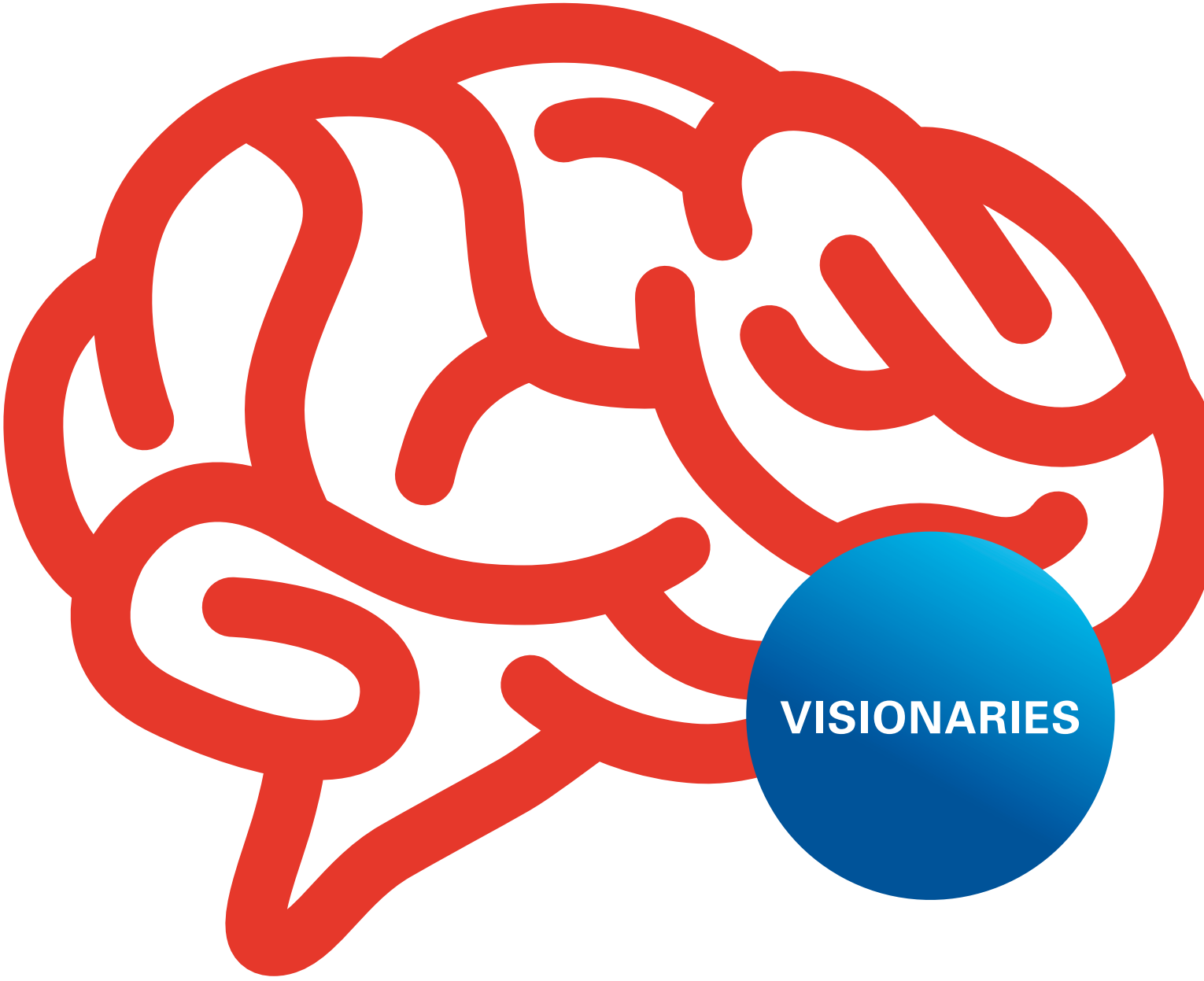
University of Stuttgart
Germany



FORSCHUNG LEBEN

THE MAGAZINE OF THE UNIVERSITY OF STUTTGART

NO. 08 MAY 2017

Dear Readers,

Photo: Uli Regenscheit

"We are thought leaders for the topics of tomorrow through the Stuttgart approach of integrated, interdisciplinary research and education".

Wolfram Ressel
Rector of the University of Stuttgart

The University of Stuttgart has developed and formulated a new mission statement in the course of an intensive discussion and consultation process over the past few months. In our mission statement, we define ourselves as a leading, technically oriented university with a global impact. Located in the heart of a region of immense economic strength and cultural integration force, we view ourselves as a centre of university-based, non-university-based and industrial research and as a guarantor for quality, holistic and comprehensive, research-led teaching. The Stuttgart approach stands for the interdisciplinary integration of engineering, the natural sciences, the humanities and social sciences on the basis of cutting edge research in each discipline.

These maxims are derived from a more encompassing vision: we want to be thought leaders for the topics of tomorrow through the Stuttgart approach of integrated, interdisciplinary research and education, because the University of Stuttgart's unique research profile gives us the ability to respond holistically to the important research problems of the future. And, because we feel a special obligation to use our knowledge, abilities and passion to make a responsible contribution towards shaping our future.

Discover just how our researchers will be breathing life into this vision in the University of Stuttgart's central research fields and what outstanding achievements they are accomplishing in this context in this latest edition of FORSCHUNG LEBEN.

Read about how we have arrived at adaptive buildings, thanks to digitalisation, with which the housing needed to accommodate an exponentially expanding global population can be built in a resource-conserving manner. See how interdisciplinary collaboration in the field of simulation technologies is enabling new approaches to the treatment of brain tumours or spinal disease.

Allow yourself to be carried away to the fascinating world of quantum technologies that are on the threshold of fundamental research to highly interesting applications in electronics and medicine. And, discover how the new production technologies – known collectively as "Industry 4.0" – are reinvigorating traditional batch production methods or what can be gleaned by reading between the lines of Shakespeare dramas with the aid of digital humanities.

We wish you an inspiring read!

... Heard in Passing

Bowing to the Victims of National Socialism

It has long been known that German universities played a crucial part in the discrimination of Jews and other minorities by National Socialists. The extent of the injustices carried out at the University of Stuttgart was discovered by Dr. Norbert Becker, Head of the University Archive, in the course of the "Persecution and Injustice at the Stuttgart University of Applied Sciences in the Third Reich" research project (Verfolgung und Unrecht an der Technischen Hochschule Stuttgart in der NS-Zeit). A total of 440 people were discovered who were subject to discriminatory treatment by the university and suffered persecution during the Third Reich period. Eleven per cent of professors and nine per cent of the assistant professor were sacked. At least two per cent of students were affected by discrimination and forced de-registration, but the victims also included forced labourers from areas occupied by the *Wehrmacht*. At a commemorative event on the 6th of February 2017, the university admitted its corporate responsibility for these injustices and its complicity with the brutal National Socialist regime and apologised to the victims in front of relatives and over 300 guests. Details of the study have been published in a document, which is scheduled for publication in book form by the end of the year.

Photo: University Archive

Twin Information Offensive

Simpler, Faster, More Networked: The mega trend in the IT sector also unites three Stuttgart-based start ups who introduced themselves together with the High Performance Computing Center (HLRS) at the University of Stuttgart stand at this year's CeBit trade fair in late March. As a co-exhibitor at the "Baden-Württemberg communal stand", the university presented attractive exhibits from the cutting edge of scientific research, which are capable of making the transition to industrial innovation in the near future,

Photo: BWI/Gabriel Poblete Young

to trade fair visitors from all over the world, including Johanna Wanka, the German Federal Minister for Research, Winfried Kretschmann, Prime Minister of Baden-Württemberg, and Nicole Hoffmeister-Kraut, State Minister for Economic Affairs.

Just a few weeks later, the university presented future-oriented research results at the Hanover Fair, and used the opportunity to underscore the need for a rapid conversion of research findings to industrial innovation. Exhibits were shown from a total of seven institutes and facilities, including the ARENA2016 Research Campus for Automobil Production of the Future, highly complex gasket and control technology, bio-based materials and material cycles in architecture as well as computer simulations from the fields of medicine and the life sciences. Also on display was a simulation process that enables robots to automatically, and without breakages, teach themselves how to pick up a coffee cup.

Gemeinsam bringen wir die Dinge voran: Wir von der EnBW entwickeln intelligente Energieprodukte, machen unsere Städte nachhaltiger und setzen uns für den Ausbau erneuerbarer Energien ein. Und dafür benötigen wir tatkräftige Unterstützung.

Egal, ob Praxiseinsätze während des Studiums oder direkter Berufseinstieg danach – wir sind immer auf der Suche nach engagierten Talenten, die sich mit ihrem Fachwissen einbringen und zusammen mit uns die Energiezukunft gestalten.
Im Gegenzug bieten wir spannende Aufgaben und vielfältige Entwicklungsmöglichkeiten.

Machen Sie jetzt mit: **www.enbw.com/karriere**

top EMPLOYER DEUTSCHLAND 2016
CERTIFIED EXCELLENCE IN EMPLOYEE CONDITIONS

HOCHSCHUL PRAKTIKUM FAIR company 2016 karriere.de

Wir machen das schon.

EnBW

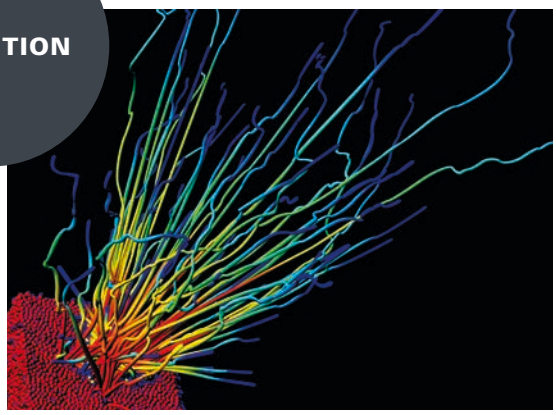


Photo: University of Stuttgart / SFB 716

In the Digital Laboratory

Scientific progress without the aid of computer simulations is highly unlikely today. They add to developing theories and supplement experiments, enable us a peak into the future and provide us with insights into areas that would otherwise remain out of bounds. But what can be discovered using simulations? Why and for what purpose are they used at all? What is a scientific model? Can everyone carry out a simulation on their own personal computer? These and many other questions are answered by the SimTech (Stuttgart Research Centre for Simulation Technology) Cluster of Excellence and the University of Stuttgart's Special Research Field 716 (dynamic simulation of systems with large particle numbers) "In the Digital Laboratory" exhibition which continues at the Stuttgart Planetarium until the 30th of July 2017. The exhibition provides a playful insight into the world of virtual experiments and invites interactive participation.

www.imdigitalenlabor.de

Awards Ten "A"s by U-Multirank

The University of Stuttgart scored extremely highly in the fourth edition of "U-Multirank", a university ranking initiative of the European Commission. A score of ten "A"s places the University of Stuttgart among the top five German universities in the category groups "teaching and learning", "research", "knowledge transfer", "internationalisation" and "regional engagement". "The University of Stuttgart did particularly well in the "research" category, in which it scored top marks in five out of ten indicators of excellence. We also did very well in the category of "knowledge transfer" with top marks in four out of nine indicators of excellence.

Data Analysis XXL

The High Performance Computing Center at the University of Stuttgart (HLRS) has put a new big-data system into operation. It is the world's first data analysis system of this size in production operation. The new computer comprises a total of 64 computing nodes of 36 calculation kernels each. With 512 gigabytes of RAM and 1.6 terabytes of local SSD space, each node is optimally equipped to deliver solutions to current and future challenges in the field of data analysis. For the first time ever, the HLRS provides its users with the ability to analyse data volumes in the petabyte range in an efficient and timely manner.

Gofuture!Klub

In addition to major corporations, small to medium-sized enterprises can also benefit from collaborations with the University of Stuttgart. To facilitate access to research services and scientists for the region's "hidden champions" and open up new vocational prospects for students, the University of Stuttgart has founded the Gofuture!Klub in collaboration with Stuttgart-based businesses Jürgen Fürst (Suxes GmbH) and Christian Dau (Dau Kommunikation GmbH). The objective is to strengthen the competitiveness and future viability of small to medium-sized enterprises and to support their strategic personnel acquisition efforts. Member organisations will have access to a plethora of exclusive events, personal contacts and opportunities for an intensive exchange of ideas with the University of Stuttgart.

www.gofutureklub.de

"Human System" Research Alliance

Human beings are highly complex biological systems, whose "sub-units" interact in a finely coordinated, intelligent, dynamic, energy-efficient manner, which is also prone to the occasional disruption. To understand this interplay and to create appropriate theoretical models of the system is the objective of a regional Research Alliance between the Universities of Stuttgart and Tübingen. The State of Baden-Württemberg is funding the initiative with a million euro over three years. The Human Model will, for example, be able to be used for the design of technical systems. Carrying out research in the failure susceptibilities of the "human as system" will also pave the way to new approaches to medical therapies, whereby one of the primary points of focus will be the central nervous system.

Second ERC Grant for Professor Wrachtrup

For the second time, the European Research Council, ERC has awarded one the coveted ERC "Advanced Investigator Grants" for experienced and excellent scientists to Professor Jörg Wrachtrup, a physicist at the University of Stuttgart. Professor Wrachtrup would like to use the new grant, worth 2.5 million euro, to show how it is possible to use quantum sensors to trace electrical fields with a hitherto unparalleled sensitivity and spatial resolution. Professor Wrachtrup's current research project "Mapping Electrical Fields in Single Molecule Charges with Quantum Sensors" builds upon his previous research into the use of atomic defects in diamonds in quantum engineering.

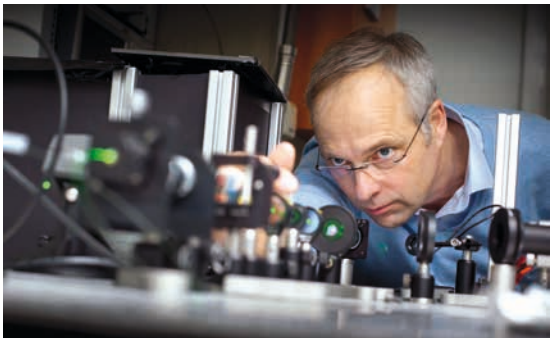


Photo: Frank Eppler

OUTSTANDING

Photo: Ferdinando Iannone

Prize for Courageous Science

Dr. Ferdinand Ludwig of the University of Stuttgart's Institute of Theory of Architecture and Design (IGMA) has been awarded the Prize for Courageous Science, which is unique in Germany, by the Baden-Württemberg Ministry of Science, Research and the Arts. A pioneer in the field of Construction Botany, Dr. Ferdinand Ludwig's research has culminated in the development of a unique variety of architecture, which involves the creation of highly original buildings resulting from the interplay between mechanical joints and plant growth. His idea of combining architecture and nature is deemed to be innovative and is viewed as a contribution to increasing our quality of life and our environment.

Outstanding Nano Robot

Peer Fischer, Professor of Physical Chemistry at the University of Stuttgart and head of the "Micro, Nano and Molecular Systems" research group at the Max Planck Institute for Intelligent Systems, received the 2016 World Technology Award in the "Information Technology – Hardware" category. Together with his group, Professor Fischer has succeeded in developing new 3D nano-fabrication methods and nano-robots including, among other things, the first reciprocal micro-swimmer and the first micro-robot, which can swim along by altering the shape of its body. In addition, the research group recently published the first ever acoustic hologram.

Global warming is both a cultural event and a natural phenomena

A plea for a partnership between the natural sciences and the humanities

As a core aspect of the "Stuttgart approach", interdisciplinarity, the interaction between the natural sciences, engineering, the social sciences and humanities, is integral to the University of Stuttgart's mission statement. Olaf Zimmermann, Managing Director of the German Cultural Council, uses climate change to exemplify why this intermeshing is indispensable and what questions are raised when the subject of culture is brought into play.

The impact of human culture on nature, i.e., on our environment, is unmistakable and no place on Earth is excluded from its influences. Nevertheless, we like to differentiate between a putative natural environment and one that is unnatural in that it is influenced by humans. The word "natural" immediately evokes associations such as "pristine", "untouched", "pure", "clean" - in a word "not artificial". Yet, this idealised vision of nature is a pure fiction. This imaginary virginity has been lost wherever the fingerprints of human culture have been left. Today, this spoor of human culture can be found in the deepest depths of the ocean, on the summits of the highest mountains and even in the eternal ice.

The "blame" for this lies in human nature: we want to cultivate our environment. In the broadest sense, the word "culture" is etymologically related to the Latin "cultura" meaning "processing", "maintenance", "agriculture", and refers to everything conceptualised and produced by humans. But such things are not an end in themselves; on the contrary, they are necessary for our survival within the environment. From the perspective of any given human, the idea, particularly beloved by nature enthusiasts, that nature is somehow better in the absence of cultural influences, because it is more pristine, and is more of academic than practical interest. Without doubt, nature would not equal culture in the absence of humans, and perhaps it would even be more beautiful, but ... humans would be unable to survive in it. Surely, that's a step too far for even the most avid nature enthusiasts!

More Contrasts than Commonalities

This notwithstanding, the terms "culture" and "nature" have implied more contrasts than commonalities in debates over the past few decades. The friends of nature and promoters of culture have often faced off like two estranged brothers. But, is this dichotomy still appropriate for our times?

After all, if pristine nature no longer exists then everything around us a kind of "cultural nature" or "natural culture". Yet, that certainly does not mean that mankind should take no responsibility for the environment in which we live. Precisely because human kind is the universal designer-creator and notwithstanding the fact that we cannot simply cease our formative influence on the environment, we humans are fully responsible for our actions, i.e., for the form and ramifications of our inevitable impact. Humans are responsible for the extinction of species, global warming and the overexploitation of natural resources.

Global Warming from a Cultural Perspective

The climate is a good example of the duality of culture and nature. To a large extent, our cultural development has been influenced by climatic factors. For over two thousand years, the projection of the Roman power was facilitated by the fact that Alpine passes were easier to traverse than they are now, even in winter – because the climate was warmer. Almost a thousand years later, glaciers that formed during a significant cold snap destroyed many Roman roads across the Alps thereby accelerating the decline of the Roman Empire. At that time, North and North West Europe were ravaged by famine

due to the same climatic change, which researchers believe to be one of the main causes of the Migration Period, a fundamental cultural transformation. Later, global warming caused extended droughts in the East, which had a long-term negative impact on trade and very probably also resulted in the ruination of the Silk Road.

Reciprocal Effects: Environment and Culture

In Northern Europe, by contrast, the effects of climatic warming were largely positive. It became greener and agriculture became possible at ever higher altitudes. Greater agricultural yields enabled population growth and supported the expansion of trade and industry. These cultural advances were slowed by the Little Ice Age, during which Europe was devastated by plague and starvation. Religious fundamentalism, another product of culture, expanded dramatically at that time, and war became a permanent fact of life with migration often offering the only hope of salvation. For 150 years the climate has been getting warmer again. This time, man is no longer simply the victim or beneficiary of this development but is himself a contributing factor to the change. The effects are already evident around the world. Stephen O'Brien, Under-Secretary-General for Humanitarian Affairs and Emergency Relief Coordinator with the United Nations, sounded the alarm this March. 20 million people are threatened with starvation in Africa and Asia due to war, displacement, and mismanagement but also to climate change. Tornadoes, heat waves, floods and other extreme weather events are set to increase around the world. Parasites and tropical diseases will spread in Central Europe and ever more people will seek refuge in Europe from natural disasters, especially in Africa and Asia. Climate changes have changed our cultures in the past and will also have an enormous effect on them in the future.

Photo: Tim Flavor

> Even in the course of everyday university life, the unity of culture and nature must be emphasised.
>
> **Olaf Zimmermann**
> Managing Director of the German Cultural Council (Deutscher Kulturrat), the umbrella organisation of German cultural associations

Rapid Counter Measures Crucial

There will be no cultural benefits in the wake of the global warming that is currently taking place and to which we humans are at least contributing. We have the data and the necessity for rapid countermeasures is actually unavoidable. So, why is so little being done?

- Because climate change is perceived as a problem of science, not culture.
- Because the need to teach environmental science as an essential aspect of cultural studies and vice versa was neglected.

· Because we have allowed a paradigm to emerge in which culture and the environment are perceived as opposites.

Parallel Lives - a Thing of the Past

Yet, what are the implications of this for a cultural association such as the German Cultural Council? One change will affect responsibilities which have hitherto been nicely divided: some people deal with nature, others are responsible for culture; some are scientists, others are scholars of culture; we have environmental activists and cultural politicians; some people are active in environmental movements and others in cultural associations. Even in universities, the traditional divide between the natural sciences and the humanities is highly restrictive in terms of peering beyond the confines of one's own academic silo. The natural sciences and humanities faculties need to come together to deal with climate change and to develop collaborative solutions. Working in splendid isolation is a luxury we can no longer afford. Even in the course of everyday university life, the unity of culture and nature must be emphasised. So far the cultural sciences have remained largely aloof from anything touching upon the natural environment. A consideration of topics such as global warming reveals how irresponsible this position has been. Because the 23rd World Climate Conference is being held in Bonn this year, the opportunity arises for the mutual reassessment of environmental issues as questions of culture. Let's get started - together!

Olaf Zimmermann

Since March 1997, professional art dealer Olaf Zimmermann (born in 1961) has served as the Managing Director of the German Cultural Council (Deutscher Kulturrat), the umbrella organisation of German cultural associations with a current membership of 257 organisations. The objective of this organisation is to encourage and promote discussion on matters of cultural-political importance at all political levels and to stand up for the freedom of art, publication, and information. Zimmermann is also the publisher and Editor in Chief of the German Cultural Council publication Politik & Kultur, as well as the coordinator and moderator on the Cultural Integration Initiative.

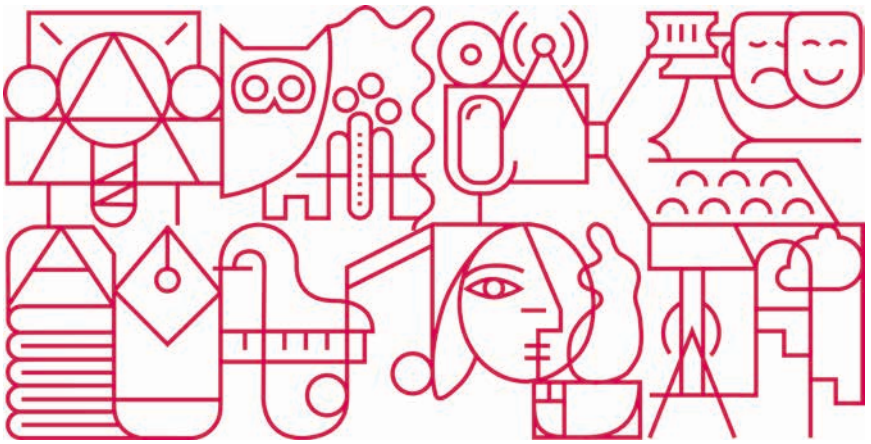


Figure: German Cultural Council

Durchstarten in Deine Zukunft!

Wir sind ein international führender Hersteller von hochwertigen Spezialprodukten der Medizintechnik und beschäftigen weltweit in über 40 Ländern mehr als 7.100 Mitarbeiter. Wir bieten kontinuierlich spannende Themen für Praktika und Abschlussarbeiten in verschiedenen kaufmännischen und technischen Bereichen an.

Schau doch rein unter www.karlstorz.com

Generation Education

STORZ
KARL STORZ — ENDOSKOPE

KARL STORZ GmbH & Co. KG, Mittelstraße 8, 78532 Tuttlingen/Germany, **www.karlstorz.com**

Adaptable Buildings
Digitisation is enabling new construction and structural forms

The world is facing a gigantic construction boom, which will not be manageable with current approaches. That's why interdisciplinary teams working in two collaborative research centres at the University of Stuttgart are looking into how novel approaches to planning, construction and engineering can help to design our built environment such that it can automatically adapt to meet changing challenges pertaining to such things as load-bearing behaviour or thermal insulation. One template from which the architects and engineers are drawing inspiration is nature.

When Konrad Zuse set about creating the world's first computer in the 1930s, the global population was hovering around two billion people. Now, just 85 years later, that figure has risen to 7.5 billion. About 2 billion children and young adults will reach maturity in the next few years, and they'll all need somewhere to live, jobs and shopping centres. According to Professor Werner Sobek, who heads up the Institute of Lightweight Structures and Conceptual Design (ILEK): "In the next 16 years, we'll have to construct as much as was ever constructed up to 1930. To avoid damaging our planet beyond all repair", he continues, ""we urgently need novel approaches that will allow us to build more with less and with the aid of which we will be able to fully reintegrate materials used in construction into natural and technical material cycles." For, the construction industry is the world's leading consumer of natural resources by far. It consumes the most energy, the most water, the most resources and produces the most waste.

Digitalisation as an Opportunity

Faced with these challenges, today's scientists are taking advantage of the digital revolution triggered by Zuse all those years ago. The German Research Foundation (DFG) supports these endeavours and is providing two million euro of funding to two collaborative research centres at the University of Stuttgart over the next four years. Both initiatives are dedicated to the development of adaptable and efficient buildings, which limit the use of resources and, therefore, help to protect the environment. However, each team is focusing on entirely different things in pursuit of this objective.

Since 2014, architects and engineers working in Biological Design and Integrative Structures – Analysis, Simulation and Implementation in Architecture (SFB/TRR 141) at the University of Stuttgart have been collaborating with biologists and physicists at the University of Freiberg and with geo-scientists and evolutionary biologists at the University of Tübingen in a dedicated effort to identity the "underlying design and construction principles in biology and architecture". As Professor Jan Knippers of the University of Stuttgart's Institute of Building Structures and Structural Design explains: "Our objective is to develop multifunctional, adaptable and ecologically-efficient structures that transcend the boundaries of traditional building construction by far." To this end, the researchers involved are taking their cue from the extraordinary variety and efficiency of natural structures and transferring the underlying principles to architecture and technology.

The "Adaptive Shells and Structures for the Built Environment of Tomorrow" (SFB 1244) collaborative research centre joined the collaborative effort at the start of 2017. Their spokesman Professor Werner Sobek wants to employ his own so-called "triple zero concept" to ensure that buildings in the future do not use more energy than they are able to extract themselves from sustainable sources (zero energy), and that they generate no damaging emissions of any sort (zero emissions) and that they can be fully recycled in natural or technical cycles without leaving any residual waste (zero waste).

A glass façade with integrated shear actuators to reduce facade deformation under heavy wind loads.

