussion about what data and results are made available and how this is done is therefore essential."

The Berlin University Alliance is committed to the principle of open science. As one of the leading academic alliances in Europe, it aims to make research transparent, collaborative, and reusable. The basis for this can be found in its mission statement for open science:

Sein Jeung
Institute of Psychology and Ergonomics

"The introduction of open science processes presents a great opportunity to value the work of fellow researchers and to fully utilize their potential. I believe this inspires people to band together more closely by sharing resources. This creates a culture where collaboration and mutual support are more important than competition."

Professor Dr.-Ing. Henning Jürgen Meyer
Institute of Machine Design
and System Technology

"As an Open Science Ambassador, I want to promote openness in research that thrives on transparency and social dialog. I would like to continue integrating these values into teaching at our university."

PHOTOS Simon Brunel / Atelier LIMO; TU Berlin / Chair of Machinery System Design

MINT Meets

How a BUA Certificate Program is changing perspectives

The Certificate Programs run by the Berlin University Alliance unite courses designed to address global societal challenges, allowing students across the Alliance's four universities to benefit from an excellent, research-driven education. Among these programs, the Gender & Diversity in Science & Technology Studies certificate is leading efforts to integrate gender studies into STEM disciplines. Professor Dr. Petra Lucht of the Center for Interdisciplinary Women's and Gender Studies at TU Berlin developed the program in collaboration with Professor Dr. Martina Erlemann at FU Berlin and has since assumed the managing role.

TEXT Julie Spielmann

AI algorithms are often trained on historical data that reflect the societal inequalities and biases of the time. Without actively accounting for gender and diversity considerations, these algorithms can yield discriminatory results; one pertinent example being the automated shortlisting of job applicants – a process that puts women and people from marginalized groups at a disadvantage. Such issues could be averted by incorporating diverse perspectives early on in technology development.

To date, gender and diversity approaches remain largely neglected in technical and natural sciences. In order to bring about change, gender perspectives must be integrated into STEM subjects at a systematic level – and now. As the influence of innovations in science and technology accelerates, the need to incorporate insights from gender and diversity research into solution development is becoming increasingly urgent. This is the solitary means of securing a sustainable and socially just future for all.

Professor Dr. Petra Lucht also sees the urgency of embedding gender studies in natural sciences and technology. She heads the Chair of Feminist Studies in Science, Technology, and Society (STS) at the Centre for Interdisciplinary Women's and Gender Studies at TU Berlin. Her academic chair, established in 2017, is unique in Germany and co-financed by the Berlin Senate's Equal Opportunities Program. It aims to combine interdisciplinary and transdisciplinary approaches to gender studies with various disciplines and paradigms from natural, technical, and planning sciences.

According to Professor Lucht, innovative curricula are essential to raise awareness of the perspectives and findings of gender and diversity research in STEM subjects. With this goal in mind, she has created a conducive framework as part of the Berlin University Alliance's Certificate Programs. "The BUA Certificate Programs bring together content in an open process, supporting the creation of a transdisciplinary curriculum that transcends the boundaries of disciplines, institutes, institutions, and degree programs," she explains. Lucht developed the Gender & Diversity in Science & Technology Studies program together with Martina Erlemann, professor of gender studies and science studies in physics at Freie Universität Berlin.

The program is open to all students of the Berlin University Alliance, regardless of their major, and teaches them about interdisciplinary and transdisciplinary approaches in scientific and technological research – with a strong focus on gender and diversity. The

ILLUSTRATION Jonas Schulte, Freepik

GENDER

curriculum tackles a variety of issues, including social inequalities arising from and exacerbated by science and technology, such as the discrimination brought about by IT applications and AI algorithms. It also addresses systemic inequalities within the scientific community and technical professions.

Students can choose to specialize in STEM or the humanities, and earn a certificate upon completion of the four semesters. Graduates of the program have a more pronounced awareness of gender and diversity issues in STEM environments, and are in many cases equipped with the knowledge and skills to explore their own research questions. As part of the program, students have the opportunity to attend seminars, participate in lectures and other classes, and even conduct their own research projects. "I'm excited to see the first student projects," says Professor Lucht. "It will be very interesting to explore the questions the students raise from their own disciplines, their projects, and what they aspire to implement."

It will be some time before they are submitted. The Gender & Diversity in Science & Technology Studies program was launched with students from TU Berlin, FU Berlin, and Charité in summer semester 2024, meaning the first cohort will complete the program after the pilot phase concludes in summer semester 2026. Petra Lucht and Martina Erlemann will conduct a comprehensive evaluation of the program in consultation with the BUA Office for Teaching and Learning. Meanwhile, efforts are underway to increase awareness of the program among students across the Alliance. Lucht is optimistic about the certificate program's potential to firmly anchor gender and diversity research within STEM fields and to promote critical reflection on gender and diversity issues.

