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TECHNOLOGY
4.0

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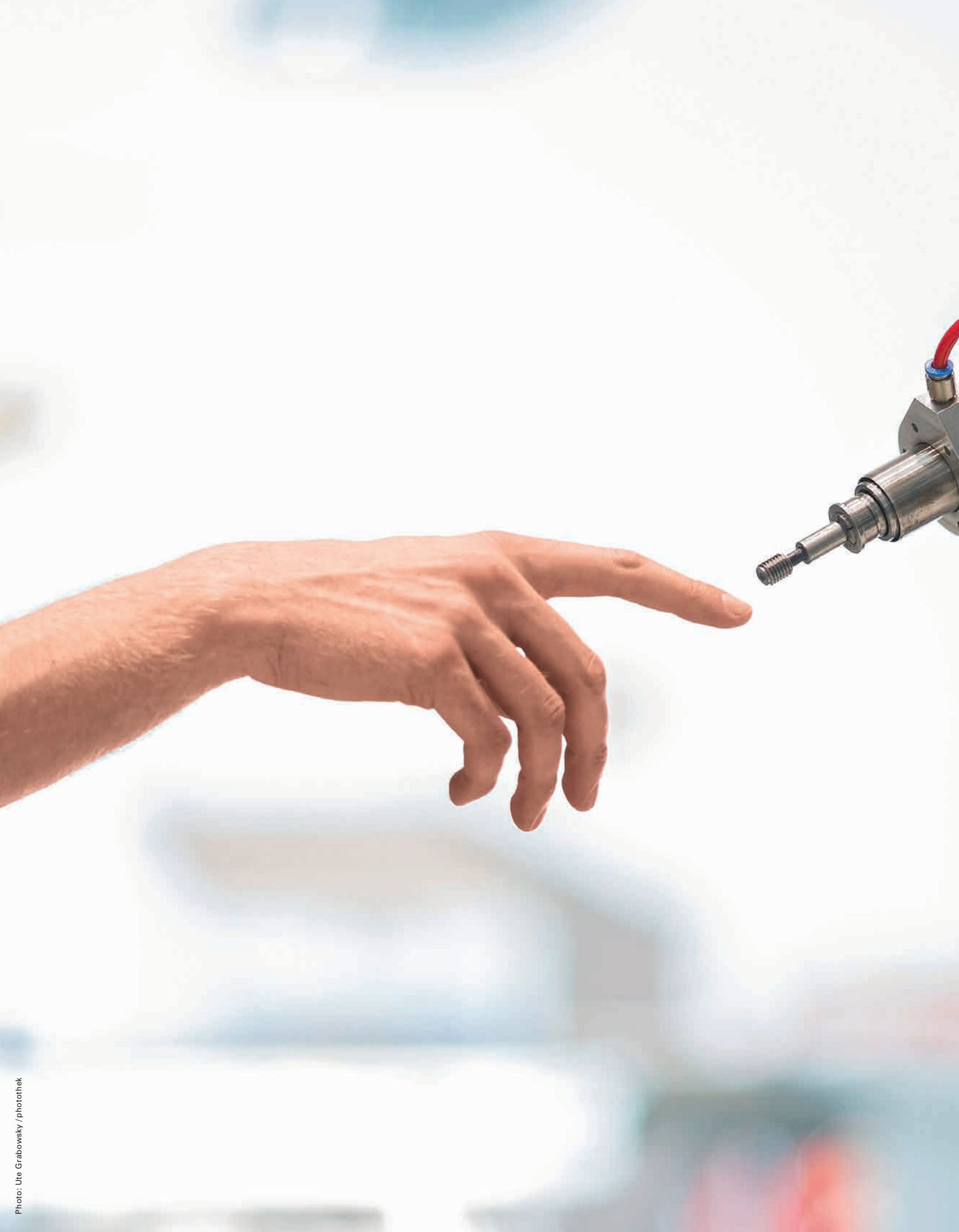

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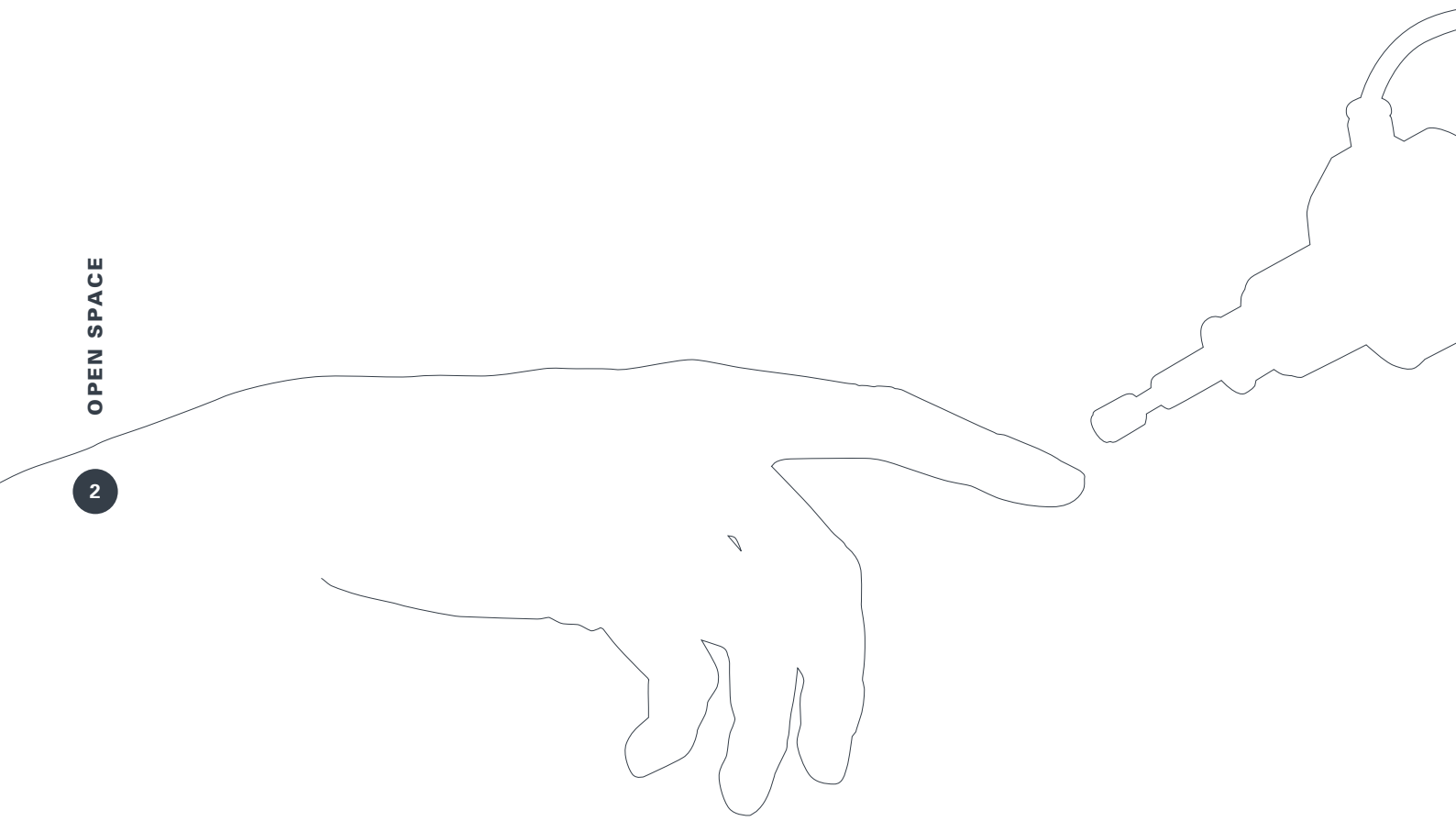

Dear Readers,

Photo: Uli Regenscheit

> "We're convinced that only this kind of comprehensive approach will enable us to successfully meet the great challenges of our time."

Wolfram Ressel
Rector of the University of Stuttgart

We plan to build on the University of Stuttgart's many successes in research and education in recent years to knit all of our university's disciplines and outside projects together in ever-more intensive collaboration. Strategically, our premise is that these disciplines should be networked into interdisciplinary research alliances. That in turn means that the next decade will see all core areas of the University drawing closer together to form a comprehensive profile, an identity that defines the university as a whole. Our name for this profile reflects its thrust: "Intelligent Systems for a Sustainable Society". The reason: we're convinced that only this kind of comprehensive approach will enable us to successfully meet the great challenges of our time: digitalization, climate change, energy, mobility, and production methods now looming on the horizon; their design and consequences are in the center of RESEARCH AND LIFE's focus.

The future of human work has been selected as the Topic of the Scientific Year 2018. Summarized in the term "4.0", this topic casts light on the breath-taking changes which digitalization is bringing about in our production, our work, and our daily world. New technologies and fascinating new manufacturing processes promise enormous growth in efficiency. But they also raise questions: How can the interaction of man with modern technology succeed? How should work flows be designed to ensure company profit and employee enthusiasm? And what challenges does this pose for the educational system?

This is the background for your present issue of RESEARCH AND LIFE. Under the heading of "Work Technology 4.0" we sum up the entire spectrum of a digitally spurred transformation process that affects every area of the economic and working world, meaning individuals, society, and the environment too. Here you will see how man and machine find a common meeting ground in the new (working) world, and how their collaboration can be controlled with tablets or a smartwatch. Step through the door of ARENA2036 to see tomorrow's production plant in reality today. Watch digitally guided vehicle fleets to find whether they in fact allay fears of a traffic collapse, or how the battery systems of Industry 4.0 can make a success out of the electric automobile.

An exciting read is before you, and I wish you much enjoyment during it!

Yours,

RESEARCH AND LIFE

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... Heard in Passing

Faster Professors

Plannable, transparent career tracks for next-generation researchers: that's the goal of a good 1,000 new tenure-track professorships, financed by Germany's federal government to the tune of a billion Euros. The first round will start by funding 468 tenure-track professors' chairs at 34 universities, twelve of them at the University of Stuttgart alone. Once each tenure-track professor has met expectations, he/she will immediately be given a lifelong professor's title. This was very cordially welcomed by Wolfram Ressel, Rector of the University of Stuttgart and himself a professor: “These financial grants for twelve tenure-track professors' chairs now give us the ability to pursue our strategic goals of sustainably promoting next-generation talent and planning our human resources development.”

Ressel announced that by the year 2030 the University of Stuttgart will use its own funds to establish chairs for ten more tenure-track professors and name their occupants. This will not only reinforce next-generation research projects with new and “faster” professorships but will also implement the tenure-track Professor's Chair as a new career track opportunity in all faculties of the University.

Excellence Strategy: Four Successful Cluster Sketches

The University of Stuttgart was given approval for simultaneous submission of four out of a possible five “cluster-sketches” as part of the excellence strategy drawn up by the federal government and Germany's 16 member states for the promotion of top-flight research.

The announcement was made by the German Research Foundation (DFG) in September 2017. Only 88 of 195 candidate sketches were selected.

Photo: Uli Regenscheit

Professor Wolfram Ressel, Rector of the University of Stuttgart, expressed his great pleasure at the expert committee's choice and said: “Today is a very good day not only for all researchers but also for all students at the University of Stuttgart. The approval for four candidate sketches at once is an outstanding success and a milestone for the University of Stuttgart.”

The University of Stuttgart has been given approval to develop a full application for “Data-Integrated Simulation Sciences,” a “cluster-sketch” following up on a very successful excellence-cluster called “SimTech” (Simulation Technology); the University now aims to make decisive improvements in the use and accuracy of simulations and the reliability of decisions based on them. The cluster-sketch called “Quantum Sciences – from Basic Principles to Application” has the goal of helping to develop quantum instruments for the future and is being developed into a full application in a project which joins the Universities of Stuttgart and Ulm, together with the Max Planck Institutes for Solids Research. The cluster-sketch “Integrative Computer-Based Planning and Building for Architecture” aims at a generalized, interdisciplinary “Co-Design” of methods, processes and systems in construction projects. And the cluster-project “Understanding Understanding” is working out new approaches to a better understanding of what happens when we do (or don't) understand language and text.

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.
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ALLIANCES FOR RESEARCH

Moving Paralyzed Hands

Researchers at the University of Tübingen Hospital, the Universities of Tübingen and Stuttgart, and the College of Reutlingen, Germany are collaborating on an exoskeleton hand which restores function to persons with paralyzed hands and makes such persons more independent in their everyday lives. Persons with unilateral paralysis, for example after a stroke, must be able to don and use the exoskeleton without the help of others. New types of transparent and elastic plastic also make it possible to take each user's cosmetic and esthetic needs into account.

So-called "electromyographic electrodes" can be used for patients who still have muscular activity in their hands but insufficient strength for firm gripping movements. The University of Stuttgart has found just the right researchers for this: Prof. Oliver Röhrle and Leonardo Gizzi from the University of Stuttgart's Chair for Continuum Mechanics. Urs Schneider, Area Director at the Fraunhofer IPA, and his team at the University of Stuttgart's Institute for Industrial Manufacture and Factory Operations (IFF) will design an exoskeleton hand for use in everyday routine and install all the required sensors in it.

Photo: Vitiello Hand

3D Cloud Printing

Low costs, shorter production times, and flexible, customer-tailored manufacturing – that's the promise of "additive" manufacturing with models, prototypes, tools, and end products. Already well-known as "3D-printing", this method also makes it possible to improve individual characteristics even during the planning stage. With help from Germany's State of Baden-Württemberg, the Karlsruhe Institute of Technology (KIT) and the University of Stuttgart have now set up a 3D Print-Cloud for additive manufacture.

Photo: Arburg

Presently conceived of as a prototype, this platform begins by digitally showing the process from the design stage to simulation of individual component properties. At that point, the user can fine-tune these properties and use the Cloud to send the result to a nearby company with systems and capacities required to manufacture the component. In this way, prototypes and even small product batches can be produced individually and in the twinkling of an eye.

New “Mass Personalization” Service Centre

The government of Germany's state of Baden-Württemberg has made five million Euros available for a "Mass Personalization" Service Centre. This was announced on 16 October, 2017 by Economic Affairs Minister Dr. Nicole Hoffmeister-Kraut and Science Minister Theresia Bauer. The Centre, a joint initiative of the University of Stuttgart and Stuttgart's Fraunhofer Institutes, will research interdisciplinary and cross-industry methods, procedures, processes, product systems and business models for the production of personalized products. Such "mass personalization" embodies a comprehensive reorientation of product design and production, starting with a comprehensive profile of potential users and ending with seamless implementation of a personalized product, service provider innovations, and costs that hardly exceed those of mass-produced items.

Top Rankings in THE

The University of Stuttgart established itself not just once but twice with a ranking of 62 in computer science and 87 in Engineering and Technology among the front-runners out of more than 1,100 of the world's best universities in “THE”, or “Times Higher Education World University Ranking 2017/18”. The University of Stuttgart was regarded as outstanding in particular for its “knowledge transfer” strategy, which in turn is financed by outside funding from the “Industry Supports Scientists” Organization. Here the University of Stuttgart's Department of Engineering & Technology scored 99.4 of 100 possible points, and the Department of Computer Science scored 97.8 of 100 possible points.
Overall, the University of Stuttgart was ranked worldwide in the group with 201-250 points, i.e. the top 25%, which put it among Germany's 25 best universities.

OUTSTANDING

Digitalization on the Airport Tarmac

Digitalization offers many opportunities in the specialized field of autonomous vehicles, where improved comfort and safety come first and foremost. In particular, safety on airport runways is both

Photo: Flughafen Stuttgart GmbH

crucial and a major financial factor, since the use of autonomous towing machines there can lead to savings in the high 5-digit Euro range.
With this in mind, the Ministry for Commerce, Work and Residential Construction of Baden-Württemberg has provided about 400,000 Euros to the University of Stuttgart's Institute for Ergonomics and Technology Management (IAT) as funding for a research project concerning innovative technologies for special vehicle designs on the runways of the Stuttgart Airport. Small and medium-sized companies above all will reap the benefits of this.

Potential Beyond Industry

The transformation to “4.0” will radically change the worlds of commerce and work as we know them today.

Even though “Industry 4.0” highlights core areas of competence in Baden-Württemberg's economic sector, many small and medium-sized enterprises still find it difficult to make the jump to intelligent production systems. How can the government help companies orient themselves on the way to Industry 4.0, and what role will research play in this? Dr. Nicole Hoffmeister-Kraut, Economic Affairs Minister in Baden-Württemberg, offers answers to these questions in a guest commentary for RESEARCH AND LIFE.

Germany's state of Baden-Württemberg holds excellent cards in making the jump to digitalized commerce. It is the heartland of German machine design and construction, and the preferred location of highly innovative automobile makers and their suppliers. It's home not only to the University of Stuttgart but also to many leading providers of industrial information and communication technology – including both globally renowned systems and highly specialized niche-market products. Baden-Württemberg's front-line research centers provide an excellent research basis, covering the entire spectrum of technologies for future digitally networked value-added chains. What especially singles out our commercial base is its ability to manufacture highly specialized products in small batches but in top quality. Industry 4.0 is going to spur our economic sector on to even greater competence in these core areas.

There is a major danger, however: many small and mid-sized enterprises (SMEs) may fall by the wayside during the development to intelligent production systems. These enterprises are essential links in the value-added chain, making them indispensable for end-to-end digitally networked processes. We thus have an ambitious goal: to reach every single enterprise, if possible, and give it the orientation it needs on the road to Industry 4.0. On the one hand, the digitalization of production-related technology has already made much progress in many companies; on the other, there is still much to do regarding the design of new business models. According to a Bitkom study of industrial enterprises with 100 or more employees, a good two-thirds would like to optimize their processes, but only 14% see it as a primary goal to develop new data-based business models. However, precisely these business models offer the greatest potential of Industry 4.0 for generating true added value.

Opportunities of Digitalization

As co-organizers of the “Alliance for Industry 4.0 in Baden-Württemberg”, we stand shoulder-to-shoulder with all the major players to put together a bundle of actions aimed at showing SMEs in particular the advantages offered them by a digital network of value-added chains and highly flexible processes. For example, in one such action, a competition called “100 locations for Industry 4.0 in Baden-Württemberg”, we identify instances of best-practice for production processes, new products, and/or business models. More than half of the prize-winners are small and mid-sized companies, which clearly shows that Industry 4.0 has become a fixture among such enterprises in our region.

Digitalization also opens up major potentials outside of industry. The transformation process will go to the roots of every major branch. The “Economic Sector Initiative 4.0”, for example, takes us beyond the production industry to the skilled trades, the area of commerce, the catering industry, and the service sector. Together, they form the stage upon which all digitalization activities of the Ministry for Economic Affairs take place. At the same time, we are laying the groundwork for the many-facetted economic sector of Baden-Württemberg to help make it continue as the leading innovation region in

Ministry of Economic Affairs, Labour and Housing

Europe even in the age of digitalization. In addition to the digital solutions already mentioned above, and especially in the context of Industry 4.0, we aim to bring digitalization as part of Economic Sector Initiative 4.0 to every part of Baden-Württemberg. That is why we plan to promote the establishment of regional "digital hubs". These digital hubs will serve as regional research beacons for digital innovation and transformation. They will provide venues for companies, start-ups and other major players, e.g. from the field of research, while also sharing experience with digital technologies and promoting the joint development of digital projects. We are also promoting innovative transfer projects in the area of digitalization of the economic sector in order to turn research insights into added commercial value. We also started a model project in July, 2017 to test a "digitalization reward" as an incentive to small and medium enterprises to take concrete steps in digitalization.

> We need creative, courageous researchers who are willing and able to see beyond their own noses.
>
> **Dr. Nicole Hoffmeister-Kraut, MdL**
> arliamentary Minister of Baden-Württemberg for Economic Affairs

The New Work World

How to shape the World of Work 4.0 is a central concern of our Ministry for Economic Affairs. After all, the intelligent, flexibly responsive production plant of the future will require an optimum interaction of human beings, technology, and organization. New challenges will face the working population. We must do a good job of preparing today's employees and the coming generation for this oncoming transformation of the working world. That is why we are promoting the establishment of 16 "Learning Factories 4.0" at vocational training schools in Baden-Württemberg. These Learning Factories, which are based on real industry standards, will make the abstract concept of Industry 4.0 tangible for the coming generation and today's employees. A large number of companies, chambers of commerce and other regional players are helping to design the layout of the schools. No other German state can boast of such intensive initiatives for disseminating the areas of competence required for Industry 4.0 to every part of Baden-Württemberg.

We also focus on management-level personnel, since they are the ones who in future will no longer solve complex problems alone but must help their employees to develop the required competence and abilities. Here the topic of flexible, mobile work is also a challenge which will require more and more attention from management-level personnel.

Digitalization of the working world also raises questions of work law, some of which cannot be fully foreseen at present and cannot be fully answered on the political level in a way that applies equally to all those involved. This will call for genuine leeway on the shop floor. At the same time, we still need clear guidelines, simply because it would be

unthinkable to sacrifice the high standards imposed by our health and work safety laws, nor do we wish to do so. That's why I'm relying on the partnership between employers and employees, both on the level of collective agreements between the labor unions and the industrial federations and in the form of agreements forged at the planning level.

Science Sets the Basis

Baden-Württemberg's state government also intends to monitor the impact of digitalization on the Baden-Württemberg's working world from the viewpoint of work science in order to lay a solid groundwork for future political discussions and decisions. We will fund over the coming years a study of the University of Hohenheim aimed at analyzing the actual status and the development of digital and mobile work in Baden-Württemberg on the basis of current data. The Fraunhofer IAO Institute is also a participant in the study. The interim results will be published regularly, for example on the website of our Ministry of Commerce. And we have funded a joint project of the University of Stuttgart which studied future areas of competence in Industry 4.0 and made recommendations for ongoing vocational training. Another of our projects focused on Industry 4.0 in actual practice for the future development and manufacture of solar cells. Just recently we have approved a research project which will focus on innovative technologies at the interface between vehicles, the infrastructure, and process chains which underlie the tarmac aprons of airports.

Technological science is making a major contribution in ensuring that Baden-Württemberg remains an outstanding and premium venue on the international stage for the digitized economic sector. Major innovations often arise at the interfaces between research disciplines, since new business models can develop only during the interaction between engineers, IT professionals, mathematicians, and business economists. The collaboration of systems specialists with occupational scientists can result in agile organizations that perfectly merge the very specific abilities of human beings and machines. We need creative and courageous researchers who are willing and able to see beyond their own noses. And also researchers who do not view the completion of a research project as the end of their commitment but rather as the beginning of implementation of what their research has uncovered in the form of concrete applications. It is my hope that more and more young people will dare to take the step of using their competence to found and build up their own companies. This will ensure that Baden-Württemberg remains young and vigorous as a venue of innovation.

Dr. Nicole Hoffmeister-Kraut

Dr. Nicole Hoffmeister-Kraut is a member of the Parliament of Baden-Württemberg and on 12 May 2016 was appointed Minister for Commerce, Work and Residential Construction of the German State of Baden-Württemberg. Born in Balingen, she studied Business Administration at the University of Tübingen and earned her doctoral degree in 2001 at the University of Würzburg.

Dr. Hoffmeister-Kraut began her professional career at the Morgan Stanley Investment Bank, then worked as an analyst at Ernst & Young in London and Frankfurt until 2005. She has been a general partner of Bizerba SE & Co. KG Company in Balingen since 1999, and sat on the Supervisory Board there from 2014 until taking office as a Minister.


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Brave New (Working) World
Researchers at the "Future Work Lab" study how man and machine can live and work together

For trained professionals, digitalized and networked production facilities are "the Fourth Industrial Revolution" – following on the heels of the steam engine, the assembly line, and the introduction of EDP. This has engendered "Industry 4.0," a term for intelligent solutions that can process and evaluate masses of data. These modern forms of technology will drastically change company workplace environments. Employees must be more flexible in future – but can also take over more responsibility.