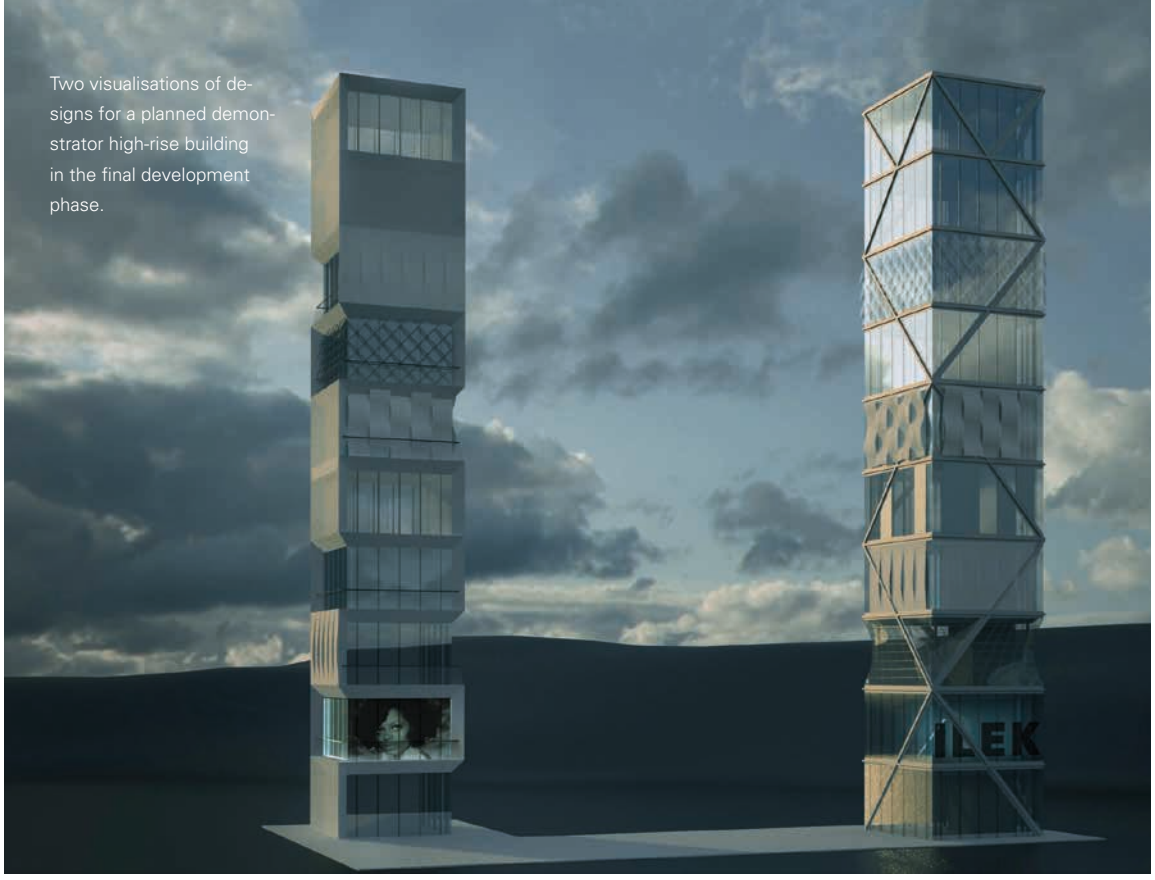
Photo: University of Stuttgart/ILEK

Buildings Adapt to Loads

A key concept along the way is “adaptability”. This completely novel approach involves a fundamental transformation of the architectural understanding of buildings, which applies equally to individual construction components and their integration into the overall system. Professor Sobek explains this in relating to the SFB 1244 using the structure of buildings as an example: to date, he explains, buildings have been designed to withstand the maximum expected loading and utilisation scenarios. However, the likelihood that such extreme conditions will ever actually materialise is pretty slim. This results in the construction of support structures that will be significantly over-dimensioned throughout the majority of their existence, with a concomitant overconsumption of materials and money. For 20 years now, researchers at the ILEK have, therefore, been conducting research into adaptable systems. An adaptive structure replaces the mass that needs to be put in place to deal with extreme loads with energy that it is only used for short periods, thus enabling radical savings in terms of the necessary construction materials.

Sobek had already researched this with other institutes in the past, particularly with the University of Stuttgart’s Institute for System Dynamics (ISYS), the head of which, Professor Oliver Sawodny, is also the Deputy Chairman of the new collaborative research centre. Previously, both of them had pooled their ideas in the “Hybrid Intelligent Construction Elements” research group (981), a productive collaboration which was to become the core of the current collaborative research centre. The “Stuttgart Smart Shell” was created in this context, which was the world’s first large-scale adaptable shell structure, which comprised a 4cm-thick wooden shell capable of spanning an area in excess of 100 square metres. It works because sensors continuously measure the loads throughout the structure. Three of its four support points can be moved by hydraulic cylinders, which enables the structure to adapt to unexpected loads caused, for example, by snow or strong gusts of wind, within milliseconds.

The SFB 1244 is continuing this research. 15 institutes from the University of Stuttgart and the Fraunhofer Institute of Building Physics are participating in the initiative alongside architects and structural engineers, aircraft and mechanical engineers and computer scientists. The researchers want to transfer the “Stuttgart Smart Shell” principle and investigate ways to use sensors and actuators to construct



Two visualisations of designs for a planned demonstrator high-rise building in the final development phase.

Photo: University of Stuttgart/ILEK

such things as intelligent high-rise buildings and bridges. Another sub-project under the auspices of the SFB 1244 involves the direct integration of so-called fluid actuators, i.e., hydraulic or pneumatic elements, into structural elements. These could then obviate the need for adaptations within the supports of the kind required by adaptive structures such as the "Smart Shell". In another project, the team also wants to develop switchable breathability for building shells.

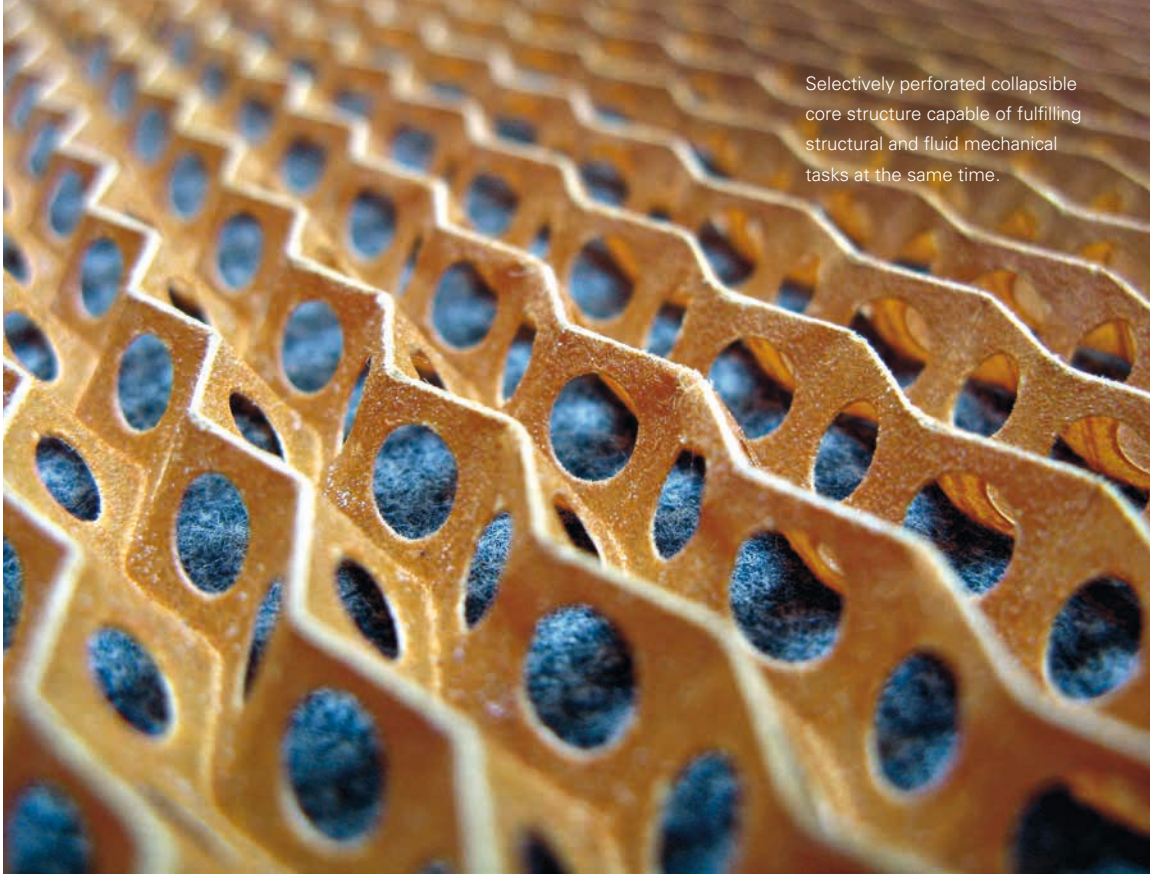
Tradition with Vision

There is a tradition at the University of Stuttgart of catalysing innovations in the field of construction engineering through the collaboration of various disciplines. The university is the *Alma Mater* of such engineering and architectural luminaries as Fritz Leonhardt, Jörg Schlaich and the late Frei Otto (1925-2015), the latter of whom became only the second German to win the Pritzker Architecture Prize in 2015. Otto established collaboration in areas in which competition reigned supreme – thereby blazing a trail for those who followed: "Since the foundation of the Institute for Lightweight Structures by Frei Otto, which I took over in 1994 and merged with the Institute of Structural Design in 2000 to form the ILEK", says Professor Sobek, "the University of Stuttgart has become a global leader in lightweight construction". The field of "ultra lightweight construction through mechanically actuated structures", which was developed at the ILEK is now a central component of the university's research profile.

As Professor Achim Menges, Head of the Institute for Computational Design (ICD) emphasises, another of Otto's outstanding achievements has been the transfer of material innovations to new forms of construction. Otto took his inspiration from nature and attempted to minimise material consumption. His successors at the SFB/TRR 141 and SFB 1244 continue to work to both of these principles. We are currently experiencing a complete paradigm shift in the field of construction just as we were then, as Menges explains, whose own institute is a member of both collaborative research centres: "Without the advent of digital technologies", he says "a structure such as the Stuttgart Smart Shell would have been inconceivable".

The Digital Revolution Needs Collaboration

The result of this are complex digital planning and production process for which all participants must work together, which the Stuttgart-based research-



Selectively perforated collapsible core structure capable of fulfilling structural and fluid mechanical tasks at the same time.

Photo: University of Stuttgart/ IFB/Y. Klett

ers want to exemplify. As Sobek explains, this will provide future planners the requisite new tools and methods with the help of which they will be able to design, configure and build adaptive systems. This knowledge is reaching the major growth regions of the world via numerous collaborative projects with foreign universities and because many young people from other continents study in Stuttgart. In addition, many German planners, architects and engineers are working on projects in those regions in which the living environment for two billion young adults must be created.

From Sea Urchin to Exhibition Hall

The interdisciplinarity concept is also following by TRR 141 (Biological Design and Integrative Structures – Analysis, Simulation and Implementation in Architecture): "Transregio's basic idea", explains Jan Knippers, "is to bring scientists and engineering scientists together". The team's objective is to extract models for plant and animal structures from nature, to digitise them and to transfer them to the field of engineering. How the process, which involves numerous researchers from different disciplines, actually works can be understood through the example of an exhibition hall for the 2014 horticultural show in Schwäbisch Gmünd. The starting point for the work was a species of sea urchin known as the sand dollar. According to Knippers: "it lives in the breakwater and its inner structure is naturally adapted to high levels of mechanical stress." The biologists captured it in computer tomographic images. A specially developed computer programme then converted the grey tones of the image to rigidity properties. These were then used to create a simulation, on the basis of which it was possible to work out how the skeleton of the sand dollar is arranged and constructed.

"This process follows certain rules that I can model algorithmically" says Achim Menges, who founded the Institute for Computational Design in 2008 to establish this type of process in architecture. Menges' team programmed a digital planning tool for the sea urchin hall. Each of the plates was generated as an individual element with specific properties, based on such criteria as material restrictions, robot-based buildability and external forces. "These so-called agents" Menges explains, "wander around in the space until they find a condition in which all requirements are met. The architect designs the process, not the final form." This results in a man-machine interaction that is beyond what either humans or computers have ever been able to achieve on their own until now.

In this case, the programme provided the data for the industrial robot, which worked out how it needed to saw, mill and drill the plates. This robotic wood processing is an innovation in itself. Next, the group built a research pavilion from these timber shell segments, which provided them with the necessary insights for the highly efficient, self-supporting exhibition hall, whose 270 plates could be put together like a 3D puzzle and disassembled whenever necessary. "We were able to enclose a 605 cubic metre space with just 12 cubic metres of timber", says Menges: "The shell has a span of 10 by 19 meters, but is only 50 millimetres thick". Since then the first construction projects that use the wooden shell segments have begun, so the principal has become established as an everyday construction activity. Describing the role of the researchers, Jan Knippers says: "In a highly developed industrialised nation, I see it as being our task to drive technological progress. When it has proven its value at the pinnacle then it will gradually trickle down to the broader base."

No Joints, Rollers or Hinges

Knippers offers the following explanation for why structures that are oriented on natural forms are superior to traditional structures: "We usually have a lot of components that we bolt together. But, the more complex the construction of a technical system, the more fault prone it is. Things jam and creak. Unless every joint is perfectly positioned exactly where it is supposed to be, there will be problems." With the aid of bionics, this mechanical

Switchable, pixelated glazing with various dimout factors and with different motifs.

Photo: University of Stuttgart/ILEK

complexity is shifted to the material, whereby one exploits two basic principles of natural forms: either an assemblage of fibres or one made of porous structures. “In both cases it is about achieving extremely finely graded physical and chemical properties”, says Knippers. This is why numerous sub-projects run by TRR 141 are dedicated to the question of how one can build flexible, adaptable structures with no joints, rollers or hinges, by applying plant movements (tropisms) to mechanical systems. Two templates for this, among others, are provided by the Venus flytrap and the opening mechanism of a pine cone. Such systems are more difficult and complex to construct, but, thanks to digital engineering, they can be used to make easier, more efficient and more durable buildings – whilst using significantly less material.

Werner Sobek estimates that it will take about a decade until all the research findings have become firmly established in the construction industry. He expects that, in a few years, it will be possible to save up to 70 per cent of the resources currently used in construction. Time is running out: as early as the 2020s the number of people living on Earth is set to top the 8 billion mark.

Daniel Völpel/amg

Info

The biological design team of Collaborative Research Centre 141 are dedicating their time between the 19th of October 2017 and the 6th of May 2018 to the special exhibition “Biological Design – Biologically Inspired Architecture” at the State Museum of Natural History (Staatliches Museum für Naturkunde) at Schloss Rosenstein in Stuttgart. The exhibition will present examples, ideas, research objectives and visions all aimed at the development of sustainable architecture that uses energy efficiently whilst being aesthetically pleasing.

Light Headed
The Elytra Filament Pavilion is based on the lightweight construction of beetle wings

Unlike humans, nature often constructs things with fibres: plants from cellulose, insects from chitin, and vertebrates from collagen. Why not adopt the same principle in the field of construction researchers at the University of Stuttgart asked themselves. In 2016, a pavilion created on the basis of their novel method was the main attraction at the Victoria & Albert Museum in London.

The Victoria & Albert Museum was founded 165 years ago to showcase the influences of industrialisation on society. In 2016, the museum wanted to exhibit the world's biggest art and design collection to emphasise how engineering has characterised and shaped the 20th century. The "Elytra Filament Pavilion" in the courtyard, which was the main attraction for the public during this "Engineering Season" originated at the University of Stuttgart. The design for this exhibit is based on the inner structure of beetle wings. It won the competition for the best exhibit in the John Madejski Garden for the Stuttgart-based team.

"Our idea", explains Professor Achim Menges, architect and head of the University of Stuttgart's Institute for Computational Design, "was to demonstrate how engineering and design could come together in future." To create the pavilion, the team led by Professor Menges and construction engineer Professor Jan Knippers from the Institute of Building Structures and Structural Design, refined a robotic process – the design was produced by a specially programmed piece of software. Then an industrial robot wound pieces of glass and carbon fibre coated in epoxy resin around a hexagonal substructure. The trick: the robot did not work to a set design. Instead, the fibres positioned themselves automatically during the winding process. This produced a total of 45 complex hexagons, each with a unique fibre

Photo: V&A London

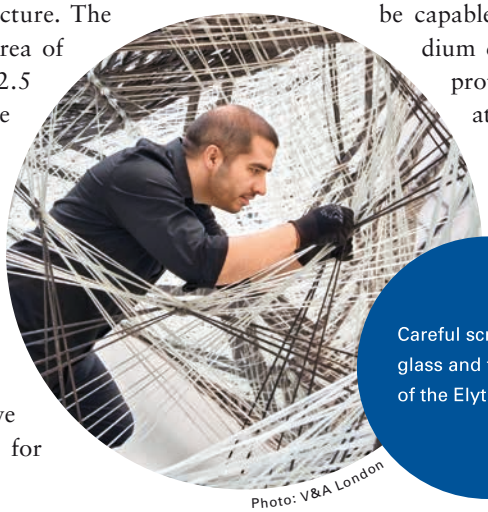
The University of Stuttgart's Elytra Filament Pavilion on display as part of the art and design collection drew crowds at the Victoria & Albert Museums in London in 2016.

Photo: NAARO

structure and adapted to its own specific function within the pavilion roof. This approach was completely new for the team: "There is a seamless flow from design to production", says Professor Menges. The scientists had copied the construction method from the elytra or hardened forewings of native beetle species. These consist of an upper and lower shell that are bound together like flattened honeycombs. Unbroken chitin fibres provide the necessary strength at the contact points between the platelets, and the wings are hollow in between. Based on this template, the team was able to produce a highly rigid, but extremely lightweight structure. The entire pavilion that spanned an area of 225 square metres, weighed just 2.5 tonnes – as much as just two square metres of brickwork on the façade of the Victoria & Albert Museum. For Menges, the Elytra Filament Pavilion embodies "the unified conceptualisation of architectural design, engineered construction and state-of-the-art production methods". It is typical for the trans-regional Collaborative Research Centre SFB/TRR 141, for which Jan Knippers is the spokesman. The interdisciplinary and integrative approach in this area brings together architects and engineers from the University of Stuttgart, biologists and physicists from the University of Freiberg and geo-scientists and evolutionary biologists from the University of Tübingen.

The researchers are currently working on a new pavilion that takes the concept further: "We now have two widely spaced robots and a drone that flies the fibres from one to the other", Menges reports. At some stage in the future, machines may even be capable of building complete stadium covers in this manner. The prototype will be on display at Campus Stadtmitte in the spring of 2017.

Daniel Völpel



Careful scrutiny: the glass and fibre cells of the Elytra Pavilion

Photo: V&A London

Broker
Cordula Kropp brings people, technology and nature together

The combination of the humanities and science permeates the life of Professor Cordula Kropp like a leitmotiv. As such, the Technical and Environmental Sociologist exemplifies the University of Stuttgart's mission statement in which interdisciplinary collaboration and the critical monitoring of science and its ramifications plays a central role. Kropp has been employed here as Professor of Sociology since August 2016 and her work focuses on the sociological aspects of risk and engineering science.

"That's a professorship tailor-made for me" laughs Cordula Kropp in response to the question why she accepted the position at the University of Stuttgart. Yet, having spent her entire life in Munich, this was no easy step for her: the decision involved leaving her house, husband and the youngest of her two grown up children there. "The interaction between technology and the environment has always fascinated me", Kropp admits. In addition, she says, her new operating base is one of three locations in Germany – next to Munich and Berlin – where research into the sociology of technology and the environment is being carried out. One thing in Stuttgart's favour is its long tradition of paying close attention to the risks concomitant with technology.

As an environmental and technical sociologist, Professor Kropp is interested in how technology develops at all and how it is disseminated. Why, for example, did cars with internal combustion engines become established at the start of the 20th century rather than electric cars? Sociologists carry out research into the opportunities and risks that are concomitant with technical advances and how people react to them. They analyse the impact of contemporary trends, such as smartphones, on society and, by contrast, how society influences technological developments. They are also interested in how societies can cope with the consequences of technical progress, such as climate change, air pollution and species extinction in order to be able to bequeath an environment worth living in to later generations. Kropp spent seven years as Professor of Sociological Innovation and Future Research at the Munich University of Applied Sciences, where she conducted research into how viable and sustainable sociological innovations developed by active, concerned citizens in response to such societal challenges as climate change or the energy transition, become established. Examples of such social innovations that break down traditional, antiquated structures are, among others, citizens energy cooperatives or urban community gardens. Such initiatives may arise in response to technology, be concomitant with technical developments or enable these in the first place.

Climate Change – But Not Here

Kropp has become particularly passionate about climate change. In a series of collaborative projects, the sociologist has conducted research into how pioneering communities in the Alpine region are reacting to climate change and what solutions they are developing. Why does one community adopt a climate-friendly approach by making the transition to regenerative energy sources and organic farming or low impact tourism, whilst a neighbouring community does no such thing? "It's not about highly educated communities with lots of cash to invest", Kropp explains, "but rather it's about visionary people with good links to politics and the economy. That's one of the success factors."

Her research has also shown that many people still do not feel personally affected by climate change. They primarily think in terms of a climatic threat to southern regions caused by cities and industrial centres. To persuade people to embrace climate-friendly behaviours, it is necessary to explain to them in

Global climate change "has to be tackled on the ground". It's not about highly educated communities with lots of cash to invest", Kropp explains, "but rather it's about visionary people with good links to politics and the economy.

Cordula Kropp

Photo: Uli Regenscheit

Heavy Rain Expected Only when people become aware that global warming and flooding are already having a concrete impact on their lives will it be possible to persuade people to embrace climate-friendly behaviours.

detail how global warming is already having a concrete impact on their lives through lower snowfall volumes or flooding, which impact local agriculture, forestry and the winter sports sector. Professor Kropp is, therefore, convinced that climate change "has to be tackled on the ground", by involving civic society and local businesses. The sociologist has coined the phrase "bottom-up climate management" and has written several book chapters and papers on the subject.

A Risky Mixture: Vague Knowledge, Poor Communication

Throughout her career, Professor Kropp has turned her attentions to different aspects of technical and environmental sociology. The charitable Munich-based Project Group for Sociological Research, in which she was participating for seven years, was primarily concerned with the communication of risk within the agricultural sector. For example, Kropp carried research into the BSE crisis, which ranks among Germany's biggest food scandals and which had negative ramifications for the mass livestock farming industry. The so-called mad cows' disease was caused by infected animal fodder made of animal meal, which farmers had fed to cows as a cheap source of protein.

Professor Kropp was interested in how the initially vague knowledge about the disease vector and the contamination potential for humans found its way from the research community to political circles and society at large and how they dealt with it. She has published on the subject of how scientists can provide politicians with appropriate advice. And she discovered in the course of another project that food scandals, but also major caesuras in a person's life such as pregnancy, illness or divorces are precisely the sorts of events that can motivate people to change their eating habits from cheap processed foods to organic produce. Professor Kropp's research portfolio ranges from the communication of risks associated with food additives and nano materials to the dissemination of reusable food packing to zero energy houses and networked mobility products and services.

"Technical structures are beautiful"

By contrast with some of her colleagues, the sociologist has always been closely involved in science and technology. Even as a young high school student in Munich her A-Level (Abitur) options included German and Physics. "I can also recognise the beauty in a technical construction", says Kropp, who has been married to an engineer for many years. "Often", she goes on to say in a critical appraisal of her own fraternity, "there is an inappropriate arrogance about sociologists, who expect engineers to think about cultural issues without themselves taking the trouble to bother with scientific theories."

Her personal route to the field of Sociology took a bit of a detour. Immediately after graduating from high school, she embarked on a traineeship as a book seller to keep her parents happy, who, at that time, regarded a degree in Humanities as a ticket to nowhere. But in the depths of her mind she was troubled by an event that took place in 1986, her high-school graduation year, that shook global confidence in technical progress to the core: the disaster at the Chernobyl Nuclear Power Plant. That incident revealed to her the charged relationship between technical progress and the environmental impact. She read books on the philosophy and sociology of technology and had deep conversations with the renowned French sociologist Pierre Bourdieu, who frequented the book shop in Paris where she worked. It was he who finally ignited a love of Sociology in her young mind. Back in Munich where she studied

Photo: Fotolia

Sociology at the Ludwig-Maximilian University, she encountered another mentor in Ulrich Beck († 2015), who was one of Germany's best known sociologists at the time. His 1986 book *Risikogesellschaft – Auf dem Weg in eine andere Moderne* (published in English as *Risk Society: Towards a New Modernity*, 1992), which coincidentally appeared just after the Chernobyl disaster, touched a nerve and became a best seller. In it, he describes the transition from an industrial to a "risk society", in which people are continually faced with new challenges as a result of technical progress, and are forced to take decisions that make life more risky.

Another School of Thought, Same Result

Under the auspices of the late Beck, Kropp completed her doctoral studies into hitherto one-sided understanding of nature within the field of Sociology in which it had been variously regarded as a world completely separate from the technological sphere or else as a source of resources larder for humanity. In the same spirit as her doctoral supervisor, however, Kropp does not recognise a delineation between nature on the one side and society and technology on the other. Each influences the other. Kropp demonstrated that many actors are involved in conflicts of nature, all of whom relate to each other in some way or other. Inspired by the actor–network theory developed by Bruno Latour, John Law and Michel Callon, Kropp not only regards humans as the "actors" in question, but also artefacts, ideas, media or policies. "If we wish to explain how risks arise, what they mean and how to assess them", Kropp explains, "then we need to bear in mind that all of these factors are interconnected at a profound level."

She now plans to lend more weight to this sociological school of thought at the University of Stuttgart. "It is a slightly different approach to that taken by my predecessor Professor Ortwin Renn, who placed more emphasis on technology impact assessment", Kropp explains, "but the results are often similar." In light of the opportunities available at the University of Stuttgart, she goes on to say, she intends to devote more of her time to infrastructures, whether as prerequisites for self-driving cars or for delivering sustainably produced food to the population. Renn's "hobby horses", risk research and technology impact assessment, will remain part of the research portfolio.

Six months after taking on her new professorship and following many meetings with colleagues from various disciplines, Professor Kropp is impressed by one thing in particular at the University of Stuttgart: "I have never encountered this level of enthusiasm for interdisciplinary collaboration anywhere else!"

Helmine Braitmaier

SOFIA and the Star Gazers

The universe – infinite distances. The milky way – home to several 100 billions of stars. And more are coming into existence all the time, especially in the dark areas of the milky way that is shown here stretching majestically across the skies of New Zealand.

Yet, spectacles such as these remain invisible to the human eye that can only perceive optical information. They become visible to beings whose eyes are sensitive to light in the infrared range. Air humidity in the stratosphere above New Zealand is extremely low in winter, which provides a better view into the infrared universe than almost anywhere else on Earth. That's why astronomers from the University of Stuttgart spend several weeks "down under" each year to research the exact process of star formation. Their platform of choice for this is the SOFIA flying observatory, whose creation and technical and scientific milestones are documented on the following pages – as is the enthusiasm of researchers working on and with the SOFIA.