Clusters of Excellence

The second funding line of the Excellence Strategy of the German federal and state governments supports projects in internationally competitive research areas. The Berlin University Alliance is home to seven of these Clusters of Excellence, with TU Berlin an applicant university for three of them. The MATH+ Cluster of Excellence is developing new methods for processing increasingly large datasets and solving mathematical problems across a variety of fields. The UniSysCat Cluster of Excellence (Unifying Systems in Catalysis) is dedicated to understanding complex catalytic reactions and harnessing them for industrial applications as green chemistry to help lead us towards a sustainable future. The Science of Intelligence Cluster of Excellence (SCIoI) observes, analyzes, and simulates the principles of intelligent behavior, aiming to deepen our understanding of intelligence and apply this knowledge to the technologies of tomorrow.

More about the BUA's Clusters of Excellence:

RENDERING SEHW_Architektur

The proposed exterior façade of the Chemical Invention Factory to be built on the TU Berlin campus.

UniSysCat

Berlin's Unique Ecosystem for Green Chemistry

TEXT Sybille Nitsche

Martin Rahmel has a knack for breaking down abstract ideas so that anyone can grasp them. When he's called upon to explain what deep tech chemical innovation means, he offers the following example: Imagine a revolutionary lacquer used to coat cell phones. This lacquer would continuously charge the phone's battery, even overnight – though only under moonlight – making it a unique invention to date. Deep tech innovations are groundbreaking ideas that don't yet exist and are developed using experimental methods that haven't been tested over the course of many years. In other words, they are truly one of a kind. This particular lacquer was invented by John Warner, the founder of green chemistry and honorary professor at TU Berlin since 2022. He also lent his name to the Chemical Invention Factory – John Warner Center for Start-Ups in Green Chemistry (CIF) – a place where chemistry is to be completely revolutionized. Martin Rahmel heads the CIF on the TU Berlin campus.

Berlin plans to become a global hub for deep tech innovations in green chemistry. Deep tech is expected

to yield market-ready products and processes that will turn the chemical industry green. In other words, transforming it into a circular economy based on renewable raw materials, shifting away from fossil fuels, natural gas, and toxic chemicals, and turning instead to biodegradable materials and significantly reduced energy consumption.

How money becomes knowledge, and knowledge money

In order to rethink chemistry and foster profitable business ideas, an innovation ecosystem has been established in the Berlin-Brandenburg region. This ecosystem is built on a foundation of excellent basic research, such as that conducted by the UniSysCat Cluster of Excellence, and strengthened by the greenCHEM consortium and the critical infrastructure that supports it. Martin Rahmel explains how these three elements interact to create an innovation cycle: "Basic research turns money into knowledge. In the greenCHEM consortium, this knowledge is then transformed into sustainable, economically viable applications. By transferring technology to established companies and startups, we generate profits, which lead to tax revenue. This revenue flows back into state coffers, which can then be reinvested in research." The Chemical Invention Factory is where startups find the infrastructure they need to transform brilliant research results into a sustainable, market-ready product."

The CIF will provide laboratories for twelve spin-off and technology transfer teams at TU Berlin from 2027. The INKULAB, a laboratory container for chemistry startups, was established at TU Berlin in 2017 as a first step to provide the necessary infrastructure for aspiring entrepreneurs. IRIS Adlershof at HU Berlin and the Scale Up Lab at FU Berlin also play an important role in supporting the ecosystem. While IRIS Adlershof primarily conducts research into optical functional materials, the Scale Up Lab provides the conditions for scaling chemical reactions to larger levels. Another player in the ecosystem is BasCat, a joint laboratory of BASF, TU Berlin, and the Max Planck Society that also works to accelerate the transfer of technology from science to industry applications. According to Rahmel, this diverse network of transfer infrastructures in chemistry is unique and a large factor in Berlin's success in the field.

He refers to these infrastructures as the "hardware," while the software is the greenCHEM consortium he coordinates. One of the groups working within the consortium is made up of people who want to establish a chemical company from their own patent. Another group offers

PHOTO Dominic Simon

An axis of green chemistry is to be created in the Berlin-Brandenburg region.

support at every step of the process – from the development of the business model and financing, to helping get the startup off the ground. It includes people like Martin Rahmel, for example, who studied Industrial Engineering and Management at TU Berlin, founded the spin-off DexLeChem, and returned to TU Berlin four years ago with the mission of advancing entrepreneurship, so that excellent research doesn't end with its publication. GreenCHEM is financed by the Federal Ministry of Education and Research and strives to deliver research findings from initiatives such as UniSysCat to the market, while also addressing sustainability issues in industrial companies.

The right instinct

Rahmel notes that it was the scientists at UniSysCat, led by TU professors Dr. Matthias Driess, Dr. Reinhard Schomäcker, and Dr. Arne Thomas, who understood early on that the knowledge generated within the University's walls needs to get out into the world if we want to get climate and environmental problems under control and fight disease and hunger. "They also want to show their graduates and doctoral candidates career paths beyond the traditional routes, which are typically limited to further research or professions in industrial companies. They opened their minds to entrepreneurship and investment consulting so that investments can be made in green chemistry startups."

However, the UniSysCat team knew that to make technology transfer a lived reality, they would need more support. CIF, greenCHEM, IRIS Adlershof, the Scale Up Lab, and BasCat in the Berlin-Brandenburg region are poised to provide a decisive boost. In 2026, construction will begin on the Center for the Transformation of Chemistry, a major new multi-billion research center located in Delitzsch, Saxony. The center was initiated by Professor Dr. Peter H. Seeberger, director of the Max Planck Institute of Colloids and Interfaces in Potsdam and a member of UniSysCat. This will create an axis of green chemistry in Germany.