Engineers today stand in their labs and discuss how to design their new robot. Where should the rocker arm go? The axles? What movements must it carry out? Words are almost inadequate to explain such issues – and technical drawings are complex. In answer, the engineers don spectacles that look like ski goggles. But these are not sport articles, but rather "mixed-reality" spectacles. They enable the wearer to guide three-dimensional projections with only small gestures that change the image on the screen. The other team members follow with their own spectacles, which have small, transparent screens. In this way, the team sees how the axes of the robot which is displayed wander from one place to another and how the gripping arm swings to various positions. Just as in an interactive video game, each member of the group can make changes in the image currently displayed.

Scenes like this are still fiction. But it may not be long before they dictate daily routine in companies which design and manufacture machines and systems. And not only in their development departments. This could give even employees who are unaccustomed to think in terms of three-dimensional space the possibility of helping to plan work steps. The right place for a machine? The optimum mode of operating tools? Questions like these could then be answered in only a few words. "Mixed-reality-spectacles" show how an adroit use of modern technology might benefit the working world of tomorrow. "Technical meetings would become more efficient, and it would be easier to present and implement ideas," says Thilo Zimmermann, a project leader at Future Work Lab, an "innovation laboratory" with a focus on the working world, the worker, and technology. Here several institutes of the University of Stuttgart have joined the Fraunhofer Institutes for Industrial Engineering (IAO) and for Manufacturing Engineering and Automation (IPA) to synergize their mutual areas of competence regarding networked production.

Advantages and Risks of the Digital Working World

The football-field-sized ARENA2036 research facility is a salient feature of the University of Stuttgart campus. It acts as a flexible "research factory," providing support for the development of products and production methods for Factory 4.0. The visitor sees fresh-plastered walls with shiny metal pipes near the ceiling. Daylight streams through a glass roof into the interior. It looks like a factory built by an iPad designer: bright and radiant. The men and women doing research here have their offices on an upper first-floor gallery. These professionals come not only from the engineering branches but also from the fields of applied economics and the social sciences. The projects which have brought them together aim to show how daily work in a digitized company might look, what advantages it has, and where risks lie in wait.

The teams at Future Work Lab have already turned more than a dozen ideas into demonstration objects. "We want to give a concrete impression of how the working world of tomorrow might look," says Zimmermann as he points to a bright orange-coloured

All the possibilities of digitalization can be exploited only when instruments and software can be operated even by non-IT-experts. For example: with smartphones, tablets, or smartwatches.

Photo: University of Stuttgart/Max Kovalenko

robot. Until now, machines like this were allowed to work only behind a protective fence, since a blow from their steel arms could be life-endangering. Now, however, the display model in the "research factory" exhibits a perfectly safe solution: the robot is not fully automatic, but can be guided by means of a "steering wheel" – much as reins are used to guide a horse. The force exerted by the user determines the power of the robot's movements. The result is not a fully automatic creation which renders human beings superfluous but rather quite the contrary: "The robot becomes the colleague," says Zimmermann. "The dexterity of man is united with the strength of the robot."

No Factories Without Human Beings

Development thinkers in the areas of machine and systems engineering have racked their brains for years to find more efficient processing designs. In the 1980s, for example, production planners came up with radical concepts, and "Computer Integrated Manufacturing" was the watchword. The target was to design a factory devoid of human beings, where products rolled out fully automatically. Controllers liked the idea, but the trade unions saw it as a sheer disaster. And Thomas Bauernhansl says today that it will never happen. He is a professor who heads up the University of Stuttgart's Institute for Industrial Production and Factory Operations (IFF) and has spent many years exploring issues involved in Flexible Production. At the same time, he believes that work in industrial enterprises is facing major changes, and that the classic industrial worker of the 19th and 20th centuries – the person standing at the assembly line, endlessly performing the same act – will soon belong to the past. As digitalization spreads, on the other hand, work scenarios will become more demanding: the person at the machine, who was traditionally responsible for only one step in the process, will in future control electronically guided machine systems while also looking for ways to make the production process more efficient. "Stand-alone work operations will grow fewer," says Bauernhansl: "Each worker will become a director who orchestrates the added value process."
Management today is becoming more and more aware that the worker at the basis is often the person who best knows how work steps should be organized. After all, he/she is often the one who has been at the same post for decades and knows every detail of the surroundings. In the past, this person was often only a factotum, while management took

Photo: University of Stuttgart/Max Kovalenko

Mini-motors increase the force of powered exoskeleton movements and lessen the strain on human beings during heavy work.

care of production planning and passed down its pronuntiamentos in classical fashion from top to bottom. The results were predictable: The person at the work station felt passed over, which in turn engendered frustration and flagging motivation. In the working world of tomorrow, in contrast, workers might have a hand in the planning process.

Smartwatch Enthusiasm

The production plant of tomorrow will, as it were, organize itself through digital technology. Michael Reutter is one of those thinking about how this will look in actual practice. After graduating in Machine Design and Construction from the University of Stuttgart, this budding young entrepreneur went on to work at the Fraunhofer IAO and then, a good year ago, founded his own company with a friend and named it "Aucobo". "Our aim is to give the worker at the basis instruments that enable him or her to profit from digitalization."

Reutter reports that modern production plants increasingly tend to curtail both incentives for employees and support for them on the career ladder. People are organized like pieces on a board, with no way to contribute the know-how they have often gathered over decades. "That's not the way to exploit the possibilities of digitalization," says Reutter. Today's industrial software can be designed for use even by persons who have no expertise with IT. After all, he points out, anyone can use a smartphone or a tablet without prior training. The basis of his program is a standard commercial smartwatch with stand-alone functions, that is, with no need of an external smartphone. The worker can use it to put together his/her own app. "It's like using a digital toolbox, much like the one used to create one's own website,," says 29-year-old Reutter. Whereas it was once quite difficult to create a personal Internet page, "Practically anyone can do it today," says Reutter. In fact, this is how Reutter and his partner programmed a mobile machine control program which can be guided intuitively via app.

The app can be used, for example, in production plants where one worker is in charge of several processing steps, such as pressing, clamping, and/or glueing. In the past, such a worker watched three machines at the same time, inserting insert material on time, adding needed components, and taking out finished parts at the end. In time this became routine, but with one disadvantage: machine downtimes whenever the worker was occupied somewhere else. Now, however, the smartwatch can sound an alarm to remind him of tasks which need immediate attention, as when a machine must be reloaded. Even when he is in another production area, he hears the humming signal and can return at once or press a button to ask a colleague to take over the task for him.

This does more than merely make communication between the human being and the machine more effective: consultation with colleagues and documentation is simplified as well. "In future, information about individual machines could be stored with electronic solutions of this type," says Reutter. While technology takes care of individual cases, the worker can store remarks at a central location so that valuable knowledge is not lost when the employee leaves the organisation. Festo,

A smartwatch tells the machine operator when it is time to insert a component or to remove a finished part.

Photo: University of Stuttgart/Max Kovalenko

the specialist company for control and automation technology, has already put the smartwatch from Aucobo to use at its plant in the German city of Esslingen, for example. This pilot project involved seven volunteer employees in the company's valve production area. “The feedback was invariably positive,” says Reutter. No reservations were voiced, quite the contrary: “Other workers heard of the pilot test, saw the smartwatch on the arms of their colleagues, and wanted one too.” But it was more than a charming design which aroused the interest and enthusiasm of the users.

Overcoming the Lack of Skilled Workers

Observers like Bauernhansl see it as a must that employees become enthused about technological progress. “After all,” he says, “all developments come in the long run from human beings. The more they enjoy such progress, the higher the quality of the results. One of the primary tasks, therefore, is

to continue the training of relatively untrained employees so that they can take over more demanding jobs in future. The alternative is a lack of workers: "We would run out of the trained workers we need for our production plants to function as well as possible." And just how many workers will be needed in the networked production plants of the future? Opinions vary widely. Four years ago, a scientific study on the subject caused a small upheaval in the working world: Carl Benedikt Frey, a professor at the University of Oxford, and his colleague Michael Osborne estimated the likelihood that work in certain professions will be carried out in the coming 20 years by new forms of technology. In Germany alone, this would threaten the existence of 59 percent of jobs. On the other hand, the Centre for European Economic Research (ZEW) came to quite a different result: experts there calculated with about the same degree of probability that only 12 percent of jobs in Germany could be automated.

Man and Machine: A Single Working Unit

For Bauernhansl there is no doubt that digital production in the age of Industry 4.0 will require fewer human workers. While this in turn will go far to defuse the serious dearth of trained workers, there's even more to think about: "As interaction increases, intelligent machines will merge with the workers to form an integrated production system." This can already be seen in very elementary forms of work. For example, omnibus manufacture requires that heavy cable bundles be installed overhead in the vehicles. This is hard work, and only young, physically fit men could do it up to now. In future, however, even older employees could be considered for it. It would then be up to them to decide whether to do the work with or without technical aids. If they feel that their strength is inadequate, a powered exoskeleton like the one on display in the Future Work Lab might be provided for them. Worn like a ten-kilogram corset, its battery-powered mini-motors take over the exertion of small movements and make it easier for human beings to carry out heavy-duty work in awkward positions.

In future, machines will thus take over the task of directly providing daily on-the-job support to the worker. This even affects the learning phase: "Classical, protracted training on the shop floor will be supplanted by ad-hoc training on-the-job," says Bauernhansl. One way to do this would involve user-operated displays with precise, clear user guidance and accompanying training videos.

A work station at the Future Work Lab gives a concrete idea of how machines might train their users: sensors attached to the worker detect his bodily position; after analysis, the machine recommends less strenuous ways of carrying out the work, e.g. by bending the knees more, lifting the chin, or standing straighter. It might even be possible one day to simplify this technology and integrate it, for example, into a T-shirt.

It will also be possible to leave it up to office workers in future how to organize their work with electronic aids. Here too, the "Research Factory" shows what an office desk of the future might look like. The person at the desk simply uses his/her hands to make contact with a touchscreen covering nearly the whole of the desktop. The virtual diagrams there can be opened up with swipe movements and reorganized endlessly, just as on a sheet of paper: adjacent to one another, in stacks, or fanned out. These electronic diagrams can be folded, rotated, and laid on their sides. The apparent chaos on the desk can be brought to order instantly and then logically stored with a click. To be successful in the new digital working world, it will be important not to be distracted by fascinating technology. Professor Bauernhansl's advice: be systematic. "Start with an idea for a business model," says he, then

work out the technological concept in a second step, but only when it has become clear what it will be needed for. After that, develop the clientele and the market parallel to the technology. “Then get the entire organisation involved.” This is the guiding principle for both the company culture and the employee abilities. If for example a company's sales area has been selling machine components for years, it must first gain the ability to offer future customers platform-based services. Digitalization is thus not an end in itself; rather, it must be guided by business logic. This applies just as much for guided robots and smart wrist watches as for mixed-reality spectacles.

Heimo Fischer

The Space is Virtual, But the Learning is Real
How Companies Use Virtual Reality and Smart Data to Continue Training Their Employees

Spreading digitalization in the working world goes hand-in-hand with a sea change in many jobs and work profiles. Companies today must offer high-quality entry-level programmed and ongoing training in order to keep employees and customers up-to-date technologically. The problem: how can complex work steps be taught with lasting effect? The University of Stuttgart's Department of Vocational Instruction (BPT), with its focus on Technical Didactics, is already answering this question in the person of Professor Bernd Zinn and his research team. They offer tailor-made virtual models of instruction and learning in the project "Virtual and Analytics Service in Machine and Systems Engineering" (VASE).

Entry-level and advanced vocational training today often retain some of the charm of long-ago schooldays: crowded rooms, uncomfortable and usually glaring lights, and tiny tables set close together and oriented toward a wall screen that replaces yesterday's blackboard and is the place where the instructor usually gives his lessons: frontally and theoretically. From an educational view, however, this "classical" form of teaching has long since gone out of style along with the instructional tools that were part of it. That is one reason why ongoing professional training today relies more and more on forms of instruction which are based on modern means of presentation and up-to-date technology. In particular, developments in virtual and augmented reality (VR and AR) have now opened up fully new worlds of teaching and learning. The transfer of knowledge through virtual reality seems almost ideal for industry, where production processes are usually characterized by complex work steps and precisely executed hand movements that cannot be explained in theory alone. Added to this is the fact that the working world is currently in a state of profound change. The spread of digitalization has brought with it an upheaval in many types of work and vocational profiles. What this means in the industrial field above all is an increase in the complexity of machine operation and maintenance. Companies whose employees are inadequately trained in this regard run the risk of production shortfalls or even downtimes due to erroneous machine operation. This calls for new instruction concepts which are especially designed for the needs of each individual company.

Virtual Learning Meets Smart Data

Although new types of technology have enormous potential here, they are still lamentably neglected. And this even though virtual reality, with its virtual learning and working environments, and smart data could help to optimize service processes. This is where Prof. Mischa Seiter comes in: he and his team of researchers at the University of Stuttgart's Department of Vocational Education and Technical Didactics (BPT) are working with the International Performance Research Institute (IPRI) to learn how to use these potentials to practical advantage. Their research and development project "Virtual and Analytics Service in Machine and Systems Engineering" (VASE) joins the technologies of virtual reality with those of service analytics.

Their target group consists above all of service technicians in the areas of machine and systems design; these are the front-line troops whose task and work areas constitute an interface between the customer and the provider. In future, they will be confronted not only with the service and maintenance of machines but also with service requirements which go far beyond, such as virtual seminars designed to train customers and colleagues in the use of modern forms of technology. This in turn leads to a new challenge: the workers to be trained will often not

Virtual learning environments are chronologically and spatially ideal for flexible learning and work. Work is now underway to tailor such environments to actual company needs.

Figure: University of Stuttgart/Daniela Leitner

work in the company's main plant, but rather at one of their company's branch offices. That means that a visit to central headquarters or even to their customers often involves a long trip. Virtual learning environments are ideal for such branch establishments because they provide both space and time for flexible learning and work.

Tailor-Made Learning Scenarios

Project leader Professor Bernd Zinn and his team have already worked in the past with the TriCAT software company in studying the use of an innovative 3D-Learning and working world. Now the two partners have adapted "VILA", as this virtual learning and work environment in their present project is called, to individual companies and can then develop it in a company-specific manner if needed. To do so, they must first identify the actual needs of the participating companies. "We start by pinpointing the various application situations and scenarios, which we call the 'Service Usecases', so that we can adapt our training courses to the respective company," says Zinn. "We also look to see what each company needs in the area of VR-technology." However, present advances in virtual technology are counterbalanced by an equal level of reservations and fear of the unknown. "That makes it all the more important to work out individual concepts that create acceptance and do away with antipathy towards use of this new technology."

From a purely technological point of view, virtual environments have now come a long way. But it has also become clear that high technological quality alone is not enough. "Just as with E-learning, technology of itself alone is not always good," says Zinn. That is why he and his team aim above all to find the right instruction methods concerning the respective technologies which are part and parcel of the project. "We have found that in order to reach our learning targets it helps to combine theories about cognition and structure with one another." This also applies for virtual learning settings, where the knowledge which is acquired can be applied and tried out. "Our pupils have the desire and the will to see the relevance of continued training for their own fields of action. That in turn is decisive in promoting acceptance and reception of these new ideas."

Experiential Knowledge is Priceless

As an aid to ongoing development of the virtual learning and work environment, the companies in the VASE project – like Trumpf, MAG, IAS and Ax-

Photo: University of Stuttgart/Max Kovalenko

From a purely technological point of view, virtual environments have now come a long way. But more is needed: user inhibitions in using this new technology must be overcome, among other things.

oom – have gathered and analyzed special process data in order to find any deficits which may exist in their work processes. "Our partners' machine systems are highly complex, and are often no longer in optimum operating condition," is how Zinn explains it. The data recordings which are standard these days provide the experts with important information with regard to steps to be taken in optimizing specific processes in the service sector. "For example, intervals in machine maintenance schedules can be adapted to actual needs and carried out only when truly needed."

The research team incorporates insights from data analysis into the respective learning and work scenarios, along with the expertise of service technicians who participate during the development of learning and work scenarios. "This experiential knowledge is priceless for us and for the project," says Zinn. "Our close collaboration with the target group also helps in creating acceptance for the new technologies." Zinn and his team think that VASE will yield both a ready-to-use virtual learning and work environment and important insights about identifying shortcomings on the basis of process data. "And on the other hand, we want to find out how we can best make use of virtual learning formats." Why? Because according to Zinn they will soon be an integral part of "real" reality in entry-level and advanced vocational training.

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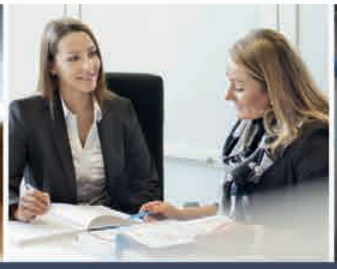


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The Development Helper
Birgit Renzl Knows the Working World of the Future

Organization is everything. That goes double for Professor Birgit Renzl, who occupies the Chair for General Applied Economics and Organization at the University of Stuttgart and is specialized in knowledge management, strategic change processes, and leadership in organizations. As an economist who is privy to the innermost secrets of big companies, she is familiar with the challenges of tomorrow. The central question which fascinates her is: how can such organizations ready themselves to cope with the issues of tomorrow?

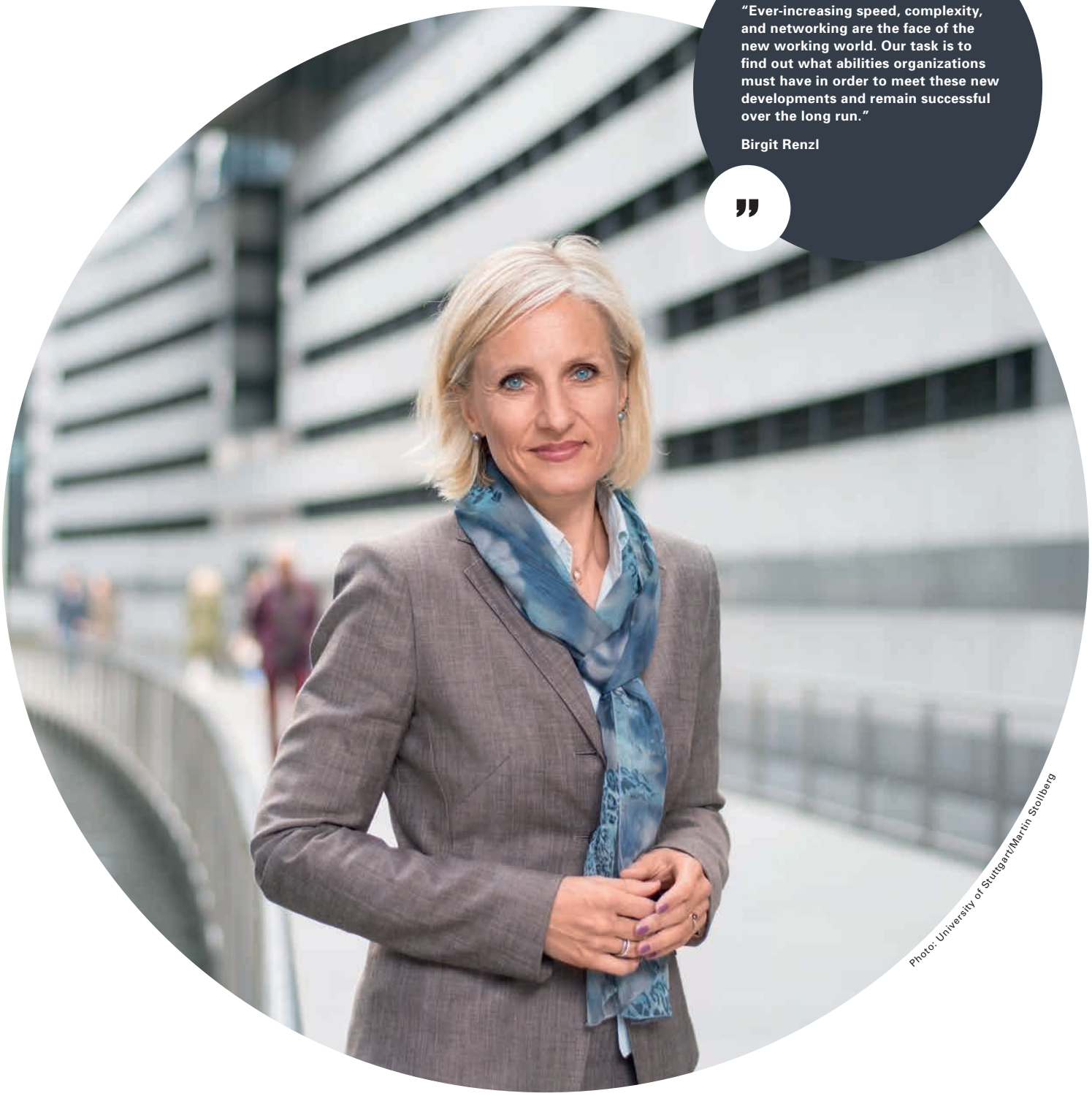
For her, the key is in Digital Transformation. "A great deal is going on in this area. As researchers, we have a unique opportunity today to tag along on the heels of this development process." For a better understanding, Renzl compares today's economic world with the results gained by research in the past; she asks what the working world was like 20 or 30 years ago. Technological revolution is not new. According to Renzl, however, the challenge today is posed by the speed with which it takes place. "Time-to-Market, that is, the period between the nascent idea and the finished product on the market, has shortened drastically." Today's achievements in information and communications technology make it possible to disseminate information in real time, which in turn creates new challenges for organizations. "The primary means of correspondence in my vacation jobs at the end of the 1980s was business mail. It often took a full week for one of these letters to be answered. And today? People ask why when an email isn't answered within two hours," is Birgit Renzl's description of the scene.

Putting Questions – and Answering Them

How will new technologies, networked structures, and real-time transfer of information impact organizations? That urgent question is Birgit Renzl's daily bread. To answer it, she gathers insights right at the source, directly where things are happening. She and her University of Stuttgart team of four employees and two external doctoral students put concrete questions in interviews, individual case studies, and broad-based, quantitative surveys in both larger and smaller companies. Birgit Renzl's interest in strategic company management began long ago. Back at the end of the 1990s she was already involved in strategic consulting and organizational development and introduced a knowledge management programmed in a light-design bureau. As research assistant at Prof. Hans H. Hinterhuber's Institute for Company Management at the University of Innsbruck in Austria she remained true to this topic, as her systematic career path shows: the doctorate in 2002, the post-doctoral degree in 2006. Her dissertation on knowledge-based interaction won her the Dr. Maria Schaumayer Foundation Prize. Then and now, practical aspects have always been important for Birgit Renzl: what bearing do the insights gained from research have concretely for organizations? "'Organization' in the company context means: implementation!" This is where she and her team want to offer their services in the form of concrete assistance recommendations for action.

Digital Transformation as a Success Factor

In her view, digital strategy is the crucial issue for organizations. Although her work still brings her at times into contact with companies which have no interest in all the "hype", there is another side too: she discovers very innovative concepts – such as that of one landscaping equipment company. Like others, that company used robots to automate processes; this really became interesting, however, when the company asked, "What's the best way for the lawn-mower robot to communicate with the sprin-



“Ever-increasing speed, complexity, and networking are the face of the new working world. Our task is to find out what abilities organizations must have in order to meet these new developments and remain successful over the long run.”

Birgit Renzl

Photo: University of Stuttgart/Martin Stollberg

Digitalization has now spread to the world of garden tools: a lawn-mower robot can communicate by app with its "boss": a new horizon for innovative business models.