Photo: Jörk Lichte, DSI

The University of Stuttgart

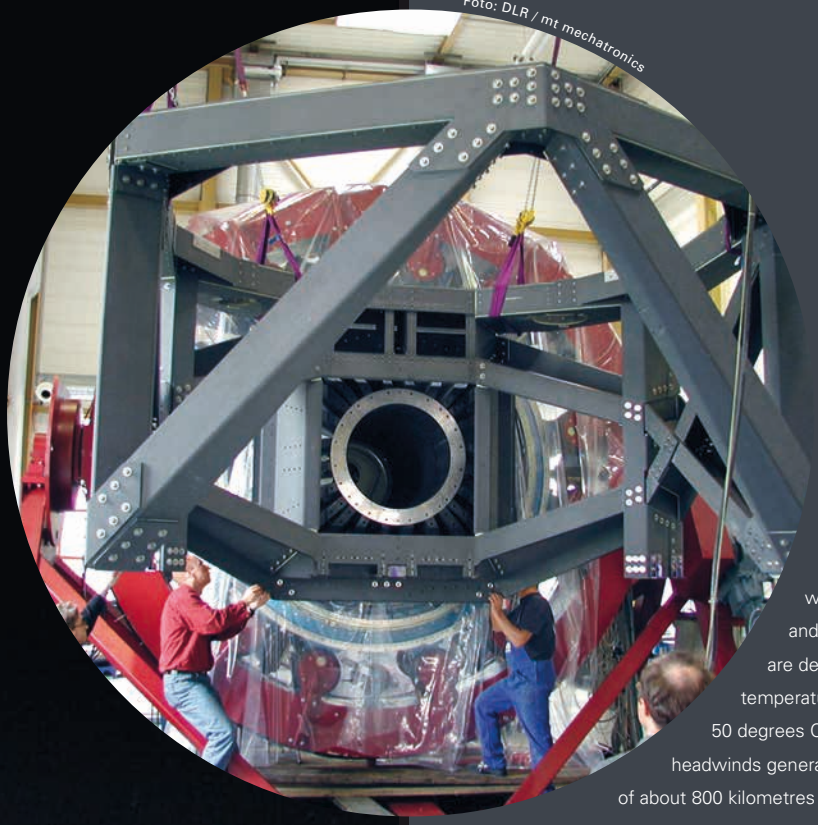
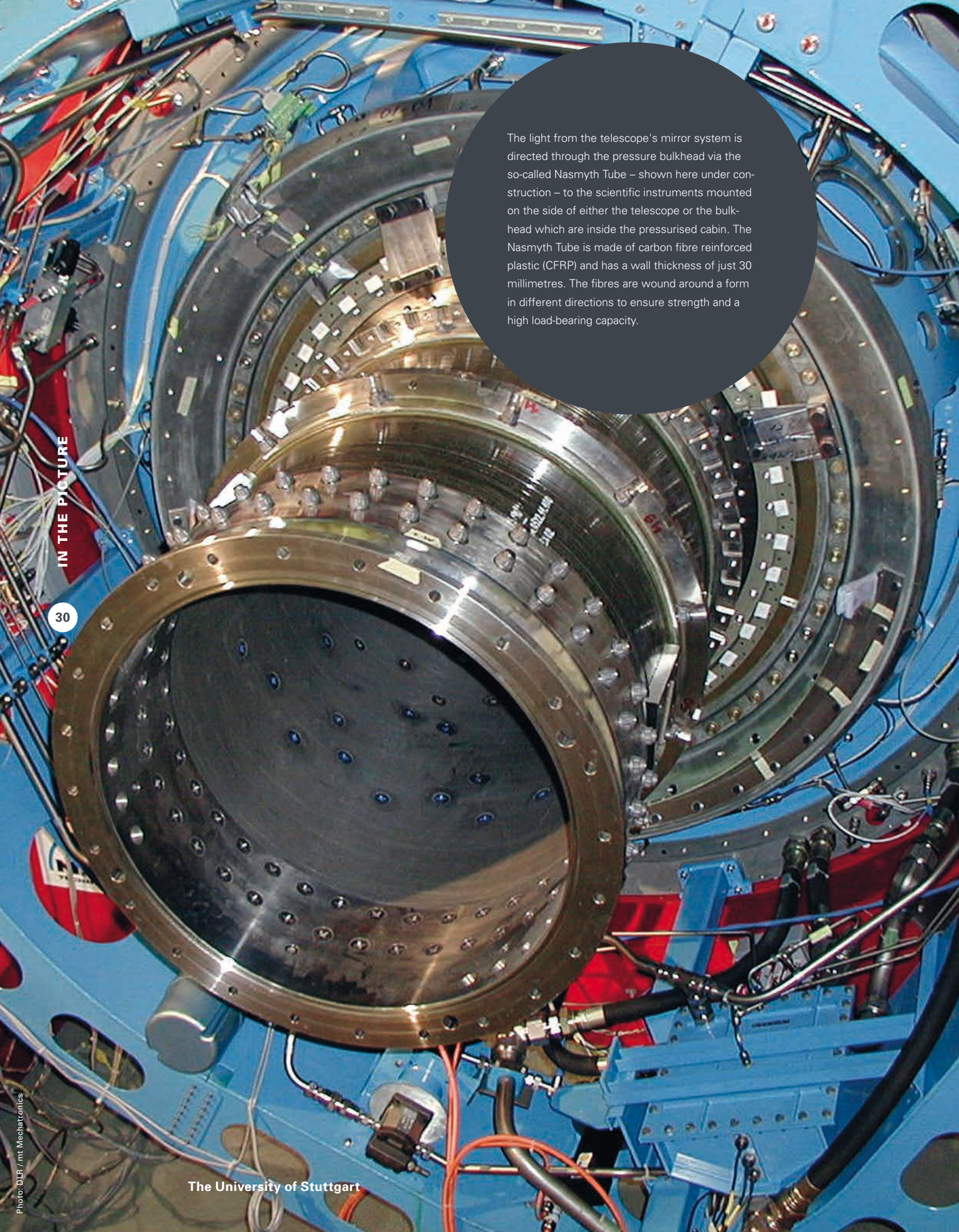


Foto: DLR / mt mechatronics

The frame of the SOFIA telescope is made of carbon fibre-reinforced plastic. During observations, when the door is open and the telescope mirrors are deployed, it is subject to temperatures of around minus 50 degrees Celsius and buffeted by headwinds generated by a flying speed of about 800 kilometres an hour.

Photo: Stéphane Guisard, DLR, Design: NIESYTO design, Stuttgart

The Stratospheric Observatory for Infrared Astronomy (SOFIA), is a converted Boeing 747SP with a 2.7 metre telescope on board. This flying observatory, the only one in the world, is a collaborative project by the German Aerospace Center (DLR) and the National Aeronautics and Space Administration (NASA). The University of Stuttgart's DSI (Deutsche SOFIA Institut = German SOFIA Institute) coordinates the German side of the scientific operations, and, working with the American colleagues, is predominantly responsible for the maintenance of the telescope and three of the other eight scientific instruments currently installed in the SOFIA. The ingress of infrared light from space is primarily blocked by water vapour in the atmosphere, and ground-based instruments can only pick up this cosmic radiation to a limited degree. That's why, several times a week, the SOFIA-based astronomers take to the skies – or, more precisely, to the stratosphere. There, at an altitude of around 13 kilometres, the influence of the Earth's atmosphere is negligible, which means that the cosmic infrared radiation can be observed without obstruction. The SOFIA's home base is the NASA Armstrong Flight Research Center in Palmdale, California.



The light from the telescope's mirror system is directed through the pressure bulkhead via the so-called Nasmyth Tube – shown here under construction – to the scientific instruments mounted on the side of either the telescope or the bulkhead which are inside the pressurised cabin. The Nasmyth Tube is made of carbon fibre reinforced plastic (CFRP) and has a wall thickness of just 30 millimetres. The fibres are wound around a form in different directions to ensure strength and a high load-bearing capacity.

The University of Stuttgart

Photo: DLR / mt Mechatronics

Two cranes were required to stabilise the telescope mounting assembly, which weighs some 9300 kilogrammes, so that it could be installed precisely within the fuselage.

Photo: DLR / NASA / L3

The centrepiece of the telescope is its mirror, which weighs around 750 kg. It is made of Zerodur®, a kind of ceramic glass that maintains its shape and dimension even under the greatest temperature fluctuations. In June 2008, the mirror was coated with aluminium for the first time to optimise its reflective characteristics. The aluminium layer is just 0.00015 millimetres thick, which is about 1/300 the thickness of a human hair, and weighs slightly more than 2 grammes, which is about one seventh the amount of aluminium used in a drink can. This image shows two members of a coating team using their own reflections to check the results of their work.

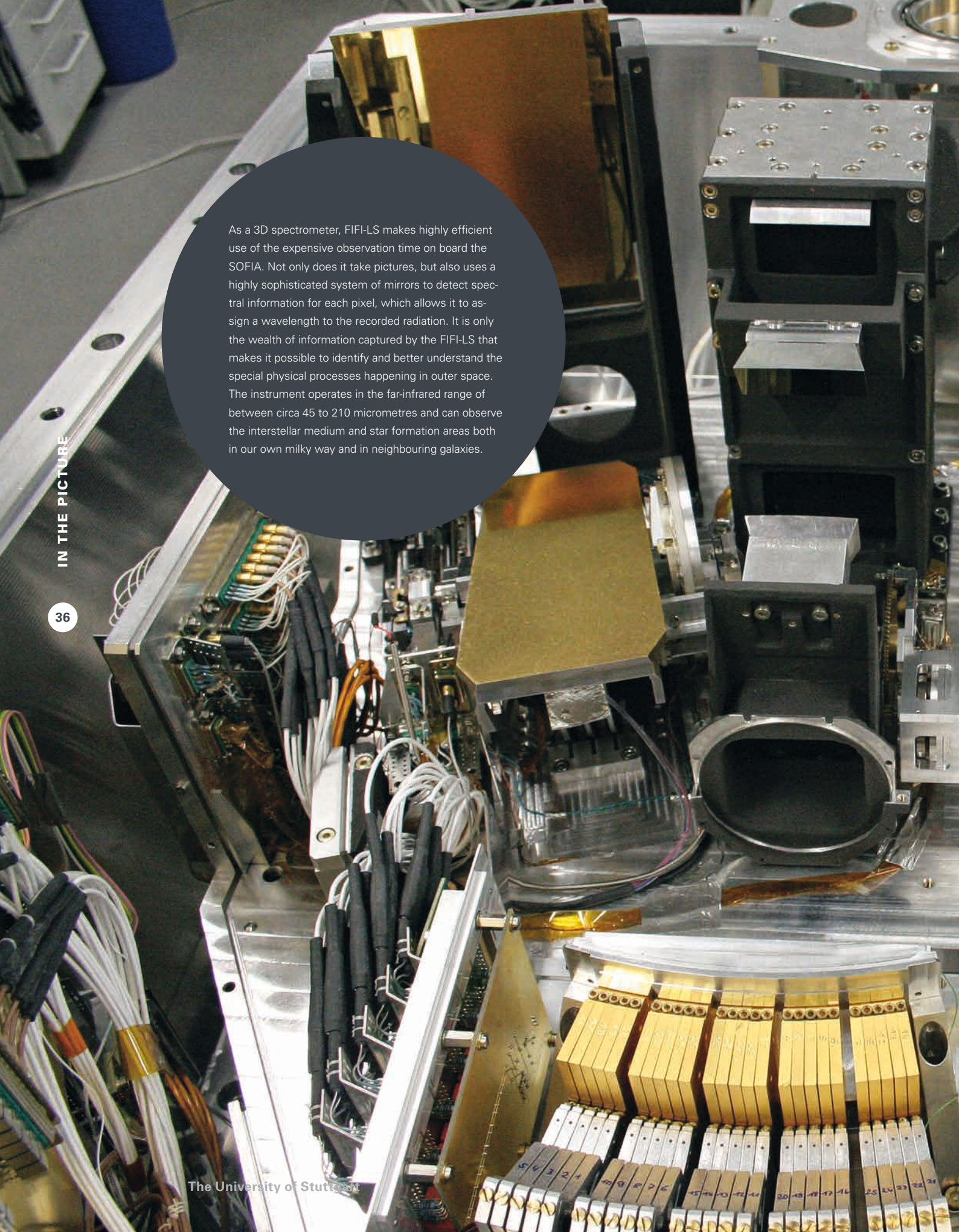
The University of Stuttgart

Photo: NASA

In the spring of 2013, the SOFIA team put the Field-Imaging Far-Infrared Line Spectrometer (FIFI-LS) into operation. Under the auspices of Professor Alfred Krabbe, his colleagues at the Institute of Space Systems prepared the instrument in Stuttgart for operations in the stratosphere. This image shows Alfred Krabbe, Felix Rebell, and Leslie Looney (back row from left to right) as well as Sebastian Colditz and Bill Wohler (front row from left to right) on board the SOFIA waiting excitedly for the first observation results. Researchers can not only use the FIFI-LS to observe the genesis of stars, but also the properties of the interstellar medium i.e., the material between the stars, both in our own and in distant galaxies.

The University of Stuttgart

Photo: University of Stuttgart/DSI



As a 3D spectrometer, FIFI-LS makes highly efficient use of the expensive observation time on board the SOFIA. Not only does it take pictures, but also uses a highly sophisticated system of mirrors to detect spectral information for each pixel, which allows it to assign a wavelength to the recorded radiation. It is only the wealth of information captured by the FIFI-LS that makes it possible to identify and better understand the special physical processes happening in outer space. The instrument operates in the far-infrared range of between circa 45 to 210 micrometres and can observe the interstellar medium and star formation areas both in our own milky way and in neighbouring galaxies.

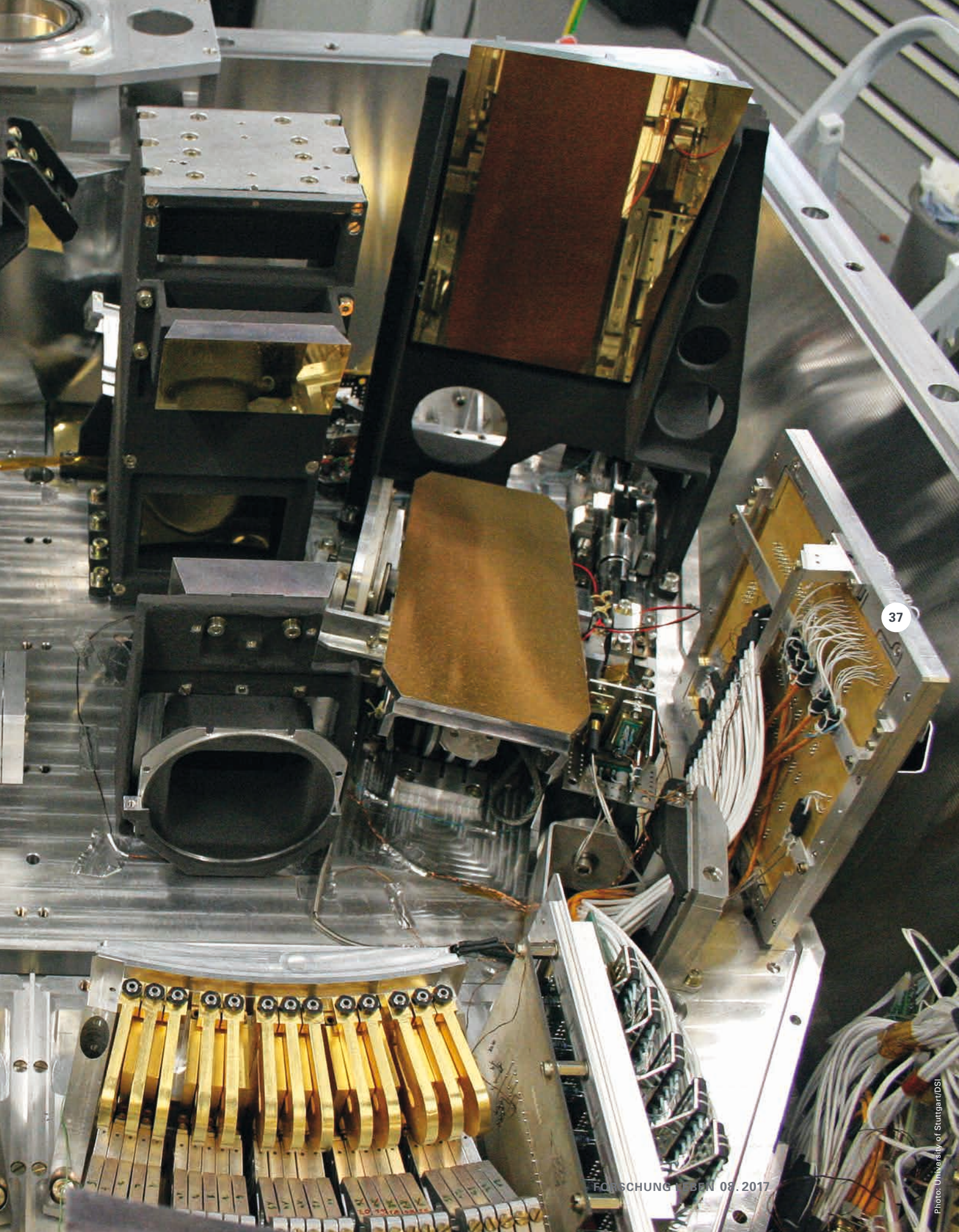


Photo: University of Stuttgart/DSI

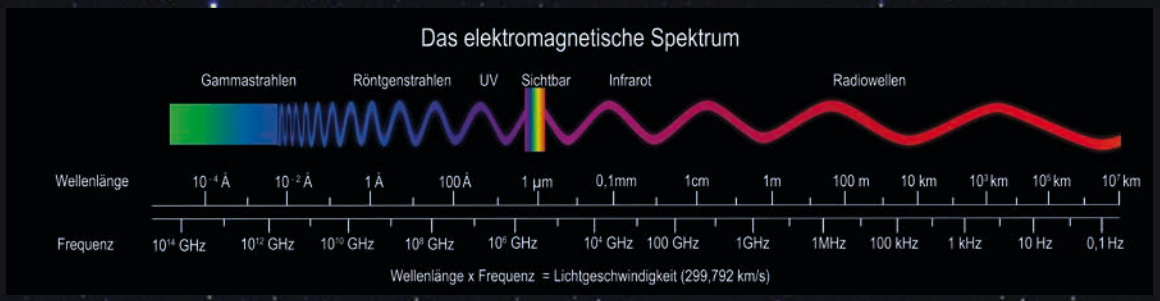
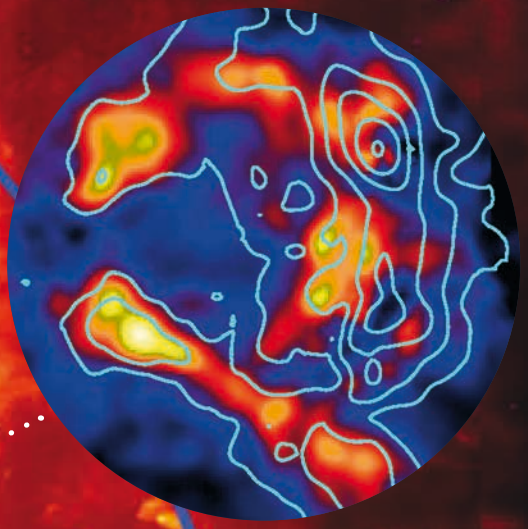


Figure: DSI

Stars never come into existence in isolation. Instead, a few hundred or even thousands of them always emerge simultaneously from some enormous cloud of gas and interstellar dust. This dust accumulates around star formation zones and screens off the view into the active centres of our galaxy. Thus, whenever we look at the Orion constellation with the naked eye, what we completely fail to see is one of the most active star formation areas (M42) in the entire milky way. However, it is visible to "eyes" that are able to see in the mid-infrared range. The FIFI-LS instrumentation, which was developed at the University of Stuttgart, allows the astronomers to measure the strength of the 146 micrometre line of atomic oxygen. Not only can the scientists use this data to estimate the volume and spatial distribution of oxygen within the star formation zone, but also the velocities, the pressure and the temperature of the corresponding gas.

The University of Stuttgart

Photo: Akito Fujii



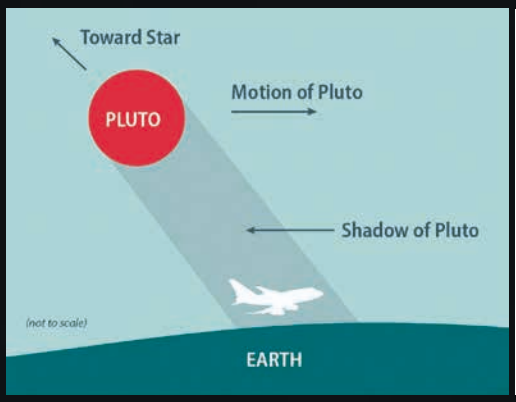
Photos: NASA

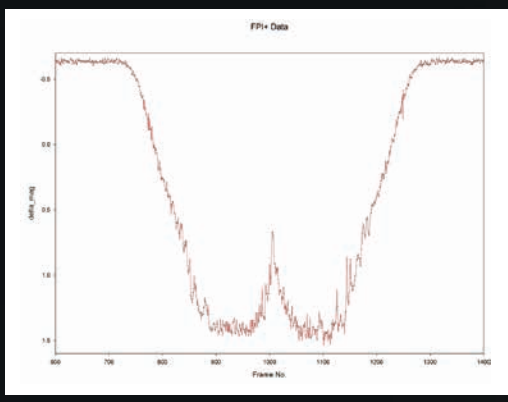
The University of Stuttgart

Whenever starts such as our own sun form, they are always surrounded by a disc of material from which a planetary system like our own can form. Yet, for a long time it was not clear whether things worked the same way for stars that are 20 or 30 times heavier than the sun. However, in combination with data gathered from other observatories, infrared data from the SOFIA – recorded using the University of Stuttgart's FIFI-LS instrument – have shown conclusively that this could well be possible. Just like their low mass siblings, massive stars can form by first gathering the surrounding gas and dust into a disc around them. Bit by bit the material on the inner edge of this disc then falls into the young star at the centre, thereby increasing it mass whilst the energy released during the processes radiates out. However, this increase in mass is not continuous; it occurs in a series of growth spurts because, rather than being distributed evenly, the material that forms the stellar disc occurs in clumps. When these clumps then fall into the central star – as observed using the FIFI-LS – they cause a sudden increase in brightness.

Artist's impression: University of Stuttgart/DSI

Occasionally, an object from our solar system crosses the path of a distant star covering it for a brief interval and casting a faint shadow on the Earth. Unfortunately, these shadows rarely coincide with the location of an observatory during the night. But the SOFIA can be positioned flexibly and can fly to the precise spot where such shadows will be cast, and it is then that the astronomers on board can "misuse" the occluded star as a bright, distant lamp to illuminate the atmosphere of the gnomon from behind. This was done during the Pluto occultation in June 2015, which was observed from the SOFIA using the Focal Plane Imager Plus (SPI Plus), which was developed by the DSI. Scientists can use the decrease and increase in brightness at the beginning and end of the occultation to draw useful inferences about the atmospheric structure and layering of the planet in question. If the star, planet and observer are exactly aligned during maximum occultation, then the illuminated atmosphere bundles the starlight like a focusing lens and produces the so-called "central flash", which is clearly visible in the FPI+ data from 2015 – in itself proof positive that the SOFIA pilots succeeded in positioning the aeroplane at the correct coordinates at precisely the right time. The fine atmospheric structures are also visible in the image captured by the New Horizons space probe two weeks later – i.e., simultaneously at astronomic time scales.





Sketch: NASA; light curve: Amanda S. Bosh; Photo: NASA, New Horizons Probe

The SOFIA is a flying laboratory and all components require regular maintenance. All scientific instrumentation on board, such as the FIFI-LS, is continuously checked for serviceability and carefully prepared by the scientists prior to each new mission on board the flying observatory. A cooling system is required to ensure that the infrared instruments do not simply register the ambient thermal radiation of their immediate environment. In this image we see Christian Fischer of the University of Stuttgart's DSI topping up the liquid helium as a coolant to prepare the far infrared spectrometer for the pending system check.

The University of Stuttgart

Photo: University of Stuttgart/DSI

Just as cars need a regular MOT, all aircraft need to pass the so-called D-check on a regular basis and the SOFIA's turn came in 2014. It is a shorter version of the jumbo jet, which means that it can fly higher than its bigger cousin and can even reach the stratosphere. Lufthansa Technik in Hamburg is one of the few wharfs that is licensed to service aeroplanes of this type. The SOFIA underwent a thorough check up, which not only involved removing all engines and testing them in the noise-protection hangar, but also inspecting all structural components for potential cracking, testing the cockpit electronics and renewing stanchions and windows as required. Five months later Lufthansa Technik returned a fully serviced and certified aeroplane to NASA under whose flag the SOFIA officially flies, ready to embark on many more flights to the stratosphere in the service of astronomy.

The University of Stuttgart

Photos: Lufthansatechnik Hamburg

The University of Stuttgart

Not only are students at the University of Stuttgart given the opportunity to fly on board the SOFIA, for example, in preparation for their bachelor, masters or doctoral dissertations, teachers from all over Germany can also apply to join a flight as part of a unique educational programme. The basic idea is to provide teachers with a chance to network with researchers and technicians and to enable them to experience scientific research first hand. The hope is that they will then go on to draw upon this authentic experience in conjunction with a broad palette of topics from the natural and engineering sciences to inspire their students with a long-term enthusiasm for these subjects. In the final analysis, this special advanced teacher training, which is unique in Germany's research topography, represents an effective investment in the future.

Photo: University of Stuttgart/DSI

Against the Grain
A digital analysis of old dramas is reading between the lines

To what extent has Shakespeare influenced German drama? How do gender roles in stage plays change over time? First and foremost, answering questions such as these involves a lot of footwork for scholars of literature, who have to read and interpret every single text, whereby the most frequent limiting factor is simply time itself. And this is where computational linguistics can help. Digital tools developed in this field can be used for the rapid analysis of numerous texts at once. That is also the goal of the two young researchers running the QuaDramA project at the University of Stuttgart.

Dr. Nils Reiter of the Institute for Natural Language Processing and Dr. Marcus Willand of the Modern German Literature II Department at the Institute of Literatures launched the Quantitative Drama Analytics project (QuaDramA) to produce new research results for the fields of Computational Linguistics and Literary Studies. In the course of the project, the two researchers, both in their mid thirties, intend to analyse texts, or more precisely 600 dramas, produced between 1740 and 1920. "From the perspective of students of literature", Dr. Willand explains, "the exciting thing about this project is that up to now we've only ever been able to consider small excerpts from all the literature that actually exists. But 600 texts gives us a lot of material to work with, for example to trace the development of historical continuous forms." Using the tools of both disciplines, the team want to study such things as the types of figures that occur in these pieces and how they interact and develop. The novel aspect of this approach is that, rather than simply interpreting various dramas, it also enables specific textual characteristics to be counted or otherwise quantified.

The researchers can use so-called word field analyses to determine the thematic tendency of any given dialogue. The graphic shows "The Suffering Wife" (1775) by Friedrich M. Klinger.

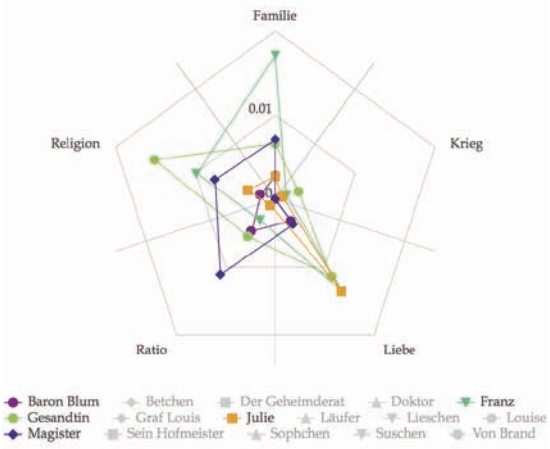


Figure: University of Stuttgart/IMS

Starting point: A Real Drama

"These texts are interesting from a technical perspective, because they have a pronounced structure", says computational linguist Dr. Reiter. "We have acts and scenes, and we know who speaks and when." The inclusion of literary texts in computer-based analyses, which have usually focused on newspaper articles thus far, is something new. That is why existing programmes will be combined and novel digital tools developed for the QuaDramA project. For many years Literary Studies have been focused on just a few works of significant authors such as Goethe, Schiller and Gottsched says literary scholar Dr. Willand, who explains that: "There has been an ambition to consider texts outside of this canon since the 1970s." So, how can dramatical texts be exploited, for example, to enable historians to extract the information that may be hidden between the lines? For example, how did the role of the father develop in the course of the 18th century and when did the patriarch morph into a loving fam-

With the aid of the computer, figures that appear in different dramas can be sorted into specific types so that similarities and differences that have developed over time, for example in the father figure role, can be revealed.