Green chemistry has already been put into practice, for example by Nano Cats GmbH, founded by two TU chemists. They developed a nanostructured coating for electrodes, which optimized what was once a very energy-intensive process of producing chlorine through the chloralkali process. If this innovation were applied locally, around 700,000 tons of carbon emissions could be saved per year. That corresponds to the current output of around 140,000 German households.

Science of Intelligence

Collective Intelligence: Robots Catch Virtual Fish

INTERVIEW Wolfgang Richter

David Mezey, you are a research assistant at the Science of Intelligence Cluster of Excellence (SCIoI) and HU Berlin. In your mixed-reality installation at SCIoI, small robots, and indeed also visitors, interact with a school of fish projected onto the floor. Can you tell us more about the project?

The virtual school of fish behaves like a real family of sardines trying to escape one or more predatory fish. The computer models that control the behavior of the virtual sardines were created by my colleague Dr. Palina Bartashevich. I then built small robots on wheels that try to catch the fish projected onto the floor. The idea is to investigate the predator-prey relationship.

Do the artificial sardines behave the same way as their counterparts in our oceans?

They behave very similarly. Our goal is to investigate the principles of collective intelligence in an interdisciplinary team. My colleagues, computer scientist Dr. Bartashevich and biologist Dr. Alicia Burns, traveled to the Pacific Coast of Mexico to study the behavior of sardines. Dr. Burns used drones to record videos of the fish and subsequently analyzed them. This works very well because the sardines are driven to the surface by their predator, the striped marlin.

How does the school of sardines evade a marlin or, as in your installation, a robot?

The sardines escape a marlin by splitting into two groups while in front of it, and then swimming in an arc to get behind the predator. Our simulated fish also show this "fountain effect." In order for the school to succeed, each individual fish only needs to follow a few simple rules. It's important that the fish evade the marlin at an angle of around 30 degrees, as Dr. Bartashevich discovered.

Does each fish know what they're doing and why?

No, the school of fish is an example of collective intelligence. It's less about how each individual behaves, and more about how they act as a group. That's how they solve problems without having to give thought to the bigger picture.

Why did you decide to reconstruct the natural world in a lab?

When new phenomena are discovered in biology, it is helpful to transfer them to other physical systems. This

PHOTO Alicia Burns / SCIoI

Sardines escape from a striped marlin using the “fountain effect.”

allows us to study behavior under controlled conditions. We also learn the effect the transfer of behavior to another body has, like from a fish to a robot. For example, fish can only turnaround as quickly as the water allows them to, while virtual fish and robots are confronted with other constraints, such as a smaller field of vision. Patterns that emerge in all systems then reveal general principles of collective intelligence.

It's also incredibly helpful for researchers to tap into experimental setups and interact with the computer simulations they have developed. I will soon be teaching a course at TU Berlin where students will learn the basics of modeling collective behavior, and then have the opportunity to implement their models in our mixed reality installation.

PHOTO Jan Zappner / SCIoI

Autonomous robots equipped with camera sensors chase virtual fish, which also often use the fountain effect to get away.

Does your research have potential for practical applications?

In the future, our results could help build robots that perform collaborative tasks in areas that are dangerous for humans, such as collective search and rescue operations in the wake of natural disasters. The general principles of collective intelligence can also enhance our understanding of human behavior, one example being the outbreak of panic in large crowds.

MATH+

Explainable AI: Unlocking the Secrets of Sophisticated Networks

TEXT Patricia Pätzold

Although we can't see them, neural networks have been all around us for quite some time: They recognize a user's face when unlocking their smartphone, and are also pivotal in helping voice assistants distinguish our own voice from somebody else's. They support diagnoses in healthcare, for example by analyzing mammograms for the early detection of breast cancer, and can be used in hospitals to predict the course of diseases. In self-driving cars, they signal to the vehicle control system whether an object on the road is a cat or a plastic bag. Neural networks are one of the most important methods in machine learning, which in turn makes up a significant portion of artificial intelligence (AI).

"Neural networks must function safely and reliably, particularly in medicine and transport," says Professor Dr. Martin Skutella, head of the Combinatorial Optimi-

PHOTO venti views / unsplash

zation and Graph Algorithms Group at TU Berlin and member of the MATH+ Cluster of Excellence. Skutella was spokesperson of MATH+ up until October 2024. "Although neural networks have proven their capabilities in many technical applications, we still don't fully understand them." But we ultimately need to avoid having to rely on a "black box" as the technology becomes more widely used. Skutella is therefore pursuing a completely new approach to shed more light on the behavior of neural networks: He is investigating their mathematical foundations using methods developed for completely different networks, such as simulations for those of traffic and telecommunications.