Photo: Husqvarna

kler system, and what app or platform can guide the process? This represented a shift in the entire business model". The insight gained by the company from this was that products of themselves are growing less and less important, while the product focus more and more is on user-friendliness, networking, and control. Birgit Renzl's appeal to companies is therefore that they permanently think about their ways of controlling current developments and use the answers to create new solutions. She wants to see this in all branches and areas of business. "We see here the inroads of digital transformation even among landscapers."

Flexible Roles

Birgit Renzl sees the challenge for organizations above all in the need to manage ever-increasing complexity . "We suddenly need to know everything, there's more information available than we can process. Keeping things in perspective will prove to be the essential success factor in future." She's backed up by "New Working Tasks and Requirements for the Automotive Industry from Industry 4.0," a study conducted by her and some of her colleagues and recently published in the Austrian Management Review. As the study shows, a willingness to learn on the part of employees and management-level personnel is becoming ever more important. "Cooperativeness and team thinking are essential in a world in which everything is networked and flexible; companies must be open to new ideas and areas of competence," says Birgit Renzl and illustrates by describing Max Grundig's development long ago of a new type of TV: he locked the development team in a closed room and didn't let them out until the product was finished. "That's no longer possible," says Renzl, and adds: "The days of closed doors are a thing of the past!" Renzl also sees even more flexibility as a future necessity. "Depending on the work to be done, one and the same person will wear vastly different hats, so to speak: project leader, case worker, or management-level personnel." Researcher Renzl is herself the best example: as a professor at the Universities of Stuttgart and Salzburg she commutes between the two cities, has already published more than 70 articles in books and professional journals, and is on the publisher's advisory board of the research magazine "Management Learning". In the past, she was a resident researcher at the University of Strathclyde in Glasgow in Scotland as well as at the University of St. Gallen in Switzerland. In 2009 she was offered a position as Professor for Strategy and Organization at Schloss Seeburg Private University in Seekirchen am Wallersee near Salzburg, Austria, and was Dean of Applied Economics as the new university took shape. She has been in Stuttgart since March of 2015, where she was very impressed to find a large number of interesting companies which are open for new forms of collaboration and competency models. "We researchers must know what's going on in actual practice. On the other hand, we have the luxury of being able to put questions in this area, to reflect on the answers, and to reflect them back to the world of actual practice."

"Something New Always in the Pipeline"

And what is coming in future? As an instructor, Birgit Renzl's mission is also to ready her students for the future: What must management-level personnel and the employees of tomorrow learn in order to ensure the long-term survival of their organiza-

tions? “We've got to give our students state-of-the-art knowledge without trying to force-feed them.” That explains her approach: always be on the ball, learn how to link the best ideas together, be ready to ask “uncomfortable” questions, read constantly about the subject, and actively go where things are happening. The best way to do all that is through dialogue. With that in mind, Birgit Renzl, her colleagues Professor Stefan Güldenberg of the University of Liechtenstein and Professors Anne-Katrin Neyer and Julia Müller along with Dr. Matthias Will of the University of Halle-Wittenberg and others will direct the study area of “Digital Strategies” at the European Academy of Management in 2018 and will invite researchers to present their research work there. One thing, after all, is clear: there's always something new in the pipeline. “I just read recently,” says Renzl for example, “that no one will still be typing a few years from now. I myself was taught the 10-finger-system, but current progress in digital speech recognition already makes it nearly obsolete.”

She puts it in a nutshell: abilities and areas of competence will change more and more quickly; some work areas and jobs will disappear, while new ones come into being. The key lies in linking places and ideas, man and machine, teaching and actual practice.

Katja Welte

ARENA2036 – Collaboration Under One Roof

Since December 2016, ARENA2036 has been the new research home and workplace for many scientists from the fields of industry and research who have come to our university campus in Stuttgart's suburb of Vaihingen.
ARENA is an acronym standing for “Active Research Environment for Next-Generation Automobiles”. The mission of the research facility is to help make Industry 4.0 sustainable while promoting a technology revolution: individual mobility with low energy consumption. After all: the year 2036 will mark the 150th birthday of the automobile.

Germany's biggest "research factory" offers 10,000 m2 of space for theoretical reflection and practical application in four open-floor research areas: 1) Materials and Design, 2) Simulation and Digital Prototypes, 3) Production and the "Research Factory", and 4) Creativity, Cooperation and Competency Transfer. Individual research projects have already taken shape in the massive hall, and their basic principles and feasibility are now undergoing testing.

The University of Stuttgart

Photo: University of Stuttgart/Max Kovalenko

In future, driverless transportation will be a major feature of automobiles, which makes it a central object of study at the research stations of ARENA2036. Among the questions to be answered are: What is the best way to build such a system and subject it to loads, and what forces can it withstand? The sample automobile body shown here helps researchers find the answers.

Photo: University of Stuttgart/Max Kovalenko

Ideas unleashed: the work area shows that ARENA2036 has been designed as a cooperation platform to promote a new form of collaboration. Glass panes serve as office "walls", and few barriers separate the offices, conference rooms, and work stations. Clearly there are no limits on ideas here, and the dearth of boundaries promotes a free give-and-take among the various research disciplines.

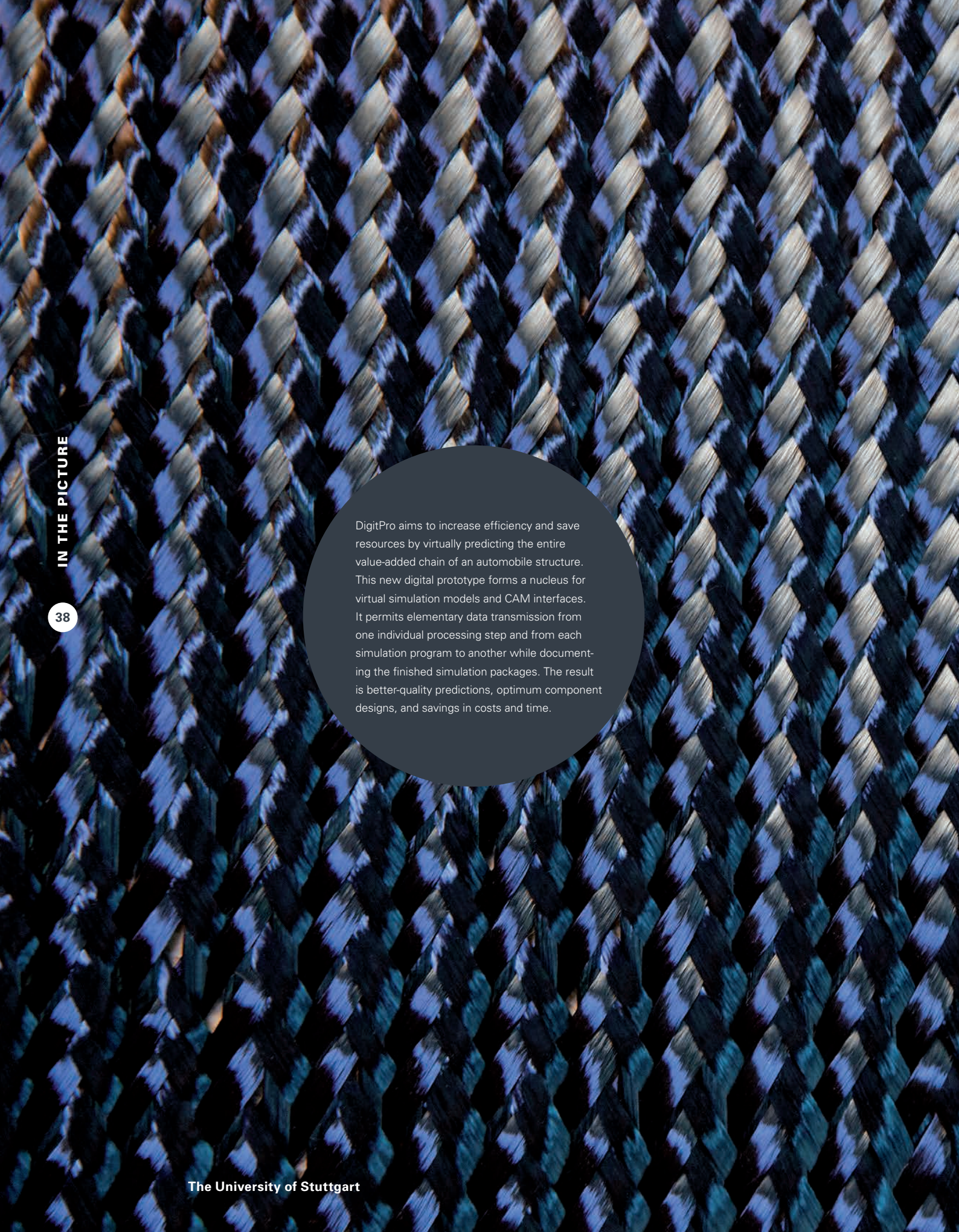
The University of Stuttgart

Photo: University of Stuttgart/Max Kovalenko

The University of Stuttgart

The first four start-up-projects at ARENA2036 are: LeiFu (Intelligent, Multi-Material Lightweight Design with Function Integration), ForschFab (Transformable Production in the "Research Factory", see photo), Khoch3 (Work Science Enhancement of a Creativity Work Environment), and DigitPro, where Prof. Peter Middendorf and his team from the Institute for Airplane Design are working on materials and processes for a digital prototype. Using this project as an example, the following pages show how work on tomorrow is already in progress today at ARENA2036.

Photo: University of Stuttgart/Max Kovalenko



DigitPro aims to increase efficiency and save resources by virtually predicting the entire value-added chain of an automobile structure. This new digital prototype forms a nucleus for virtual simulation models and CAM interfaces. It permits elementary data transmission from one individual processing step and from each simulation program to another while documenting the finished simulation packages. The result is better-quality predictions, optimum component designs, and savings in costs and time.

The University of Stuttgart

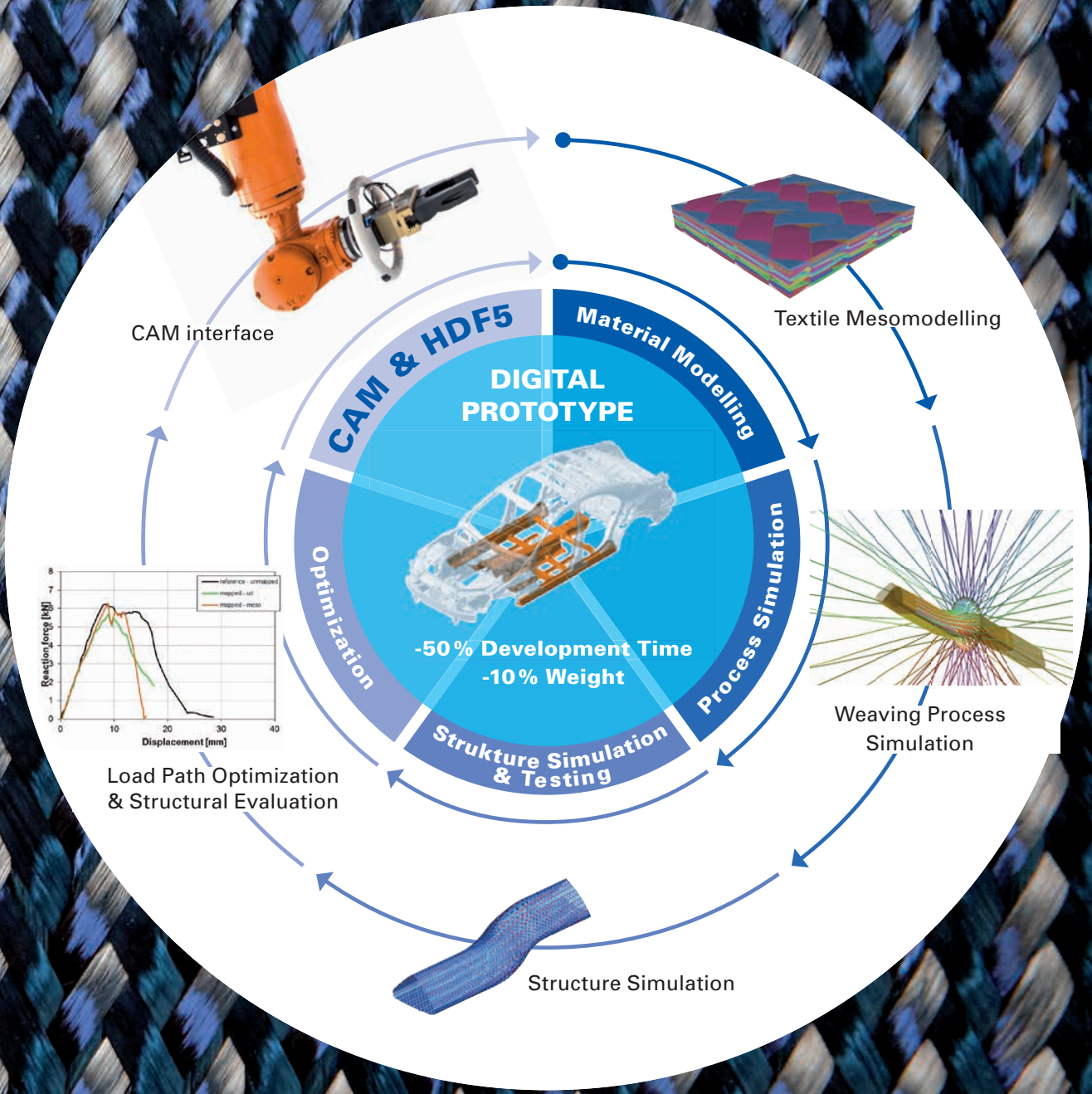
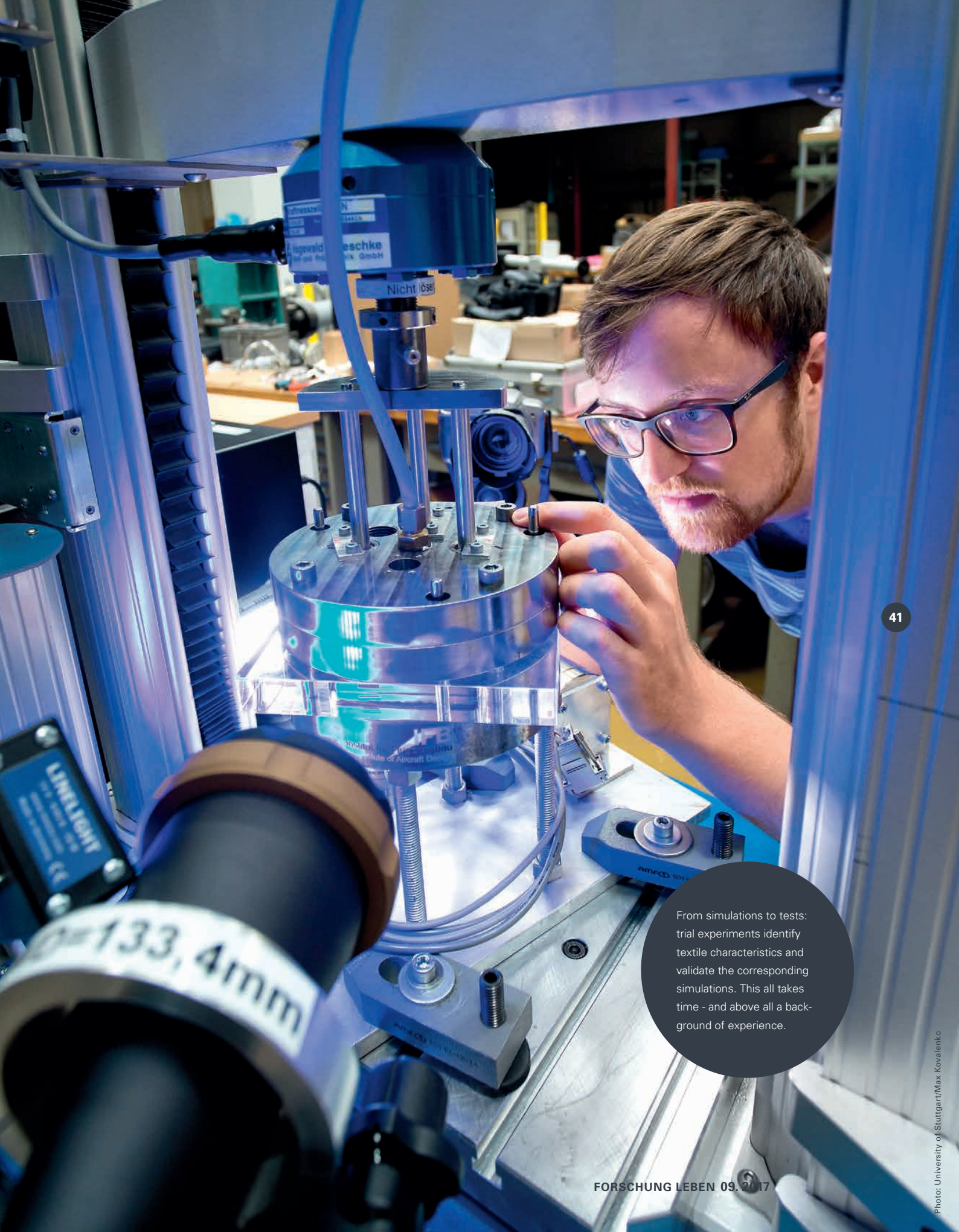


Photo: University of Stuttgart/Max Kovalenko, Figure: University of Stuttgart/Institut für Flugzeugbau

Material modelling is followed by virtual processing steps which simulate the production of these materials and forms. Long before the corresponding lightweight design structures are actually used, such virtual material tests reveal properties and performance characteristics so that these can be evaluated and the follow-up processes optimized.

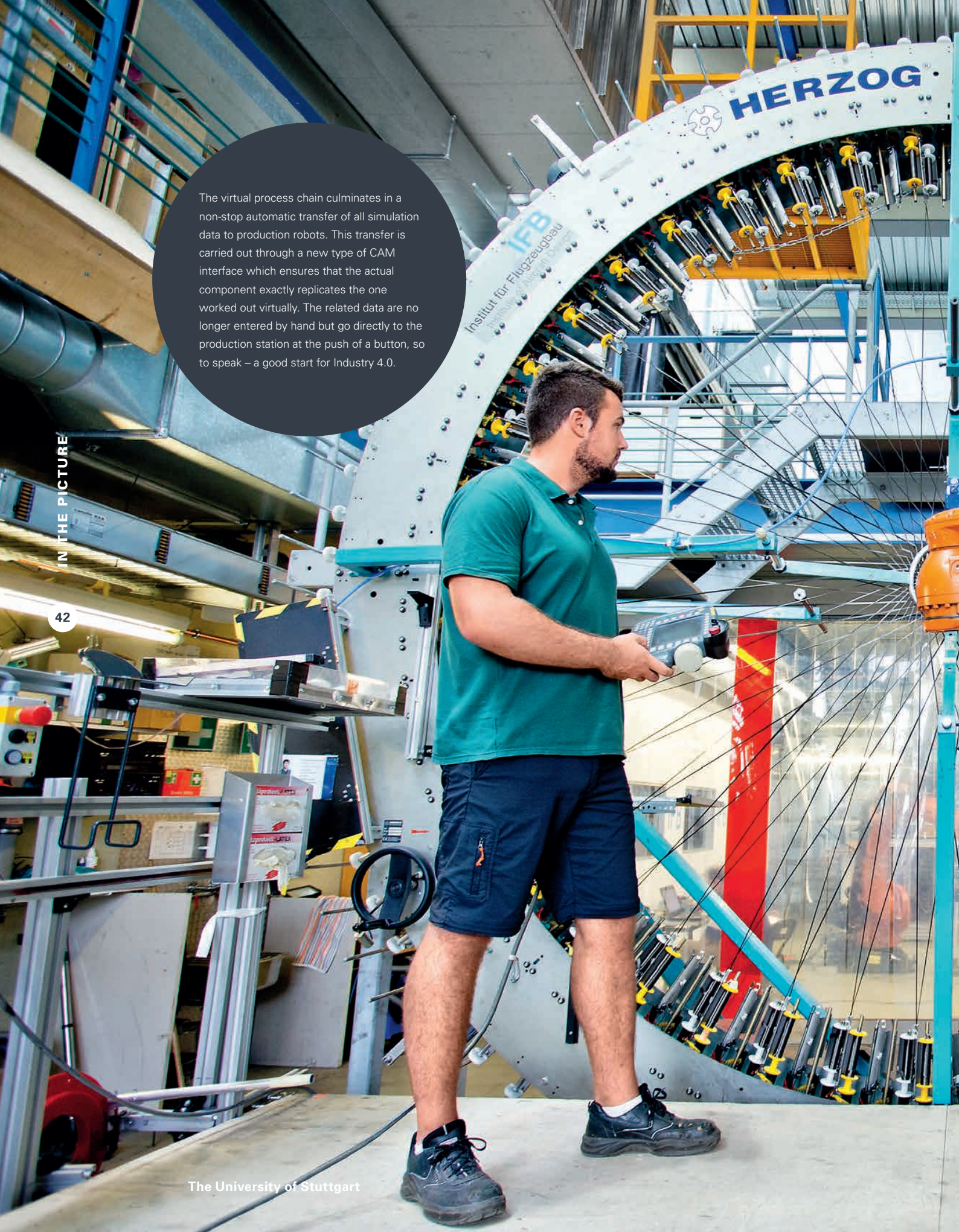
The University of Stuttgart

Foto: University of Stuttgart/Max Kovalenko



From simulations to tests: trial experiments identify textile characteristics and validate the corresponding simulations. This all takes time - and above all a background of experience.

Photo: University of Stuttgart/Max Kovalenko



The virtual process chain culminates in a non-stop automatic transfer of all simulation data to production robots. This transfer is carried out through a new type of CAM interface which ensures that the actual component exactly replicates the one worked out virtually. The related data are no longer entered by hand but go directly to the production station at the push of a button, so to speak – a good start for Industry 4.0.