Photo: The Badisches Staatstheater, Karlsruhe

ily father? “By analysing specific character roles in a large number of works produced during a given period”, Dr. Willand explains, “we can better understand the concomitant social changes.”
This opens up a new approach for Dr. Reiter too, who is interested in comparing specific characters, whereby the question as to who should be compared to whom inevitably arises. “So”, he explains, “we decided that we need characters that were created for specific roles based on such categories as, for example, gender or age, but also their part in the plot, their social role and similar things.” The software tool will sort the various characters by type to reveal similarities and changes that have thus far remained hidden. “Until 1750, tragedies were always set in the courtly milieu and the father figure was either a king or heir to the throne”, Dr. Willand explains. “After that, the typical setting is moved to the world of the bourgeoisie. Now, we could look at the father’s interlocutors: does he speak to his sons or his daughters? And how does he talk – does he use more of a martial or an affectionate vocabulary?

Tracking Shakespeare

Doctors Reiter and Willand are currently working on an article that addresses the importance of William Shakespeare for German drama. They are looking into the question of the English playwright's influence on the authors of the so-called *Sturm-und-Drang* (storm and stress) period in the second half of the 18th century. “The *Sturm-und-Drang* authors noted that Shakespeare developed his characters based on naturalistic models and that they were, therefore, not artful”, says Willand. “But the question is: how could one measure that?” To answer this question, the two researchers want to analyse linguistic features, such as the language used by specific characters and their share in the dialogue, rather than simply focusing on the purely structural data.
Reiter and Willand have already completed some important groundwork. They have developed a method that enables the supplementation of structural data with a computational linguistics based analysis of the speech of specific figures. One aspect of the modern approach to the so-called Digital Humanities is to use digital networking to make research results available to research communities as they are still being processed. The two researchers use the “quadrama.github.io” blog for this.
Thanks to funding from the Volkswagen Foundation (German: *Volkswagenstiftung*), the researchers

Photo: Max Kovalenko

Literaturwissenschaftler meets Computerlinguist: Marcus Willand (li.) und Nils Reiter arbeiten im Projekt QuaDramA an der raschen Analyse einer Vielzahl von Texten per digitaler Werkzeuge.

are in a position to pay for two doctoral students and a number of research assistants to help with the QuaDramA project. One of their main tasks over the next three years will be to programme a software tool that can resolve co-references, for example, when various linguistic structures, such as a functional title, a proper name or a personal pronoun, refer to the same character . The purpose of the algorithm will be to keep track of and precisely assign such co-references throughout changing characters, scenes and stage directions. To this end, the researchers mark specific points in the sample texts and feed them into the algorithm, which then uses what it has learnt to process new texts. Mastering this challenge will move the research group closer to their ultimate objective, which is to be able to automatically identify and analyse specific figure types in a large number of dramatic texts in short order. The information thus gleaned will then be used to comment upon the significance of the individual works in the historical development of the drama genre – perhaps even without having ever read them!

Daniel Völpel

The Significance of Minor Nuances

Computers are using algorithms to learn to understand what it means to understand something

Photo: University of Stuttgart/IMS

She is intelligent, beautiful and empathetic, "she" being Ava, a "female" android from the film Ex Machina. Even though it looks and acts like a human, that's not what it is. What distinguishes this humanoid machine from other robots is its capacity for independent speech and ability to listen to others and understand what is being said. Whilst Hollywood has been conjuring up images of artificially intelligent entities on screen for decades, we are still a long way from building them in reality. There is one crucial thing missing which is preventing the development of computers that can process languages without errors: they first need to be taught to understand human language. Scientists at the University of Stuttgart are currently working on this.

Computational linguist Sebastian Padó, a professor at the Institute for Natural Language Processing, is currently conducting research into the principle of language comprehension. The one aspect of language that computers have thus far been struggling to grasp involves context and contiguities. They are simply unable to recognise unspoken but implied meaning. Humans, by contrast, can immediately contextualise what they are hearing and relate it to what they already know. "Computers have no personal knowledge about language" says Professor Padó. "For a computer, a sentence consists of nothing more than a sequence of symbols, with which it can initially do nothing." The professor and his team want to change that in future. To this end, they are primarily concerned with so-called distributed meaning descriptions. They are attempting to teach meaning to computers. "We do that by telling the computer To look at how we are using the words

we are speaking", Padó explains. Essentially that works a bit like when a human learns to master a new language

by inching forward step-by-step.

That is what computers should also be capable of in the future. To this end, the team are inching their way towards the meaning of a word one step at a time by including the preceding and following parts of the sentence. The process can be described as follows: When a person hears an unknown word such as "the gurmel" for example, he or she initially has no idea of its meaning but, if the word is followed by "is standing in the byre", then one may assume that it could be some sort of animal. If this is then followed by "and says 'moo'" then the word very probably means 'cow'. "Our research involves a similar line of thought", Padó explains: "We feed the computer with an enormous volume of text and get it to analyse which words are used in which context." This principle is used, for example, in search engines that can use the approach not only to search for the specified search terms, but also related words. Automatic translation algorithms work in a very similar manner, by performing the same kind of analysis on large volumes of pre-translated text. This enables them to discover how words are used in similar ways across different languages and to suggest possible translations. To ensure that the computers succeed in this, the computational linguists had to develop specific algorithms that perform the appropriate analysis on the texts.

"This part of our work combines linguistics with computer science and machine learning", says Padó. This means that the algorithms are not only motivated by information and mathematical concepts, but also by linguistic theories. For example, Padó's computer programmes analyse individual nouns with the aid of the associated adjectives and verbs to learn their meaning. As the professor explains: "using our algorithms, the computer perceives that the word 'gurmel' tends to be associated with adjectives such as 'large' and 'pied' and with verbal constructions such as 'says moo' or 'ruminate'. By considering all of this additional information together, the computer figures out that the word refers to a cow."

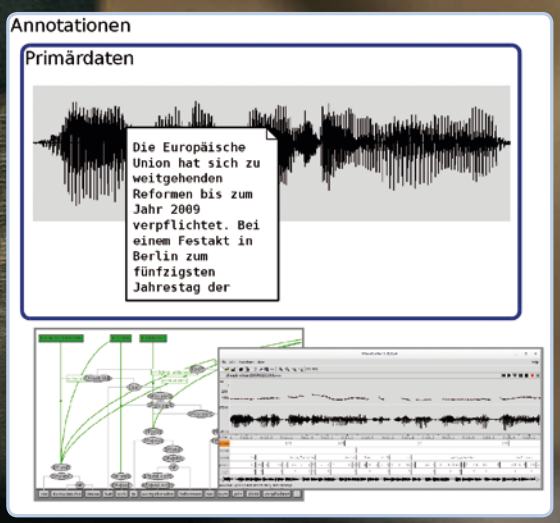


Figure: University of Stuttgart/IMS

Supplementing the Tried and Trusted with New Knowledge

The field of Linguistics can also garner new knowledge from the combination of linguistic theories and algorithms, as the analyses help to confirm existing linguistic theories – or else to disprove them. "What our text corpus reveals to us time and time again", says Padó, "is that the reality of the situation is not as simple as the theory would have us believe." Whilst linguistics tend to work on the assumption that human speech is grammatically correct

Metadaten

ResourceTitle	Discourse Information Radio News Database for Linguistic analysis
Modalities	spoken written
Topic	radio news
Project	SFB 732 A1
TotalSize	5 hours 3221 sentences
Speaker Demographics	professional speakers 5 male, 4 female

and, therefore made up of well-constructed sentences, the reality looks rather different. “There are major differences between language usage in books and newspaper articles on the one hand and comments posted on the Internet on the other”, says Padó “Usually the latter do not consist of complete and grammatically correct sentences.” This notwithstanding, the computational linguistic methods can also be used for linguistic analysis as Padó explains: “For example, we search large volumes of text to determine the presence and frequency of specific words. This allows us to track the usage of neologisms such as ‘Brexit’ or changes in meaning over time”, a Sisyphean task that a human could barely manage. “We, on the other hand, can simply write a programme that can analyse the entire text corpus within a few minutes. This provides linguists with an effective tool.”

Making Texts and Knowledge Accessible

In the final analysis, the findings from Professor Padó’s research have ramifications for us all, for example, because they may help to improve translation systems or voice controlled programmes. For Professor Padó, however, such areas of applications are already part of the status quo. He is far more interested in the fact that the majority of knowledge generated within human society is still recorded in text form. “So, language is the key to knowledge”, says Padó. “Our objective is to make texts accessible to automatic processes which will allow us to access the data they represent. That goes far beyond any simple Google search.”

Nevertheless and despite significant advances achieved over the past few years, the ultimate destination of his research remains an open question. “We’re still years away from being able to construct a machine that can speak, listen and learn language as well as humans can.” Until then we shall have to make do with Hollywood’s film versions of computers who understand language and artificial intelligence.

Constanze Trojan

Digital Goethe
Humanities scholars in the engine room

What do Goethe's The Sorrows of Young Werther and Adorno's Aesthetic Theory have in common with the Parzival romance and speeches made at the German parliament (Bundestag)? They are the focus of a collaborative project at the University of Stuttgart that promises new insights for Humanities scholars. The project involves philosophers, political scientists, linguists and literary scholars, who aim to drive progress in the field of digital research methods. In collaboration with computational linguists and experts in visualisation technology, the researchers are developing programmes to enable computers to analyse large volumes of text rapidly and efficiently. Research in the Humanities or Sociology usually entails a lot of reading.

Yet, no matter how much one works on a given subject, the results will always be fragmentary given the plethora of available sources and literature. Computers, by contrast, can swiftly analyse huge amounts of text – but only at the structural level. A collaborative research group at the University of Stuttgart is now giving their digital colleagues a leg up: the Center for Reflected Text Analytics (CRETA) intends to develop algorithms for contents-based textual analysis. The head of the CRETA, Professor Jonas Kuhn of the Institute for Natural Language Processing (IMS), is convinced that this will lead to new developments in textual analysis. The interdisciplinary field of Digital Humanities combines both the Humanities and Cultural Studies with the systematic use of computer-aided processes for research purposes. The foundations of the CRETA were laid by two projects, both focused on the use of digital resources for textual analysis. A team led by literary scholar Professor Sandra Richter collaborated with Professor Kuhn and his colleagues in the "ePoetics" project to develop tools for the computer-aided analysis of poetic texts spanning three centuries. Political scientist Professor Cathleen Kantner and her group joined forces with computational linguists in the "e-Identity" project to design a programme to interrogate almost a million newspaper articles to discover the extent to which collective identities, such as religion or nationality, had served as the basis for specific courses of action in crisis situations in the relevant period. Both teams are members of the CRETA, which has received funding for the next three years from the German Federal Ministry of Education and Research. Others involved include representatives from the fields of Literary Studies and Linguistics, the Institute for Visualization and Interactive Systems and the IMS. As Professor Kuhn explains: "the ministry was interested in establishing digital humanities centres at various universities to promote the digitalisation of scientific methods." He is particularly pleased that the University of Stuttgart has established a professorial chair for the Digital Humanities at the Institute of Literature, which was one of factors that contributed to the CRETA being awarded the funding in early 2016. The current holder of the professorship, Professor Gabriel Viehhauser, is also a member of the CRETA team.

Computers and Simplifying Text Analysis

As Professor Kuhn elaborates: "One of the things we do is to canvas opinion among experts in Literary Studies, Political Science, and the Philosophy of Science as to which questions commonly recur in textual analysis in each of these disciplines and then to develop appropriate ways to address them. This interdisciplinary approach is something of a new departure." Because the CRETA is focused on basic research, one of its main outputs are prototypes for machine learning models, which are then continuously optimised. Professor Kuhn uses an example to explain how research carried out on this basis

Researchers from multiple disciplines come together in the CRETA workshop to develop digital research methods.

Photo: Uli Regenscheit

might look. It may be possible, for example, to develop software tools that would parse historic texts for references to dates, locations or even certain linguistic features. “If I then combine three tools like this to analyse huge bodies of text”, says Kuhn, “then I may notice surprising configurations that I may never have stumbled upon through traditional reading.” The participants meet twice per year for a three-day CRETA workshop to develop tools likely to be of use in several disciplines. The first project to crystallise out in this context addresses the need to be able to recognise specific entities, such as dates, people and locations, in texts. Whilst it is true that parsing software can already identify specific entities in texts, researchers in the Humanities need to be able to use other categories of analysis. To enable the computer to recognise the criteria compiled by the team, the sample texts are marked up with a series of annotations. In parallel, the computational linguists are developing tools designed to identify and analyse interesting linguistic features in texts at different levels, whilst the computer scientists are looking at ways to visualise the results. Every two weeks, the researchers discuss their progress and any difficulties they have encountered or which may arise, which helps them to refine their tools.

Online Task Sharing

The group has ventured into terra incognita by publishing “shared tasks” on the Internet. The published corpus includes excerpts from Werther, Parzival, and Aesthetic Theory as well as speeches, including some from Dr. Angela Merkel. Researchers around the globe are then invited to try out various analytical tools and approaches. “It is interesting per se that one can annotate the same entities in such a heterogeneous collection of texts”, says Dr. Nils Reiter, who is responsible for the internal coordination of the CRETA project. “We’re keen to develop this shared task idea”, he continues, “because we believe that the concept is of interest within the field of Digital Humanities.” In the medium term, findings from the CRETA will also be exploited within the wider economy. Some firms, for example, want to be able to automatically record how consumers rate products on Internet sites. Professor Kuhn is certain that “it will be necessary in the long-term to include those with a fundamental interest in the impact of specific texts in the development of the relevant technologies.” That is exactly what the CRETA is about – far more than Goethe, Adorno and Merkel.

Daniel Völpel


Photo: University of Stuttgart / PI 4

Novel Membrane Laser

The Institute of Semiconductor Optics and Functional Interfaces and the Institute of Laser Technologies at the University of Stuttgart have been looking into ways to further improve the output capacity of semiconductor-disc lasers without risking the loss of their advantages, which include an outstanding beam profile and the ability to modify the wavelength during live operations, among other things. The solution turned out to be a weight loss programme! The experts completely removed the substrate layer onto which the semiconductor substance is deposited and replaced the semiconductor mirror that is an integral component of all semiconductor-disc lasers with an additional external mirror. All that remained was a laser-active zone just 100 nanometres thick. This was pressed between two layers of diamond because the transparent jewel happens to serve as an excellent integrated heat sink. The diamond-semiconductor sandwich could be used, for example, in medical lasers used in photodynamic therapy, because the wavelength can be adjusted to suit any given light activated medicinal compound.

Eagle-eyed Sensors

Eagles can spot a mouse from an altitude of three kilometres whilst simultaneously keeping an eye out for enemies approaching from the side thanks to their exceptionally wide peripheral vision. A similar ability would be extremely useful for driverless cars; a camera capable of recognising specific obstacles ahead and estimating the distance to the vehicle in front, but which could also "keep an eye on" the peripheral environment. Until now, the ability to do this has required the installation of multiple cameras and sensors around the vehicle or else a rotating camera on the roof.

Scientists at the Institute of Applied Optics and the Institute of Physics (4) at the University of Stuttgart have recently developed a sensor that models the eye of the eagle in a small area. To do so, the researchers printed an array of four micro-lenses on a high-resolution CMOS chip, each of which has a different focal distance and

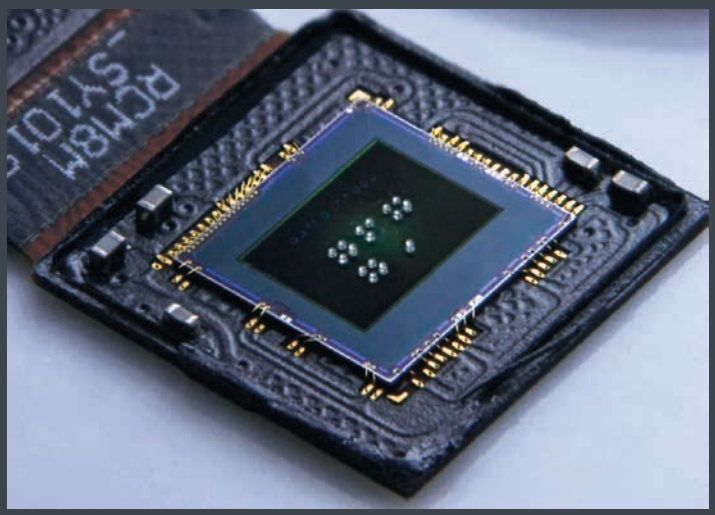


Photo: University of Stuttgart / IHFG

visual field. All four images that the lenses project onto the chip are electronically read out and processed simultaneously. whereby a small algorithm compiles the images such that the high-resolution image from the telephoto lens can be projected in the centre whilst the image from the wide angle lens appears on the periphery. The entire sensor system is just a few square millimetres across and could be used not only in cars but also in new types of miniature drones or in Industry 4.0 applications.

Photo: Björn Oldsen

Mars Mission via the Black Forest

Not only are there such things as earthquakes and moon-quakes, scientists also suspect that mars-quakes occur on our neighbouring planets. Investigating the geophysical properties of the red planet is one of the objectives of the InSight Mars mission, which is scheduled for launch in 2018 under the auspices of the NASA and European partner organisations. One of the main instruments on board will be an ultra sensitive seismograph which will be deployed as part of the Seismic Experiment for Interior Structure (SEIS). The "qualifying model" – a kind of sister device to the seismometer – will be tested at the Black Forest Observatory in Schiltach, which is owned by the Karlsruhe Institute of Technology (KIT) and the University of Stuttgart. The SEIS instrument package will contain six seismographs with which ground movements can be recorded in the vertical and two horizontal planes. At their base in the Black Forest, the team will test the interactions between the various components produced in France, Germany, Britain, Switzerland and the USA.

More Electricity from Wind

An optical device is being used in a new process to improve the regulation of wind turbines. The process is based on lidar technology, a laser-optical process that can determine wind speeds at remote locations. The device analyses the data so that the rotor speed and other operational control parameters can be adjusted for the expected wind speed before the incoming wind front reaches the turbine. This will reduce the material requirement for the construction of wind turbines and increase the energy yield. David Schlipf, of the Institute for Wind Energy (SWE) at the University of Stuttgart, won the "Excellent Young Wind Doctors Award 2016" for this development. The prize is awarded annually for the best European doctoral thesis in the field of wind energy.

Satellites in Near-Earth Orbit

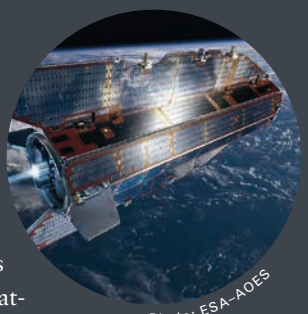


Photo: ESA–AOES

Just as air resistance exercises a breaking effect on vehicles on Earth, the residual atmosphere slows the progress of satellites in space. A team at University of Stuttgart's Institute of Space Systems wants to solve the problem in the context of the EU's DISCOVERER project by converting the atmosphere that is causing the resistance to energy. To achieve this, the project partners are working on the development of a propulsion system that differs from current technology in some fundamental ways. Rather than using fuel carried aboard the satellite, it will use air-breathing batteries. This represents a step towards smaller, more cost-effective satellites that will orbit the Earth at low altitudes, produce sharper images and generate less space waste.

Hard Shell, Soft Hands

The Graduate College of Soft Tissue Robotics is teaching robots to handle soft materials

Doctoral students at the University of Stuttgart are researching ways to get robots to handle things with a more gentle touch, which will allow them to operate in completely new fields. Among other things, they are taking inspiration from farms in New Zealand.

Robots can already do many things: they can paint cars, cut out panels, glue glass panels in place and react to specific commands. However, there are also many things that robots are still incapable of: they have trouble picking fruit, they cannot fillet a side of pork and are unable to recognise human tissue. In a nutshell: when hard robots come into contact with soft materials, problems ensue. Oliver Röhrle and Alexander Verl are just two scientists among many who want to change that. Oliver Röhrle, Professor of Continuum Biomechanics and Mechanised Biology at the University of Stuttgart, heads up the International Graduate College of Soft Tissue Robotics. The team uses computer simulations to find out how robots could learn how to handle soft materials. The project receives funding from the German Research Foundation (DFG) and involves a collaboration with the University of Auckland in New Zealand, a long-term partner of the University of Stuttgart. This research was also at the centre of the New Zealand-Germany Science Circle, Stuttgart, an event held in March 2017 to celebrate the 40th anniversary of German-New Zealand Science Cooperation Agreement.

At least ten scientists in Germany and another ten in New Zealand are working on the relevant research at any given time. The college operates on an interdisciplinary basis. “We’re exploiting synergies that arise from the research specialities of both universities”, Röhrle explains. In addition to simulation technologies, these include biomedical sciences, robotic engineering and cyber-physical systems. Röhrle emphasises the fact that the current project is about pure science and that this will only feed into specific applications at a later date.

Simplifying Abattoir Work

One of the ideas for the project originated in New Zealand which is dominated by its agricultural industry. The country is home to a population of just four million people, yet some 30 million sheep are slaughtered there each year. There are plans to automate the meat processing industry. However, the plan is currently coming up against certain technical limitations, as identifying and sorting various cuts of meat such as hearts, liver and kidneys is no easy task for a robot. The situation is similar when it comes to harvesting apples or kiwis. To date, all attempts to automate this task have failed. Robots are apt to squash the fruit they pluck, which makes them worthless as an export product.

Robots at the Operating Table

The same problem is encountered in medical engineering. Whereas robots can carry out operations with a far greater degree of precision than humans and already perform millions of operations on humans, there are risks involved: any uncontrolled movement by the robot could injure the human patient. Yet, the future applications in the medical engineering are enormous. For example, it has long been possible for doctors to differentiate between a tumour and healthy tissue using computed tomography scanning (CAT), and operations are performed based on this information. “A robot may be able to do that better in the future”, says Professor Alexander Verl, co-spokesman of the graduate college and head of the Institute for Control Engineering of Machine Tools and Manufacturing Units at the University of Stuttgart. But for that, scientists would first have to know much more about the interface between robots and soft tissue.

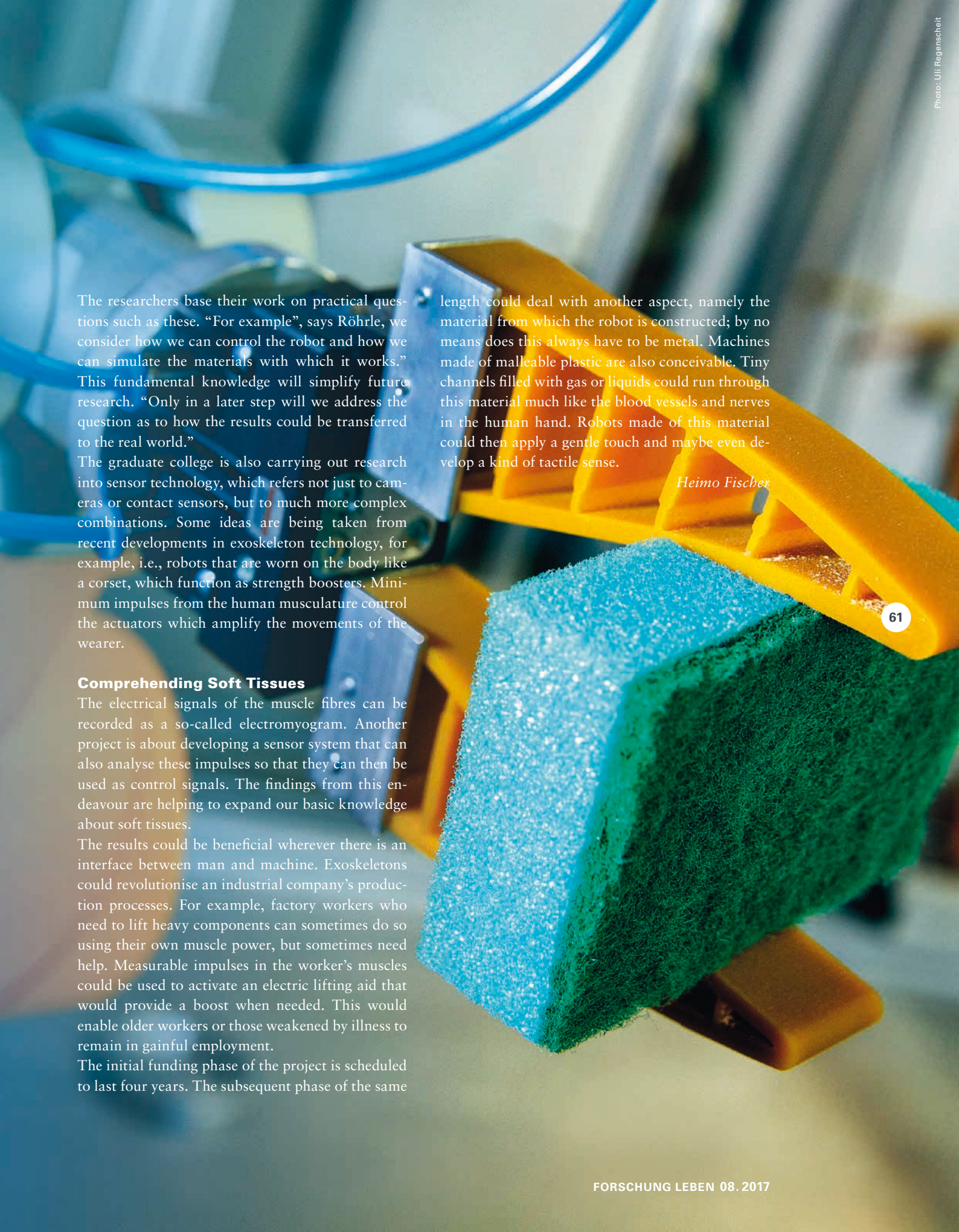


Photo: Uli Regenscheit

The researchers base their work on practical questions such as these. “For example”, says Röhrle, we consider how we can control the robot and how we can simulate the materials with which it works.” This fundamental knowledge will simplify future research. “Only in a later step will we address the question as to how the results could be transferred to the real world.”

The graduate college is also carrying out research into sensor technology, which refers not just to cameras or contact sensors, but to much more complex combinations. Some ideas are being taken from recent developments in exoskeleton technology, for example, i.e., robots that are worn on the body like a corset, which function as strength boosters. Minimum impulses from the human musculature control the actuators which amplify the movements of the wearer.

Comprehending Soft Tissues

The electrical signals of the muscle fibres can be recorded as a so-called electromyogram. Another project is about developing a sensor system that can also analyse these impulses so that they can then be used as control signals. The findings from this endeavour are helping to expand our basic knowledge about soft tissues.

The results could be beneficial wherever there is an interface between man and machine. Exoskeletons could revolutionise an industrial company’s production processes. For example, factory workers who need to lift heavy components can sometimes do so using their own muscle power, but sometimes need help. Measurable impulses in the worker’s muscles could be used to activate an electric lifting aid that would provide a boost when needed. This would enable older workers or those weakened by illness to remain in gainful employment.