"Neural networks get their name from the fact that they have a similar structure to our brains. In the latter, information is processed by a dense network of nerve cells called neurons. When we learn something, connections between neurons that are useful for solving a task are strengthened, while futile ones atrophy," explains Skutella. Neural networks in computers are designed to recognize patterns in large datasets and make certain predictions. These networks are made of layers of interconnected artificial neurons. The first layer, called the input layer, receives the data, which is processed through several hidden layers before producing the output in the final layer. Each neuron is connected to many other neurons in both the previous and subsequent layers. "These connections are weighted, and training a neural network essentially means optimizing these weights so that the network then either reads out known patterns in new, unknown input data or makes the best possible prediction," Skutella says. The learning process follows the trial-and-error method, much like a toddler learning to walk: The weights of the neuron connections are altered randomly, and only those that show improvement are retained.

The mathematics of traffic networks can also be applied to neural networks.

These learning processes often require many tens of thousands or even millions of training data points, such as images of cats and plastic bags, to teach the neural network the difference. "Training systems in this manner is not only expensive, but it also requires a lot of electricity, in turn driving up the carbon footprint of AI. This creates a further incentive to look into the mathematical foundations of the networks, as these could provide impetus for more efficient training practices."

As neural networks are so ubiquitous, Martin Skutella was initially interested in them simply as a tool. At the time, he was working on projects with TU transport researcher Professor Dr. Kai Nagel, who is also a member of the MATH+ Cluster of Excellence. Their work resulted in sophisticated simulations of road and rail networks in order to improve the sustainability and efficiency of transportation. "As scientific and societal arenas started calling for an 'explainable AI,' my team and I wondered whether we could apply our mathematical expertise of networks to neural networks and thus unlock their secrets."

Depth is decisive

One of the biggest unresolved questions in deep neural networks is why the depth of the network, i.e. its many layers, makes it so effective. "Why can't we expand laterally and construct a huge carpet of neurons?" Skutella asks. In the meantime, he and his team have been able to prove mathematically, at least under certain conditions, that the possibilities of a neural network increase significantly with the number of layers. For simple tasks, they can now even specify how many layers are required: "For example, to solve the problem, 'Which of the n numbers is the largest?' the number of layers the neural network has must be at least as large as the base-2 logarithm of n." Such findings are by no means purely academic in nature, but could also help design efficient network architectures.

Another success the researchers have achieved is the development of algorithms that ensure that two different inputs produce two different outputs – in other words, there are no ambiguities where cats and bags produce the same output value. "We have proven this mathematically, and it is an important aspect for the security of neural networks," says Skutella.

What fascinates him about working on neural networks is the variety of mathematical fields in which he can find solutions to problems. These include optimization methods, geometric considerations, and complexity theory. "AI is finding its way into more and more aspects of our lives. Mathematics is the only way to understand how these highly complex structures really work."

UniSysCat

A Marvel of Nature: An Enzyme that Provides Climate-Neutral Energy

TEXT Patricia Pätzold

Harnessing hydrogen as a clean energy source and sustainable raw material is a dream being researched worldwide to replace gas, coal, and oil for the production of fertilizers, fuel, concrete, and textiles, and thus put an end to the destructive exploitation of the Earth. It is the vision of a hydrogen economy capable of supplying the world's growing population with renewable energy and everyday products in harmony with nature, without emitting CO_2 or other greenhouse gases. Chemists at TU Berlin are working to realize this vision in the UniSysCat Cluster of Excellence, in collaboration with numerous partners from other areas of science and technology. The focus of their work is on the enzyme hydrogenase, a tiny marvel of nature that, when greatly scaled up, looks rather like a serving of spaghetti.

"Hydrogenases are almost ideal biocatalysts. They are present everywhere: in the soil, in the sea, in our bodies. They can split hydrogen molecules at lightning speed, releasing energy and, conversely, produce hydrogen," explains Dr. Oliver Lenz from the Max Volmer Laboratory at TU Berlin. "In our bodies alone, billions of chemical-catalytic conversion processes take place every second."

And the best thing about hydrogenases is that they accomplish all these conversion processes without consuming themselves, almost like a perpetual motion machine. They are so important that a scaled-up model has even been exhibited at the Humboldt Lab in the Berlin Palace. However, we still don't know exactly how hydrogenases work. Another challenge lies in the fact that they quickly break down if removed from their natural environment. In order to uncover their secrets, researchers must not only explore their almost infinite genetic diversity, but also the interaction between their thousands of atoms.

Research is helped by bacteria, which also make use of hydrogenases

The research group led by biochemist and microbiologist Dr. Oliver Lenz wants to use microorganisms to find out how hydrogenases convert hydrogen. "From the cells of soil bacteria that produce hydrogenases, we purify those that are suitable for this process. We then measure their catalytic activity, that is to say how many hydrogen molecules they convert per second." Further spectroscopic and structural biology methods are used to find out how the atoms are arranged in the catalytic center of the protein, what role the metals there play, and why toxic substances such as carbon monoxide are also present in the hydrogenase.

"In our gene laboratory, we can also genetically modify the enzyme to see which genes are necessary for catalytic activity. What we are researching is a very special hydrogenase that tolerates oxygen. Oxygen has a toxic effect on the vast majority of hydrogenases, so a hydrogenase that tolerates oxygen makes it much easier to conduct complex lab work," explains Oliver Lenz. "The natural conversion process normally takes place in an environment without oxygen."