The University of Stuttgart

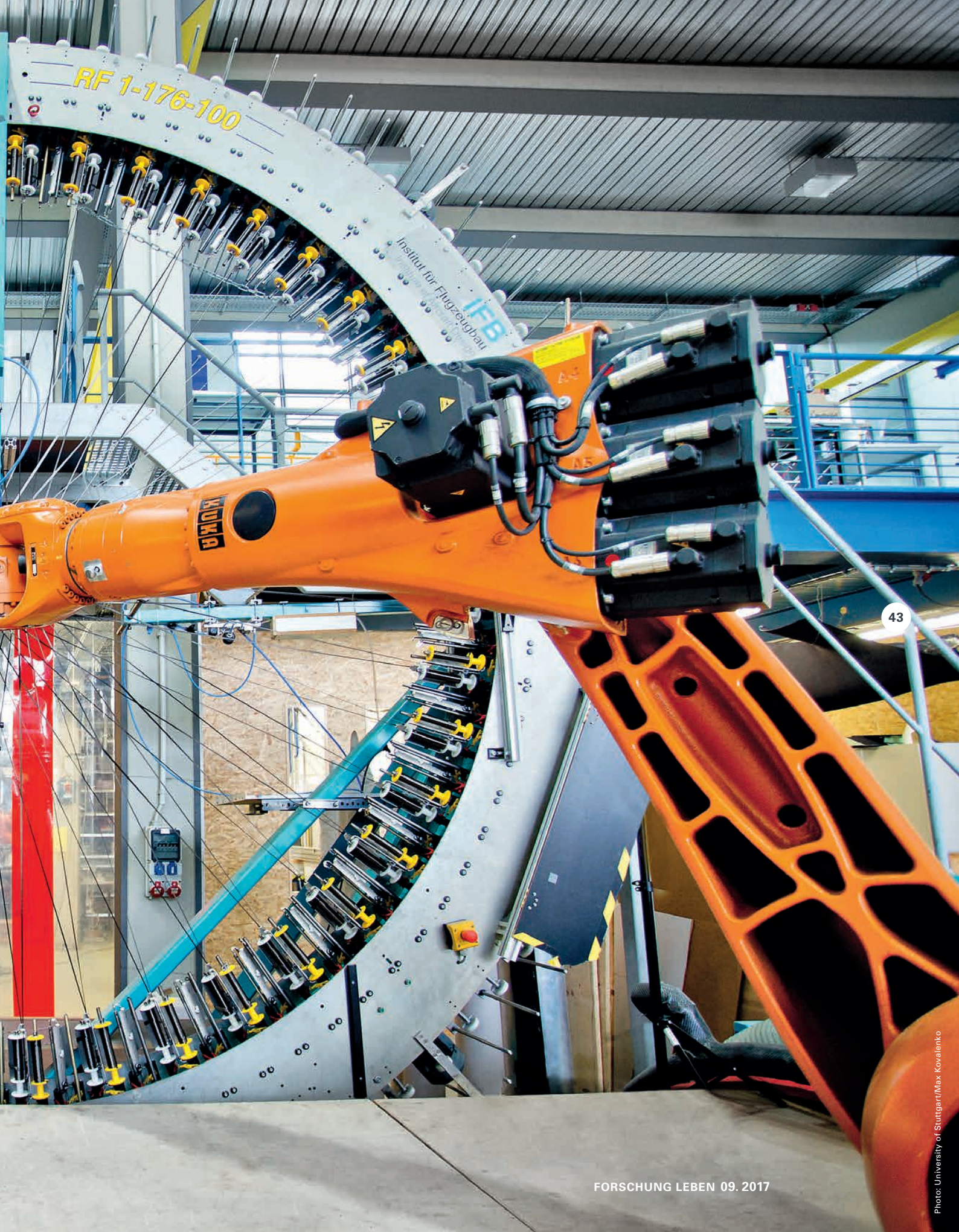


Photo: University of Stuttgart/Max Kovalenko

Currently it is planned to incorporate the results of the "Digital Prototype" project into a subsequent "Digital Fingerprint" project. The data structure already in place will be used and enhanced with new applications. The team is now working intensively to ensure a smooth transition between the two projects, and the first project phase will come to an end in 2018. ARENA2036 will then come under the sway of new project topics.

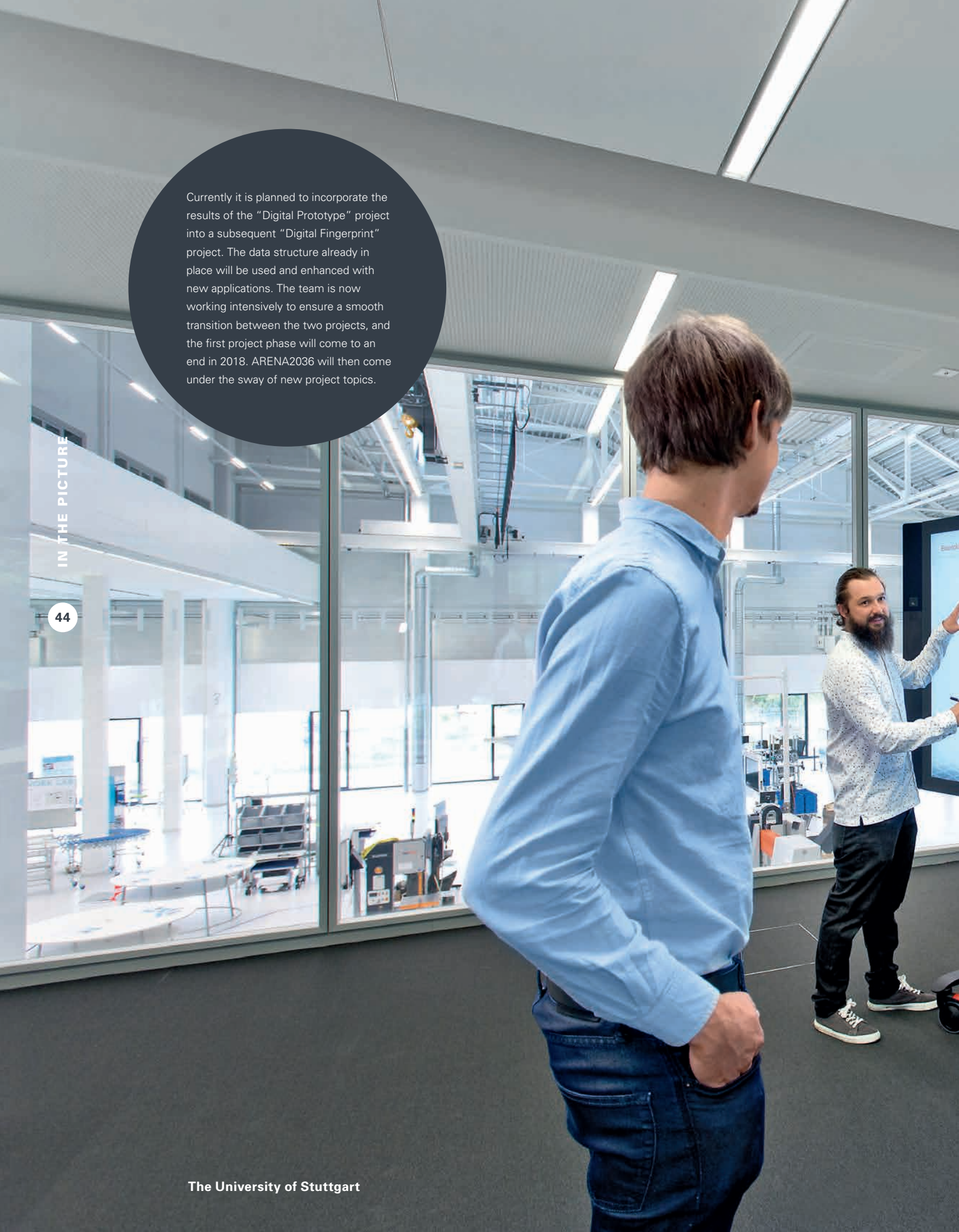


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Photo: University of Stuttgart/Max Kovalenko

The Forgotten Engineer

Romance Language Philologists and Germanists Study the Role of Technology in Stage Plays

Interpreting a theatre play requires more than mere text: it's also important to know how the play was staged in its day. That's no elementary task when it comes to classic French theatre, but it's exactly what the University of Stuttgart's academic researchers and a group of Master's Degree students have tackled in a joint project.

The darkness conceals pitfalls and debauchery, and only at sunrise do daylight and order return: day and night are locked in a symbolic combat in the "Ballet royal de la Nuit", first presented in the year 1653. The work's final scene made history because Ludwig XIV, King of France, himself donned the "Sun's" costume and performed the victory dance over darkness. Ever after, he was known as "the Sun King". For Professor Kirsten Dickhaut, Director of Romance-Language Literature I and Professor Sandra Richter, Director of Early Modern German Literature I at the University of Stuttgart's Institute of Literature Studies, it is a scene which also casts light on the technology of the classical 17th century French Theatre: the Italian engineer Giacomo Torelli had built a specially-designed machine which wafted the King in a crescendo of fireworks and light onto the stage. To learn more about the technological finesse behind such "mises en scène", the two professors and their Master's Degree students conducted an interdisciplinary seminar entitled "Early Modern Drama and Dramatic Poetry (France and Germany)".

To properly evaluate the pieces, the group needed first to set them in their historical context. As Dickhaut explains, the theatre of that time was far different from that of today: "It was customary for a prince or king to schedule a festival of many days duration at his court, such as a victory celebration, a baptism, or a marriage, and to spice up the afternoons and evenings with ballet or theatre for the entertainment of his court". As a result, behind-the-curtains production work was very demanding. At that time too, opera was just emerging as a new form of entertainment to rival the theatre. "Technology was so central to theatre productions that the latter were also labelled 'machine theatre', says Dickhaut".

Historic Festival Reports Describe Stage Techniques

One source where the researchers found such information was in contemporary festival reports.

French King Ludwig XIV himself donned the "Sun" costume and danced the final scene of the "Ballet royal de la Nuit" - which earned him the appellation of "Sun King".

Illustration: Henri de Gissey/via Wikimedia Commons

"Deus ex Machina": During the baroque era the technology of stage plays aroused so much attention that it was even called "machine

Photo: National Castles and Gardens/Norbert Stedler, 2007

These went into minute detail – even to the number of onstage candles – and were enhanced by sometimes elaborately colored graphic sketches. "We used these sketches to deduce what the stage scenery looked like and what movements were produced by the stage machinery," says Dickhaut. Both fire and water were possible, along with moving candelabras which could be refilled during the performance. Ships sailed across the stage and even turned into dragons as fireworks went off. "In view of the available technology, it is astounding what the engineers of that day were able to design, build and carry out on stage," says Romance language philologist Dickhaut. And the Producer-King, of course, always had to be a visible source of radiance.

It is no coincidence that the University of Stuttgart can boast of an International Centre for Research on Culture and Technology (IZKT), which it funds in view of the project's combined German-French emphasis. This year, for example, three international experts at the Centre presented the results of their research into the above-described theatre technology. The University also plans to establish a virtual exhibit concerning the art of theatre engineering, and "a research-oriented Master's-Degree seminar will be the first step in that direction," says Dickhaut.

French Works for German Audiences

The seminar group has studied not only theatre technology but also the impact of French stage plays, some of which are still seen today, on German literature in the 17th and 18th centuries. "The French works almost immediately became a sensation at German courts," says Dickhaut, "but German studies to date have largely ignored this." The Master's Degree students in the project described here compared a French Original in each case with its German translations. "This was an important step toward understanding the interrelationships and seeing the major influence of the French theatre in Germany," says Felicitas Mössner, a research assistant who tracked down the historic texts and translations in libraries and archives. The pieces were often adapted in the country on the right bank of the Rhine River, as when they were rewritten for middle-class audiences who, in contrast to the court of Versailles, came as paying guests to theatres in Heidelberg, Freiburg or Hamburg. theater‘, and the premieres were open to those outside of court society. "The transition from Catholic to Protestant beliefs is very striking in these productions," says Dickhaut; "it had consequences regarding public views of the supernatural and Divine Providence."

For Protestants, for example, the supernatural was viewed as unlikely – and was therefore bowdlerized out of existence. The research group thus needed to put both the probable and the improbable in their relative contexts, that is: "Audiences of that day thought it probable that gods might float down to the stage, just as early modern audiences thought an angel could do the same," says Dickhaut. "Today, in contrast, we're at least skeptical about such things." It's thus no accident that the forgotten stage tricks of those old engineers found expression in the term "Deus ex Machina" or "God from the machine", to describe how stage contraptions could produce a godhead out of nowhere. "We're not talking here about the 'great aunt from America' who gives the narrative a new twist, but rather about an unexpected godly intervention descending to the stage thanks to ingenious technology," explains Dickhaut. The "forgotten engineer" was thus a key figure; the true "hidden God" of the theatres was the person who made him appear.

Daniel Völpel

A Question of Perspective
For Shut-Ins, Digitalization Can Level the Playing Field

Photo: Fotolia

Persons with physical challenges often yearn for a paying job as a door-opener to a life of their own. Both an income of their own and an ensured place among colleagues or a daily work routine play a major role for their inclusion in society. Assistance systems can help to draw such persons more into the working world.

Having a job that "pays the bills" has great importance in our lives. It ensures that we can earn a living and helps us in planning our lives and reaching our prized goals, like starting a family, building a home, or going on trips. But there is a higher purpose: work gives meaning to life; the ability to pay one's way by holding down a job is an expression of autonomy and moral dignity. Those with moral standards in our modern, collaborative society are dependent on one another, whereby this dependency is of a reciprocal nature, meaning a mutual give-and-take. Ensuring that each member of society can earn his own way prevents improper dependency of one person on another and results in a just distribution of earnings and burdens in a collaborative society.

Work Provides Identity

In his political and philosophical controversy with Nancy Fraser, social philosopher Axel Honneth underscored the importance of social recognition through work as one condition for a successful formation of identity. As Honneth wrote, the special value of work for us is that social recognition is essential to the successful development of practical identity – an identity which goes beyond individual uniqueness and includes an actively emerging relationship with oneself that appears above all in interactions with others. One of the central areas of this interaction is the economic sphere, which in our society is organized as a free market system and is of central importance in the world of work.

This line of argumentation from recognition theory makes possible a critique of the concept of an "unconditional basic income", like that of Jeremy Rifkin, who proposes this as a way of defusing the disappearance of jobs currently projected to result from the digitalization of work. But if social recognition through work is so important for the successful formation of a "practical identity", there are those who ask, like Beate Rösler in her essay on "Meaningful Work and Autonomy", whether a basic income may not rob those affected of the possibility of receiving this form of recognition. Such reflections show how important it is not only to think about the consequences of digitalization of the working world in terms of economic categories but also to incorporate ethical aspects. A central aspect here, in my view, is to distinguish the impact of digitalization of the working world with regard to different employment groups.

Digital Assistance for the Handicapped

A group especially dear to my heart in my research consists of handicapped persons. Politicians too are increasingly aware that a living wage is no less important for the handicapped than for the non-handicapped. A central demand of the UN Convention on the Rights of the Handicapped, ratified in Germany in 2009 with the status of basic and enforceable law, is that efforts must be made to include handicapped persons in the working world.

A living wage has high value for handicapped persons. Researchers who currently study how assistance systems can support them in their work also take ethical criteria into consideration.

Photo: Fraunhofer Institute for Work and Organization (IAO), /Ludmilla Parsyak

Assistance systems can help here, as was made plain by a recently concluded research project called "MotionEAP", which was funded by the Federal Ministry for the Economic Sector and Energy. The project's goal was to develop a system for increased efficiency and assistance in industrial production processes on the basis of movement recognition and projection. The part of the project of which I was in charge studied the ethical implications of such systems. Here it was found that assistance systems in particular can improve the performance of persons with severe cognitive handicaps and are experienced very positively by them. One area of application was the assembly of screw clamps. Persons with mental handicaps experience such work with the aid of an assistance system as less strenuous mentally, and they are also less dependent on personal feedback and support. This gives them more self-confidence, and they not only carry out the respective work process with visibly less strain but also exhibit more enjoyment and motivation. And they can fit into the work process smoothly even after long interruptions.

Blessing or Curse – A Question of Perspective

Various factors thus determine how Industry 4.0's mechanization of work is to be evaluated. This includes the design and scope of application of digital technologies. On the one hand, the latter can lead to the development of complex tasks and cognitively and socially more demanding areas of activity. On the other hand, they can also contribute to a simplification of work processes. Whether this development is to be viewed as ethically positive depends, among other things, on the target group at issue. In particular, however, new perspectives can emerge from all this for handicapped persons. This has ramifications for inclusion in the first job market and for the application of digital technologies in work areas manned by handicapped persons.

Prof. Catrin Misselhorn,
Institute for Philosophy, Chair of Science Theory and Technical Philosophy

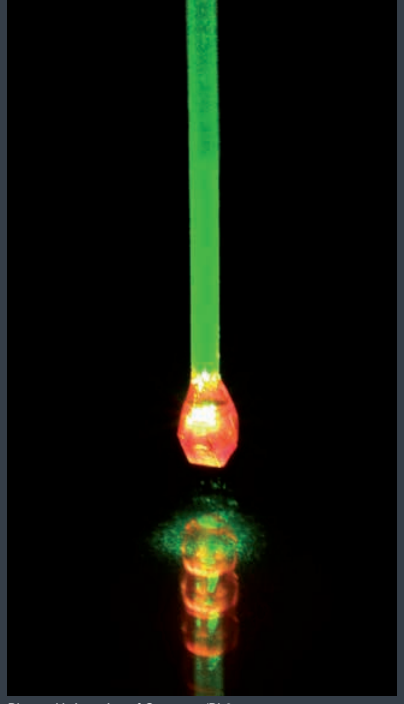


Photo: University of Stuttgart/PI 3

MRT-Images More in Focus

Molecules betray their presence with a magnetic fingerprint. Today's medicine turns this to advantage with magnetic resonance tomography, in which the magnetic fields generated by the nuclear spin of molecules can be used to create bodily images or evaluate the composition of the molecules. One drawback in the past, however, was that large sampling quantities were required, which in turn rendered it impossible to show minute details on a monitor. Now Prof. Jörg Wrachtrup and his team at the University of Stuttgart have found a way to track molecular signatures by means of an atomic quantum sensor. The resulting sensitivity is a trillion times better than before. This new type of sensor makes it possible to recognize individual molecules like those in proteins and study their dynamics in detail. This could improve the resolution of magnetic resonance tomographs so radically that they might even be used for early recognition of tumors. Quantum sensors in diamonds could also be important for the miniaturization of nuclear spin spectrometers and could greatly lower their acquisition costs.

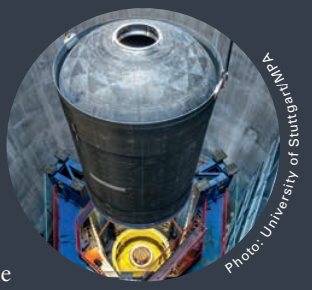


Photo: University of Stuttgart/IAG

Rockets Under Pressure

How much pressure can the newly designed solid-fuel "booster" tanks of Ariane 6, Europe's future carrier rocket, withstand? The answer to this question came with a loud bang at the University of Stuttgart's Materials Test Centre when a demonstration version weighing many tons was deliberately pressurized until it burst. The spectacular burst test showed that the safety parameters of the new tanks, which are now made for the first time of carbon fibers, were far above the actual requirements. This composite fiber material technology helps reduce the rocket's weight and ensures that European space flight will remain competitive on the world's hotly contested market.

Fast, Efficient, Quiet

The high-speed "Racer" helicopter from Airbus Helicopters triggered a media sensation in June at the Paris Air Show in Le Bourget. This fast prototype, designed to dart across the sky in future at 400 kilometers an hour, is part of the "CleanSky2" research program with which the European Union aims to make flying more environmentally friendly and economical.

Simulations for the Racer are carried out by the University of Stuttgart's "Helicopter and Aeroacoustics" Team at the University's own Institute of Aerodynamics and Gasdynamics (IAG). The requisite research calculations were crunched at the University's high-performance computing center. Three doctoral students have worked on optimization and risk reduction shoulder-to-shoulder with the manufacturer since early 2016 in preparation for the first flight, now planned for 2020. Their focus is on maximum operating limits and on flight stability in all possible helicopter situations, as for example when flight is carried out at a tilt – and backwards! A further aim is to optimize the helicopter's efficiency, environmental friendliness and noise level in flight as far as possible by means of a vast array of control mechanisms.

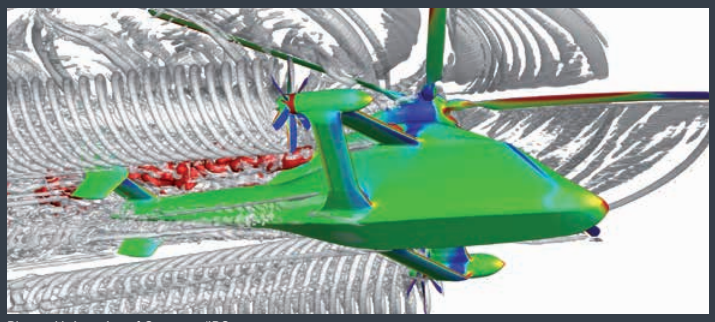


Photo: University of Stuttgart/IPC

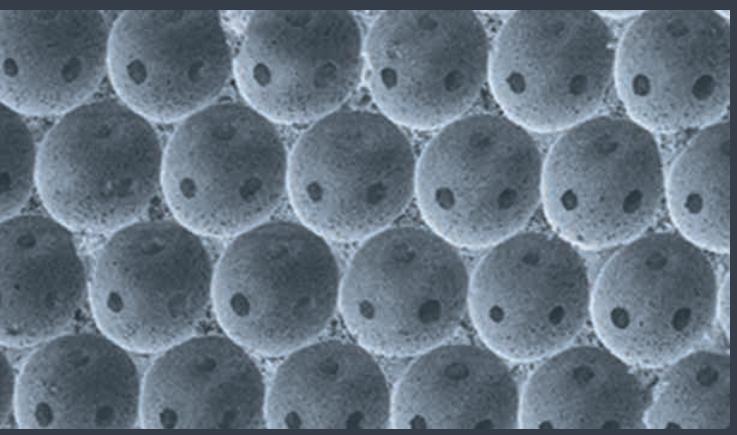


Photo: University of Stuttgart / IPC

Honeycomb Sponge Rubber

Sponge rubber with an open cell structure is useful for filters, sponges or tissue cultures, while closed cell structures are better for heat insulation or in packing materials. Now Prof. Cosima Stubenrauch and her team at the University Stuttgart have found a way to produce both types of sponge rubber – with open or closed cells – at will.

The team worked with a fluid matrix containing layers of thickly packed, spherical water drops. The matrix, consisting of monomers (single molecules), was compacted to form a polymer (polysterol) through the addition of a so-called initiator. In the process the researchers made a startling discovery: it turned out that highly compacted fluid spheres form hexagonal structures with homogeneously thick walls during their compaction. The key to this puzzle is the initiator, the agent of polymerization und hardening: globular sponge rubber results if it is present in the monomer, but a honeycomb structure if it is present in the water drops. The team theorizes that something similar may occur when hexagonal honeycomb cells develop in beehives.

Extreme Light Compression

Until now, the prospect of extreme compression of visible light's wavelength was only a theory. Now, however, scientists at Physical Institute 4 of the University of Stuttgart were able to demonstrate this effect for the first time in collaboration with research groups at the University of Duisburg-Essen und in Haifa. A trick enabled them to narrow a focal point of light to only 60 nanometers. This success opens the door to new possibilities for technical application, as in optical components for computers or in the realm of high-resolution microscopy. The feat was made possible by new types of gold films with an extremely high surface quality. The scientists also employed a new method which made it possible to create atomically smooth, monocrystalline gold surfaces only a few micrometers in size and adjust their thicknesses on top of extremely smooth silicon surfaces.

Photo: University of Stuttgart / PI 4

Tracking the Digital Twin
A Merger of Physical and Virtual Worlds in Production

A united research project shows the benefits of joining metal-forming machine technology with information technology. Partners in the project are the University of Stuttgart as chief sponsor along with the University's Institutes for Metal-Forming Machine Technology (IFU) and Industrial Automation and Software Engineering (IAS).

Production components with unvarying quality at all times: theoretically elementary, and a given. Sadly, the reality looks different in many industrial production plants. Factories often work with idealized models of production materials, machine functions and manufacturing processes – and find to their dismay that things look different in the real world. Changes in underlying conditions can affect relevant production parameters, with inevitable fluctuations in quality. Here it is hoped that new concepts proffered by Industry 4.0 will help.

This is where EMuDig4.0 comes in. This collaborative research project entitled "More Efficiency in Massive Forming Through Development and Integration of Digital Technologies" has brought together a consortium of colleges and manufacturers to study warm forging processes with steel and aluminum. The project will span the years 2017 to 2019 and aims to construct an Industry 4.0-ready model production plan at the IFU. Concepts worked out here for data-driven warm forging processes will then be adapted by two of the project's industrial partners and then go into operation with real production data.

Combining a QR-code with a numbering procedure ensures clear identification of the semi-finished product from beginning to end of the manufacturing process.