The initial funding phase of the project is scheduled to last four years. The subsequent phase of the same length could deal with another aspect, namely the material from which the robot is constructed; by no means does this always have to be metal. Machines made of malleable plastic are also conceivable. Tiny channels filled with gas or liquids could run through this material much like the blood vessels and nerves in the human hand. Robots made of this material could then apply a gentle touch and maybe even develop a kind of tactile sense.

Heimo Fischer

“If possible, please turn back”
A “sat nav” for the energy transition is being developed at the University of Stuttgart

The energy transition is supported by a broad political and social spectrum in Germany. However, the more progress is made towards practical implementation, the greater the challenges, particular from a societal perspective. The aim of the project “Energy Transition Sat-Nav for the Recording, Analysis and Simulation of System Networks” (ENavi) at the University of Stuttgart is to ensure that the social aspects of the energy transition are factored in during the early stages of the development of solutions and transition paths.

“The objective of the ENavi project is to gain a robust knowledge base to give us a better understanding of the complex processes involved in the energy transition and in particular one that takes account of all relevant perspectives”, says Professor Kai Hufendiek, Director of the Institute of Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart, Chairman of the Stuttgart Research Initiative on Integrated Systems Analysis for Energy (STRise) and member of the Project Steering Board. The ENavi project team views the energy transition as a process of transformation of society as a whole and combines scientific analyses with socio-political needs. Technical feasibility, ecological compatibility, economic sustainability and social equity are all given equal importance.

Previous approaches to the system change concomitant to the energy transition have primarily focused on technical and economic aspects, according to Martin Steurer, research group leader for energy markets at the IER and Managing Director for the STrise. It was then left up to sociologists to get the necessary social buy in for whichever solution was deemed to be the optimum one. That has led to, and continues to cause, friction and implementation challenges – and often ultimately to higher costs. The ENavi project takes a more integrated approach: the research will factor in the social aspects right from the start. As Steurer points out, there is no master plan for achieving the overriding objective of the energy transition, which is to convert the existing energy system to one that is largely CO_2-neutral and based on renewable resources. In addition to the technical and economic aspects, far more emphasis needs to be placed on societal trends, which leads rapidly to complications, particularly at the personal level. “The transition should be cost effective, be more convenient and suit one’s personal lifestyle”, says Steurer, “it is often only then that ecological aspects are considered.” In his view, one of the “hard nuts” that the ENavi project will also need to crack is the fact that If Germany wants to make an effective contribution to climate protection then, in addition to the development of novel technologies compatible with industrial policy, there will be practical consequences and behavioural changes will be required, which are far harder to communicate in positive terms.

Germany’s Biggest Collaborative Project

The ENavi project, with over 200 participants, was launched in December 2016 in Berlin, where, according to both Hufendiek and Steurer, there was a “totally new spirit” in the air. For it is not only the sociologists whose views will also be considered, but rather, the project is deemed to be Germany’s biggest ever collaborative sociological project because, in addition to sociologists and economists, engineers and representatives of a host of other disciplines are also being included.

The ENavi project is one of the four “Copernicus Projects” inaugurated by the German Federal Ministry of Education and Research (BMBF) and

ENavi

forming the biggest energy transition research initiative to date. The collaboration involves 84 partner organisations throughout Germany, whereby, as the partner with the greatest investment in the project, the STRise research group plays an important role. The STRise research partnership includes researchers from the University of Stuttgart's IER and the Stuttgart Research Center for Interdisciplinary Risk and Innovation Studies (ZIRIUS) in addition to the Institute of Engineering Thermodynamics at the German Aerospace Center (DLR) and the Centre for Solar Energy and Hydrogen Research, Baden-Württemberg (ZSW). The researchers at Stuttgart have a budget of 60 man years to cover the initial three-year phase of the ENavi project. During this phase,

Professor Kai Hufendiek presenting the Copernicus Project at the Hanover Fair.

Photo: Bw-i/Dieter Meyer

the IER, for example, will be looking into new economic approaches for the energy markets of the future that also take account of the preferences and acceptance criteria of the various participants. Conversely, the ZIRIUS will play a leading role in the project's sociological workstream. All participants place great store in maintaining a vibrant culture of communication between all partners.

From the Drawing Board to Practical Trials

As Professor Hufendiek emphasises, the optimisation of the energy transition in respect of all sustainability factors should not take place on the drawing board alone. Therefore, three model regions have been selected for the ENavi project in which research findings will undergo practical trials. The Baden-Württemberg model region will be the focal point for innovation and industrial culture, whereas the urban Ruhr District will be used to study the transition in highly populated areas. Among other things, research in Berlin-Brandenburg will focus on the interaction between rural areas and the Berlin metropolis. Practical approaches will primarily be tested in "living laboratories" in the second phase of the project, whose total estimated duration will be ten years. The vision and objective of the participating scientists is represented by the ENavi energy transition navigation device, whose resemblance to the familiar sat-nav commonly used in cars is not coincidental. As Martin Steurer explains: "We're planning a data-based model that will meet the needs of the extremely dynamic processes that the energy transition will entail. We will need to be able to immediately adapt the direction that energy transition developments may be taking at any given time to keep abreast of framework contingencies." Various energy scenarios, simulations and behaviours will be saved in the ENavi programme, and the system will indicate how specific objectives can be achieved. "The basic idea", says Steurer, "is that rather than determining a single route, the system will suggest various options that all lead to the defined objective." The energy transition process presents some enormous challenges, the greatest of which will be maintaining the ability to always react appropriately to short and longer-term developments. The purpose of the navigation system is to make it easier to make such adjustments in future, which will increase popular acceptance.

Jens Eber

Support for the Doctor
Spinal simulations designed to help with the treatment of scoliosis

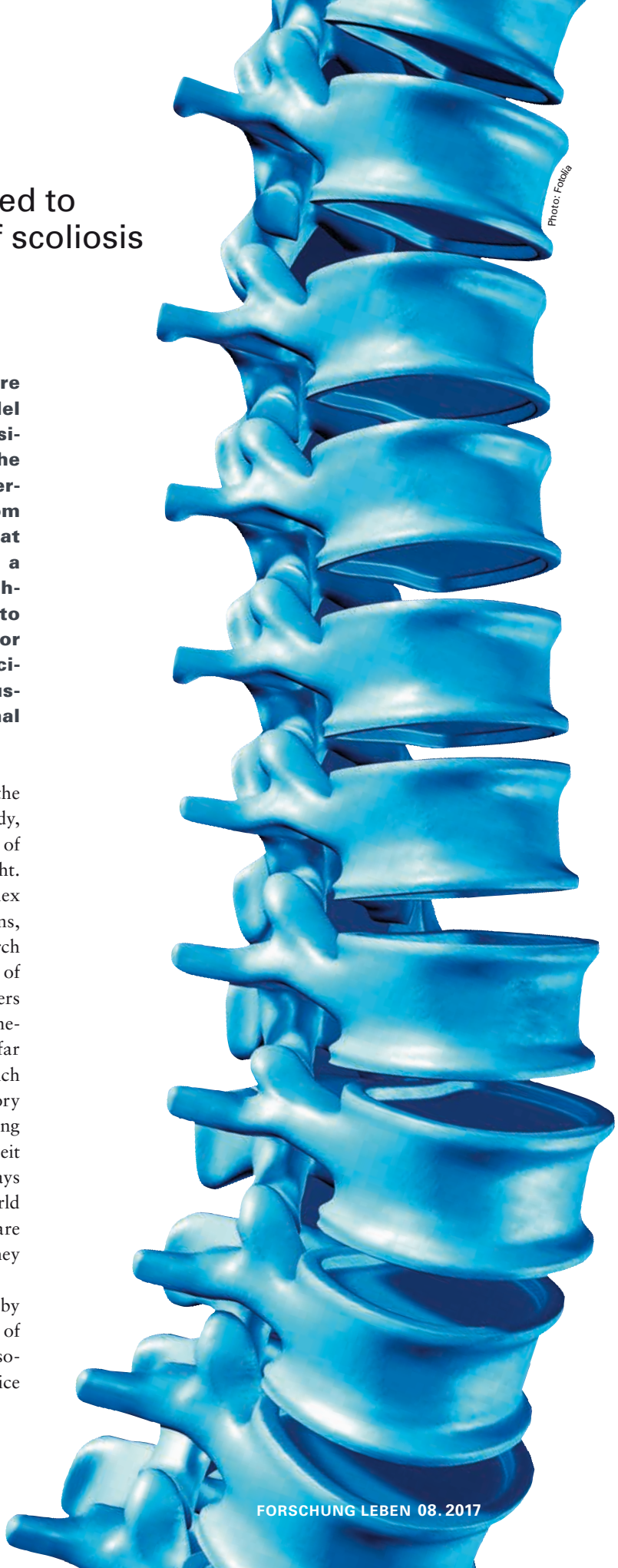


Photo: Fotolia

Physicist Syn Schmitt and his team are working on a simulation that will model the spinal column as realistically as possible in order to provide surgeons with the ability to better estimate the value of certain operations. To date, the findings from the simulations, which were generated at the University of Stuttgart's SimTech, a Cluster of Excellence for Simulation Technology, have not yet found their way into therapeutic practice. However, the junior professor from the Institute of Sports Science is working with colleagues in Australia to improve the treatment of spinal curvatures.

The spinal column is a complex structure: it is the central supporting component of the human body, serves as a shock absorber, distributes the weight of the body to the legs and enables us to walk upright. This multi-functionality is the result of a complex interplay between bones, spinal discs, tendons, ligaments and muscles. And, although research into the spinal column is ordinarily the preserve of physicians and biologists, engineers and researchers from related disciplines have been studying its mechanical properties for quite some time now. As far back as 50 years ago a paper was published in which the spinal column was described as two oscillatory masses between which a shock absorbing spring is positioned. "One can accept this as an – albeit very simplistic – model of the spinal column", says Schmitt. Since then, researchers around the world have developed new spinal models. "Now, there are loads of them", Schmitt explains, "although they differ widely in terms of usefulness."

Spinal models based on the same principles used by engineers to simulate the stability and dynamics of bridges are very common. Models based on this so-called finite element method (FEM) employ a lattice

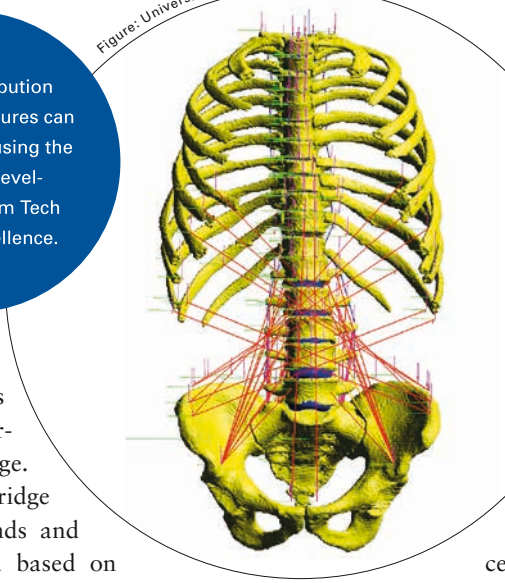


Figure: University of Stuttgart/SimTech

The load distribution between structures can be calculated using the spinal model developed by the Sim Tech Cluster of Excellence.

of simple geometric bodies to represent the load-bearing elements of a bridge. The loads to which a bridge is subjected through winds and traffic can be calculated based on the interactions between the various lattice elements. In simple terms, if none of the parameter values for local stress forces exceeds certain set limits during the simulation, then the bridge is deemed to have passed the stress testing. "The FEM can also be applied to the spinal column", says Schmitt.

As this x-ray image shows, the spinal column in sufferers of scoliosis (spinal curvature) diverges laterally from the central axis of the body.

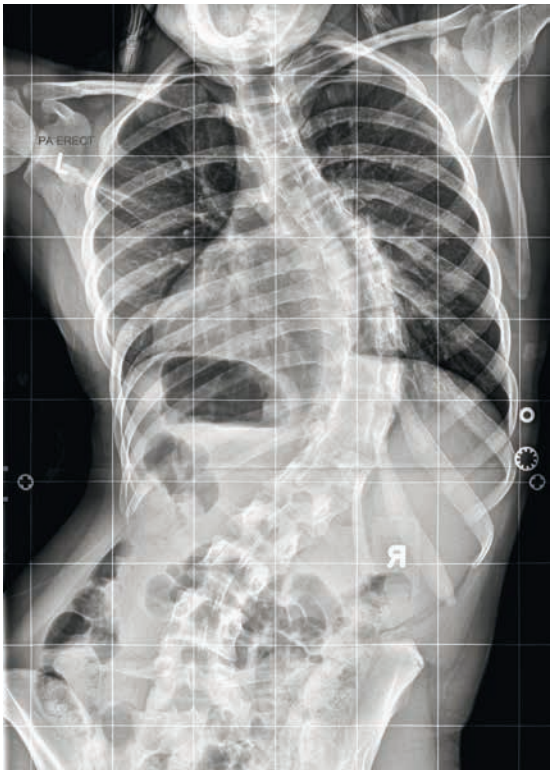


Photo: QUT/CHRC Brisbane/Australia

"These days it works pretty well, although the limitations of these models become apparent when one tries to simulate dynamic processes." The load changes that occur during sequential standing, sitting down and standing back up, for example, are not easy to calculate using FEM-based models.

The Spinal Disc as a Simulator

That is why researchers at the SimTech Cluster of Excellence in Stuttgart are taking a different approach. The load distribution between structures can be calculated using the spinal column model developed there over the past eight years. "For example, we can calculate the forces operating on a ligament or disc during a given movement", the junior professor explains. The simulations are programmed with details of the backbone geometry including all the spinal discs, ligaments, tendons and muscles and their material properties. "That would not have been achievable without the interdisciplinary collaboration at SimTech", Schmitt continues. The original spinal disc model was developed by a team working under the auspices of Wolfgang Ehlers, Professor of Continuum Mechanics at the Institute of Applied Mechanics and Managing Director at SimTech. The fact that the model calculations are executed more rapidly now – just a few seconds per disc and load case rather than the five hours it used to take – is thanks to the work carried out by the group headed up by mathematician Professor Bernard Haasdonk. Another team led by Wolfgang Nowak, Professor of Stochastic Simulation and Safety Research for Hydrosystems, helped to improve the means of estimating the reliability of the simulations. Schmitt's work group then focused on the spine as a complete locomotor system, i.e., on the mechanical interplay of the individual components.

Computer Supported Treatment

Schmitt and his team are currently collaborating with scientists in Australia, to investigate the explanatory power of the Stuttgart spinal model in relation to a specific medical problem known as scoliosis or spinal curvature. In sufferers of this condition, the spinal column is laterally displaced from the centre line and the individual vertebrae are twisted to a greater or lesser degree. Symptoms first appear in the childhood years and often worsen during puberty, although sufferers usually only experience severe disability in adulthood. Severe cases are, therefore, treated by inserting spinal supports during the growth phase to force the backbone to maintain the correct form. In Brisbane, simulation experts at the Queensland University of Technology and medical physicians from the Centre for Children's Healthcare have been collaborating closely to determine the precise number of vertebrae that actually require bracing in specific cases with the aid of simulations. "Our Australian colleagues are utilising a patient-specific finite element model for this", says Schmitt: "And we use their results to compute load cases that also factor in the relevant muscles." These results are then fed back into the Australian FE model where they help to simulate realistic movements. "Our hope", says Schmitt, "is that we can achieve a better prognosis quality for individual patients than has been possible till now." For, implants sometimes fail under load because the concomitant forces are far greater than those that occur during walking or sitting.

The German-Australian team have recently simulated their first concrete case, and the intention now is to use this as the starting point for a long-term project. The Stuttgart-based researchers would very much like to find an additional medial research partner in Germany or elsewhere in Europe. Although, as Schmitt admits, the "approach is still very unusual from a physician's perspective."

Michael Vogel

Computer-based tumor research
The SimTech Cluster of Excellence works to deepen our understanding of cancer

Using an interdisciplinary approach, researchers at the University of Stuttgart build computer models of the dispersal and effectiveness of therapeutic agents used to treat brain tumors. They also seek to solve a fundamental problem of cell biology on the computer: how can patient-specific therapeutic approaches be developed for treating brain tumors?

Brain tumors are a relatively rare type of cancer. The German Cancer Society estimates it represents roughly two percent of all cancers. Nevertheless, brain tumors are especially problematic. Even when they are benign, they can seriously impair the affected patient severely due to the mechanical pressure they exert on brain tissue that is unrelieved in the rigid cranial vault. "As much of a tumor as possible located in an easily accessible area of the brain is first removed surgically. The surgeon tries cause the least amount of damage to the surrounding brain tissue in doing so," explains Prof. Markus Morrison, director of the University of Stuttgart's Institute of Cell Biology and Immunology. "This is followed by radiation and chemotherapy. However, to date, curative treatment of a malignant tumor has rarely been achieved." The blood-brain barrier – actually, one of the body's protective mechanisms – prevents transporting novel and potentially more effective therapeutics via the blood. As part of clinical studies, surgeons therefore try to place such therapeutic agents directly into the brain. "These procedures also can damage brain regions that are not diseased," explains Morrison. "A big problem here is striking the right balance between efficacy and harm." At the University of Stuttgart, researchers in the SimTech Cluster of Excellence are developing methods in an interdisciplinary fashion that will lead to a better understanding of brain tumors and the tissue surrounding them. It is basic research that certainly still has a long way to go before it will result in new clinical treatment options. But, eventually it is expected to lead to a better understanding of this severe illness.

Tissue influences how therapeutics disperse

A team in the Institute of Applied Mechanics led by Prof. Wolfgang Ehlers, who also is the cluster's coordinator, is currently attempting to model the dispersal process and distribution of therapeutic agents in the brain. Per Dr.-Ing. Arndt Wagner, a researcher at the Institute of Applied Mechanics, looking at this medicobiological problem from a mechanics perspective is a terrific example of interdisciplinarity. "The dispersal depends substantially on the individual properties of the tissue. This is what we are trying to model."

A tumor deep inside the brain is not operable and cannot be reached via catheter used in positioning the therapeutic agent next to it. The surgeon consequently must inject the therapeutic into the brain from farther away but so as to let it reach the tumor by the quickest route. If it fails to do so, it will cause unnecessary damage to healthy tissue. "The direct path from the catheter tip to the tumor does not necessarily have to be the geometrically shortest one," explains Wagner. "It is how the nerve fibers line up that determines the preferable direction of dispersal." To put it another way, it may be better the send the therapeutic agent through the brain to the tumor by a detour. "It is this question that we have studied with the help of simulations," says Wagner.

Therapeutic infusion and spatial distribution within a brain hemisphere during cancer treatment.

In the underlying mathematical model, the cells are depicted as a solid object that forms a kind of porous skeleton. Embedded in it are two "cavity systems," the blood vessels and the interstitial space in

Researchers in pure science are attempting to understand how cells process information and what effect various therapeutic agents have on the signal paths of cancerous cells.

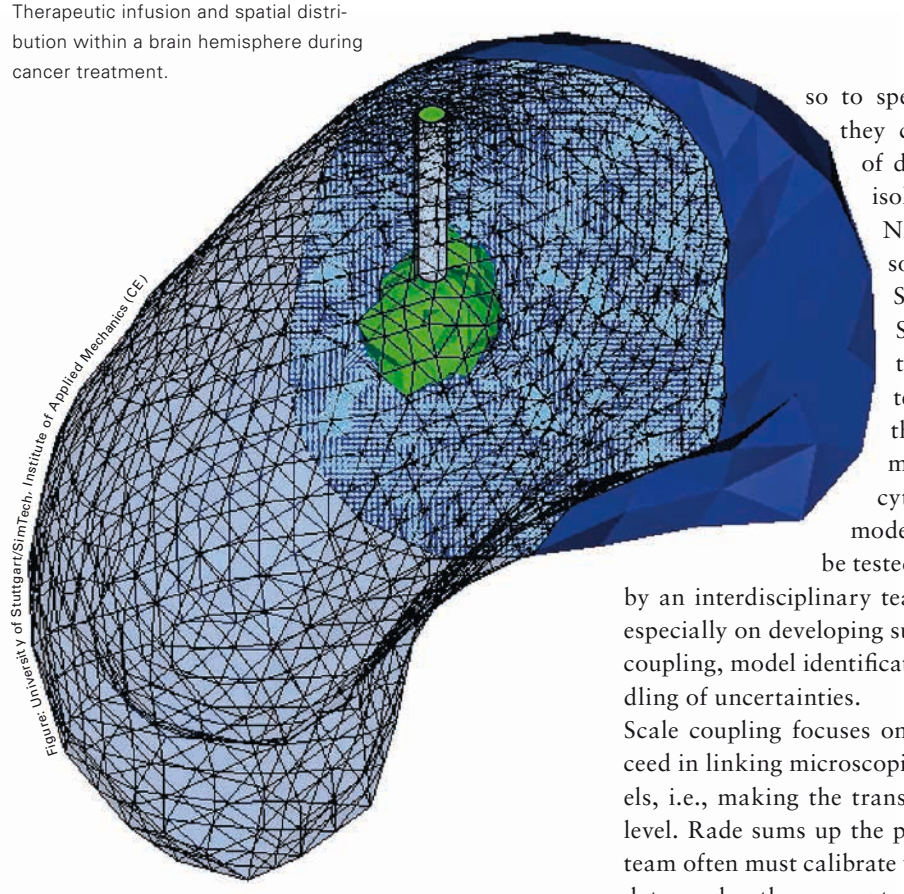
Photo: Uli Regenscheit

which the therapeutic agent disperses. While both are separated from each other by the blood-brain barrier, they still interact through mechanical impulses. The brain model developed at the Institute for Applied Mechanics furnishes a homogenized macroscopic description. What happens at the cell level, on every cell membrane in other words, is not calculable on a scale involving centimeters for the entire brain, because the tissue's microscopic structure is so complex.

The shortest way is not always the best

"Using this approach, we can simulate brain behavior under mechanical and chemical influences," says Wagner. This calls for considering the general conservation equations, such as those for mass and momentum balance, for the entire system and its individual components. "We also look at the characteristic behavior of the material, which is also essential for the therapeutics dispersion in the system," adds Wagner. The requisite patient-specific data can be captured with special measurements in an MRI scanner. Finally, the simulation then makes it possible to state how the therapeutic agent is distributed spatially and temporally in the brain. "We were able to demonstrate in computer-based case studies that there is something like an optimal spot for administering the therapeutic, depending on the tumor's location and local tissue characteristics," Wagner sums up. "However," he cautions, "it is still unclear if the simulation can be reproduced in a meaningful way in a clinical application."

A colleague at the Institute for Applied Mechanics is currently investigating ways of expanding the model to have it describe the therapeutic effect on the tumor. Eventually, that means findings at cell level must be transposed to the entire brain system. This is no small undertaking, as another SimTech project also dealing with patient-specific treatment of brain tumors has shown. "Invariably, many therapeutics work only for a fraction of patients, even when they all have the same diagnosis," biologist Morrison says. They are intensively researching why this is so, with the additional goal of treating tumors in the future tailored to the individual in optimal fashion. Morrison goes on to say: "Basic and clinical research have for a long time concentrated on identifying genes and proteins, so that they might predict how patients would respond to certain forms of therapy. It turned out that such data becomes useful only when we allow for the complex interactions of these genes and proteins in



Therapeutic infusion and spatial distribution within a brain hemisphere during cancer treatment.

Figure: University of Stuttgart/SimTech, Institute of Applied Mechanics (CE)

mathematical models. Many cellular functions actually only arise on the level of the biological 'circuits,' and the same holds true for cell interactions and communications in tissue."

Reconstructing how cells transmit signals

Biologists do basic research to understand how cells process information, how they build signaling networks among themselves, and what therapeutics do with signaling pathways in cancer cells. Subsequently, these findings can be transferred to larger systems, for instance, entire affected organs. Researchers like Morrison experiment with this under laboratory conditions – in the petri dish, so to speak. From their results, they can predict the efficacy of different therapeutics for isolated brain tumor cells. Nicole Radde, a professor at the University of Stuttgart's Institute for Systems Theory and Automatic Control and her team then try to refine the signal transmission models based on the cytological findings. The model's predictions can then be tested again in the laboratory by an interdisciplinary team. Prof. Radde focuses especially on developing suitable methods for scale coupling, model identification, and consistent handling of uncertainties.

Scale coupling focuses on methods that will succeed in linking microscopic and macroscopic models, i.e., making the transition from cell to organ level. Rade sums up the problem that she and her team often must calibrate with few, highly variable data under the concepts of model identification and handling uncertainties. "When we train our models with these data, naturally uncertainties attach to the predictions," she explains. "Hence, the question becomes how reliable the predictions based on these models are." But it does not mean that unreliable data inevitably yield even more unreliable predictions! "It can happen, for example, that only some variables in the model actually become more uncertain," stresses Radde, "while others remain fairly independent of the initial uncertainties." In this context, so-called statistical learning methods offer a powerful tool; however, since they are also very cpu-intensive they must first be optimized. This is where model reduction methods come into play. Since complex models

tend not to lend themselves to being computed in a reasonable timeframe, it is time to call in the mathematicians and informaticians from SimTech, such as the teams around Prof. Guido Schneider from the Institute of Analysis, Dynamics and Modeling or around Prof. Daniel Weiskopf in the Institute for Visualization and Interactive Systems, to ponder new approaches, such as reducing the number of observed parameters in the model elegantly, that is, without sacrificing meaningfulness. Radde has the last word: "Only through this interdisciplinary approach can we even hope to make advances in our research projects."

Michael Vogel

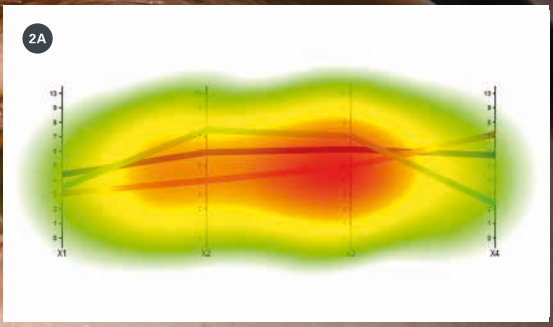
Just a moment, please!
Eye-catching Research into Gaze Tracking

To know what the consumer likes – eye-tracking makes it possible. Thanks to eye-tracking systems, marketing experts can make precise statements about the visual preferences of their target customers. Which products elicit the greatest interest? What details catch the eye? Is the viewers attention really directed at the product being advertised in TV commercials? Researchers at the University of Stuttgart Visualisation Research Centre (VISUS) are trying to develop innovative software products for the visualisation and analysis of highly complex eye-tracking data that should be able to answer these questions.

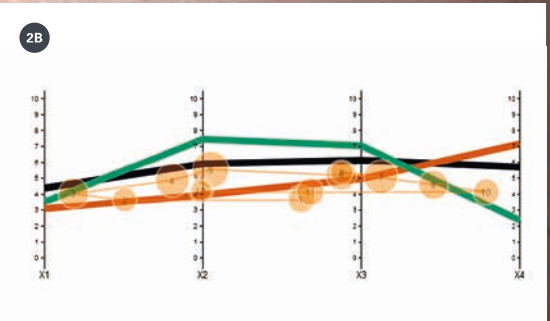
1 Eye-tracking systems use cameras, light sources and algorithms to trace eye movements. To this end, test subjects are equipped with eye-tracking glasses and, for example, positioned in front of a filled supermarket shelf. The spectacles track and record every movement of the eyes. The eye-tracking device projects an infrared light onto the retina of test subject. The reflection of this ray, which is invisible to the human eye, provides the system with information about the direction vector and spatial distance. Up to 60 data points are recorded per second. There are over ten known eye movements, which can be summarised in three categories: fixations (focusing the eye on a single point), saccades (eye movements between two fixations) and tracking (following a moving object with the eye). Algorithms convert the collated data into statements about the eye movements of the test subjects.