Producing hydrogen with sunlight and without rare metals

Chemist and materials scientist Professor Dr. Arne Thomas is trying to improve the stability of hydrogenases that have been exposed to air. He is one of the spokespersons of UniSysCat and heads of the Chair of Functional Materials at TU Berlin. In order to stabilize the hydrogenases, his team is developing porous materials with holes in the nanometer range in which the enzymes are then enclosed.

"To achieve the desired transformation to climate neutrality, we need to move away from conventional catalytic processes," explains Pro-

PHOTO Kevin Fuchs

fessor Thomas. "These often require high temperatures and rare metals, and emit pollutants. This damages the environment, is energy-intensive, and also expensive. Nature shows us that there is another way." Trees and leaves produce carbohydrates from CO_2, water, and sunlight through photosynthesis – without rare metals, toxic solvents, or high temperatures. The microorganisms in which the hydrogenase converts or produces hydrogen also use iron and nickel, which occur frequently, rather than platinum, which is rare and still required to achieve these reactions in modern methods.

But how do you trap the unstable hydrogenase in order to use it to produce hydrogen?

"Imagine a cube in which many very small holes have been drilled," says Arne Thomas, offering an analogy to explain this complicated process. "The result is a cube that still has the same volume, but now has a huge surface area. Except that no holes are drilled; instead, the material is built up from molecules as connecting struts, like a nano-sized climbing frame. The choice of molecules determines the architecture of the material, which in technical jargon is referred to as 'covalent organic frameworks,' or COFs for short. This allows us to produce materials with a surface area of well over 1,000 square meters in a single gram. To give you a better idea, the surface area of an entire football field would fit into just one hand. We now insert the hydrogenase into special cavities inside this scaffold material. It cannot pass through the surrounding smaller holes, so it can no longer escape. However, the individual hydrogen molecules that it produces or uses can pass in both directions."

Chemist Arne Thomas (left) and biochemist Oliver Lenz are researching how hydrogenase can be used for natural hydrogen production.

Many small enzyme factories

COFs possess another property that is even more exciting: Depending on their structure, they have a different color. This is because they absorb different colors from the spectrum of sunlight and transfer its energy to the hydrogenase inside the COFs to produce hydrogen. This allows the energy of the sunlight to be converted into hydrogen, which is a storable chemical energy carrier. If the COFs, which are in powder form, are placed in water and irradiated with light, the trapped enzymes begin to produce hydrogen, which can be seen bubbling up. By following nature's example, it will be possible in the future to produce hydrogen in a simple way in many small enzyme factories.

Science of Intelligence

Event Cameras Can Improve Smartphones – and Observe Penguins in Ecstasy

TEXT Wolfgang Richter

It's an hour-long trek from the Spanish research station on Deception Island, located in the north of the Antarctic continent, up to Punta de la Descubierta. The latter is a rocky ridge exposed to the elements and sparsely covered with algae. But it is nonetheless home to a colony of chinstrap penguins, who populate Antarctica in generous numbers. "There's a total of around 20,000 animals living there, who are undeterred even by the frequent gusts of over 100 kilometers per hour," says Dr. Ignacio Juarez Martínez of the Department of Biology at the University of Oxford. In his doctoral dissertation, Juarez Martínez researched the behavior of chinstrap penguins using a new camera technology. One of the places where this technology is now being further developed is at the Science of Intelligence Cluster of Excellence (SCIoI).

Rather than record entire images at once as conventional cameras do, these event cameras only register the changes in brightness for each pixel separately – the "events" that give the technology its name. Event cameras are very well suited to poor lighting conditions, consume little energy, and have a short response time. Large chip manufacturers are already working to incorporate them into smartphones. The SCIoI Cluster of Excellence is investigating their potential applications in robotics and autonomous driving. It has now been shown that event cameras are also very useful for observing wildlife.

"With our footage, we were able to shed light on a previously misunderstood but common behavior penguins show, the ecstatic display," says Juarez Martínez. During ecstatic display, penguins stand up tall, look up to the sky,

PHOTO Ignacio Juarez Martínez

flap their wings, and let out a loud call. "One of the few studies on the topic looked at Adélie penguins, a relation of the chinstrap, and claimed that only males showed the ecstatic display, and primarily did so during the Antarctic spring in October," says Juarez Martínez. The researchers therefore assumed that it might be a mating ritual. "We were able to prove this theory wrong."

Ignacio Juarez Martínez enjoyed one of those coincidences in science that happens when researchers from different disciplines come together. The Science of Intelligence Cluster of Excellence promotes precisely this scientific exchange by bringing together researchers from over 12 disciplines to investigate the principles of intelligence. One of Juarez Martínez's doctoral supervisors, Professor Dr. Alex Kacelnik, is exploring the intelligence of animals in the cluster. He got into conversation with Professor Dr. Guillermo Gallego, who heads the Chair of Robotic Interactive Perception at TU Berlin and is also a member of the Cluster of Excellence. As part of his research into new perception systems for robots, Gallego has significantly advanced event photography. Gallego and Kacelnik both recognized the potential of event cameras for wildlife observation, and so the collaboration between Juarez Martínez and doctoral researcher Friedhelm Hamann, whose supervisor is Gallego, took flight. "Our collaboration will provide new insights into event cameras and intelligent behavior in general, and thus benefit the entire cluster," says Hamann.