Photo: University of Stuttgart/Max Kovalenko

Digital Twins for Better Tracking

"Forming processes have difficulty in creating a truly precise digital twin when warm forging is involved" says IFU-Director Prof. Mathias Liewald. The reason: the blank undergoes a process that completely alters its microstructure and geometry. This in turn makes it difficult to ensure that the manufacturer and the raw material batch remain clearly identifiable, since the relevant data cannot be simply attached to the metal surface via barcodes and/or radio labels. Warm forging always proceeds according to a specific sequence of steps: the raw material – typically in the form of rods up to ten centimeters thick – is cut into pieces of a set length. The problem, as Liewald explains, is that "This results in a box filled with hundreds of pieces. In the worst case, deliveries from different manufacturers may even be mixed together." The heated cylindrical blanks, now as semi-finished products, are then put into the two halves of the forming tool, and the halves are then brought together under enormous pressure by a press. The relevant temperature required for warm forming of aluminum is nearly 600°C. The major advantage of this forming technique is that the material's microstructure becomes aligned with the future direction of stress to which the component will be subjected – useful in the automotive industry, for example, for axle and drive train components.

A consortium of colleges and manufacturers is studying warm forging processes with steel and aluminum in the "EMuDig4.0" collaborative research project.

Photo: University of Stuttgart/Max Kovalenko

Liewald goes on: “Our modelling process employs a two-stage forging die much like the ones used by our industrial partners in their forging processes.” Clear identification of the finished parts from beginning to end of the production chain, that is, from the raw material producer through the production process to actual delivery, impelled the IFU researchers had to find and test a suitable procedure. “We chose laser marking because it enabled us to put QR-codes, for example, on the surface of the semi-finished products,” says Liewald. Although this QR-code is destroyed during the forming process, the researchers can read it off directly before the forming process begins and thus identify the semi-finished product during every forming step through a numbering process. Once forming is finished, the individual components again receive a permanent laser marking. This procedure makes it possible to guarantee that the components can be tracked all the way back to the raw material. “Both the production facility and the supplier are indispensable partners in accurately tracking all parts in the process chain – and it's not easy to ensure that,” says Liewald. The final link in the information chain is the very last step: component quality control. “Top persons in warm forging plants have told us that half the battle lies in ensuring accurate trackability throughout the production process chain,” says Liewald.

Accurate Identification Is a Must

A digital twin also has much more to offer – if used correctly. That's why the “EMuDig4.0” research team wants to create a model showing how to make the production process more robust and how to increase machine system efficiency. This has ramifications for future production jobs, since the production plant of tomorrow will be able to use data acquisition and its intelligent analysis to avoid fluctuations in quality during production while also lowering costs. As a further advantage, the relevant know-how will be available not merely as experiential knowledge in the minds of long-term employees but will also be available in future at all times to everyone as an aid in designing new types of forged components. Here both institutes of the University of Stuttgart have the support of the Technical University of Dresden, the South Westfalian Professional Training College in Iserlohn, and three industrial companies. After completing and testing the model production plant at the IFU, the project partners will further test the concept on a produc-

tion line at the Otto Fuchs Company in Meinerzhagen, Germany. This will be followed by adaptation to a press line at the Hirschvogel Automotive Group in Denklingen, which processes steel rather than aluminum semi-finished products. The employees of both of these companies will have the model production in Stuttgart at their disposal during the learning process, thus facilitating further adaptation in their own plants.

Another partner in the project is the machine systems maker SMS Group, which will direct the creation of data-supported models for forecasting preventive care in maintenance and service of the forming presses. In this way, a machine can be scheduled for exclusion from ongoing production operations before unexpected downtimes occur which may affect the entire production area. In addition, the South Westfalian Professional Training College plans to develop additional warm forging forecast models as a means of predicting the service life of forging tools, which are subject to constant wear during the forming process. For its part, the Technical University of Dresden will contribute its expertise to the project during both the research and the data-intensive calculations which are required.

Steel, Iron and IT

The design of the IFU's model production plant is now nearly complete and will go fully online in early 2018. The control systems of the presses will generate relevant data for the forming process. For example, sensors will take note of maximum permissible temperatures for heating the semi-finished products. Moreover, test reports on incoming raw materials will be available for study, and the workpieces will be individually noted by means of their QR-code laser markings. This, by the way, is where IAS Director Michael Weyrich and his team enter the picture: they ascertain which data are relevant for further analysis so that the production process with its var-

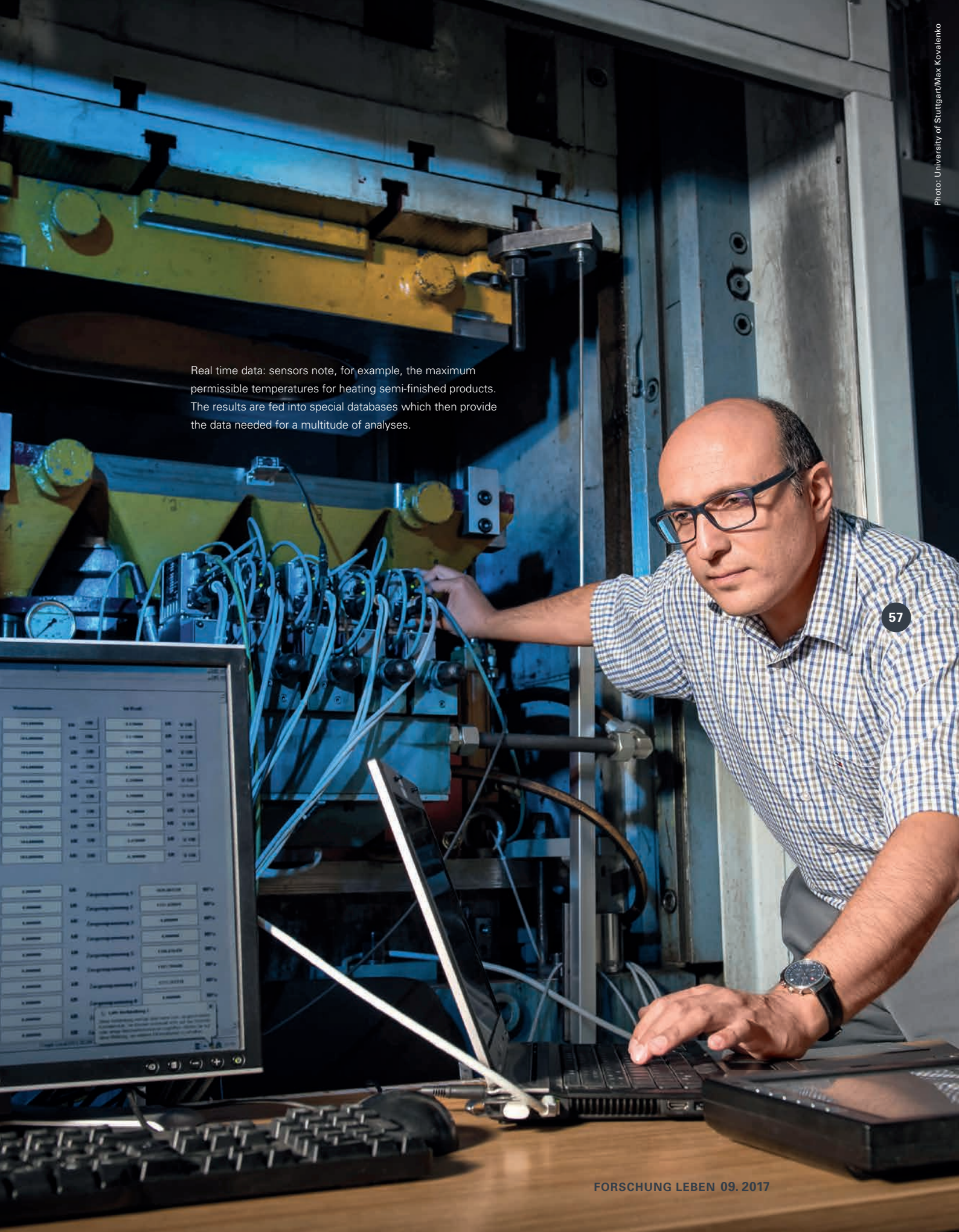


Photo: University of Stuttgart/Max Kovalenko

Real time data: sensors note, for example, the maximum permissible temperatures for heating semi-finished products. The results are fed into special databases which then provide the data needed for a multitude of analyses.

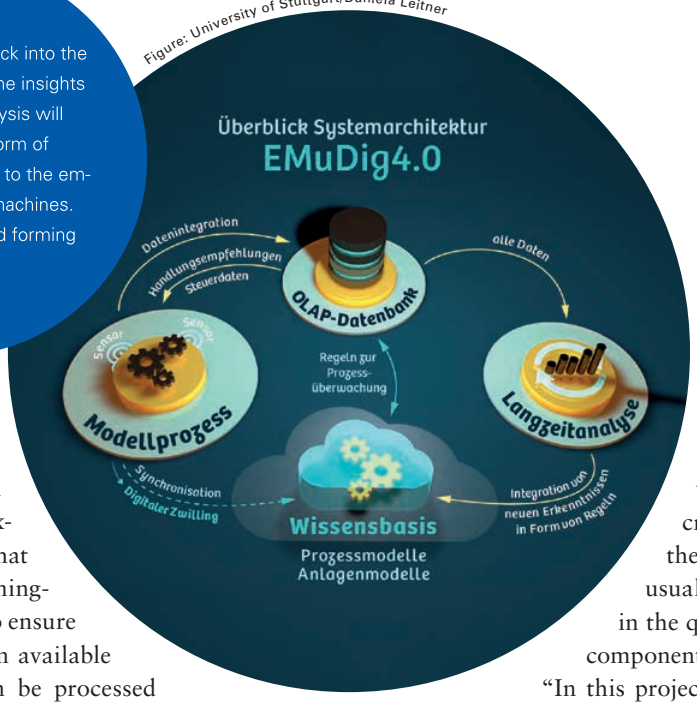


Figure: University of Stuttgart/Daniela Leitner

From the database back into the production system. The insights gained from data analysis will be passed on in the form of operating instructions to the employees running the machines. The goal: an optimized forming process.

ious controlling and regulation loops can be processed in real time. "The IFU's experts let us know what they consider meaningful," says Weyrich. To ensure that the data are then available in a form which can be processed and evaluated, he and his team must then go into far greater detail: are the individual data types whole numbers? Behavioral curves? Data fields? How often do these data change? Do open interfaces permit access to the data? And how can the data best be stored so as to be flexibly useable? As Weyrich points out, "Large quantities of data come together very rapidly," and much that is initially collected is later discarded because its contents are of little informative value. "Intuitive research is called for," says Weyrich, also in order to "coordinate the different thought cultures in the world of steel and iron and the world of information technology." The project workers had to find a "joint basis for judging the relevance of the different kinds of data."

In order to derive real time data, Weyrich's team uses fast algorithms like those found in "Online Analytical Processing". In addition, the data is stored in special databases from which it can be read out flexibly and in many different ways in order to be linked as needed for the respective analysis. Insights gained in this way flow back into the production system and serve to further optimize the forming process as much as possible.

With the support of the metal-forming experts, Weyrich and his researchers thus look for correlations which ideally lead them back to causal interrelationships. Just to give a possible example: when the warm forging temperature is within a specific range termed X, and this range is reached within a certain time window Y, and if the raw material of the semi-finished products has a certain metallurgic microstructure Z, then there will always be unusually large fluctuations in the quality of the finished component.

"In this project, we at the IAS are doing empirical research," says Weyrich. "In the present case, there's no way to work out a theory of data acquisition and analysis which correctly reflects real circumstances. It's much more the case that we need true production data in order to generate a correct digital twin." The challenge is also exemplified by so-called "big data analyses": "They are carried out with machine learning techniques, but there's no way to tell in advance which of the many algorithms in use are best suited for a concrete problem," explains Weyrich. This can only be done by means of systematic testing with real production data, which is where the IFU's model production plant comes in. In the final analysis, the true litmus test consists of the data gathered by the Otto Fuchs and Hirschvogel Companies. "Our goal," says Weyrich, "is to pass on the insights from these analyses in the form of clear operating instructions that benefit the employees running the machines; this in turn will improve the concrete forming process."

Michael Vogel

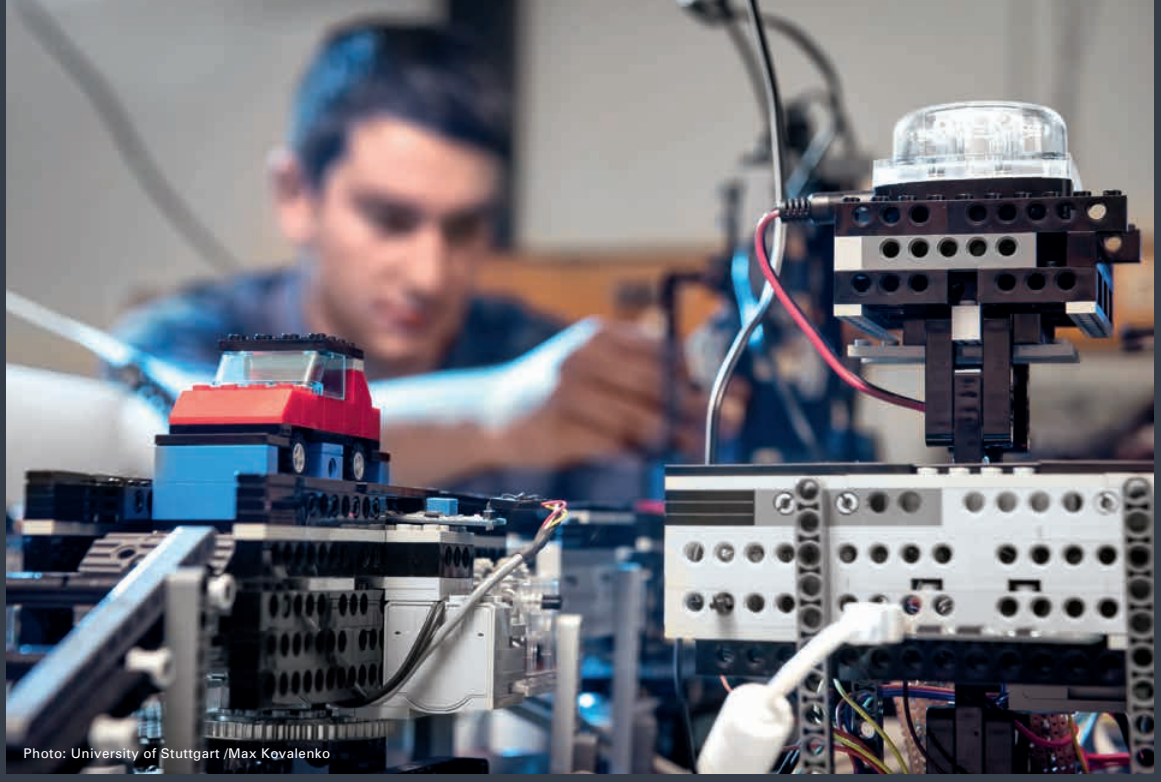


Photo: University of Stuttgart /Max Kovalenko

The future "en miniature"
A Lego-piece demonstration unit shows the potential of Industry 4.0.

Prof. Michael Weyrich and his Team "play" with automobiles made of red and blue Lego pieces. More accurately, they let someone else make the cars, and that "someone else" is an electrically operated production facility – itself made of Lego. It includes two stock areas, two placement stations, two pressing stations, and several transport systems, including a mobile transport robot. This miniature version of a highly complex automobile production area can simultaneously turn out two vehicles – one blue, one red – with no mutual interference of the production processes. This Lego production plant was developed by Weyrich's team over the last few years. Rather than being a plaything, it serves to demonstrate a complex software program. "Our model is part of a serious research project," emphasizes Weyrich, Director of the Institute of Industrial Automation and Software Engineering (IAS) at the University of Stuttgart. The individual stations of the mini-production plant can network ad hoc among themselves via software agents. While such "agents" of themselves are not new, they were previously superfluous in industrial practice. They are programmed which can carry out specific tasks autonomously and without supervision. "Their interaction is reminiscent of a marketplace," says Weyrich, who is a trained engineer. "When a vehicle is planned, its "agent" contacts the Lego manufacturing stations, finds out all on its own which station is available at the moment and whether the right pieces are there." Then the agent, "representing" the product, negotiates the best route through the manufacturing area. If one station is "booked up", the manufacturing process becomes more expensive; if, on the other hand, a station is running empty, it can offer its services to the agent more cheaply in order to increase its degree of utilization. A tablet shows what the vehicle will look like even before production starts.

The advantage for the operator of such a production plant is: flexibility. "The production controller no longer has to work out a precise sequence of production steps for different kinds and variants of vehicles; now he can react flexibly to demand fluctuations," says Weyrich. This type of Industry 4.0-concept permits highly individual production of vehicles, regardless of their accessories. The production plant adapts quickly and imperturbably to new requirements; it is adaptive, agile, and able to learn.

“Smart” Means: Cost-Effective
Support for small and mid-sized companies now entering Industry 4.0

Small and mid-sized enterprises (SMEs) also face the implementation of Industry 4.0 but often lack the requisite resources and strategies. The University of Stuttgart aims to help eliminate hurdles and smooth their first steps with the “Smart Factory Hub” Project of the Institute of Human Factors and Technology Management (IAT).

Digitalization is certainly the most dynamic economic trend since decades. It is leading to new products, new production techniques, and even new markets under the headings of “Industry 4.0” or “The Intelligent Production Plant”. While big companies intensively carry on development and implementation of digital processes and can simply purchase expertise as needed, SMEs are often at a loss for answers: “How do we introduce smart production? Will it pay off for us? And where do we begin?”

The “Smart Factory Hub” Project promises not only answers but also concrete assistance; since January 2017 it has been the baby of Jonathan Masior and Marco Kayser of the University of Stuttgart's Institute for Human Factors and Technology Management. The aim of these two researchers is to accelerate and intensify the knowledge transfers needed for Industry 4.0 in Europe's Danube region, that is, in the Mid- and Eastern-European countries bordering the Danube River. For example, during the life of the project, which is designed to last until June 2019, the task of setting up learning and training networks will be heavily dependent on expertise contributed by researchers at the University of Stuttgart.

Marco Kayser makes it clear that “every production project creates its own ecosystem,” with its own details and process steps. Nevertheless, as a look at the “intelligent production plant” shows, some challenges, like those of logistics, quality management, and documentation, are universal. “What's smart is what's cost-efficient,” says Kayser. SMEs above all need to find a solution that pays off for them most quickly in terms of higher productivity or reduced expenses. “Companies are often intimidated because they see a gigantic range of ideas and don't know which ones to put into practice,” adds Jonathan Masior.

Production plants can be toured via computer simulations even before they're built.

Photo: Dürr

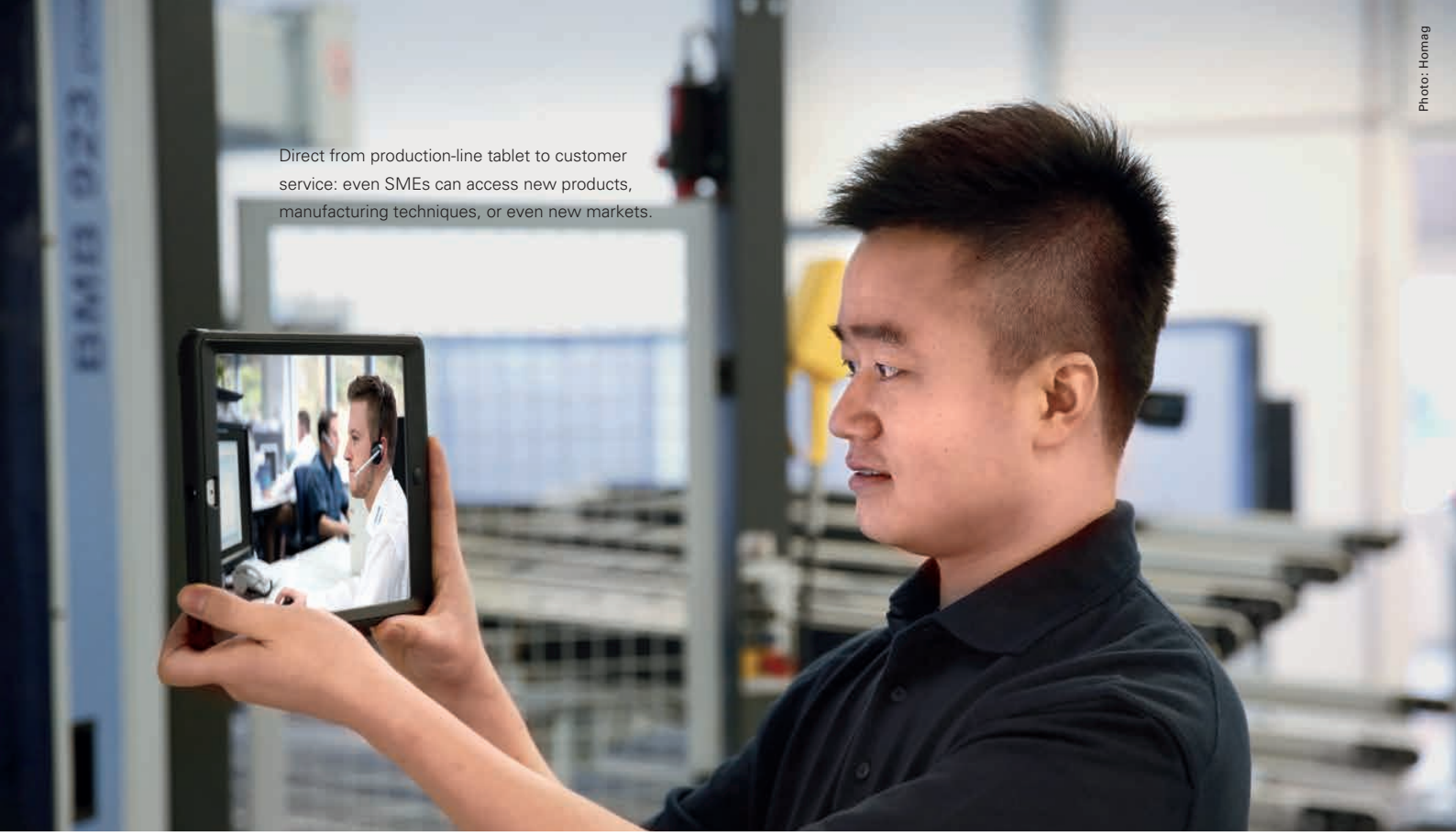


Photo: Homag

Direct from production-line tablet to customer service: even SMEs can access new products, manufacturing techniques, or even new markets.

A Wikipedia-Type Information Database Under Construction

A basic idea behind the "Smart Factory Hub" Project is that each company need not re-invent the wheel: "Small- to medium-size companies usually lack both the time and means to tackle this process alone," says Kayser. But that doesn't mean that SMEs cannot learn from the successes and mistakes of others. The IAT team aims to gather such "best practices" in a database containing not only concrete instances of application but also their pros and cons. "We're aiming at a Wikipedia-type technology and info-database for Industry 4.0," emphasizes Masior. The database will offer support as a first introductory info-platform and help to do away with the trepidation that often arises in the face of Industry 4.0. Masior and Kayser plan to develop training sessions in the project that will lead companies through their first steps in the form of practical exercises. A first line of approach might be to assign written processes for mobile digital devices. This creates both transparency and more real-time feeling in production.

Marco Kayser and Jonathan Masior started work in January 2017 on the "Smart Factory Hub" Project.

Photo: University of Stuttgart/IAT

At the moment, a chasm looms between big companies and SMEs – that is, SME-industrial suppliers in particular must change their ways. For example, it will be important for them to create IT-type structures as soon as possible. This will make it easier later on to react to any new requirements on the part of their customers and tackle those requirements step by step. SMEs will also collaborate concretely in the "Smart Factory Hub" Project, and if they assist in its development they will receive free innovation gift certificates for consultation, workshops, or actual implementation.