Analysing such a wealth of data is a major challenge. The most common ways of coping with it in static images involves the use of so-called attention heat maps and gaze plots. Attention heat maps 2A provide a visualisation of the points on which

eyes have been focused and use colour coding to emphasise any regions that one or more test subjects have focused on more intensively. The warmer the



colour, the longer attention has been focused on the area. Gaze plots 2B also make use of the paths traced by eye movements. Fixations are represented by dots, whose circumference increases in line with the attention duration, whilst saccades are repre-



sented by the connecting lines between points. As such, gaze plots measure both the intensity of focus as well as the chronological sequence of the eye movements. However, neither method is suitable for work using film or other dynamic stimuli, because the complexity of the collated data exceeds the capacity of traditional 2D visualisation techniques. Professor Weiskopf and his team from the VISUS are currently looking into ways of deciphering and visualising complex spatial data of this type. The ISeeCube System 3, which was developed at the VISUS visualises eye movements that occur when watching films and animated graphics. The points of attention from all test subjects is projected onto the film material in a three dimensional presenta-

tion 3A. The provides an instant impression of which areas the test subjects have primarily focused on. In addition, a detailed analysis is enabled by a so-called scarf plot 3B and the gaze stripes 3C, whereby the data points from all test subjects are plotted along a timeline in the form of image sequences and are automatically grouped by attention patterns. This makes it possible to discover both individual differences between the test subjects as well as to define areas of shared interest.

Bianca Finkel

Photo: Max Kovalenko, Rudolf Netzel, doctoral student at VISUS (University of Stuttgart Visualisation Research Centre)

Full Steam Ahead for Artificial Intelligence
Remaining on top of the world with the new Cyber Valley Research Partnership

The more knowledge is concentrated at a given location, the more attractive it becomes, i.e., the more it comes to function as a hub or hotspot. Since the 15th of December 2016, the Stuttgart-Tübingen Region has had its own official hotspot, known as "Cyber Valley". Cyber Valley researchers want to tap into a new pioneering spirit to send intellectual shock waves through Baden-Württemberg: full steam ahead for artificial intelligence!

The bar has been set high: The Stuttgart-Tübingen Regions own Neckartal (Neckar Dale or Valley) is squaring up to take on North America's Silicon Valley. "We want to be the best!" declares Professor Frank Allgöwer, head of the Institute for Systems Theory and Automatic Control at the university of Stuttgart. Allgöwer, who specialises in Cybernetic Engineering and Applied Mathematics is absolutely convinced that this is a realistic aspiration and that the state of Baden-Württemberg is already playing at the highest international level.

The initial impetus for Cyber Valley came from the Max Planck Society for the Advancement of Science and the Max Planck Institute for Intelligent Systems in Stuttgart and Tübingen. Allgöwer and his Stuttgart colleagues Professor Marc Toussaint, Head of the Machine Learning and Robotics Lab at the Institute of Parallel and Distributed Systems, Professor Andrés Bruhn of the Institute for Visualization and Interactive Systems (VIS), and Professor Albrecht Schmidt, Head of the Department Human-Computer-Interaction at the VIS were all present at the very beginning. They are all driven by the thought that the alliance between the Universities of Stuttgart and Tübingen and the Max Planck Institute for Intelligent Systems working in close collaboration with partners from the industrial sector will result in a paradigm shift.

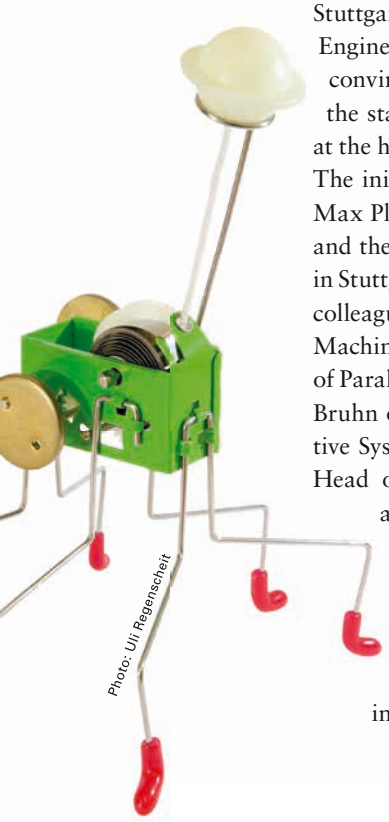


Photo: Uli Regenscheit

Cybernetic Control Circuit as Basis

The entire Cyber Valley concept is basically an initiative that has come to fruition over many years. "We're not talking about a car or aeroplane here", Allgöwer emphasises. "The approach is purely method based and is founded on the cybernetic control circuit." The "observe, learn, act" triad encompasses such disparate subject areas as Robotics, Control System Theory, Computer Vision, Artificial Intelligence and Machine Learning.

Behind the cybernetic cycle there is a control circuit with an incredibly high number of implications. False learning can lead to a completely false perception return. The professor cites autonomous driving as an example: the artificial intelligence system would recognise the fact that the driver had steered the car too far towards the left-hand side of the lane. However, if it has not been correctly programmed then the system would initiate too sharp a turn to the right, which the system would again recognise as a problem and would again over correct for it. Consequently, the system would fall into a never-ending pattern of right-left-right zigzagging and the driver wouldn't be able to keep the vehicle in the middle of the road. In the worst case scenario, the faulty feedback loop would result in disaster. Such issues are referred to as "instabilities" – and they can occur all too easily. In the case of the Chernobyl disaster, for example, the cybernetics in the control circuit were fundamentally flawed. Allgöwer refers to this as a "text book instability".

All the more reason why in all the research being carried out in the new Cyber Valley the control circuit is regarded as a mantra that has observed with painstaking care. Algorithms must absolutely be capable of learning. Machines should become intelligent and therefore adaptive and self optimising.

In terms of pure software developers, Silicon Valley is slightly ahead. "But what we have in the Neckartal is unique know-how in respect of the production

Photo: Uli Regenscheit

"We want to be the best!"
Professor Frank Allgöwer, Head of the Institute for Systems Theory and Automatic Control at the University of Stuttgart, is one of the founders of Cyber Valley.

of cars and machines of all types." Artificial intelligence and learning algorithms should, therefore, be integrated into all new production plant, vehicle components, robots or household appliances, which will significantly expand their functionality as well as increasing their performance and flexibility. Crucial in this context is the fact that, far from being a short-term project, Cyber Valley represents a fundamental conviction about how science and industry should mesh with one another in future. This hotspot of science should evoke the same connotations as the famous creative idea incubators in Palo Alto, California: entrepreneurial spirit and optimism.

Entrepreneurial spirit and optimism

What gives Baden-Württemberg's Cyber Valley the edge is that its focus is far broader. "We've got everything at this location", Allgöwer states with glee: "world-class research institutes and high-tech' industrial enterprises. That represents a huge potential advantage over the American hotspot with its narrow focus on software alone." He goes on to say that: "Major changes are taking place all around us right now. We would do ourselves a disservice in Baden-Württemberg if we failed to pro-actively establish the additional infrastructure needed to add even more value with services and application, i.e., with data." The state of Baden-Württemberg has donated a building to Cyber Valley that is intended to serve as the centre of the new emancipated culture of ideas. It will be open to everyone – entrepreneurs from the industrial sector, scientists and young university graduates with an idea. Another benefits of the Cyber Valley ideas incubator is that: "as a university, we obviously aren't out to earn money. On the contrary – we're the ones spending money!" Allgöwer explains with a chuckle. And, with a good conscience, because research institutes turn out many young people, who later go on to become active in the market as (post-doctoral) engineers.

By working together with the industrial sector, research findings can immediately be put to practical use. Conversely, industrial players can approach scientists for help with some interesting challenges. This dialogue, which is a long way from the "ivory tower paradigm", is automatically conducive to the kind of entrepreneurial culture that is crucial to maintain if the region wishes to remain in the premier league of those out to breathe artificial intelligence into the machines of tomorrow.

Susanne Roeder

Man Proposes, Cloud Disposes
Researchers are working on cloud-based production control systems

Factory machines need modern control systems to work efficiently. Yet, the software used locally is often outdated. A research project at the University of Stuttgart is now working on ways to update or completely replace control systems from a remote location, which would have many benefits.

Modern production plant is multi-talented, a fact, which is exemplified by a highly flexible furniture factory. A conveyor belt transports wooden boards to a place where they are sawn down to size and milled to the desired shape. The machinery involved performs a plethora of discrete and fully automated tasks cleanly and with a high degree of precision, whereby complex control systems ensure that each machine always "knows" exactly which parts to process and how. Finally, the factory-made, customised sideboards, shelving units and chests of drawers are sent out to customers.

Control systems are the brains of any production facility whether it makes furniture, machine components or car accessories. The electronic component groups are placed either directly in the individual machines or in switch cabinets connected by cables and positioned within the production hall but some distance away from the production line. These control units run complex software programmes, which control the production process in accordance with the firm's specifications.

Factories today depend on such computer programmes to fulfil their orders in an efficient manner, yet the programmes in question are frequently antiquated. This is because, unlike computers that run the Microsoft Windows operating system, they are not automatically updated via the Internet every few months. On the contrary, for many companies, updating production plant represents an organisational challenge. As Professor Alexander Verl explains: "it is not unusual to see a member of staff walking around the production facility with a USB stick in his hand from which he copies the required update to each machine individually." Professor Verl heads up the Institute for Control Engineering of Machine Tools and Manufacturing Units at the University of Stuttgart. His research concerns the viability of off-loading industrial control technology to the Cloud. In this context, the term Cloud, simply refers to a central server located at a service provider's facility that may be hundreds of kilometres away, which the factories can access via the Internet. One of the benefits of this type of virtual plant control system is that production software could be updated or even completely replaced in a matter of minutes.

Software is the Key to Success

This would open up new possibilities for production. Until now, automatic production processes have been organised hierarchically, i.e., update decisions are taken at the upper management levels, whilst those lower down in the hierarchy implement the plan until, in the final step, the machine in question is equipped with new control software. There are advantages to this system, but it does lack flexibility, which is becoming increasingly important in the modern production industry. Production plant attached to the Cloud (Internet) could be updated automatically as soon as new software became available.

Today, any advances in modern machine tool manufacturing will be entirely reliant on software. The actuators and mechanical systems are already fully developed and offer little scope for further improvement. "Most hardware is pretty standard", says Verl. This is because machine tool manufacturers procure their components from an ever diminishing pool of suppliers. "Therefore", Verl continues, "without bespoke software, it is virtually impossible to gain a competitive edge." Because, the quality of a piece of manufacturing plant is determined by the software

Modern manufacturing is network based: groups of machines are formed into intelligent solutions through the interaction and collaboration of individual devices – totally networked and with a continuous data flow.

Photo: HOMAG Group

that controls it. If, for example, a fully automated milling mechanism is used to shape a wooden board, then it needs to do so as precisely and as rapidly as possible. The more up-to-date the software, the more efficiently even an older machine can perform its allotted tasks. In future, it may be possible to download updated control software directly from the Cloud to the machine by a simple mouse click, and use it immediately.

New Value-Added Services

The situation is similar with respect to special functions, such as collision monitoring. The associated software ensures that mechanical arms used to wield and apply a given tool do not cause damage by following collision-prone trajectories. The programme knows the length, breadth and height of the machine as well as the action fields of action of both the arm and the tool. Based on these parameters, the software can calculate the movements for the subsequent task in advance and ensures that the workpiece is processed right from the initial step in such a way that collisions are avoided.

Whether a collision avoidance system is required or not depends on what is being fabricated and how. In some cases, it is not required and can be switched off, which saves resources, as the additional process costs both computing power and sometimes time. "Therefore, the collision monitoring service could be paid for as a value-added service and could be toggled in from the Cloud whenever it is really needed", says Felix Kretschmer, an expert in networked (distributed) production who works under Professor Verl.

Kretschmer coordinates the PICASSO project, which stands for *Projekt Industrielle CloudbASierte SteuerungsplattfOrm für eine Produktion mit cyber-physischen Systemen* ([the] **P**roject for an **I**ndustrial **C**loud-**ba**sed Control Platf**o**rm for Production Using Cyber-Physical Systems). The project involves collaborative research between technology companies and the University of Stuttgart into how to increase industrial production efficiency through the flexible provision of control system technology. The project is funded by the German Federal Minister for Research and is supported by the Karlsruhe Institute of Technology (KIT).

Many of the functions performed by production plant can be off-loaded to the Cloud, but not all of them. Sensors that determine the dimensions of a given workpiece must, of course, remain within the machine. "But", says Verl, "everything that is calculated on the basis of these dimensions can be done in the Cloud."


Photo: Dürr AG

Digitalisation is also gaining ground in the furniture industry: networked production plant, such as that at the HOMAG Group, a subsidiary of Dürr, is currently producing bespoke kitchens in batch sizes of 1, with the efficiency of highly automated serial production.

"The processes need to happen extremely rapidly, usually in a matter of milliseconds, but, anyone who regularly accesses the Internet knows how difficult that can be. Yet, whilst Internet latency can be a minor annoyance for the office worker, the consequences of unduly long transmission speeds in a production scenario could be very serious. As Kretschmer explains: "the revolving hourglass familiar from our PC screens could result in a total production plant outage." Or it could cause costly production errors. If a milling machine (or router) suddenly stops whilst cutting its way through a piece of timber, the result is a black area of burnt wood. The workpiece is damaged and processing cannot continue. Therefore the quality of the Internet connection is crucial.

Limited to the Speed of Light

The transmission speed depends on the network technology used. It needs to ensure that a production facility's data signals are prioritised over other data traffic using the same network. Additionally, data from the Cloud needs to arrive simultaneously at the factory. "Our research is about finding ways to do this", says Verl.

So-called time-sensitive networks offer one solution. The way they work can be explained using the example of home loudspeakers connected via a WLAN. In this case too it is important that signals reach each of the speakers at the same time. That was first made possible using technology developed by a company called Sonos. As Verl explains: "it was they who succeeded in creating a prioritisation protocol for use in home WLANs. Attempts are currently ongoing to create a similar method of transmitting production data packets, whereby one of the most significant challenges is to unify the various available standards, which differ significantly from one another. However, there will always be a limit to the rate at which data can be transmitted, the limiting factor being the speed of light, which is the speed at which electronic signals travel. In the course of the PICASSO project, for example, the time taken for an electronic signal to travel between a Google data centre based in Northern Europe to Stuttgart and back was measured. The lower limit was around 20 milliseconds. However, for certain production tasks a single millisecond represents the critical threshold. "What this means", says Verl as he describes the challenge, "is that the control system for an application based in Stuttgart cannot be located further than 150 kilometres away, which would be somewhere like Frankfurt am Main." Yet, he does not see this as an insurmountable obstacle. The Cloud could be distributed across a number of data centres, each of which would be rapidly accessible by factories with a certain region. It would also be possible for companies to maintain their own Cloud systems located as close to the centre of their various facilities as possible.

Combating Cloud-based Hackers

Security presents another challenge for Cloud-based control systems, and that too is being tackled by researcher in the PICASSO project. Hackers have demonstrated on multiple occasions that it is easy to gain access to industrial plant via IT systems. For example, cyber criminals succeeded in shutting down a blast furnace at a German steelworks in 2014. The Israeli secret service used the Stuxnet computer worm to sabotage Iran's nuclear power programme a few years ago. If the connection between production plant and control systems runs via public networks in future, hackers could easily find a way in. So, the IT security demands are high. The data must only be accessible by authorised people and systems.

Unauthorised manipulation must be impossible, yet, at the same time, the data must always be available whenever it is needed. The data must be encrypted as a matter of course, but there are still debates surrounding the question of whether that should be the case throughout the entire connection between the Cloud server and the production plant. This is because the various parties involved have completely different interests. The factory operators want absolute control over access to their systems, which means that they need to know the exact origin of data being transmitted to their machines. For them, therefore, end-to-end encryption is out of the question: as a minimum, they want to be able to check the origin of the data just before they are fed into the factory systems. However, the Cloud operator is not interested in this: they want to protect their proprietary know-how, which is encoded within the transmitted data packets, and which nobody but them should have access to. Therefore, a reconciliation of interests between the sender and receiver is an important prerequisite for effective monitoring of the data stream.

New Dimension in IT Security

Modern encryption techniques are extremely secure. As Verl points out: "even government agencies struggle to crack modern encryption codes." These days, the most common way in which such codes are cracked is simply by spying on someone who holds the decryption key, which can sometimes be done with very simple methods, such as breaking into business premises and stealing the relevant passwords. However, new IT applications are not the only route in for hackers. Older systems provide points of attack. Verl knows that: "some factories are still using operating systems that are 20 years old." In such cases, a single USB interface could be all it takes to access and manipulate a system. However, the plant manufacturers are just glad if their machines work as promised and that they are able to sell them. They have no interest in continuously updating them, which is precisely what could leave them open to cyber attacks. For Verl that is an important argument: "systems attached to the Cloud can be kept continuously up-to-date with the newest technical developments, particularly in terms of security." *Heimo Fischer*

Industrialised Uniqueness
High tech' unites an unequal combination of mass and unit production

Industry 4.0 is now a practical reality. In a series of studies and with the aid of a recently founded high performance centre, researchers at the University of Stuttgart are currently looking for a connection to another major contemporary trend, namely personalisation. Customisation could bridge the gap between automated mass production and the creation of bespoke items in the pre-industrial era. The current buzzword is "mass personalisation".

As one of the pioneers of this vision, Professor Thomas Bauernhansl, who heads up the University of Stuttgart's Institute of Industrial Manufacturing and Management (IFF) as well as the Fraunhofer Institute for Production Engineering and Automation (IPA), takes a long-term view. "Prior to the Industrial Revolution", he reminds us, "most products were made by hand. A cobbler would make a pair of shoes to fit a specific customer, and every pair was made to measure." A pair of shoes could cost a month's wages and quality could vary if a particular cobbler was not particularly good at his trade. This diversity was reduced to mass production through industrialisation, until personalisation took hold in the middle of the last century and with it – based on the building block principle – the differential assembly of standardised components, which resulted in the product variety seen in today's shoe shops.

For Bauernhansl and his colleagues, the next logical step is for everyone to have bespoke shoes made to measure, but for the same price and at the same consistent production quality as mass produced products. "We'll still use the building block principle, but to a lesser extent", Bauernhansl explains: "But will also develop and manufacture items in batches of one – and all with the aid of new technologies, such as 3D printing." At the same time, the researchers are thinking beyond relatively banal products, such as shoes. In their "Mass Personalisation" study, the five Stuttgart-based Fraunhofer Institutes are focusing on mobility, housing and health – all of which are topics that combine great social relevance with multiple facets and major technical challenges.

Dissolving Traditional Boundaries

"The trick is to dissolve traditional boundaries between producers and consumers", says Bauernhansl, who explains that: "A given customer doesn't necessarily wish to buy a drill. What he wants is a hole in the wall. And that's what we need to give him." With the participation of many value creation partners, "ecosystems" built around customer needs could enable the provision of shared platforms that would offer them personalised services. The researchers refer to this concept as "B2U", which stands for "business to user", whereby all efforts are centred on the user. Bespoke production at no significant additional cost: that initially presents a conceptual obstacle. After all, a tailor-made suit costs much more than one off the peg. Bauernhansl dispels such concerns: "Until now", he explains, "manufacturers have had to anticipate what their customers may wish to buy at some point in the future. But now customers can utilise specialised services to participate personally in the development process, which reduces costs arising directly in connection with complexity." Schunk, a company based in Lauffen am Neckar, which specialises in the production of gripper sytems and clamping technology, has already developed a working example of this. The company launched the eGrip platform to which users can upload 3D models of the objects to be gripped and, with the assistance of the Development Department, can design the appropriate gripper device. Bauernhansl is certain that the development could be completely automated in a next step or else purchased as an additional service, always with the long-term goal of enabling personalised production at the cost of mass production in

Photo: Fotolia

Mass personalisation spells the end of the uniform look.

order to ensure the project's long-term economic viability. The purpose of the "Mass Personalisation" study was to identify the need for action and nascent solutions. Research is now focusing on a high performance centre for mass personalisation, which the University of Stuttgart and Fraunhofer are supporting with funding totalling 12.5 million euro. In addition, existing institutions, such as the ARENA 2036 research campus in Stuttgart, should play an important role, for example by developing "smart" cars for personalised mobility.

From Housing to Digital Doctors

The researchers see good opportunities in the housing sector for the asymmetric combination of mass and bespoke production. Of courses, many houses are already built to bespoke specifications. But, reconfiguring a house to suit new lifestyle requirements later in life, is usually a very expensive undertaking. Therefore, says Bauernhansl: "We're searching for novel concepts for rooms that can be adapted more easily." So-called "smart" construction technologies have a role to play in this context, for example, to enable older people to maintain an independent lifestyle for longer. The third point of focus from a mass personalisation perspective is health, whereby the long-term vision is the "digital doctor". "Personalisation is essential in this field to increase quality whilst simultaneously lowering costs", says Bauernhansl, who goes on to explain that data collated via sensors could be analysed to develop individualised therapies or ideally customised medicines. A crucial prerequisite for this, he says, is the continuous availability and protection of patient data. This, according to Bauernhansl, requires the intervention of the legislators.

In the opinion of the head of the IFF, a concept such as B2U is an opportunity for high-wage countries, such as Germany, to remain competitive, especially since personalised production promotes regional manufacturing to prevent the inherent time savings from being negated by lengthy delivery routes. Bauernhansl is convinced that "the concept is perfectly suited to our high-tech' capabilities." German machine engineering could also benefit from the fact that much of the existing manufacturing plant would have to be updated or redesigned. "Today, many companies already understand that force and logic of the concept", says Bauernhansl, as it enables them to lower development costs and increase customer retention and loyalty.

Jens Eber

How Does a Drop Behave on a Hot Stone?
Doctoral students with DROPIT are gaining insights into the behaviour of the smallest possible water elements

Which of us has never seen rain drops landing in a puddle? Whilst keen amateurs claim to be able to predict the duration of a shower of rain based on the nature of the impact, researchers at the German-Italian DROPIT graduate college at the University of Stuttgart are conducting research in to how rain drops interact with one another and their environment. The answers to these questions are important for many industrial applications.

In a laboratory at the Institute of Aerospace Thermodynamics (ITLR) at the University of Stuttgart, doctoral students Anne Geppert and Ronan Bernard are using a new, highly modern system. The technology, known as Micro-Particle-Image-Velocimetry (Micro-PIV), is a non-contact, laser-optic velocity measuring system based on the detection of the tiniest particles added to a flow, or rather their deflection. To this end, the researchers implant a droplet with luminescent particles that fluoresce when illuminated by a green laser. By photographing the positions of the particle at defined points using a high-resolution camera, the speed of the particles can be measured by calculating the distance they have covered due to the flow within a specified period. "What's special about this process", says Anne Geppert, an associate member of DROPIT, "is that we can even measure flow fields in the micrometre range by combining a PIV system with a microscope."

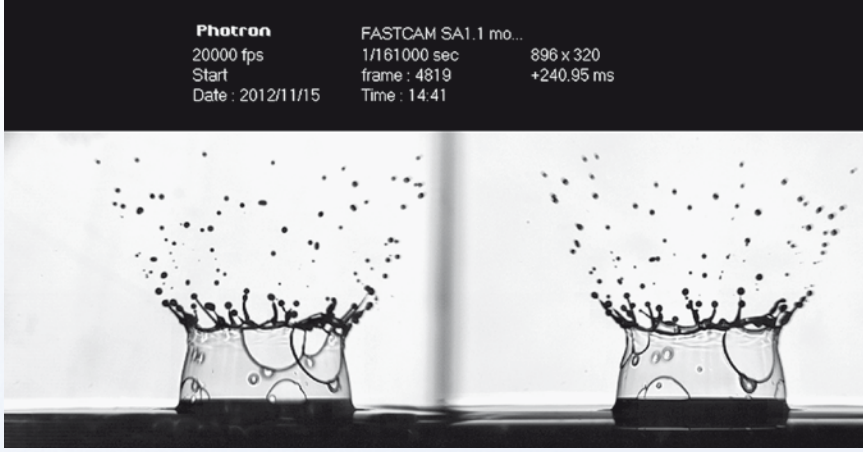
Understanding How Drops Interact

What happens when droplets interact with, are atomised or evaporate upon contact with specific media, materials and surface structures is still largely unknown. "Drops are more than just rain", says Professor Bernhard Weigand, Director of the ITLR, when describing the research team's fascination for the "life" of these objects, which is so short but yet so complex. "Our research objective", Weigand explains, "is to get to the bottom of the influence of microscopic structures on visible effects." What has already become clear is that even the most minute changes to the surface structure of the droplet or the surface which it strikes can lead to completely different results. That is all pure science. Yet, the DROPIT researchers are also thinking in terms of practical applications. Whether the spray cooling of food, evaporation processes or combustion processes are concerned – success is always dependent on the behaviour of tiny droplets.

Three target definitions were defined for the DROPIT area of study. In one series of experiments, the doctoral students are looking into vaporisation processes with a view to improving carburation in internal combustion engines. As Dr. Grazia Lamanna, senior academic adviser at the ITLR, explains in summing up the ambitious research objective: "it is possible to reduce fuel consumption by altering the frictional resistance." Another point of attention involves so-called super hydrophobic surfaces, of the kind found in extremely water repellent textiles or windscreens. The third area of research is dedicated to interactions between different liquids. "For example, these methods are useful for the development of new medicines in which one liquid is surrounded by another", Anne Geppert explains.

A Lively Exchange Across National and Academic Boundaries

The graduate college was found in Bergamo in the north of Italy in October 2016. DROPIT, which is an acronym for "Droplet Interactions Technologies", is one of the collaborative projects launched as part of the strategic partnership between the Universities of Stuttgart and Bergamo. The University of Trento is also involved. Around 20 researchers are working in parallel in Germany and Italy. Annual seminars



With the aid of the Micro Particle-Image-Velocimetry (Micro-PIV), the speed of the particles can be measured by calculating the distance they have covered due to the flow within a specified period.