Fast cameras without exposure time

Event photography is inspired by human vision: Similar to the way the retina functions, each light-sensitive pixel in the camera contributes at different times to the overall image; this means there is no exposure time following which all pixels are read at once. As the pixels only send a signal when the intensity of the incident light changes, event cameras use relatively less energy. What's more, because there is no exposure time for the camera to decide on, both dark and bright areas can be depicted almost equally well. Again, since they do away with exposure time, event cameras also boast a shorter reaction time. This makes it easier to analyze quick movements, such as a penguin flapping their wings.

Event cameras are ideal for remote locations with poor lighting conditions. The tripod must be secured with stones against the strong winds.

"Through comparative tests, we determined that the event camera used for the project consumes five times less energy than a conventional camera," reports Friedhelm Hamann. "Combined with good image quality in low light conditions, this feature makes the event camera ideal for use in remote locations such as our penguin colony. We were able to observe the animals almost continuously." Sixteen nests were filmed for several weeks during the

nesting season. The researchers then examined 24 ten-minute video sequences and tagged the points at which a penguin showed the ecstatic display. "It happens surprisingly often, around 20 times an hour," says Hamann. These tagged video sequences were used to train algorithms that could then extract footage with ecstatic displays from the total material. "These algorithms were originally developed for games consoles to detect player's movements," explains Hamann.

In addition, blood samples were taken from the penguins to determine their sex, as there is no way to do this just by looking at them. "Our investigations revealed that both male and female penguins show the ecstatic display with the same frequency. Since we observed the penguins outside the mating season, it cannot be a mating ritual," confirms Ignacio Juarez Martínez. Instead, the scientists found that the ecstatic display is virtually contagious; penguins in the near vicinity feel compelled to join in. "This can actually cause a kind of ecstatic wave to run through the entire penguin colony," says Juarez Martínez.

The ecstatic display increases the longer the penguin's mate is away

What's much more interesting is the fact that the longer each penguin has to wait for its mate, the more often it performs the ecstatic display. "Penguins take turns during the incubation period and share parental duties when the chicks hatch. One will be sitting on the nest while the other takes to the ocean to hunt for krill. The parents regurgitate their stomach contents to feed the young birds," says Juarez Martínez. At feeding time, the number of ecstatic displays increases exponentially the longer it has been since the last changing of the guard. "Especially after the sixth hour, when a penguin's mate should really have already returned, the prevalence increases dramatically." Why they do so is still unclear to the researchers. They think it plausible that it is some kind of territorial behavior, and want to use this working hypothesis to conduct further research.

"The high information value of the data collected with the event camera was what helped us study the ecstatic display in such detail," says Juarez Martínez. The scientists at the SCIoI Cluster of Excellence at TU Berlin have arranged further projects with wildlife researchers. One example is using the event camera to analyze bird behavior. "The camera's fast reaction time is particularly advantageous here, as it allows extremely slow-motion shots," says Friedhelm Hamann.