Jens Eber

It's tall as a human being and swings its arms: the Adaptive Assistance System will assist the surgeon of the future in minimally invasive procedures.

Photo: University of Stuttgart/IKTD

The Cockpit of the Future
New Paths in Man-Machine Communication

Autonomous vehicles and machines will be designed in future to make our everyday lives and work easier. However, the more automated and networked they become, the more complex they will be. To ensure that we can talk freely to the machines of tomorrow, engineers at the University of Stuttgart's Research and Teaching Section for Technical Design are developing cockpits and control panels to fit the user and the situation.

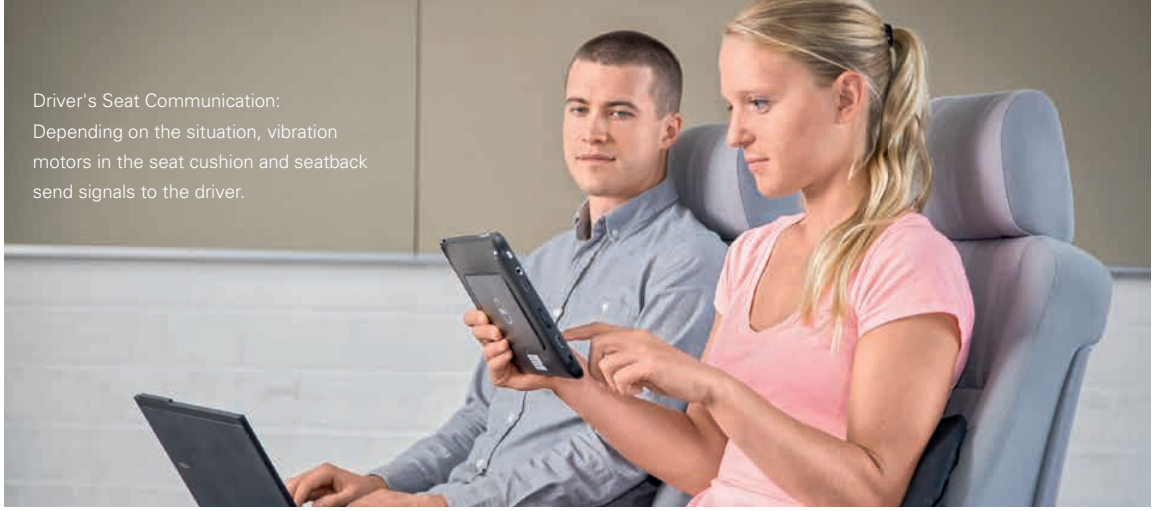
As early as 2008, Germany's first pilotless subways were rolling under Nurnberg – guided by a fully automatic, computerized network that keeps them in a constant give-and-take of data regarding the route, the signal boxes, and a central routing nerve center. The "driver in this case sits at a desk in the routing nerve center and supervises operations on ten monitors. Now the German Bundesbahn is testing driverless trains in initial pilot projects, and the first driverless municipal busses will enter the public transportation system in selected cities before year's end.

Digitalization made its first inroads into agriculture as far back as the mid-1990s. Long before autonomous autos made their maiden trips on the road, farmers already had the option of lifting their hands from the steering wheels of tractors and agricultural harvesting machines, which then moved sure-footedly over the fields via GPS and sensors. In future, the farmer will plan and monitor how his autonomous vehicles plow and plant his fields from the comfort of his own home. True, we are still a long way from autonomous machines that need no human beings at all to "see that they don't get into mischief". But we're moving in that direction; more and more often we see fully or partly automated machines that require human intervention only in an emergency and can take over the work of manually operated vehicles. As Markus Schmid, group leader at the University of Stuttgart's Section for Interface Design and Usability Methods says, "This is a very different kind of workplace" Today's users are bombarded every moment by innumerable items of information regarding, for example, automatic lane changes, parking movements, and networked units like smartphones or interconnected agricultural machines. "How can any person absorb so much information and react in time?" has long been Schmid's question. His research area is part and parcel of the University of Stuttgart's Research and Teaching Section for Technical Design, headed by Prof. Thomas Maier of the University of Stuttgart's Institute of Engineering Design and Industrial Design (IKTD).

Schmid focuses on designing optimized user-friendly interfaces and environments. At the interface where man and machine come together, he and his team want to make interactions more intuitive and uncomplicated – whether in traffic, in agriculture, or in the hospital operating room. A current trend in this effort is to shift functions to the virtual menus of touch-sensitive computer screens. "At some point we have passed the stage where increasing complexity can be controlled with switches and buttons," says Schmid, a university-trained precision engineer. In the past, many thought that virtual interfaces would solve the problem, but Schmid is certain that "We'll still encounter control sticks and regulator dials in the cockpit of the future". Human beings simply like to have something they can take hold of and feel. Schmid gives an example: "Physicians can't carry out operations on a touchscreen!" The issue here is to find the right balance between a virtual image on the screen and real control panels.

Design Determines Direction

Even joysticks and the like still offer much room for improved user support. For example, motor-con-



Driver's Seat Communication: Depending on the situation, vibration motors in the seat cushion and seatback send signals to the driver.

Photo: University of Stuttgart/IKTD

trolled movable disks could change their constellation at the turn of a rotary dial. “The arrangement clearly shows me which way to turn. I no longer need to look but can simply sense what is to be done,” explains Schmid. In aISA, for example, a collaborative project involving the University of Hohenheim and the elobau Company, adaptive interface systems are being developed for tractor cockpits. The idea is that the control panels will change their shape, color, overall appearance or arrangement whenever a new unit like a manure spreader or a baling press is attached to the tractor. In theory this will reduce the risk of operating errors by the farmer which might involve danger for him or others. Cockpit developers must also take into account that more and more older persons will be working longer in future. This will call for age-appropriate user environments, since many older persons experience a gradual diminution of sensory, cognitive and motor abilities. One solution envisioned by Schmid's team, for example, would be that control dials would automatically change from a round to a square shape when the older person lacks the strength required to turn them.

A further step would be to control future machines simply with our eyes. “That would make sense for persons who are paralyzed or who must keep an eye on several work station computer screens at once,” says Schmid in describing yet another area of research in his team. The user's eyes would then merely trace a certain path, like a square, on the computer screen and could then receive information, page through menus, or operate a machine with no need of a mouse.

The visual user environment can also be enhanced by a tactile control interface to help human beings cope with the flood of information. For example, Matti Schwalk, a doctoral student in mechanical engineering and a member of Schmid's team, is experimenting with a vehicle seat in which he has installed 16 vibration motors like those in standard commercial cell phones. He has also positioned 25 vibrator motors in the seatback. When these motors vibrate together or in succession, different kinds of patterns are felt on the back or buttocks of the person in the seat. As Schwalk explains, “When the driver of a partially autonomous vehicle in future diverts his attention from the roadway in order to read or check his emails, it will be difficult to visually call his attention back to the task of driving.” In that case, an added “poke” from the driver's seat will do no harm.

Vibration Patterns as Friendly Warnings

Up to now, the team has tested only elementary tactile systems: a tap from the left or right seat cushion area or the seatbelt when a driver or a blind person should make a turn, vibration in the steering wheel when a vehicle drifts away from its lane, or generalized vibration for unspecified warnings. For his part, Schwalk is testing up to 30 different kinds of patterns. His aim is to learn which tactile patterns are clearly recognized by the test persons and above all how many such patterns they are capable of recognizing. Schwalk also wants to know whether human beings intuitively associate certain patterns with specific information, as is the case with pictograms.

“We've found that our participants link X-patterns to errors,” says Schwalk. While admitting that it wouldn't make sense to convey every possible item of information in tactile form in a vehicle, he still believes that vibration stimuli in future will not only show the driver where and when he must turn, or give a warning when he drifts out of his lane, but will also call his attention to an impending

Photo: University of Stuttgart/IKTD

Markus Schmid and his team aim to make man-machine interactions more intuitive and less complicated.

collision or an incoming phone call or will confirm input from him. “Tactile information systems like this could be integrated into auto seats, tractors, or even the hand rest of an OP device,” adds Schwalk's Group Leader Schmid.

A few doors down the hall, machine design and construction engineer Kristian Karlovic has worked with control engineers of the University of Stuttgart's Institute for System Dynamics (ISYS) to construct a completely adaptive assistance system. The room leading to his office is dominated by a 6-foot tall, somewhat humanoid test stand whose movable arms are designed to support the forearms of future surgeons during minimal-invasive surgical interventions. “During an interdisciplinary project called ‘IoC-103’, which we carried out with our partners at the University Clinics in Tübingen,” says Karlovic, “we found that surgeons often experience very pronounced muscular stress in their shoulders and the back of their necks during surgical procedures, and that this can affect the quality of the procedures.” It is not unusual for minimal-invasive interventions to last for hours. Such procedures require surgeons to introduce OP-instruments and an endoscopic camera system through small openings in the abdominal wall and advance them to the desired organ while following the procedure on a computer monitor.

An Arm-Supporting Machine

Operating the newly developed OP-assistant is simple: When forearms are placed on them, the armrests move as if glued to the forearms and support them. One requirement on the part of the project partners was incorporated into the system: a quick upward arm tug frees the physicians' forearms from the system. To date, the project team has tested the arm assistant system with gynecologists and urologists in a simulated OP-theatre at the University Clinics of Tübingen, and has found that stress and fatigue in the muscles of the upper extremities were in fact reduced. Karlovic now aims to fine-tune the system and will describe this in his doctoral dissertation. For example, he wants to determine how much force the machine must exert on the forearms in order to provide them with optimal support and also to find the ideal design for the armrests.

In future, however, it will be important to do more than develop serviceable machines with adaptive interface designs. Esthetic aspects too will play a major role. The question here is: where is the proper balance between esthetic appearance and user-friendliness in a product? A modern airplane cockpit, for example, would most likely never win a prize for design attractiveness. Beautifying it, on the other hand, would soon be limited by safety considerations. For that reason Group Leader Schmid, who will in future be working on his post-doctoral dissertation, has developed a method that helps engineers proceed step by step to the most esthetically attractive man-machine interface designs with no loss in user-friendliness. A factor not to be ignored, after all, is that the user should enjoy using the machines.

Helmine Braitmaier

R2D2's Clever Brothers and Sisters
Intelligent Robots for Hospitals and Nursing Homes

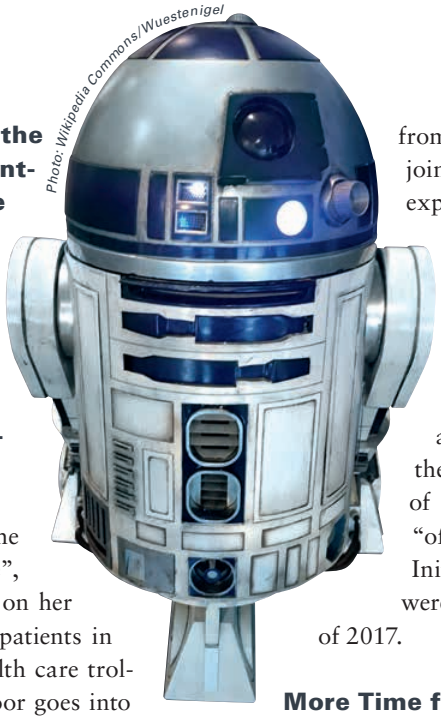


Photo: Wikipedia Commons/Wuestenigel

Several research projects at the University of Stuttgart currently focus on robots as service providers. In addition to studying the uses of intelligent robots in hospitals and nursing homes, one goal is to create an Internet robotics platform that will network customers and manufacturers.

If we look in on a hospital station of the future, we see nurse "Sandra Franke", as we'll call her, making selections on her mobile phone after caring for two patients in one of the rooms. The result: a health care trolley full of clinical supplies at the door goes into motion with a soft hum. As Nurse Franke moves on to the next room and greets the patients there, the health care trolley has already preceded her and taken up its position so that she can easily remove bandages or medical ointments and immediately dispose of used materials. She documents every nursing care action immediately online; an ingenious logistics system ensures that the compartments of the health care trolley always contain an adequate supply of materials for her daily care of the patients. This scenario is not merely "future music": prototypes of such intelligent health care trolleys are already rolling through various hospital wards and homes for care of the aged in Mannheim, Germany. An evaluation of the test phase is still pending, but it is already clear that the insights gained from this project, named "SeRoDi", could be put to practical use in many areas. In German, "SeRoDi" stands for "Service Robot Services" for the support of person-related care. Under the leadership of the University of Stuttgart's Institute of Human Factors and Technology Management (IAT), scientists from a range of disciplines have joined forces with medical care experts to test scenarios in which service robots can contribute to health care in actual practice. A first step in the project, which will extend to the end of October 2018, will be to develop a service assistant which will traverse the corridors of homes for care of the aged and for example "offer" beverages or magazines. Initial tests in actual practice were scheduled to start at the end of 2017.

More Time for Patients

"Some things are even more important than the development of new technologies," says IAT-employee Christian Schiller, a leader of the SeRoDi Project. The focus must rightfully be on the human being. "Acceptance is a priority aspect," says Schiller, and explains it this way: "Our aim was to involve health care personnel directly and learn with their participation what they would require from a service robot." It would also be essential for them to really welcome new aids, like the intelligent health care trolley, on their wards and health care stations and to view these aids as supportive tools rather than as substitutes for human employees. "People have a high level of acceptance for innovative devices when the latter take over time-consuming routine tasks and leave more time for interaction with the patients," is how Schiller sums up the insights gained from collaboration with psychologists from the Ernst-Moritz-Arndt-University in Greifswald (in Germany's Mecklenburg-Vorpommern area).
This approach of "participative technical genesis", meaning the development of new technology by col-

When bandaging materials, ointments, and syringes are needed, nurses and orderlies need only a glance to see the materials and quantities carried by the intelligent health care trolley

Photo: Fraunhofer IPA/Heike Quosdorf

laborating with even non-scientific users, has made it possible for health care personnel at the institutions in the project to contribute insights gained from their professional experience throughout the entire course of the project. All persons in the project also had an opportunity in joint workshops to directly communicate suggestions regarding hardware, for example, or the user interface of the health care trolley to their technological partners at the University of Stuttgart's Institute for Control Technology of Machine Tools and Manufacturing Units (ISW) and the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA).

"Health care personnel know precisely where they need support and what can make their workday easier," says Schiller. This kind of input turned out to be very important. In addition, the researchers themselves spent a week going through work shifts on wards in order to pinpoint the drawbacks of conventional health care trolleys and sound out the potential of a new type of driverless device.

Parallel to this, machine engineers from Stuttgart's Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) and the University of Stuttgart's Institute for Control Technology of Machine Tools and Manufacturing Units (ISW) monitored the technological side of operations: the health care trolley must infallibly recognize stairways and stop before reaching them. The engineers were also able to train the health care trolley to use building elevators all by itself. They also studied how the health care trolley should react in case of a fire alarm so as not to block rescue routes.

One Building Block in a Whole

Instead of viewing the health care trolley 's uses in isolation, the IAT experts viewed it as one building block in a logistics system – and found potential simplifications. For example, one ward is normally visited every week by a big wheeled cart bringing new materials which the ward personnel sort out, put onto shelves, and later use to stock the health care trolley. All this takes time that could be better used to work with the patients. "Working with logistics experts from a health care institution, the project developed a new solution: standard modular baskets were packed in advance elsewhere and now need only be inserted directly into the health care trolley on the ward," says Schiller.

In the past, the health care personnel re-stocked the conventional health care trolley at the end of each shift. This meant that work had to be interrupted

for a trip to the storeroom whenever something was forgotten or an insufficient supply was loaded into the health care trolley. Such stress factors can be minimized by using an intelligent service robot. A tablet-type computer is integrated into the health care trolley and keeps a running record of how much material is used. This allows the health care trolley both to "warn" the health care personnel when material supplies are getting low and also to send an automatic order for replenishment of the ward's stocks. As a result, logistics are "leaner" and function more smoothly.

Guidelines for Future Projects

The SeRoDi research team's comprehensive and in-depth analysis of health care trolley requirements yielded so much material that Schiller and his colleagues intend to draw up guidelines for similarly designed future projects. "We want to make projects more down-to-earth," says Schiller, and adds that health care in general offers other interesting processes for future study. In addition, the results gained from studying these processes could also be applied wholly or in part to other areas like the hotel industry or "Ambient Assisted Living", which would involve the use of assistance systems for self-determination in the lives of older persons. During the course of SeRoDi the IAT-team has already learned that those who run hospitals and nursing homes are very interested in such supportive tools. "They want to lighten their health care work load and in doing so make the occupational profile more attractive." Further developments are already in view, such as personal lifting devices or robots for transporting patients. More conclusive knowledge is needed about how patients will react to service robots, but Schiller thinks that this might also be a generational issue. Whereas today's older persons may view robotic assistance somewhat reservedly, younger persons are much more accustomed to this technology and would presumably have a higher level of acceptance for it. One thing which is also clear is that robots cannot compete with human beings in situations where empathy and direct interaction between two human beings are decisive factors. This too is one reason why the SeRoDi project is working to develop supportive actions while still leaving direct interactions with human beings to the experienced health care personnel.

A Virtual Link Between User and Provider

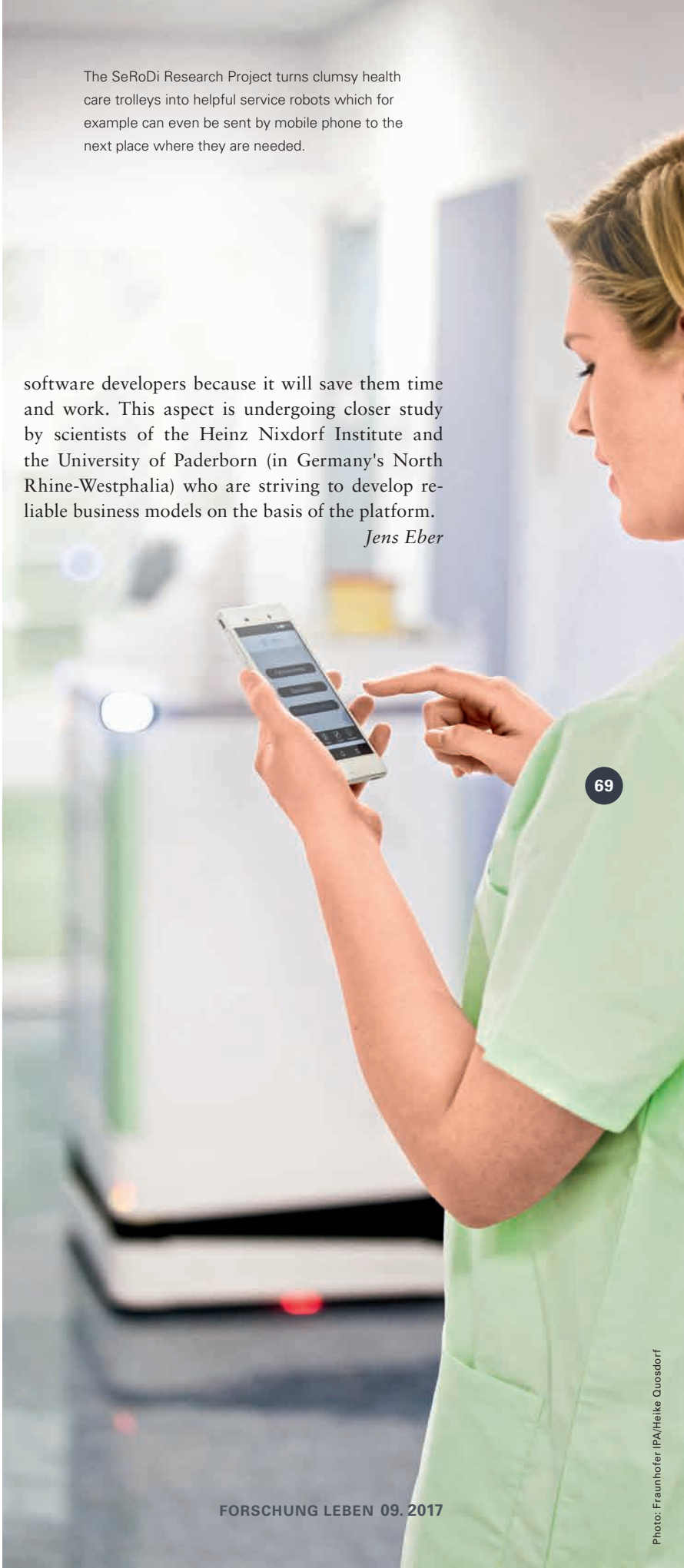
Service robots are still mostly very expensive because so few are currently being produced. However, demographic developments can be expected to cause a rising demand for service robots. With this in mind, a team of researchers at Stuttgart's Institute for Control Technology of Machine Tools and Manufacturing Units (ISW)
is working in the project "SeRoNet" on a development which may give further impetus to service robotics. "The idea is to set up an online platform which will bring all those involved in a development process together virtually at the same table," is how ISW-employee Sebastian Friedl explains it.
Up to now, the purchase of a service robot proceeded somewhat as follows: the end customer defines his requirements, then searches for suitable providers who in turn develop the hard- and software and integrate the robot into the customer's systems. The number of such development processes is usually in the low double-digit range, and development costs are correspondingly high.
"We want to help lower these costs with SeRoNet," says Friedl. Put simply, the planned platform will function like an app store: The customer will describe his problem, and the providers linked to the platform will react accordingly. It is also planned that manufacturers, for example, will be able to offer their material or software components directly. On the other hand, the platform will also consist

of a database of information concerning service robotics and will offer corresponding development tools. “Our aim is for the end customer to find a central point of initial access to service robotics,” says Friedl. Depending on requirements, those visiting the platform will receive a list of suitable manufacturers along with general prices and can then contact a manufacturer with specific requests. “Our vision for the platform would be: I describe a problem and the platform presents me with a complete, configured robot,” says Friedl. However, that will not happen in this first stage. In order to establish the database, many parameters must be sorted out, and already existing know-how must be recorded and formalized into a kind of “service robotics and component catalogue”.

Such robotics know-how will come to SeRoNet not only from the University of Stuttgart but also and above all from KUKA, the robotics manufacturer, and from the Fraunhofer IPA and the College of Ulm. The project was started in March of 2017 and is planned to run for four years. A prototype of the online platform will be in the starting blocks next year. Many interfaces must still be processed in this area. For that reason, the ISW is concentrating above all on such things as greater ease and, if possible, standardization of internal communication among robots. The aim is that future components will be installed in the robot directly and ready-to-use. To that end, the ISW will design a communication architecture in which the individual components can “talk” to each other. This will be the basis for a demonstrator model. In the long run a comprehensive service robotics database will emerge with solutions for as many applications as possible. This plan could well replace today's overly complex and costly individual development of new technology for products made only in small batches with easily adaptable products.

This platform should be especially interesting for software developers because it will save them time and work. This aspect is undergoing closer study by scientists of the Heinz Nixdorf Institute and the University of Paderborn (in Germany's North Rhine-Westphalia) who are striving to develop reliable business models on the basis of the platform.

Jens Eber



The SeRoDi Research Project turns clumsy health care trolleys into helpful service robots which for example can even be sent by mobile phone to the next place where they are needed.

Photo: Fraunhofer IPA/Heike Quosdorf

Blending Out Glare and Its Dangers

Display and LED technology lead to intelligent vehicle lights.

Working together with an industrial consortium, the University of Stuttgart's Institute for Large Area Microelectronics (IGM) has successfully integrated a liquid crystal display screen into an LED high-beam light – with a resolution of 30,000 pixels and adaptive light distribution practically in real time.