Photo: University of Stuttgart/ITLR

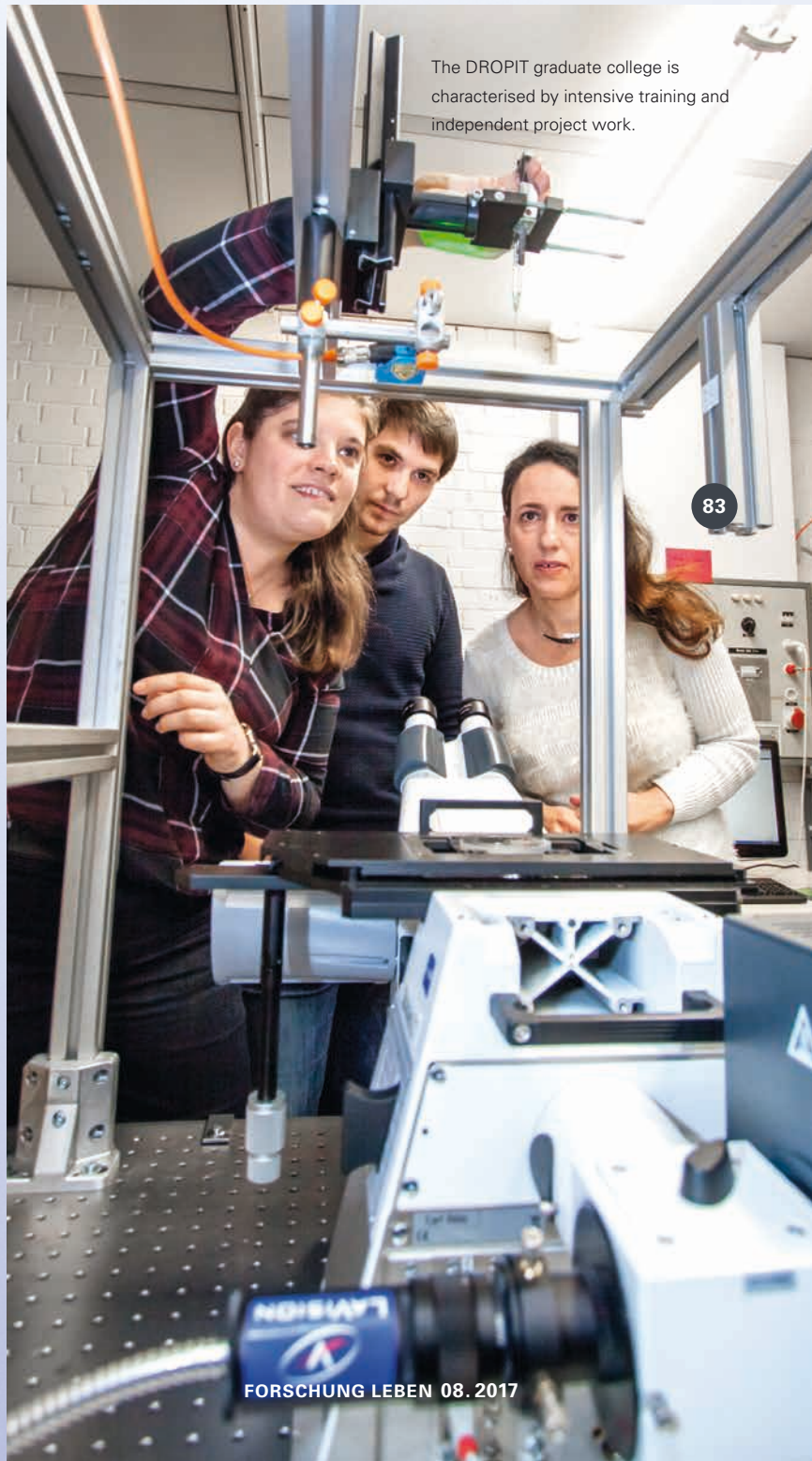
and special lectures for doctoral students will be held throughout the active period of the graduate college, which has initially been set at four years. Study exchange periods of six months in the respective partner countries are also planned.

Contributions from many fields of knowledge will be required to cover the wide range of scientific questions raised by the various aspects of droplet interactions. That is why the DROPIT team includes researchers from a broad range of disciplines including Mathematics, Computer Science, Fluid Mechanics and Thermodynamics.

In Weigand's opinion, "the very high number" of applications is as much a result of the excellent technical equipment available to the college as to the project's thematic scope. Grazia Lamanna is certain that: "the intensive training given to the doctoral students in combination with their ability to carry out independent project work will open up great career opportunities for each of the graduates." All participants also agree that the intensive collaboration with the University of Bergamo offers great benefits in terms of content. A micro-CT scanner of such excellent quality like the one built by Maurizio Santini at the University of Bergamo is, as Bernhard Weigand explains, so far unique in the world. The device enables 3D scanning to illuminate and photograph objects in the micrometre range.

Jens Eber

Photo: Jens Eber



The DROPIT graduate college is characterised by intensive training and independent project work.

Ready for the Second Quantum Revolution
The expertise of Stuttgart and Ulm all under one roof

With the Center for Integrated Quantum Science and Technology (IQST), the Universities of Stuttgart and Ulm are jointly positioning themselves for a development leap that will affect many areas of technologies. It is expected that sensors, communication technologies and computers will eventually be able to exploit fundamental quantum physical effects to become more sensitive and reliable than their contemporary counterparts. Scientists are now collaborating in an interdisciplinary effort to ease the transition path from pure science to technical application.

We have now become so accustomed to certain everyday technological innovations that nobody really thinks any more about how some of these things even work the way they do. DVDs, smart phones, the Internet, flat-screen TVs, LEDs – yet all of these things that we now take for granted are the results of research carried out decades ago at a whole range of scientific research institutes. For example, some of today's most common devices are only possible at all due to discoveries in solid-state and quantum physics and their later technical exploitation in integrated circuits or lasers. And, this development is far from finished. On the contrary, "we are currently undergoing a transition to the era of quantum technology", says Professor Jörg Wrachtrup, Director of the Institute of Physics (3) at the University of Stuttgart. Experts use the term "quantum technologies" in this context as shorthand for novel technical approaches that exploit specific properties of systems whose behaviour can only be explained through quantum physics. "The situation in which we currently find ourselves", says Wrachtrup in an attempt to point out the potential implications, "is comparable with the transition between semiconductor physics to microelectronic components and integrated circuit boards that took places during the 1950s and '60s." Scientists at the Universities of Stuttgart and Ulm and the Max Planck Institute for Solid State Research have reacted to this development by founding the Center for Integrated Quantum Science and Technology (IQST). Two professors in particular were the driving force behind the idea: Wolfgang Schleich, Head of the Institut for Quantum Physics at the University of Ulm, and Tilman Pfau, Director of the Institute of Physics (5) at the University of Stuttgart. The roots of the IQST stretch back for over a decade. According to Professor Pfau: "the initial seed was the Transregio21". Founded in 2005, this Collaborative Research Centre for Quantum, Atomic and Solid State Physics involves the participation of the Universities of Stuttgart, Tübingen and Ulm as well as the Max Planck Institute for Solid State Research. The third and final funding period is just coming to an end. Collaborative research carried out there over the past twelve years has ensured that sensors, computers and communication technologies based on quantum systems no longer represent some kind of utopia. "Very often what we have succeeded in doing in the laboratory is still a long way from any real-world technical application", says Pfau, who is also the spokesman for the IQST. "But scientists have learned that they need to be involved throughout the entire process from pure research to industrial feasibility trials both from a conceptual and a research perspective."

Multi Award-winning, Internationally Renowned

The IQST provides unified expertise for this. A total of 20 institutes and 22 professors from the Universities of Stuttgart and Ulm are involved. Between them, the centre's participating scientists have won many prizes and attracted many funding programmes including: four Leibniz Prizes, two Max-Planck Prizes, two Humboldt Professorships, 15 ERC Grants and

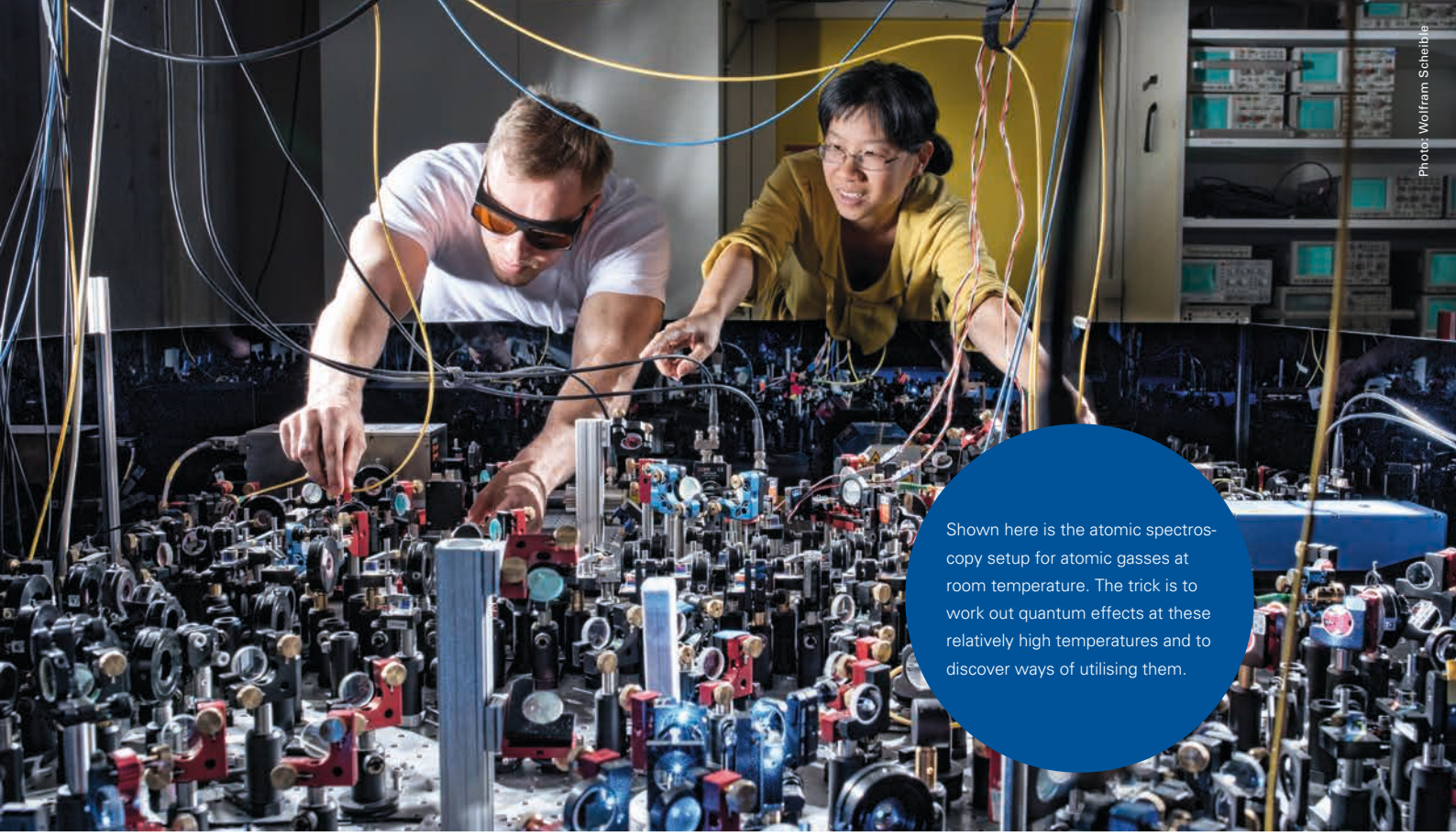


Photo: Wolfram Scheible

Shown here is the atomic spectroscopy setup for atomic gasses at room temperature. The trick is to work out quantum effects at these relatively high temperatures and to discover ways of utilising them.

one ERC Synergy Grant. Four researchers at the IQST are among the world's most frequently cited scientists. Two research buildings are being constructed to ensure that they can all work under the optimum conditions in terms of infrastructure. The University of Stuttgart is home to the Centre for Applied Quantum Technologies (ZAQuant), whilst the Centre for Quantum Life Sciences (ZQB) is located at the University of Ulm.

Professor Peter Michler, Director of the Institute of Semiconductor Optics and Functional Interfaces (IHFG) at the University of Stuttgart, describes a complex example of the kind of work performed at the IQST: "We're conducting research into light sources that are subject to the laws of quantum physics, and want to use them to verify the presence of specific biological molecules with the aid of a sensor" he says. To this end researchers from the University of Stuttgart are collaborating with a team led by Professor Boris Mizaikoff, who heads up the Institute of Analytical and Bioanalytical Chemistry at the University of Ulm. "We're the experts for the light source and our colleagues Ulm are biosensor experts", Michler explains. The physicists at the IHFG make their light sources from semiconductor systems by creating very small three-dimensional structures. These structures, known as quantum dots, emit light when exposed to an energy source, but not by emitting a high number of photons, i.e., light quanta, like traditional light sources. Instead, the quantum dots emit photons one at a time, which means that the"resulting "illumination" is also subject to the laws of quantum mechanics. "We then redirect our photons into a specially formed wave guide in order to created entangled photon pairs", says Michler.

Effects, that Contradict Common Sense

Quantum entanglement is a property that should not be possible by the standards of everyday physics. Two entangled photons no longer behave independently of one another, regardless of the distance that separates them. On the contrary, measuring any property of one of the entangled photons immediately affects the properties of the other one. Science has now advanced to the point where this effect can be made visible in the macroscopic world – which more or less means with the use of ordinary technology. Michler's team provided the entangled photons to their Ulm colleagues for the experiment so that they could prove the existence of biomolecules. Recently, Michler and his team were able to create a state of quantum entanglement for the first time,

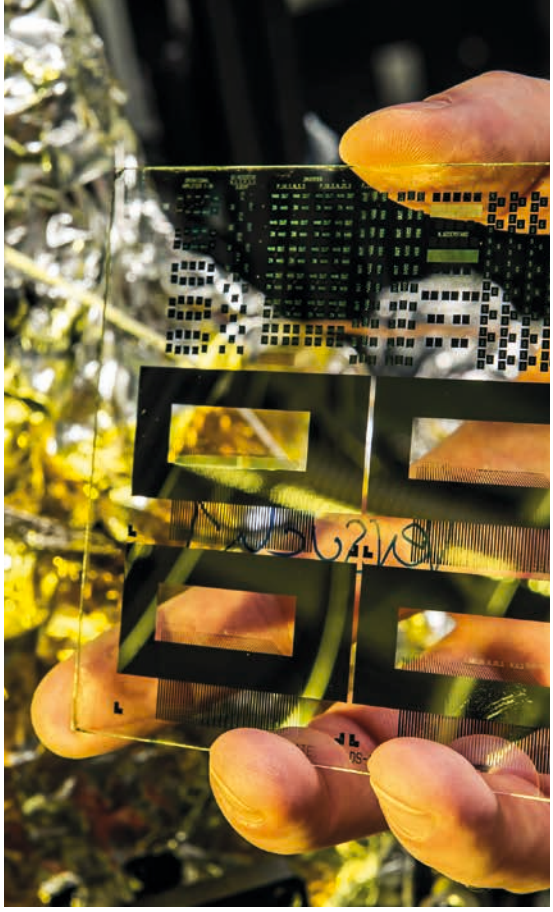


Photo: Max Kovalenko

There are already many integrated components for electricity, such as switches, capacitors etc., but components would still have to be developed for light to make use of its quantum mechanical effects.

which enabled more sensitive measurements than are possible under the normal laws of physics. “In this way we have proven that, in principle, entangled photons created by quantum dots can be used to build a better sensor than with traditional light, for example from a laser”, says Michler. The objective of both the Ulm and Stuttgart-based work groups is to integrate both their light source and their sensor on a single chip. This is still just a vision – the scientist are still at the very beginning.

This project, like all other projects at the IQST, requires interdisciplinarity, a buzzword that has been pretty overused in science for a long time. Nevertheless, the next technological revolution will not be possible without collaboration across discipline boundaries. Jörg Wrachtrup illustrates this with a tangible example: quantum sensor for neurosurgery. “The idea”, he explains, “would be to directly check the local activity of the affected area within the head during surgery to remove a brain tumour.” This would allow the surgeon to recognise what should be removed and what should be left untouched. This type of diagnosis requires a highly sensitive sensor based on quantum technology combined with an endoscope capable of positioning the sensor at the correct spot in the brain. “Developing a prototype for this application will require the collaboration of physicians, biologists, engineers and physicists”, says Wrachtrup. Because, the surgeon knows how to operate on the patient; the biologist knows what is happening at the cellular level; The engineer would be required to integrate the sensor and the necessary electronics in the endoscope – in compliance with the medical products law; and the physicist can develop the quantum sensor and configure its resolution and sensitivity properties. “It would be easy to provide other examples”, says Wrachtrup, “to show why we will not make progress in the upcoming quantum revolution without interdisciplinary collaboration.”

Justified Hope of Funding

The current funding provided for the IQST by the Universities of Ulm and Stuttgart and the state of Baden-Württemberg is particularly valuable in terms of interdisciplinary collaboration. For a five-year period beginning in 2014, 750,000 euro have been made available each year for research projects that would otherwise have fallen through the traditional funding net. Tilman Pfau explains: “One of the consequences of our approach at the IQST is that certain unconventional projects would be overlooked for funding awarded on the basis of traditional conceptual paradigms.” Based on the funding that has been provided the IQST has been able to provide important stimuli.

Pfau is hoping that funding for the IQST will also continue to be made available going forward, including from the European Union among other sources. For, in response to an invitation issued by the EU, several authors published a “Quantum Manifesto” in the spring of 2016, which calls upon the European Commission to provide funding for a broad range of projects forming part of the – as it is called in the manifesto – “second quantum revolution”. For one particular flagship project, the talk is of funding worth billions of euro. One of the six authors of the

manifesto was Professor Tommaso Calarco, spokesman for the IQST and one of the two leaders of the Institute for Complex Quantum Systems at the University of Ulm. Since its publication, the 20-page document has been signed by over 3600 representatives of the sciences and industry. The desired EU would finally ensure the IQST's long-term viability.

Michael Vogel

Collaboration with Industry and Foreign Universities

The Alliance for Quantum Innovation also falls under the auspices of the Center for Integrated Quantum Science and Technology (IQST). The programme was initiated by Professor Fedor Jelezko, Director of the Institute of Quantum Optics at the University of Ulm, and Professor Jörg Wrachtrup, Director of the Institute of Physics (3) at the University of Stuttgart. "The route from basic research into quantum technology and the technological application in the development department of a commercial enterprise is extremely long", says Wrachtrup. "That's why we want to boost our collaboration both with industry and our international partner universities." The heart and soul of the Alliance programme is a graduate school, whose doctoral students can combine their research activities at the IQST with fellowships and internships with the collaborating partner organisations. The programme started in autumn 2016. Representatives from the industrial sector currently collaborating with the IQST are Bosch, Bruker BioSpin and Zeiss. University collaborators include the University of British Columbia in Vancouver, the Hebrew University in Jerusalem, and die University of Tokyo. In addition to the Alliance graduate school, the Hebrew University will be funding another five doctoral students, who can study at the IQST. "Naturally", says Wrachtrup, "we "would welcome additional partners."

Using diamonds to reduce the size of hard drives

Quantum technology makes it possible to measure the magnetiv field of write head on the nanoscale

More information saved in a smaller space - this has been the dominating trend for decades when it comes to storing digital data. It was thought that this miniaturization had reached its limits, but the University of Stuttgart is ready to prove otherwise.

In 1956, the first IBM hard drive weighed almost a ton and had a diameter of 61 centimeters and a storage capacity of just under 4 MB. These days, five terabytes can be stored on a device measuring just a few centimeters and storage space for a single bit measures just 20 nanometers, a thousand times smaller than a human hair. But increasing digitalization means that the amounts of data to be stored in the future will require a much higher storage density.

In order to fully comprehend this challenge, it is important to understand how files are written onto a hard drive: A bit is saved when the write head, a tiny electromagnet, magnetizes a section on the hard drive. To do this it has to precisely apply a strong magnetic field within billionths of a second without overwriting neighboring bits. At this point a bit is much smaller than the resolution of typical micro sensors, which is why these are barely capable of providing accurate data about the condition of the magnetic fields. “Currently, new write heads can only be developed by using simulations based on the principle of trial and error”, explains Ingmar Jakobi, a doctoral student at the University of Stuttgart’s 3rd Institute of Physics. “The industry is reliant on new sensors if it is to continue miniaturizing its storage devices.”

The 32-year-old researcher is part of Prof. Jörg Wrachtrup’s team, which has managed to measure a write field at the required length scale. To do this, the physicists used a material that is more commonly seen in a jeweler’s window: a diamond. Or, to be more precise, the nitrogen defects, which give these precious stones a pink color when present in high concentrations. These color centers are atomic flaws in the diamond’s crystal lattice, where a carbon atom is replaced by a nitrogen atom and the neighboring position on the lattice is empty. Single electrons get trapped in this structure and their spin, i.e. a quantum mechanical molecular magnet, reacts sensitively to magnetic fields, but are otherwise relatively shielded from the surrounding environment. The spin has an effect on the fluorescence of the color center. This means that a magnetic field on a single color center can be optically identified using a microscope.

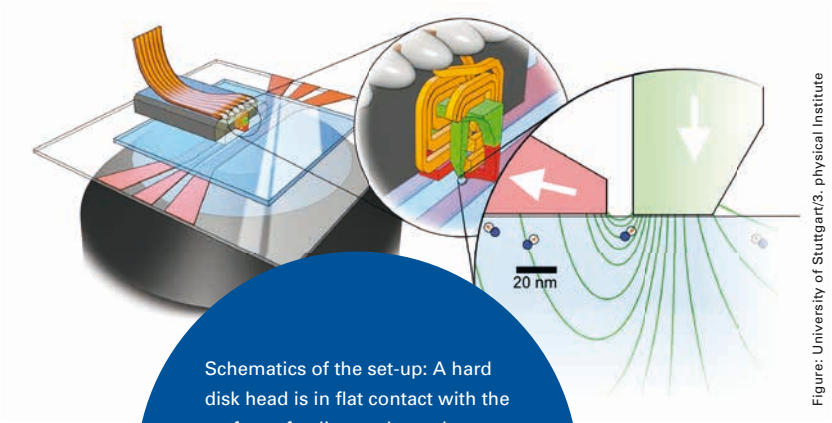


Figure: University of Stuttgart/3. physical Institute

Schematics of the set-up: A hard disk head is in flat contact with the surface of a diamond membrane. An objective granting optical access to the NV centers and a microwave control structure are located on the back surface of the membrane. The writer is embedded in the head.

Measurable Field Intensities Varying from A Few Microtesla to Hundreds of Millitesla

As part of an experiment, the team of scientists supporting Wrachtrup moved the hard drive write head gradually over the surface of a diamond crystal where the colour centers were located close to the

These physicists rely on diamonds to enable them to measure a write field at the necessary length scale.

Photo: University of Stuttgart/3. physical Institute

surface. During this process, they were able to use the color center to measure field intensities ranging from just a few microtesla to hundreds of millitesla – both static fields and alternating fields with frequencies in the gigahertz range.

"Our magnetic field sensor is unique because of its 'size'. The lattice spacing of the atoms in a diamond is just 150 picometers, that is 1000 times smaller than the pole of the write head and 100 times smaller than a bit on the hard drive", explains Ingmar Jakobi, who published the study's findings in the scientific journal Nature Nanotechnology* as lead author. He also states that the sensor is easy to use: "Because the spin is trapped in the defect we measure the volume of an atom, but can easily control the position thanks to the size of the whole crystal. The resolutions depend upon how accurately we move the diamond and how close the hard drive head is to the surface."

The project is the perfect example of successful cooperation between the industrial sector and science, say representatives at Seagate Technology, a leading hard drive manufacturer: "write heads are designed to create huge magnetic fields on the smallest possible space to achieve the best possible storage capacity. The ability to measure these on the nanometer scale is an outstanding development for our industry", says Dr. Fadi El Hallak, Head Developer at Seagate and co-author of the study.

Magnetic resonance imaging on single molecules

For the Institute director Prof. Jörg Wrachtrup, the findings achieved as part of the special research project SFB/TR 21, mark an important step in establishing a further practical application for quantum technology. Wrachtrup also hopes that this will open new perspectives for the field of research that go far beyond micro electronics: "The findings show that it is possible to use write heads for our experiments and that we can utilize the extraordinary properties of the write field. The strong gradient of the field could make it possible, for example, to use nitrogen defects to carry out magnetic resonance imaging on single molecules." Subsequent projects of this kind could also involve the Interdisciplinary Center for Applied Quantum Technology ZAQuant at the University of Stuttgart, where physics, engineering sciences and industry want to work together to research and develop new quantum sensors and operational prototypes.

Andrea Mayer-Grenu

“It’s all about the students!”
For Markus J. Buehler, scientific progress means investing in young scientists

The materials scientist Markus Buehler is the Dean of the Civil and Environmental Engineering Faculty at the world famous Massachusetts Institute of Technology (MIT) where he is the current holder of the prestigious McAfee Professorship. In this interview, the alumnus of the University of Stuttgart talks about his research – and points out the importance to science of transcending the boundaries of status, institutions or cultures.

? Professor Buehler, your research is associated with catch phrases such as “nanotechnology “bordering on biology”, “cobweb-like proteins” and “renewable steel”. What’s behind all of that?

› Our central mission is the discovery and fabrication of new materials, whereby the overriding objective at the MIT is to make nanotechnology useful in everyday life and especially for materials and products that can be manufactured in large quantities. Computer simulation plays an important role in this context. This work enables us to virtually optimise a novel material atom-by-atom on the computer before actually creating it in the laboratory later. Ultimately, this is the core vision of the physicist Richard Feynman in the 1950s, which was to be able to write the entire contents of the Encyclopædia Britannica on the point of a needle. Part of that vision was the ability to be able to manipulate materials at the atomic level to create new phenomena. Today, we’re in a position to be able to do that. One of the greatest challenges in this context is to develop models capable of describing all properties from the scale of a single atom to the structure of a given component or product and across all interim stages, so-called mesoscopic scales, which form the bridge between the nano and macroscopic scales. Much of our research work involves biological materials such as spider web silk and bones. These materials are examples of how nature utilises multi-scale design to achieve specific material properties regardless of the fact that the underlying chemical building blocks aren’t ideal. In this way, for example, ultra hard and durable materials can be produced from the same chemical building blocks and gelatine. Examples of this are the sinews in our bodies, spider silk, which is stronger than steel or certain body parts of marine worms.

? What are your next research objectives?

› For us engineers, nature is an infinite source of inspiration. But, we don’t just copy nature. Instead, we try to improve on it. Going forward, I can see interesting possibilities for being able to integrate “life” into certain materials, for example based on findings from the field of Synthetic Biology in which biologists, chemists and engineers collaborate to create biological systems that do not occur in nature. For example, we are looking for new strategies to make new products from sustainable materials such as proteins, wood or other renewable materials, which are currently made from petrochemical products in very energy intensive ways. For instance, the production of steel and cement are two of the most CO_2-intensive processes on the planet. The use of new materials could result in a significant reduction in emissions. In my capacity as Head of the Civil and Environmental Engineering Faculty, I invest a lot of time and effort into developing teaching and research strategies. This has resulted in a reorientation of the faculty towards “big engineering”, whereby the integration of multiple disciplines plays a significant role.

? You moved to the USA in 2005 when you were still a very young scientist: what are the differences between the research conducted there and in Germany?

› During my time at the Max Planck Institute (MPI)

Photo: Alan Sitten

Wants to invent and manufacture new materials: Markus J. Buehler, an alumnus of the University of Stuttgart, is a scientist at the renowned Massachusetts Institute of Technology (MIT).

for Metals Research, now known as the Max Planck Institute for Intelligent Systems and at the University of Stuttgart I found myself in an excellent environment – that period left a deep impression on me. The best conditions always arise when highly talented people create the prerequisite conditions in which young scientist are able to acquaint themselves with different working methods and perspectives and to achieve excellence. The MPI was always a major centre for materials science. We continuously hosted scientists from all over the world and I was fortunate enough to be mentored by some very special people. The systems and cultures at the California Institute of Technology (Caltech), where I went as a postdoc after completing my dissertation, and at the MIT where I later settled, are very different. At the Caltech, I found myself in an office in the second basement level that I had to share with other postdocs and students. So, we made sure to hold as many of our meetings as possible in the coffee shop and to enjoy the California sunshine. All together students and scientists worked very closely together there, and collaborated often, irrespective of background or status and across various faculties. Funding, the procurement of third-party funding, was always a major challenge – I learned a lot there. The method of working various ideas into project proposals requires teamwork and usually gets better results.