MATH+

A Digital Twin for Controlling Our Electricity Grid

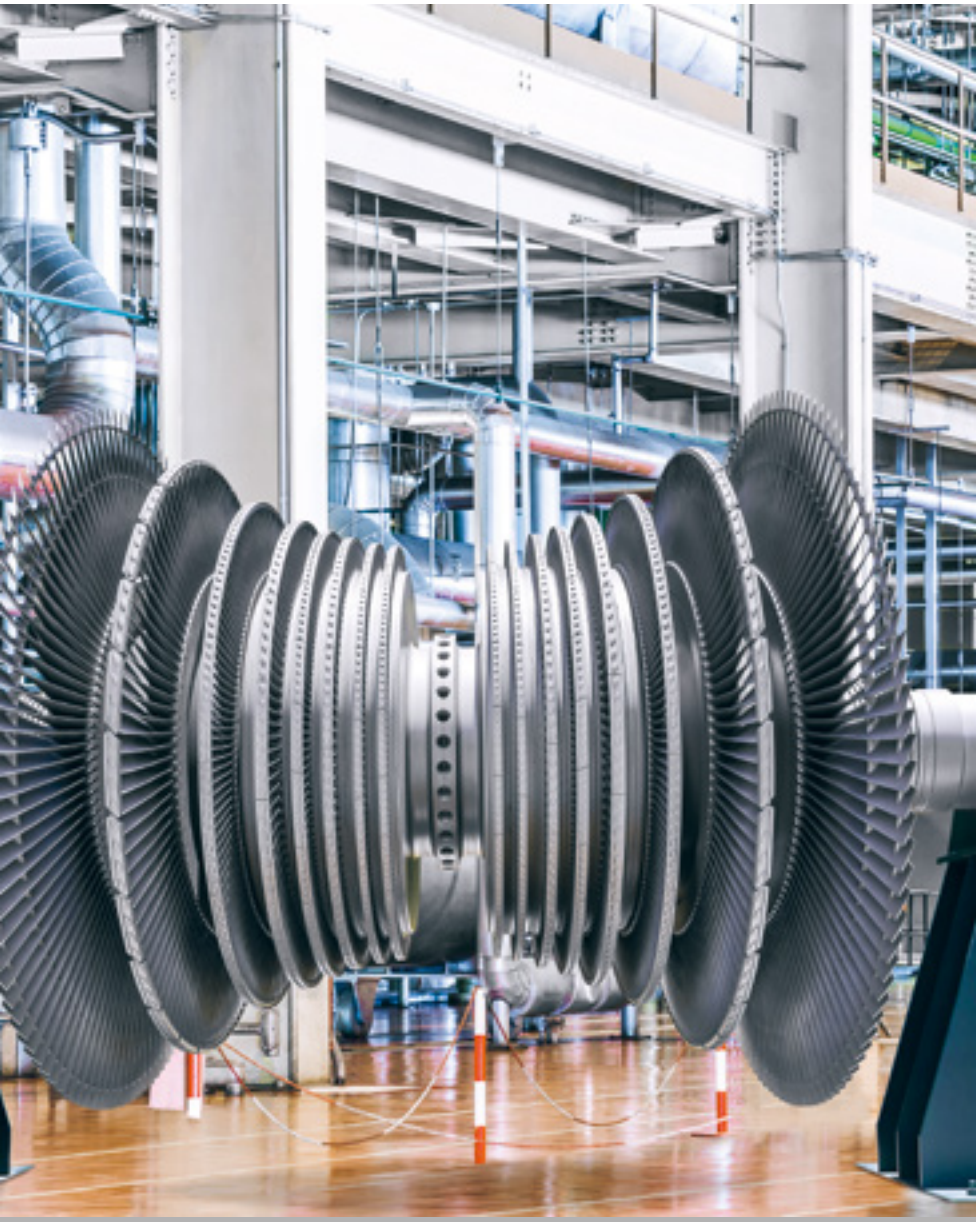
TEXT Wolfgang Richter

PHOTO Getty Images / iStockphoto

Implementing the energy transition is a major undertaking. In addition to solar cells and wind turbines, it requires the safe transportation of hydrogen as an energy storage medium. The reliability of our electricity grid is also important, as solar and wind energy produce more dangerous fluctuations in current and voltage than existing power plants. One of the projects at the MATH+ Cluster of Excellence is working to develop a digital twin of the electricity grid. This tool will play a decisive role in controlling our future energy grids.

"Digital twins are used to simulate real objects and processes as accurately as possible," says Professor Dr. Volker Mehrmann, head of the Numerical Mathematics Research Group at TU Berlin. "What's special about this technology is that sensors located on the real objects report changes to the digital twin's simulation software. These are used to calculate a new, more realistic image of reality." This makes it possible, for example, to predict fluctuations in the frequency of the power grid and take swift corrective action. "The principle of the digital twin can be applied universally, even to machines or an entire train. It could revolutionize production and operations in the future."

In collaboration with the Werner-von-Siemens Centre for Industry and Science, Professor Mehrmann's team of researchers has already built a real demonstrator consisting of two coupled electric motors. It represents a key technical element of the energy transition: the combination of a gas turbine, which is powered by hydro-



A turbine in a power station. A simulation of which would constitute a building block for a digital twin of our power grid.