Right at the start of the above project, Christiane Reinert-Weiss, a research assistant at the University of Stuttgart's IGM Institute, came up with a thought which is perhaps typical in the engineering profession: "It won't work, but let's do it anyway!" The approach taken in the project "Fully Adaptive Light Distribution for Intelligent, Efficient and Safe Vehicle Lights" (German abbreviation: "VoLiFa2020") sounded at first like a herculean task: a team of researchers and developers wanted to integrate a liquid crystal display screen into an automotive LED high-beam light. The goal: adaptive light distribution to avoid blinding oncoming vehicles due to glare. "However, a screen of this type contains many elements which cannot withstand extreme temperature ranges in automobiles or the intense brightness required by high-beam lights," says engineer Reinert-Weiss. But that didn't keep the IGM research team from taking a conventional series-production high-beam light and trying to install a screen in it. They first tested all components and layers in a long series of tests – and in the end constructed some two dozen prototypes by hand. The solution of Christiane Reinert-Weiss and her two IGM colleagues not only convinced many industrial representatives, but Reinert-Weiss also won a development prize at the world's biggest professional trade show for displays, the Display Week of the Society for Information Display (SID) in Los Angeles in May of 2017. And the automobile supplier Hella, which commissioned the IGM to carry out the project, announced at the end of June that it would introduce the system under the designation of "Liquid Crystal HD" in 2020.

Fewer Light Diodes, More Pixels

"Our advantage is that we need only 25 LEDs but it's enough for us to project 30,000 pixels onto the road, each with 16 individually defined grey levels. Conventional series-produced systems have 84 LEDs and only the same number of pixels," says Reinert-Weiss. "We reach 30,000 pixels, and our system's principle is highly efficient regarding both energy and costs." Not only that, but her system meets the stringent requirements of the automobile industry: such components must withstand temperatures of -40° Celsius to +125 degrees Celsius and have a service life of at least 8,000 hours.
This adaptive lighting innovation is controlled by systems already present today in upper-class vehicles, such as radar, GPS, or cameras, and is capable of recognizing oncoming traffic in near real-time and blending out the corresponding areas from the high-beam light. Not only that, but the system can also call attention to bicycle traffic, can display the distance required to avoid it on the street, and can show the vehicle width of nearby construction vehicles.

Positive Feedback

Prototypes of the system were built into a Porsche Panamera in April 2017. Since then, Porsche has been testing its different light functions in studies with test drivers. "Test drivers and experts who carry out test drives with no knowledge of what is being tested immediately recognize the potential of the new light functions and speak very positively of them," is the interim summary of Porsche spokesman Dr. Hermann-Josef Stappen. Christiane Reinert-Weiss was also able to go along on a test drive and sums it up as follows: the high-beam light

adapts so precisely and quickly that passengers don't even notice it, while oncoming traffic sees only a normal low-beam light.

“Of itself, the idea has already been around for many years,” says engineer Reinert-Weiss, “but only now has it become technically feasible to put it into practice.” She also points out that the IGM has no competitors in this area, since there is no other public institution in Europe which can take over the complete chain of processing steps ending with manufacture of a finished prototype.

Jens Eber

Photo: University of Stuttgart/IGM

"Here's Looking at You, Kid": Autos can look at each other without glare now, thanks to adaptive light distribution.

Photo: Fotolia

Reliable Processes, Fewer Construction Sites

Together, science and industry are developing long-lasting, sturdy concrete autobahns.

Concrete autobahn surfaces last much longer than asphalt surfaces – but also cost more. Now an interdisciplinary team from the University of Stuttgart will work with six industrial partners to improve the process chain for creating concrete autobahns – from production and installation all the way to afterwork.

About 30% of Germany's autobahns have a concrete road surface, while 70% are of asphalt. Although roadways of concrete are more expensive to produce, the Federal Highway Research Institute (German: "BASt") has found that a concrete autobahn will remain in use for 30 years, whereas asphalt surfaces usually require resurfacing after only about 15 years. Longer cycles of renewal mean fewer construction sites, with potentially fewer accidents. The call for greater numbers of concrete autobahns is thus understandable. But as Prof. Harald Garrecht, Director of the University of Stuttgart's Institute of Construction Materials (IWB), points out, "Correct processes in the production of vehicle roads depends heavily on the expertise of the respective roadway company". He and his project partners want to change that – not just because the idea is attractive of itself, but rather because reliable processing is a basic condition for meaningful privatization of roads or for public-private roadbuilding partnerships. "This is the only way to clearly answer questions concerning liability and warranty for all those involved," says Garrecht with conviction. "Today it is often the case that the company offering the lowest price receives the nod for building a stretch of roadway; in future, it must be the company that can offer a 30-to-40-year warranty on the properties of a roadway, and these properties must be defined according to a basic set of target values." A present-day example that Garrecht likes to point to is Austria, where road-building companies must pay heavy penalties for roadway shortcomings. In Germany, on the other hand, the statutory limit for damage claims is only five years.

"Well-known standards for concrete roadways have emerged from years of practice, and a great deal also depends on the experience of the employees," says Garrecht. But precisely because this alone cannot guarantee processing reliability, the research project "Concrete Roads 4.0" aims to provide remedies. This project, funded by 4.7 million Euros from the Federal Ministry of Transport and Digital Infrastructure, has brought together the University of Stuttgart's IWB, its Institute for Materials Testing, Materials Science and Strength of Materials (IMWF), and its Institute for System Dynamics (ISYS) as well as six companies which represent the entire chain of concrete roadbuilding.

Mobile mixing units make it possible to process the basic ingredients quickly and directly at the construction site.

Photo: Liebherr

Experiential Knowledge

The project team first analyzes the processes and the concrete found at four autobahn construction sites where concrete road surfaces are in use. "Concrete is not always the same," says Garrecht. "The characteristics of its basic ingredients can differ due

Only about 30 percent of autobahns in Germany have a concrete surface. Such surfaces are more expensive to produce, but last twice as long as asphalt surfaces.

Photo: Fotolia

to surrounding conditions, such as temperature or humidity." If the basic ingredients during processing are too dry, for example, the resulting concrete will be too stiff and the roadway may ripple later on. Mobile mixing units stationed near the work site during autobahn construction mix an enormous 300 cubic meters of concrete every hour. The mixing process must take place very quickly. Dump trucks then bring the concrete to the final processing location, where it is uniformly spread over the roadway substructure and sealed. Only in this way will the concrete surface withstand future mechanical stresses due to traffic and the influence of rain or de-icing salt for years on end.

After a half-day's wait, the concrete-makers make cuts in the concrete surface transversely to the direction of traffic flow. These are then filled with elastic filler which joins the individual sections together. "Using a metal tool, an experienced employee scratches the concrete surface to determine the best time for filling the joints," says Garrecht. "If the joints are filled too soon, their edges can tear away from each other; too late, and the concrete has already been stretched so far that cracks may form in it." In the end, the autobahn builders create a so-called 'washed concrete surface'. "They do it by covering the concrete surface with a delaying chemical which penetrates superficially into the surface and prevents further hardening," says Garrecht. Then they use brushes to scrape cement lime out of this layer. Like other work steps, this too is currently based purely on experiential knowledge.

By this time the concrete roadway is basically finished. However, the road workers process it in another step to ensure lower noise emissions. "To do this, they use a milling machine to cut superficial grooves in the roadway; these in turn reduce the noise emitted by rolling tires," says Garrecht. "However, this process, called 'grinding', is not economically feasible if the roadway is too uneven."

United Expertise

The project team of the university and its partners now aim to establish data-based decision-making criteria instead of the experiential knowledge which has been so decisive up to now. For example, a process of data exchange between the mixing site and the roadbuilder will ensure proper consistency of the concrete at all times when the concrete is shaken, since the load on the motors of the mixing unit provides feedback on the degree to which the concrete can be processed. Another point of approach is that

of surface testing prior to cutting the joint seams: The university team aims to determine how the concrete behaves as it solidifies in order to derive quantitative criteria about the optimum time for cutting the seams.

"After analyzing four autobahn locations, we can use the information gained to develop a new processing chain for making the concrete," says Garrecht. To this end, the university team is constructing what is presently the world's "smallest possible true-to-scale facility". The team will then transfer the basic principle of this laboratory mixer to a larger unit made by the Liebherr Company, its project partner, with the collaboration of Cavex, a manufacturer of power trains for the production of cement. The same principle will also be used in a mobile mixing unit. The Wirtgen Company, a subsidiary of John Deere, will re-equip concrete mixing units and machinery to this end, after which the Heinz Schnorpfeil Company will then lay two demonstration roadway stretches with concrete which has been processed in this manner. Afterwork on the stretches will be carried out by the Otto Alte-Teigeler Construction Company to create a "washed concrete surface", and the engineering firm of Lehmann & Partners will carry out measurements of the demonstration stretches. "The insights we gain," says Garrecht, "can be transferred later on a one-to-one basis to actual practice."

Michael Vogel

Autonomous Collapse

Traffic Researchers Calculate the Impact of Driverless Car Fleets

"Autonomous vehicles will make driving safer and more comfortable," say all the media. But what will be the impact of such vehicles on traffic in general and in our cities? This is the question put by Markus Friedrich, a traffic researcher at the University of Stuttgart. His calculations give a warning: cities will die of suffocation unless the political arena makes massive course changes.

Professor Markus Friedrich occupies the Chair for Transportation Planning and Traffic Engineering at the University of Stuttgart's Institute for Road and Transportation Science. Taking the Stuttgart region as an example, Friedrich and his assistant Maximilian Hartl have calculated different scenarios for the autonomous transportation of the future. Their primary aim was to determine the impact of large automotive vehicle fleets when these are driven autonomously by different kinds of users (e.g. in carsharing). They have summarized their results in a study entitled "Model Results of Autonomous Carsharing in Public Regional Transportation" (German: "MEGAFON"). Their study constitutes an alarm call for the political sphere, since automotive traffic could grow enormously in future. The study was commissioned by the Industrial Federation of German Transportation Companies together with the Stuttgart Traffic and Tariff Association (VVS) and the Stuttgart Streetcar AG (SSB). The Office of Public Municipal Transportation (ÖPNV) is currently scrambling to prepare itself for these new kinds of automobiles. "Business models with carsharing and autonomous vehicles could well draw paying passengers away from public transportation systems by offering transfer-free travel at a low price," explains Thomas Knöller, Director of the Planning Department at VVS. On the other hand, autonomous vehicles might make sense as gap-fillers

Photo: Fotolia

in public transportation systems, e.g. with routes that extend all the way to poorly accessible areas. Initially, however, the use of autonomous vehicle fleets will put pressure on urban public transportation systems. MEGAFON showed this: Friedrich and Hartl were able to create a detailed model of traffic in the Stuttgart region in order to calculate the 5.1 million routes traveled every day by Stuttgart residents with motorized vehicles. The model was based on questionnaire data concerning the mobility of more than 10,000 persons living in and around Stuttgart. The model distinguishes passenger car travel from that carried out by foot, by public transportation vehicles, and by bicycle and was expanded by the university team to include carsharing vehicles.

Streetcars and Subways Go the Way of the Dinosaur

Since the costs of operating autonomous vehicles are still unknown, Friedrich and Hartl took as their premise that people would have only one criterion for their trips: the fastest means of travel. In addition, the two assumed that city busses would be completely supplanted by autonomous vehicles – just one more reason why Friedrich hopes to see his work recognized as more than idle dreaming and not as some "apocalyptic view of possibilities in an extreme future".

Even when "time" was taken as the only factor, the automobile proved better in many ways than subways and streetcars. The research team therefore reduced urban speed limits in the model from 50 to 30 kilometers an hour and in residential areas from the present-day 30 kilometers an hour to 20. The result: just about as many persons were using public transportation as before.

The researchers then tried out nine different scenarios for their calculations by varying the percentages of autonomous carsharing and privately-owned vehicles, and even left railway traffic completely out of consideration. One resulting insight: although many parking spots could be eliminated in future, the streets would be even more crowded with traffic. Today, about two thirds of the region's 1.6 million registered vehicles are in motion, and "These motorized vehicles – nearly a million of them – are on the road for about an hour a day. All of today's traffic jams occur simply because about 120,000 vehicles are traveling simultaneously at peak traffic times," explains Friedrich. "If we were to use carsharing vehicles on the same routes, we would need only 19 percent of that number, or about 200,000 instead of one million. Street traffic is also congested because each vehicle averages seven hours of use and may also travel without passengers."

Only one unmanned passenger car scenario drastically reduced the amount of traffic: Friedrich calculated the impact of so-called ridesharing vehicles, that is, autonomous minibuses which brought up to six persons individually to their doorsteps and were capable of "bundling" destinations. Ridesharing is still in the design stage, but it would have a highly positive effect: If all denizens of the city were to travel only by ridesharing and rail, about 70,000 such vehicles could serve the entire region. The result: traffic levels would drop significantly almost everywhere.

"Shared Automobiles" Would Have to Offer More Comfort

This could therefore well be an area of future activity for personal transportation companies. On the other hand, billions in investment would be required for fleets of this kind. Decision-makers at the Stuttgart Traffic and Tariff Association (VVS) therefore want to use the above-described study to make active changes in basic conditions: "Traffic services with autonomous vehicles will require communal control in order to ensure that they cooperate with

The Stuttgart region's 2.7 million residents travel over some 5.1 million routes, primarily via automobile, bus, and rail.

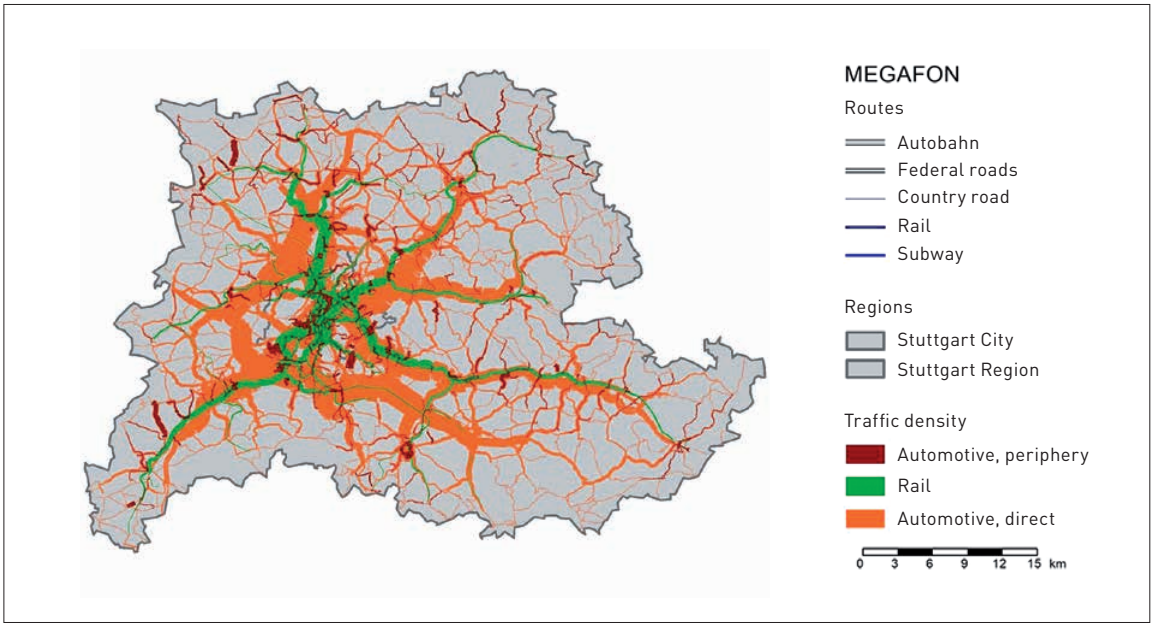


Illustration: University of Stuttgart/Institute for Street & Road Traffic

public transportation systems rather than cannibalizing them," says VVS-Director Knöller. In future, communes will have to decide who will be licensed to operate autonomous automotive fleets. "A further alternative which might be discussed, of course, would be for publicly owned companies to submit such offers," says VVS Director Knöller.

However, the idea of ridesharing will hardly be persuasive for persons who are accustomed to using their own automobiles. "For that reason, these vehicles will have to offer a sense of privacy and unusual comfort," says Friedrich. "And getting into and out of them with baggage will have to be quick and easy," since more persons will travel more frequently than today. "If autonomous driving is to make the world a better place, we will have to make ridesharing more attractive," is his reminder. In his view, that will succeed only by means of auxiliary measures like lower speeds, a system of graduated road toll charges for street use, and access restrictions. Here Friedrich's experience has made him pessimistic: "We could have already had all this 40 years ago, but almost nothing was done. So why should we think that anyone will have the courage to take such steps?" Even though his primary task as a scientist has been to find algorithms for carsharing traffic models, Friedrich sums it up this way: "There is a need for societal discussion of this, and quickly. Otherwise we may find ourselves in 30 years living in cities that no one ever wanted."

Daniel Völpel

Flexibility is Tops
The SynErgie Project Readies Industry for Renewable Energy

Even today, more electric current can be produced under ideal conditions with renewable forms of energy than Germany needs at peak load times. On the other hand, wind and sun are not constant, and the amount of energy generated by them therefore fluctuates widely. For that reason the energy revolution can succeed only if industrial electricity consumption levels become more flexible. To that end the University of Stuttgart's Institute for Energy Efficiency in Production (EEP) has joined more than 80 partners in the "Copernicus / SynErgie Project" to find out how energy-intensive production plants can adapt to changing supplies.

An aluminum smelting furnace is either on or off – there's no in-between stage with less energy consumption. Because an aluminum smelting plant consumes enormous amounts of electric current, however, it would be the ideal candidate for finding ways to cope with power grid fluctuations. This has resulted in a highlight research project entitled "Synchronized and Energy-Adaptive Production Technology for Flexible Adaptation of Industrial Processes to Fluctuating Energy Supplies" with the German abbreviation "SynErgie". As part of the project, the Trimet Company in Essen, Germany, intends to convert its electrolysis ovens to put out 50%, 70% or 90% of their peak output as needed or to function with 50%, 60% or 70% of energy consumption. As things stand today, it's either 100 or 0 for both output and consumption. This is only one way in which the SynErgie Project aims to help cope with the Energy Revolution, explains Prof. Alexander Sauer, Director of the University of Stuttgart's Institute for Energy Efficiency in Production (EEP). "Germany has arrived at a 30% share of renewable energy, and this is the point at which the electrical system must become more flexible," says Sauer. He is currently the coordinator for SynErgie, and in 2019 he will take over the its spokesman role from Prof. Eberhard Abele of the Technical University of Darmstadt, Germany.

Sauer points out that theoretically about 100 gigawatts of electric current with renewable forms of energy are already available in Germany. The peak load is currently at about 90 gigawatts. Now it is up to electricity consumers to adapt to fluctuations in

Industry consumes about 40% of all electric current in Germany. To be successful, the energy revolution will require production plants in future to be more flexible in their electrical needs.

Photo: Fotolia

renewable energy production with storage units and with flexible demands. The 80-odd project partners want to achieve this by developing new forms of technology in six clusters and by changing processes in the production sector. Of the four Copernicus projects, the Federal Ministry of Education and Research is funding SynErgie with ten million Euros annually.

Industry: the Key to Ups and Downs

"Since industry uses about 40% of all German current," says Sauer, "it's where we want to start making current consumption more flexible." For example, about two thirds of German industry's energy needs consist of heat, and electricity could generate more of this than at present. But then: what about the 'sunless months' of October and November? One solution might be to generate synthese-gas ('syngas') from surplus sun- and wind-generated electricity and burn it during these months. To show how that could work, Sauer points to the C&C Bark Magnesium Foundry, which is nestled in the hills of Schömberg, Germany. The company uses electric current to operate its casting cells and would require a separate system for gas-powered operations. Now Sauer and his team want to develop a casting cell which can be switched from electrical to gas power. "We're deliberately trying to go beyond the present state of the art in technology," says Sauer. "As a consortium, that makes us highly oriented toward production technology."

The foundry is only one of 13 sub-projects in the "Key Production Process" Cluster' which Sauer heads up and which has brought together production

In future, Trimet's electrolysis ovens will be able to operate with variable energy consumption levels.

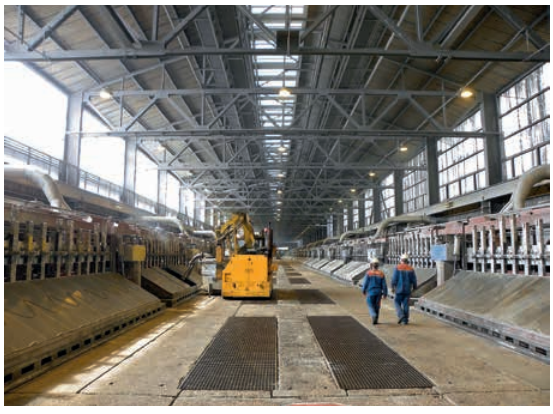


Photo: Trimet

The magnesium foundry is collaborating with the research team to design casting cells which switch back and forth from electrical to gas operation according to energy demands.

Photo: C&C Bark

plants from key industrial areas like the automotive and chemical industries and the areas of machine and systems engineering. The focus is on two questions: Where is there presently a potential for flexible use of energy? And: Where is further development needed to increase such use? Industrial suppliers in the "Production Infrastructure" cluster are also working out how to make basic processes more flexible, e.g. in producing pressurized air or generating cold or heat.

Energy Flexibility as a Commodity

Under the direction of the Fraunhofer Institute for Production Technology and Automation (IPA), the members of the "Information and Communications Technology" cluster are developing the IT platforms and services required, for example, by the magnesium casting cell mentioned above so that it knows when to switch on its production of electric current. This in turn will require a near-instantaneous calculation of energy prices in view of consumption, costs, and the degree of machine efficiency. As Sauer says, "What's important for us is that all this must be done automatically to relieve the system operator of extra work". This cluster also has the task of "bundling" information: each IT platform will collect the respective company's internal energy data and issue a possible flexibility offer to the market. Power plants and network operators will

thus offer energy at a virtual marketplace, and industry will be connected with the market platform via an interface "where supply and demand will come together and energy transactions can be negotiated". The "Market and Current System Cluster" will establish basic conditions for the providers: the energy industry will clarify what types of flexible purchase the industry can offer and what new types of technology the respective provider would need to meet flexible demands. The aim is to create a market model for negotiating the flexible purchase of available current.

Under Alexander Sauer's direction, the EEP researchers are also at work in a cross-disciplinary SynErgie cluster called "Potential Analysis and Systemic Overview" where they extrapolate potentials found in key branches of industry to the Federal Republic of Germany as a whole and thus provide key figures. The aim here is to deliver a plausible estimate of the share of electric current which could be consumed flexibly and how much it would cost, and to achieve this goal by the end of the first project phase in the autumn of 2019. The team knows full well: without SynErgie there can be no energy revolution.

Daniel Völpel

Energy Efficiency for SMEs

Energy consumption, a major factor affecting costs and competition, is of prime importance for every company. Small and mid-sized enterprises (SMEs) are particularly challenged here because they cannot match the resources, bargaining capabilities, and investment options of major companies. The "EntschEff" (Decision for Energy Efficiency) Research Project aims to provide a solution to this dilemma. The project is directed by the Energy Centre for Decentralized Energy Systems and Energy Efficiency (REZ) in Reutlingen, Germany with the assistance of the University of Stuttgart's Institute for Energy Efficiency in Production (EEP) and the University of Vienna. These three are supported in turn by seven SME production companies from Baden-Württemberg, along with partners from the public domain. Together they are investigating how SMEs organize energy supplies and demands in daily practice: How are decisions reached concerning energy efficiency activities? What problems arise here, and how can they be resolved? The project's aim is to identify and understand processes which promote or hinder energy savings and those which are needed to implement energy-efficient forms of technology. The findings will be used to develop recommendations for action along with improved instruments and communication strategies and better energy efficiency in SMEs.

amg

Going Into Turbo-Drive
Baden-Württemberg Opens Lab Network for Electromobility

Engineers have more or less carte blanche in designing the power trains of electrical or hybrid vehicles, since no uniform concept has yet emerged. Up to now, individual power train components have usually been developed in isolation from one another. But now Baden-Württemberg's Lab Network for Electromobility (German abbreviation: "XiL-BW-e") makes it possible to view the vehicle as a holistic system and use it to test components at an early stage of development, even if they do not yet exist or are at another location. To this end, the University of Stuttgart's Institute of Electrical Energy Conversion (IEW) and its Institute for Internal Combustion Engines and Automotive Engineering (IVK) have networked their test stands with those of partner institutes.