? The MIT is regarded as one of the best technical universities in the world: what do you find particularly fascinating about it?

› I have accepted a tenured professorship at the MIT and have built up my own team. I've spent a lot of time exchanging ideas with top notch scientists, learning from their experience and then developing my own visions and plans. My greatest pleasure at the MIT was and is the collaboration with excellent students, postdocs and colleagues. It is hugely enriching that we're such a varied bunch in this community in which we're working on a shared vision. Without that we wouldn't succeed!

Interdisciplinary working is very important here. We're always trying to find and implement new approaches. That can only be achieved if people from various disciplines work hand in hand. We encourage an open door culture at the MIT. So, it's not important whether someone is a new student or a senior professor; all are equally approachable. It is not rank or past achievements that count here, it's potential. That was one of the things I loved about the MIT as a young scientist. I was able to implement and refine my own ideas whilst benefiting from colleagues who were already more experienced. Not infrequently, some of the best ideas and most innovative concepts have come from students. If someone has a good idea and is able to convince others of its merits then, as a matter of course, we work collaboratively to see it realised. As an immigrant to the USA I have always been made to feel welcome and have always had the feeling that all options are open to me. On the other hand, taking personal responsibility is deeply embedded in American culture, even in universities.

? What can the German system of science learn from its American counterpart?

› I think that an important aspect of a successful

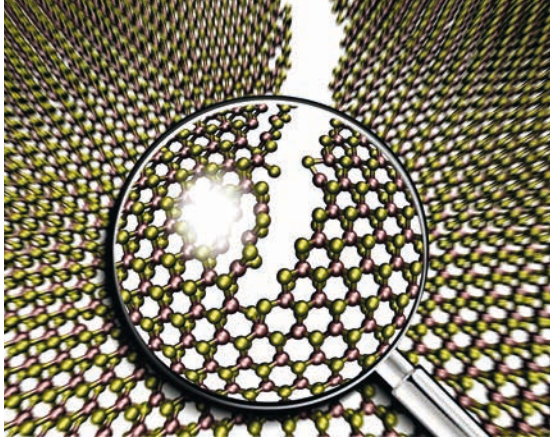


Photo: Zhao Qin and Markus Buehler (MIT)

Atomic simulation of the spread of a crack in MoS2, a crystalline sulphide of the chemical element molybdenum. Simulations of this sort provide insights into the fundamental properties of materials, as one can observe the crack spreading as chemical bonds are torn apart, whereby new surfaces are created.

research and teaching operation are the people, who work to achieve their goals with passion and enormous commitment – both as part of a team and across disciplinary boundaries. On the other hand, American universities could learn from the German system, for example, in terms of collaboration with industrial partners, which is particularly outstanding at the University of Stuttgart.

? The USA is in the throes of a political upheaval which is also affecting universities. A so-called "March for Science" was held in April, which also involved the active engagement of German scientists. How is the change affecting you?

› There are changes in the wake of every administration change, especially when it involves a complete change of course. I think it's important for all sides to communicate frankly with one another and to find new ways to bring about positive developments. Germany, for example, could contribute to creating a greater role for production in the USA – and, of course, the University Stuttgart plays a leading role in that. The interest in the German model of education and training also presents an opportunity for dialogue. We must not permit the dialogue to breakdown. We need to find and resurrect common ground. I am certain that the transatlantic link will remain strong and will continue to be the basis of many new developments.

? The MIT stands for a culture of excellence, a value, that practitioners in the German sciences are striving to achieve within the "Strategy of Excellence" initiative. Do you consider this initiative to be an appropriate strategy for increasing Germany's competitiveness as an international research location?

› Yes, I think the "Strategy of Excellence" is very good. Of course long-term funding will need to be secured and the focus needs to be on the retention of the most talented researchers. In the USA, the recruitment of top professors is done in almost the same way as the recruitment of football stars in German, including transfer negotiations and retention bonus offers. These days, the best minds in science are "traded" throughout the world. It is important for Germany to keep pace with this development and to attract the best people.

It is important to ask oneself what the fundamental elements of excellence actually are. In the final analysis, it's all about the people who breathe life into the concept. That's why a culture is needed that makes it possible to bring people together whose perspectives may differ greatly but who can collaborate on achieving a shared goal. Diversity is an important aspect in this context, because one can really build something special with people from different backgrounds. That is one of the MIT's explicit objectives. Another area of focus is "impact". The linking of the findings of pure science with the goal of channelling them into products that are useful to society as a whole. This spectrum from pure science to practical applications that benefit millions of people is the MIT's premier objective, rather than simply carrying out science and developing theories for their own sakes.

? The provision of support for up and coming scientists is another of the MIT's primary objective and is also at the centre of the MISTI programme of which you are the scientific director: What are the objectives of the programme?

› MISTI stands for "MIT International Science and Technology Initiatives". Like so many new projects at the MIT, it began as a small experiment that a few professors carried out with Japan. The programme is a good example of how new initiatives arise at the MIT – not so much in the minds of the administrators, but more at the grass-roots level. The idea included a strong cultural component. The

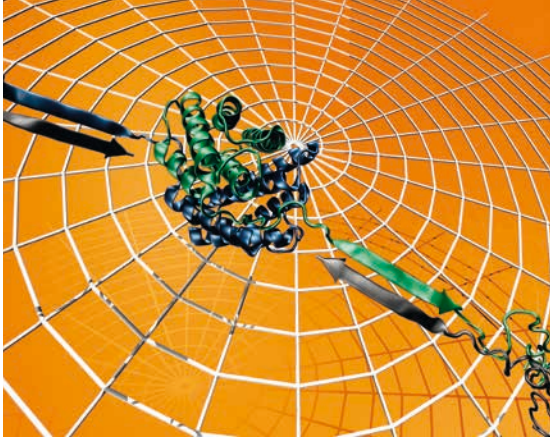


Photo: Zhao Qin and Markus Buehler (MIT)

Molecular model of a spider protein for observing the effects of salt ions on folding behaviour and stability. A model of a spiders web is visible in the background, which is used for research into the mechanical properties. The image illustrates the link between the molecular and macroscopic scales.

goal of the Japanese project was to provide students with an opportunity to spend time living in a foreign country, experiencing foreign cultures and, in particular, to learn about how they do research and how innovations come about there. The majority of our students learn the language of their host countries and take courses on the respective cultures and undertake intensive preparations for the work they will be performing before leaving the MIT. This model is so successful that it has now been extended to many other countries, including Germany. There are currently over 25 programmes in operation with countries throughout the world. Almost 1000 of our students travel abroad every year and we have in excess of 450 partnerships with institutions, regions and countries.

This year we're celebrating the 20th anniversary with MIT Germany. We're sending around 70 to 80 students to Germany under various programmes which include internships, research or secondary school teaching. One example is the Global Teaching Labs Programme. We now have a very successful "Seed Fund Programme" with the University of Stuttgart, to make it easier to initiate joint research projects as it enables professors from both universities to collaborate and exchange personnel. Thus far it has proved possible to provide funding for four projects and the next Call for Proposals will be issued in September 2017. This new connection between the MIT and Germany is extremely important to us.

? You were personally involved in setting up the "Seed Fund Programme" with the University of Stuttgart: what motivated you?

› Study abroad is an incredibly important aspect of any degree course. I wanted to provide students at the University of Stuttgart with the chance to spend time at the MIT. One thing that motivated me was the fact that there is a strong tradition of technology-based research at the University of Stuttgart. There are excellent students there, who I think are an excellent match for the research environment at the MIT. In return, the University of Stuttgart is an important partner for the MIT, especially due to its strong links to industry and certain global enterprises, which are based in Stuttgart. Beyond that, the small to medium enterprise sector is an interesting area with great potential.

? As an alumnus you still maintain close ties to the University of Stuttgart, being a frequent guest and taking up-and-coming research students from Stuttgart to the MIT. What advice would you give to your Alma Mater?

› It's all about the students! Investing in the next generation and in existing staff is of the utmost importance. Young people starting their university studies right now need to be inspired and be rapidly involved in ongoing research. Allowing visions to develop organically and having researchers and professors act as mentors and teachers for the next generation is hugely beneficial for one's own work. Researchers gain the greatest influence over those members of the younger generation whom they train and support. That not only lets their own ideas live on, but also breathes new life into them. The university should do everything possible to support and reinforce this.

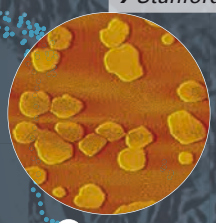
Thank you for the interview.

The interview was conducted by Andrea Mayer-Grenu

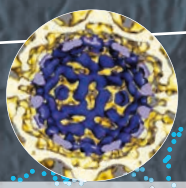
On the Trail of Clever Natural Solutions

Lightweight but robust bones, gelatinous vertebral discs, flexible vines; nature produces materials with properties that make materials scientists envious – and challenge them. Researchers at the interdisciplinary "NanoBioMater" project centre at the University of Stuttgart are attempting to imitate nature and to improve technical solutions by integrating natural components. Their objective is to develop bespoke functional materials using biological and synthetic building blocks for use in medical engineering, diagnostics and environmental analytics. The name NanoBioMater" speaks for itself: Nano stands for the sub-microscopic world into which researchers in the natural ,materials, and engineering sciences immerse themselves; "BioMater" is an abbreviation for biological materials and biology-based material elements, which they hope to develop. Whereas most previous collaborations have primarily involved the exchange of samples for analysis, this project centre at the Stuttgart-Vaihingen campus, which is funded by the Carl Zeiss Foundation, also provides a physical space for the exchange of ideas and conducting experiments. Three team leaders ensure the smooth interaction between all participants in the interdisciplinary projects. They tie together the various collaborative projects, provide access to partner institutes and organise regular events, such as an international conference held every two years and an interdisciplinary summer school. The next of these is scheduled for 2017. Between the 27th and 30th of June, scientists from around the globe will be travelling to Bad Herrenalb to discuss the latest findings relating to such things as biologically-inspired mineralisation for structural and adjustment functional materials, nano to meso-scale biological components from plant viruses to chemical synthesis, the processing and integration of adjuvants in soft hydrogels, among other things – and all with the aim of coming one step closer to the ingenious ideas invented by nature.

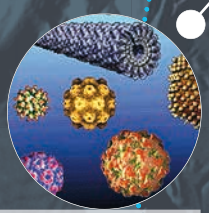
Martina Hönekopp



Curtis W. Frank · Polymer Interfaces and Macromolecular Assemblies
› *Stanford University*



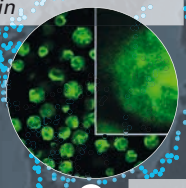
Steven Lommel · Plant Pathology, Red Clover Necrotic Mosaic Virus (RCNMV)
› *NC State University, Raleigh*



Qian Wang · Bio-nano-templates for Applications in Medicine and Material Science
› *University of South Carolina, Columbia*

Tanja Weil · Polymer Research, Precision Macro Molecules and Hybrid Materials
› Max-Planck-Institut for Polymer Research, Mainz

Rainer Haag · Supra-molecular Chemistry
› *Freie Universität Berlin*



Carole Perry · Bio-molecular Materials Interface, Peptide Modelling
› *Nottingham Trent University*

Ute Kaiser · Materials Scientific Electron Microscopy
› *Ulm University*

Jens Friedrichs · Extra-cellular Matrix and Hydrogel Derivatives
› *Leibniz Institute for Polymer Research, Dresden*

University of Stuttgart
Germany

International NanoBioMatter Conference

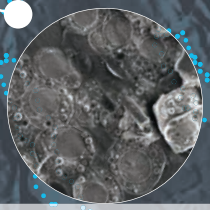
27th to 30th of June in Bad Herrenalb Germany

Dirk Schüler (l) · Microbiology Protein Modification
› *University of Bayreuth*

Thomas Scheibel (r) · Bio-materials, Protein Modification
› *University of Bayreuth*

Günter Gauglitz · Analytical Chemistry, Biological and Chemical Sensors
› *Eberhard Karls University of Tübingen*

Fernando Ponz · Plant Virus Biotech
› *INIA-UPM, Madrid*



Steve Weiner · Bio-mineralisation
› *Weizmann Institute of Science, Rehovat, Israel*

Picture credits: Curtis W. Frank: Center on Polymer Interfaces and Macromolecular Assemblies, Standford University / Steven Lommel: North Carolina Agriculture Research Service, USA / Qian Wang: University of South Carolina, Columbia, USA / Carole Perry: Notingham Trent University / Tanja Weil: Ulm University /Tanja Weil / Rainer Haag Free University of Berlin/Prof. C. Schalley / Jens Friedrich Leibniz Institute, Dresden / Dirk Schüler: University of Bayreuth / Thomas Scheibel: Steve Weiner / Steve Weiner: Weizmann Institute, Rehovot, Israel / Ute Kaiser: Ulm University / Günter Gauglitz: AK Gauglitz, University of Tübingen / Fernando Ponz: INIA-UPM, Madrid

Danger of Collapse Averted

Dr.Ing. Akanshu Sharma, a structural engineer from India is making buildings safer

Whether they are subjected to earthquakes, terror attacks or explosions, buildings need to be able to withstand a whole range of calamities. Structural engineer Dr. Akanshu Sharma is conducting research into where the weakest points of buildings are found and how these can be retroactively reinforced to withstand shocks, heavy impacts and fire. In January 2017, he took up a junior professorship in "Innovative Reinforcement Methods with Fixings" at the University of Stuttgart. The chair was donated by the Fischer Group, the global leader in fixing systems.

In 2016, a series of earthquakes in central Italy killed over 300 people, destroyed numerous buildings and left tens of thousands of people homeless. Germany too experiences several thousand earthquakes per year – primarily in the Rhine Valley Rift and Swabian Jura regions as well as in and around Gera. Most of these are weak shocks that barely register on the Richter scale. But, stronger earthquakes also occur here every 30 years on average. Whilst they never reach catastrophic dimensions, they do cause visible damage. The worst such quake since 1900 occurred in 1992. The epicentre was close to Roermond in the Netherlands and the quake measured 5.9 on the Richter scale. Houses shook, chimneys and roof tiles fell down, and trees toppled over, causing millions of euro of damage.

A standardised map of earthquake risk zones in Europe published in 2013 shows that magnitude 6 earthquakes are not improbable even for Germany. "In such cases, many buildings in Germany's earthquake risk zones would be at risk", says Dr. Akanshu Sharma of the Institute of Construction Materials. That is especially true of buildings constructed prior to 1980. At that time, engineers had not yet began to design buildings to withstand the sometimes powerful horizontal forces generated through the sudden jerking back and forth of the bedrock. The structural engineer is critical of the fact that, even today, many Germans remain unaware of their country's earthquake risk. "In countries whose earthquake risk is significantly higher, such as Japan, the USA, but also Italy and India, the regulations for earthquake-proof construction are much stricter", says the 38-year-old.

Cracks – Location is Everything

Modern buildings usually comprise a reinforced concrete frame into which the slabs and walls are integrated. The weakest points in older buildings are usually the nodal points in these reinforced concrete frames, i.e., the points at which the vertical columns and horizontal beams intersect. The greatest risk is that one of the load-bearing columns of a building buckles without warning, causing the ceiling slab to collapse, potentially burying people below it. "Our goal is to ensure that people can get out in time and survive the quake", Dr. Sharma explains. Smaller cracks in a beam are acceptable, he goes on to say; they can even be allowed to bend. But, the main thing is that there is sufficient warning before a structural failure and that the building doesn't suddenly collapse like a house of cards. "By contrast with normal buildings", says Dr. Sharma, who previously worked as a building safety engineer at the Bhabha Atomic Research Centre (BARC) in his native India, "we do not accept any cracking whatsoever in nuclear reactors through which nuclear radiation could escape." The main cause of building collapse is concrete, which has outstanding compression resistance properties but fails to withstand tractive forces. In the event that a frame node is insufficiently reinforced by steel reinforcing rods, then it will collapse. By comparison with concrete, steel has a high tensile strength and will, therefore, bend without simply breaking. Engineers can still improve the earth-

quake resistance of older buildings by retroactively reinforcing the sensitive frame nodes. One option that Dr. Sharma discovered in the course of his doctoral studies at the University of Stuttgart involves steel diagonal members (gusset plates) attached to the inner corners of the frame node. This deflects some of the forces around the frame nodes so that, instead of appearing in the nodes themselves, any cracks will appear in the connecting beams. However, according to Dr. Sharma's findings, that only works if the steel diagonals are firmly fixed to the concrete.

Photo: Uli Regenscheit

Know-how: Eliminating Weak Points

Whenever he attached a steel angle member with a diagonally welded gusset plate to a scale model of a frame node, he discovered that the resulting behaviour essentially depended on the fixing materials. For example, he tried concrete screws, metal expansion dowels and bonded anchors glued into a hole drilled into the concrete. If these are unsuitable for cracked concrete and seismic loads, the result can be unwanted failure profiles. As Dr. Sharma observed: "the deflection of the fixing mechanism can be too great, which in turn weakens the steel diagonals." Whether a given fastening element is suitable for this application can be estimated using data from the general type approval documentation, as the expert explains.

Originally, researchers in New Zealand thought of fastening the steel diagonals to the reinforced concrete frame using threaded rods, which they would insert through both the beam and the supporting column. The benefit of Dr. Sharma's solution is that the frame nodes only need to be accessed from the inside and that the slab does not need to be drilled through. He has also developed numeric models with the aid of which it is possible to study the failure of specific structural components in detail on the computer, as well as engineering models that can be integrated into traditional engineering software packages. Engineers can use the latter to calculate the likelihood of a given building being able to withstand a future earthquake or some other heavy stress load. The same scenario can then be repeated on the computer but with reinforced frame nodes. This enables construction experts to calculate such things as the ideal dimensions of the steel diagonals or which fastening system would be best suited to secure the building against future earthquakes. "Many of these models are already mentioned in the relevant literature, but they are much too complicated for daily use and are relatively costly", As Dr. Sharma found: "I was al-

ways fascinated by the question of whether we could find a way to ensure that building structures behave exactly as we want them to under specific conditions rather than in a completely unpredictable manner", says Dr. Sharma, who, even as an adolescent, visited high-rise building sites with his father, who was also a structural engineer. Ultimately, the son followed in his father's footsteps and studied structural engineering. He loved his later work at the BARC in India. Nevertheless, Dr. Sharma began to realise that he was being forced to spend more and more of his time on administrative tasks, which limited the amount of research he was able to do. Finally, nine years ago, he took the risk of leaving India for the first time – and arrived at the University of Stuttgart. He first arrived as a visiting researcher as part of an Indo-German collaboration at the Institute of Construction Materials. A short time later he returned for his doctoral studies, which he completed at this institute and in India.

Construction Boom versus Renovation

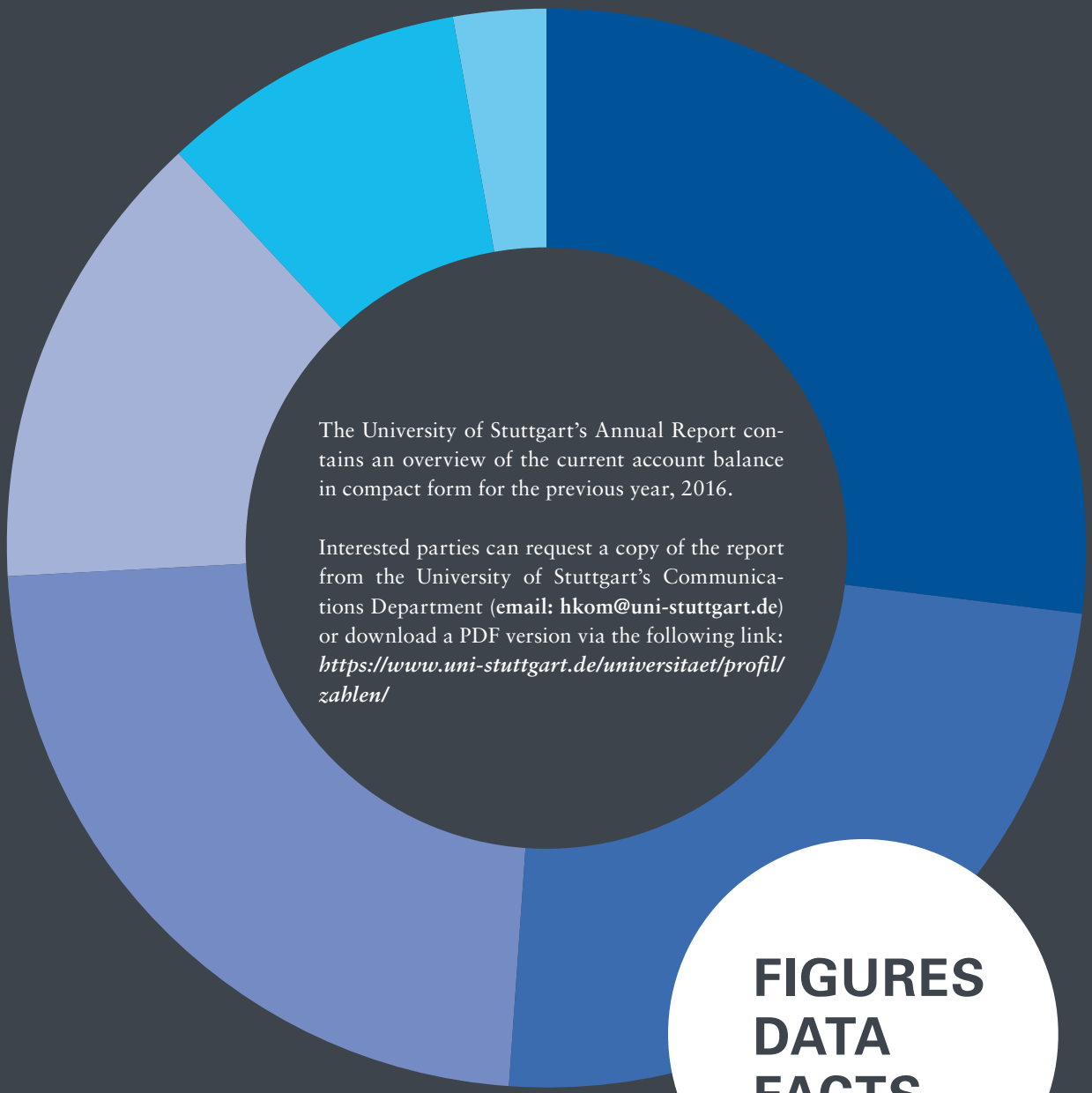
"One of the benefits we have in the Indian public sector", says Dr. Sharma, "is that we can conduct our experiments cost-effectively and that the research work is primarily funded through equity capital. On the other hand, Germany offers an excellent research environment with fewer restrictions. However, that also means that one is responsible for finding the necessary funding." One thing in particular strikes the structural engineer about Germany. Dr. Sharma comes from a country where buildings are shooting up everywhere, thanks to the current economic boom, and where new bridges and subway tunnels are being built in many places. In Germany, by contrast, he is confronted with a completely different set of challenges: "Most bridges and buildings are over 30 years old and are showing the initial signs of decay. They need to be reinforced and gradually renovated." Four years have now passed since Dr. Sharma made the final break with India and relocated with his family to Fellbach to pursue his research career in Germany. "Although the decision was not easy for us", he says, "I had the full support of my wife and my daughter, who is now eleven years old." As Group Leader for Reinforcements and Fixing Systems, Dr. Sharma is now also looking into the behaviour of reinforced concrete structures exposed to fire or impact loads, such as a heavy collision. The overriding question for all of these aspects is how structural weak points can be retroactively reinforced. The primary focus of the new Endowment Junior Professorship is on fixing and fastening systems for reinforcement measures carried out, for example, on dilapidated buildings – Dr. Sharma's area of specialism.

Experience with Shoring and Fixing Engineering Technologies

Dr. Sharma has observed that: "there are many engineering scientists around the world who are familiar with reinforcement methods, but only a few have any experience with fixing and fastening systems." Someone who was already thinking about fixing and fastening systems some 50 years ago was the inventor Artur Fischer, who achieved world renown as the inventor of the wall plug (German: Fischer-Dübel). The company founded by Fischer will be funding the Junior Professorship at the University of Stuttgart with 1.6 million euro over the coming six years. In retrospect, relocating from India to Germany was a huge step for Dr. Sharma, but one that he in no way regrets. The initial language problems are now largely a thing of the past, even though, as an ardent cinema goer, he still prefers to watch films in English. "Once one is properly set up and is able to speak the language", says Sharma, "life here is pretty easy." The only thing he has not yet succeed in getting used to is the fact that the shops are closed on Sundays!

Helmine Braitmaier

University of Stuttgart Annual Report



The University of Stuttgart's Annual Report contains an overview of the current account balance in compact form for the previous year, 2016.

Interested parties can request a copy of the report from the University of Stuttgart's Communications Department (**email: hkom@uni-stuttgart.de**) or download a PDF version via the following link: ***https://www.uni-stuttgart.de/universitaet/profil/zahlen/***

FIGURES DATA FACTS

2016

Imprint

Publisher: University of Stuttgart

Address: University of Stuttgart, Keplerstraße 7, 70174 Stuttgart
Telephone 0711 685-82211, Fax 0711 685-82291
hkom@uni-stuttgart.de, www.uni-stuttgart.de

Editors: Dr. Hans-Herwig Geyer, Andrea Mayer-Grenu,
Sympra GmbH (GPRA)

Concept: Tempus Corporate
www.tempuscorporate.zeitverlag.de

Design and implementation Zimmermann Visuelle Kommunikation
www.zimmermann-online.info

Advertisements: ALPHA Informationsgesellschaft mbH
info@alphapublic.de, www.alphapublic.de

Printing: W. Kohlhammer Druckerei GmbH & Co. KG, Stuttgart

Printed copies (German version): 7,500

ISSN: 2198-2848

Internet: www.uni-stuttgart.de/forschung-leben/


Universität Stuttgart
TAG DER WISSENSCHAFT
Die Universität Stuttgart öffnet ihre Labortüren!
01.07.
2017
Vorbeikommen
Staunen
Lernen
13:00–19:00 Uhr
Campus Vaihingen
Informationen zu Studiengängen, Aus- und Weiterbildung
Schüler-Campus mit Workshops und Mitmach-Experimenten
Mehr Infos und Programmheft unter:
www.uni-stuttgart.de/tag
Gestaltung: www.buero-schwab.com; Illustration: Arne Beck

Starten Sie auf der Überholspur des Daten-Highways

Hinter jedem komplexen und leistungsstarken Netzwerk auf der Welt verbirgt sich mit ziemlicher Wahrscheinlichkeit ein einziges Unternehmen. Und das sind wir: Viavi. Mit weltweit über 3.300 Mitarbeitern entwickeln, unterhalten und perfektionieren wir Kommunikationsnetze rund um die Erde. Es sind unsere Innovationen und Lösungen, die neue Dimensionen in eine digitale Zukunft ermöglichen. Für unseren Standort in Eningen bei Stuttgart suchen wir:

- **Ingenieure Elektrotechnik (m/w) Soft- und Hardwareentwicklung**
- **Informatiker (m/w)**
- **Ingenieure (m/w) Marketing und Vertrieb**

Werden Sie Teil unseres Teams und starten Sie in Ihre Zukunft auf der Überholspur des Daten-Highways. Wir freuen uns auf Sie.

Viavi Solutions Deutschland GmbH · Herr Markus Schindler
Arbachtalstraße 5 · 72800 Eningen u. A. · Telefon 07121 86-1207
karriere@viavisolutions.com

www.viavisolutions.de

VIAVI