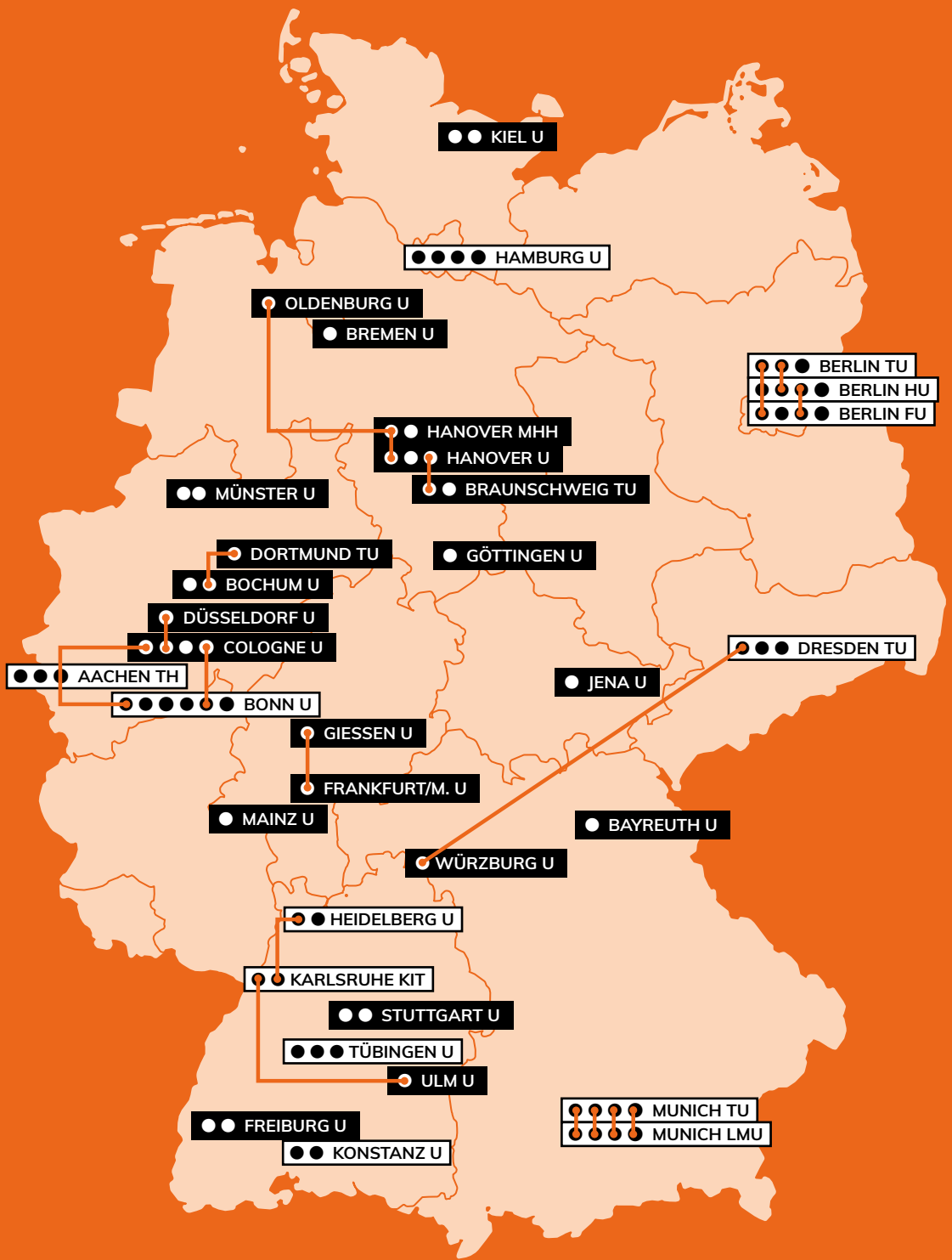
gen for example, and a generator to produce electricity. “If you want to develop a digital twin for such a system, you are faced with the problem that mechanical and electrical variables have to interact with each other in the simulation," explains Mehrmann. This is problematic because, on the one hand, the numerical values in the engineering world differ greatly between mechanics and electrics. While the standard units kilogram and second are suitable for the mechanical description of a machine, for example, the standard unit farad is not used for its electronic control, but rather the microfarad, which is smaller by a factor of one million, and is normally used to specify a capacitor’s capacitance. In simulation programs, this purely numerical imbalance leads to the electronic components simply "disappearing" in certain calculation processes.

Energy unites mechanics, electrics, and thermodynamics

"The other problem is that engineers understandably like to use variables in their equations that they can also measure on their machines," says Professor Mehrmann. "However, these are often no longer the variables that appear in the basic physical equations." As an example, he cites entropy, a physical measure of disorder in a system, which is replaced by temperature as a measurable variable in the engineering sciences. However, a direct link between mechanics and electrics can only be established via the basic physical equations. "As such, the simulations for both fields were developed separately in the past and then married together by hand – a very time-consuming and expensive process."

To circumvent these problems, the researchers reduced all the equations that describe the electrical, mechanical, and thermal properties of their demonstrator to the behavior of energy, a variable that appears in all three worlds. Using this trick, they were initially able to achieve a consistent simulation of their demonstrator based on the exact laws of physics. However, this requires a lot of computing time, so the team developed a kind of hierarchy of simulation models that become increasingly coarser, but are faster to calculate. "Think of it like the shadow cast by a geometric object. It's two-dimensional rather than three-dimensional and contains less information, but still tells us something about the original object," says Mehrmann. The time savings are enormous: Instead of the two months of computing time on a mainframe computer required for the high-resolution model, the most reduced model only requires milliseconds. "This is very important to achieve a quick response, for example if an appliance is about to fail." If simulations of all electrical components in the power grid were available, such simplifications could also be used to develop a digital twin of the entire grid.

The Excellence Strategy of the German Federal and State Governments



Top-level research
The German federal and state governments promote top-level research at selected universities. Through the Excellence Strategy, they strengthen the international competitiveness of German universities and support both Clusters of Excellence and Universities of Excellence with a current annual budget of 533 million euros. From 2026, this will increase to 687 million euros. Researchers are free to choose their research fields. The aim of the strategy is to advance excellent research, strengthen universities institutionally, and further develop the higher education system.

Find out more about the Clusters of Excellence:

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Signaling Effect

The public event series "Loops," which takes place in the old reading room in the Main Building at TU Berlin, invites you to explore current social issues at the exciting interface of art, design, science, and technology. At the center of the room is the Loop – a striking structure that not only creates space for stimulating discussions, but also uses light signals to set the time frame for the talks.

The topics revolve around the early recognition and targeted shaping of technological developments and their social, economic, and ecological impact. The event series is held as part of the Design and Computation master's program at TU Berlin and UdK Berlin and is funded by the BUA. In 2024, it received the prize in the "International Attention" category at the Berlin Design Innovation Challenge.

www.newpractice.net/loops

PHOTO Nikolaus Brade

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