Engineers who develop an electric vehicle today have at their disposal a range of production numbers, vehicle types, and arrangements of electrical motors, power trains, and battery systems. However, there is still no final consensus about battery charging techniques (cable or cordless). To add to the confusion, hybrid vehicles supplement fully electrical vehicles by offering not only an electrical motor but also a combustion engine. In addition, the components cannot merely be joined together like children's building blocks. "A systematic interrelationship of individual components must also be taken into account," says Florian Winke of the IVK. For example, current-hungry components empty batteries faster, thus reducing the driving range of electrical vehicles. Then too, the range is also affected by individual driving styles, ambient temperatures, and roadway situations. Moreover, the charging technology affects battery service life and therefore vehicle costs as well. Currently, restricted travel ranges and high battery costs are among the central weaknesses of E-autos. Thus it is increasingly important that all developers be able to test their modules as soon as possible in the context of the vehicle as a whole.
"Our basic idea is to bring the system together as a whole, with components designed by specialists who contribute their know-how, their models and their test stands and are mutually networked," says Winke, who is himself a trained machine design and construction engineer. As a representative of the University of Stuttgart, he and his colleague Jannis Noeren of the nearby IEW have worked to establish the Baden-Württemberg Laboratory Network for Electromobility (German: XiL-BW-e). Collaborators in this research and test stand alliance, which the German State of Baden-Württemberg is funding with 10.3 million Euros, are not only the University of Stuttgart but also the Karlsruhe Institute of Technology (KIT), the University of Ulm, and the Colleges of Esslingen and Aalen.

A Hybrid Automobile at Four Locations

The laboratory network was festively inaugurated in October of 2017 at the IEW. Since then, engineers from industry and research have been welcome there to study under near-real conditions how different kinds of systems and power train components interact with each other and with new kinds of batteries. For example, in a first actual practice test guided by the IEW's Noeren, the network partners created an entire simulated hybrid vehicle, complete with driver and environment. For its part the IEW contributed a newly purchased electric motor test stand, a simulation model for the electronic power features, and a virtual driver and digital roadway environment. For his part, Winke saw to it that the IVK's combustion engine test stand was correctly integrated into the network. The colleagues in Karlsruhe linked themselves into the project with a power train test bench and simulation models for the wheels, side shafts and

The XiL-BW-e Alliance wants to network test stands like this one.

Photo: University of Stuttgart/IEW

the car body. And the University of Ulm completed the simulated "Hybrid auto" with a battery cell and a computer model of the battery as a whole. Winke says, "Now I can link together different kinds of components on the Internet with just a few mouse clicks." Anything that does not yet really exist can be added via a real time simulation feature.

In this way, vehicle designers can quickly determine whether their prototypes are feasible and where optimization is required. This saves both valuable time and development costs as well. "Up to now, joining heavy motors or engines with power trains required a crane and was overly complex. Or measurements were carried out at isolated test stands, then virtual components were integrated into the measurements, and all this was merged into a full model at the computer," explains Noeren.

Data Scurries Around the internet As if on Wings

Researchers ensure such high speeds with the glass fiber cables of Baden-Württemberg's academic network, known in German as "BelWü" ("Baden-Württemberg Extended LAN"), which links together the academic research institutions of this German state. A mere three milliseconds suffice to send measurement data from the motor test stands in Stuttgart to the power train test stand in Karlsruhe and send a reaction from there back to Stuttgart. Noeren's comment: "These lightning-fast times are necessary in order for us to display dynamic processes like the startup of the combustion engine during electrically-powered travel or the switching operations in the power train". Just for comparison: home cable internet connections offer speeds of only 10 to 20 milliseconds. With the help of informatics specialists at the College of Esslingen, the Stuttgart vehicle experts have now built up a "virtual private network" (VPN) among the various project locations. Only the project partners have access to it, and it allows them to encrypt and send the measurement data of the various test stands via the Internet.

The partners hope to interest other research centers in this idea of "networked laboratories". With the help of the Test Stand Association, the team hopes in future to develop intelligent operating strategies, for example, and to investigate the behavior and ageing of battery cells, to carry out research on cordless charging techniques, and to analyze actual emissions of pollutants by hybrid vehicles in street traffic. As Winke points out, "With topics like these, it's especially important to view systems realistically in their entirety". In any case, it is clear that the laboratory network offers vast potential for promoting the development of electromobility.

Helmine Braitmaier

Wasted Potential
Modular Battery Design for More Efficiency

Lithium-ion cells could be called the heart of the battery in an electric car. The problem with them is: 50% of the cells' potential driving range remains unused in actual practice due to inefficient battery design. Kai Peter Birke and his team at the University of Stuttgart's Photovoltaics Institute hope to change that, and have developed an Industry 4.0-adapted approach.

Tesla, the BMWi and the Opel Ampera all contain batteries for full or partially electric driving. But a look at the "innards" of the three batteries shows that they are radically different from one another. Tesla uses about 10,000 cylindrical cells, while BMW's i-models contain prismatic, cuboid cells, a design that permits a relatively large, high-nominal capacity with only about 100 cells. The Ampera's battery, on the other hand, contains "pouch" cells that look like the vacuum packs used for coffee. Professor Kai Peter Birke, Director of the Department of Electrical Energy Storage Systems at the University of Stuttgart's Photovoltaics Institute, sums it up by saying, "The production of batteries for electric cars is still in its baby shoes, with very small series or manual work." In addition, each manufacturer has a different technique for each individual car model. In Birke's opinion, "That makes it almost impossible to fully exploit the added value of batteries with designs that are generally accepted today."

To properly understand this it is only necessary to see what happens with energy density during the transition from the individual cell to the battery system as a whole. "It drops from an order of magnitude of 200 kilowatt hours per kilogram to only 100," says Birke. However, it is precisely energy density which directly affects the travel range of an electric car. To put it somewhat flippantly, electric cars cannot leave the horsepower of their cells on the road. "That means that better battery design is the key to longer driving ranges," says Birke. But there's more: he also sees suitable battery designs as the way to better production, repairs, and recycling. Birke's team is presently demonstrating this in a three-year project called "Libelle" (short in German for 'Lithium-Ion Batteries with Self-Sufficient and Light-Weight Units'), under the direction of Christoph Bolsinger. The project is sponsored by the Vector Foundation in Stuttgart and will end in early 2018.

Stable, But Not Heavy

"Modern batteries need to be light in weight," says Birke; "that will automatically increase their energy density." Quite the opposite is true of today's established lithium-ion batteries: they require a stable housing which can protect them against environmental factors and against destruction in case of an accident. Even at today's highly-developed stage, the technology of lithium-ion cells is highly delicate, as becomes clear when electric cars burn – seldom as that may be.

The battery design which has been developed in the 'Libelle' Project exploits the mechanical sturdiness of such cells according to the principle that "one toothpick alone can't support much weight, but many toothpicks together can carry a lot." The Stuttgart team's modular design is also compatible with independent and flexible production of all cell types – an option to be found nowhere else in actual practice at present. "We take an Industry 4.0-compatible approach," is how scientist Birke sums it up. To achieve this, Birke and his team use a standard commercial cylindrical cell type with a diameter of 18 millimeters and a length of 65 millimeters, since cylindrical cells offer the highest energy density per kilogram at comparable volumes. The research team puts seven such cells into holes drilled in a honeycomb-shaped thin plate. "Our experiments have shown that these cells can withstand the physical stresses which typically arise in car accidents, no

Seven at one blow: when firmly fixed in place in thin, honeycomb-shaped plates, the cylindrical storage cells become sturdy modular units that make optimum use of available packaging space.

Photo: University of Stuttgart/Max Kovalenko

matter whether they are horizontal or vertical in direction," says Bolsinger. "We use this in our design to turn the cells into self-supporting units." Another, identical plate tops off the cells, which stand vertically in their base plate. "The honeycomb shape allows us to make entire systems with these modules and to make optimum use of the available packaging space," says Bolsinger. The modules can be placed next to one another or stacked. Insulating or conductive elements which establish mechanical and electrical connections are inserted by the research team into spaces intentionally designed into the honeycomb module plates. A printed circuit board for electronic monitoring is located parallel to the cells at the edge of each module. "The housing of the finished battery now need protect the battery only against environmental factors like moisture or dust," says Birke. "That makes it very light in weight."
Such a modular principle also makes it possible to recycle the battery, since there are no longer any welded connections.

One-Third More Efficiency

The research team has constructed laboratory demonstrator models with both series and parallel wiring and has successfully achieved an operating voltage of 48 volts. "That is of course inadequate for use in electric cars, which require 400 to 800 volts," says Birke. "But our aim was simply to demonstrate the feasibility of the principle; we can scale upwards at any time."
Whereas energy density in classical designs drops by a factor of 2 during a transition from the cell to the system as a whole, this factor is only 1.8 in the demonstrator models – even without cooling. "Given adequate cooling – and we're working at present on it with the University of Stuttgart's Institute for Plastic Technology, we hope to achieve a factor of at least 1.5, and are even aiming at 1.2," he says. At an energy density of 200 kilowatt hours per kilogram on the cell level that would then be 133 kilowatt hours per kilogram on the battery level, which would be 33% more than is presently possible.

Michael Vogel

The Master of Saws
Dr. Nikolas Stihl Introduces the Digital Age to Motorized Manual Forestry

Anyone who works professionally or privately with wood knows them: the motorized saws from Stihl. And with good reason: these hand-held tools with their characteristic bright-orange color are regarded by experts and users as "the Mercedes" of motorized saws. And their fame is worldwide. This family-owned company and its products have dominated the market and the competition, apparently with ease, for more than 90 years. In doing so, they have quietly and unobtrusively mastered the many challenges raised by the onset of digitalization and the inexorable march of Industry 4.0 into production processes and the modern working world. The reason for this success? "It's because we began facing the challenge 20 years ago," says Nikolas Stihl, Ph.D., an alumnus of the University of Stuttgart. He should know: he is, after all, the grandson of the company's founder and has chaired the Advisory Board of Stihl Holding since 2012 while also serving as Chairman of the Supervisory Board of Stihl AG.

? Dr. Stihl, you once said, "We have 90 successful years behind us and every reason to think that this success will continue" – what makes you so confident?

› I'm a firm believer in our strategy; it has proven its value up to now. We have been the technological leader of our industry since the company was founded. My great-grandfather invented the original product, and we have continued to develop it ever since.
We have reached our present position by always being quicker and better than the competition, and we still are. I have great confidence in our engineers and in all of our employees. The areas of competent applications which we have built up over the years will continue to put us on a solid footing. And no matter what power system we might use in future, we'll still be delivering the best products on the market. I'm convinced of this.

? You're a manufacturer of manual tools: doesn't the whole issue of Industry 4.0 give you pause?

› We've basically been digitalizing our products for 20 years, and we have a long history of working digitally in both the primary and secondary value-added chains. For example, our two-stroke motors have an exhaust gas filtering system that produces more than 80% fewer emissions than 20 years ago, and that would have been impossible without digitalization. I see our technological leadership not only in our development of new products but also in the fact that we produce a high proportion internally. We have built up a global production alliance that can function only if all of our plants communicate with one another: unthinkable without digitalization.

? Are you saying that Stihl has already integrated Industry 4.0 into its production processes?

› We're working on it.

? And also into your products – for example with regard to "Smart Gardening", meaning automatic groundskeeping?

› There too, we're in the thick of it. For example, we've introduced electronic motor control systems and are currently developing systems that network our individual products and either make them intelligent or digitally generate value-added chains be-

"We've basically been digitalizing our products for 20 years, and we have a long history of working digitally in both the primary and secondary value-added chains."
Dr. Nikolas Stihl

Photo: University of Stuttgart/Max Kovalenko

tween the products and the retailers. This, of course, also makes it possible for our end customers to use our products more accurately and more economically thanks to their own digital areas of competence.

? When a company is to be digitalized, do family-owned companies have an advantage over corporations because of their clearly organized structures?

› No doubt about it. But the all-important thing is to believe in what you're doing and stick to it. Fundamental changes require time and vast expenditures. It would be easy to increase profits in the short term by throttling expenditures. But we don't buy that. This is where a family-owned company has an advantage inasmuch as its management structures remain constant over a very long period of time. That makes it possible to think much farther into the future and pursue a long-term strategy.

? Digitalization requires support from the employees. How is that working out at Stihl?

› Our management-level personnel have the task of uniting our employees behind us on this path. For their part, our employees can be sure that we will not let anyone go in order to streamline our operations. Every employee is free to submit improvement suggestions without fear of reprisals. We promise each person that he or she will be given a job that is at least equivalent to their present one, and we've always kept our word on that up to now.
But in addition to making big leaps in innovation we also need the many small, iterative steps that make our products better. That in turn requires well-trained employees, and this is an area where we have implemented the German dual training system worldwide – not only in production, but also in our business procedures and in the technological area. These trainees are often the very ones who come upon good, often highly innovative ideas.

? That brings us straight to your own training at the University of Stuttgart. What did you gain from that time?

› How to work intensively at research. That is still helping me today in speedily opening up new areas. And we mustn't forget that while the University of Stuttgart is a research center with outstanding basic research facilities, both its own institutes and those

Their orange-colored housing stands out from the crowd: high-tech motorized saws from the House of Stihl.

Photo: University of Stuttgart/Max Kovalenko

of the allied Fraunhofer Society provide an excellent link to the world of actual practice. Even when I was there, many institutes had lines of contact to the region's major companies. Research is the important central task of all universities, but basic research also needs to be actually applied – and Stuttgart offers both in a very attractive mixture.

? Would you say that today's young people who graduate from our universities are well-prepared for actual practice in companies?

› They're well-prepared, but it usually takes up to a year before they find their footing in the different kinds of company areas. The possibilities and requirements offered by a university are not the same as those in a production company. But their motivation is invariably very high because they enjoy working with concrete products.

? And what about the Stihl Company's next generation?

› My son is studying chemistry – at the University of Stuttgart, I might add – and my daughter is a liberal arts student, and the children of our company's other managing partners are also in the midst of their training. So I see no reason to exclude a possible order of succession. But every person must first find his own path in life. For us it has never been

– and still isn't – a question of “You must” do this or that. What comes first is “You can" and then, if willingness is present, “You may" do it.

? Is that why you yourself first went out into the world?

Yes, a person wants to prove something to himself or herself. If a person does well in other companies, he can be confident that any praise he earns is genuine. And also it does no harm to gain experience and to do things that aren't done in one's home company. I'm sure I could have done the work of my first job as a designer at Mercedes in my family's own company, but things were completely different in the world of management consulting; I learned a lot there. I wouldn't want to have missed those days.

? What does the future of Stihl tools look like today?

Digitalization, rechargeable drive batteries, environmental protection, and systems concepts – those are the issues that will occupy us for the foreseeable future. We must continue to develop in all of our areas. That also means multiple-track progress, for example, as in the optimization of our combustion engines on the one hand and ongoing development of rechargeable drives on the other. And then there's our transformation from a product manufacturer to a systems provider. But these issues are not unique to us; they are the major challenges facing the whole of Baden-Württemberg's industrial world.

Many thanks for taking time for us!

The questions were put by Dr. Hans-Herwig Geyer and Martina Hönekopp

Dr. Nikolas Stihl studied machine design and construction at the University of Stuttgart. After graduating as a diploma'd engineer, he got his Doctor's Degree at the Faculty for Machine Design, Construction and Processing Technology at the Technical University of Chemnitz, Germany. The topic of his dissertation was “Complex Optimization of Motorized Manual Forestry as a Work System”.
Stihl first gathered practical experience from 1987 to 1990 as an engineer at Mercedes-Benz AG in Stuttgart, where he helped develop a 12-cylinder engine. He then worked as a management consultant at the German branch office of Arthur D. Little in Munich. That same year, Stihl rose to the position of Assistant to the Managing Directors of the Stihl Business Group. Shortly thereafter he was directing product management at the motorized saw division of Stihl Incorporated in Virginia Beach, U.S.A. In 1993 he then took over management of Viking GmbH in Austria, a position which he held until 2011.
As a Managing Partner of Stihl Holding AG & Co. KG, Dr. Nikolas Stihl became Chairman of the Advisory Board of Stihl Holding AG & Co. in 2012 and at that time also took over the Chairmanship of Stihl AG's Supervisory Board from his father, Hans Peter Stihl.

Networks 4.0

Digitalization and Industry 4.0 are not only changing our worlds of production, work, and life with breathtaking speed. They are also redefining the worldwide division of labor and are leading to new forms of collaboration without regard to the borders between countries and continents. This makes globalization and internationalization a central challenge for schools of higher learning. Where, after all, is there a better place to learn networking solutions for global problems than at a college or university whose student body includes a high proportion of persons and scientists from abroad? Or during a period of study or in a research sabbatical in another country?

The University of Stuttgart prides itself on being a "networked player on the international stage"; that is part of its philosophy and one of its strategic aims, and this manifests itself in the University's internationalization strategy. One of the building blocks in this is the University's participation in international training and career fairs around the globe; they give visitors from elsewhere a glimpse of the possibilities for study and research offered by the University of Stuttgart and establish first contacts with them.

In line with this, the University's Rector, Prof. Wolfram Ressel, along with Dr. Wolfgang Holtkamp, Senior Advisor for International Affairs, like to appear personally and talk about career tracks at the University of Stuttgart at important forums like the annual meeting of the German Academic International Network (GAIN), which is the largest network and career fair for German researchers in the USA and Canada. Moreover, the University of Stuttgart and its international partners are regularly represented at network trade shows for the European, American and Asia-Pacific areas and actively campaign for cross-border research exchanges.

Boston
2013/2014/2015/2016/2017

San Francisco
2013/2015/2017

Washington
2016

Saragossa
2017

Mérida
2017

Guadalajara
2017

Medellín
2013/2015

Bogotá
2013/2014/2015/2017

Cali
2014/2017

Lima
2015

Antofagasta
2013

Santiago de Chile
2013/2015/2017

São Paulo
2013/2014

Concepción
2013/2017

Universität Stuttgart

International Trade Show Attendance by the University of Stuttgart in the years 2013 to 2017

Izmir *2015*

Ankara *2015*

Istanbul *2015*

Seoul *2016*

Taipeh *2014/2015/2016*

Taichung *2016*

Tainan *2014/2015*

Campinas *2013*

Johannesburg *2016*

Kapstadt *2016*

- MIT European Career Fair
- GAIN
- Europosgrados
- Promotion Tour Brazil
- Expo Estudiante
- European Education Fair Taiwan
- IEF Türkey
- Study in Europe Fair

Attendance at Network Trade Shows:

· NAFSA (North America)
St. Louis, San Diego, Boston, Denver, Los Angeles.
· APAIE (Asia-Pacific):
Hongkong, Seoul, Peking, Melbourne, Kaohsiung.
· EAIE (Europe):
Istanbul, Prag, Glasgow, Liverpool, Seville.

Programming Happiness

In Austria's Southern Tirol, Daniel Graziotin and his team seek to pinpoint happiness factors for software developers

All-around contentment can improve a software developer's ability to analyze and solve problems by five to ten percent. That's the finding of Dr. Daniel Graziotin and his colleagues at the University of Stuttgart's Institute of Software Technology (ISTE). Now the team is conducting a major study in Stuttgart, Germany, Bolzano, Italy, Trondheim, Norway, and Helsinki, Finland to find out what makes developers happy or unhappy in their (professional) lives. The insight to date: companies have more influence than previously thought.

Google offers a masseur and a fitness studio in its wellness center at Apple's central headquarters – just one example of how IT companies often make headlines with extras for their employees. And the studies of 30-year-old software technology researcher Daniel Graziotin show that they are not far off-base in trying to improve the productivity of their employees. The figures show it: satisfied program developers write better software. What can a company do to influence the contentment of its employees? To find this out, Graziotin and Xiaofeng Wang and Pekka Abrahamsson (now in Trondheim, Norway), his former thesis advisors at the Free University of Bolzano, and Fabian Fagerholm of the University of Helsinki interviewed more than 2,000 software developers from 88 countries. So many answers came in from all directions of the compass that the four-man team is still evaluating them bit by bit. But as the initial study results show, no matter what the nationality of the software developers may be or in what part of the world they live, their work satisfaction is only rarely affected by private problems and never by their salaries. On the contrary: the factors centrally affecting developers' emotional wellbeing are superiors, colleagues, and work resources.

The research team worked out and used a two-part online questionnaire. The first part included the widely-used psychological SPANE Test (SPANE = "Scale of Positive And Negative Experience"). This test makes it possible to determine the interviewee's degree of personal contentment. "If we look at Internet texts written by developers, we find a wealth of lamentations and complaints about superiors, colleagues and the work environment," reports Graziotin. "This creates the impression that developers tend to be unhappy people. But then, surprisingly, we found that they are a comparatively happy segment of the population." On the SPANE-Test scale of -24 (very unhappy) to +24 (very happy), the developers had an average score of +9. The average among the general population is about +3 to +6. "We still don't have an explanation for why software developers are happier than other professional groups, but at least we know now that it is a fact." Now the team aims to answer four central research questions using the second part of their survey: what are the reasons why a software developer is happy? What makes him unhappy? What is the result when he is happy? And what is the result when he's unhappy? Since the participants wrote their answers in open text boxes, Graziotin and his team are currently processing a mountain of data. "We have the dimensions 'happiness' and 'unhappiness', and we now have the reasons for and the consequences of both. Up to now, we have analyzed their consequences and the reasons for unhappiness. But what we still don't know is exactly what makes developers happy. We're still working on it," says Graziotin.

It's Not the Private Sphere

The private sphere is usually not a primary factor, but the results to date were sometimes astonishing. The team found a distinction between internal influencing factors stemming from the respective developer's personality, and external factors that affected

his or her work from the outside. “It was also surprising for us that external factors were four times as often present in unhappiness as internal ones. That means that superiors can do a great deal here,” says Graziotin. “We had expected to find that a negative attitude in most cases is connected with personal problems and with events in the private sphere; but our study showed that feelings of unhappiness most often had to do with technological problems related to resources and work processes.” The researchers divided the 219 factors named by the survey participants into 18 categories. The one most often named was: “No progress in solving problems”. In terms of method, this is one of the internal factors, but of itself it yields little information, according to Graziotin. “Many added that they lacked proper resources or were blocked by their colleagues or management personnel,” he says. “That's interesting here, since this concerns precisely the background information that we want to extract from the data.” The second most important category is “time pressure”. “There's no way to avoid this entirely,” says Graziotin, “but there are tricks for reducing it. We've found that overtime work does not contribute to higher productivity” (this is supported by other studies as well). That means that it is often better to eliminate the stress and let people go home on time. The result: they are well-rested and more productive the next day.

Photo: University of Stuttgart /Max Kovalenko

Software developers like to deliver good quality, as was shown by the third-most frequently named category, “Poor code quality”. For many IT companies, speed is the only value, says Graziotin. “It helps when a company says in effect, ”‘Good quality is important to us’”. Another category often named was 'boring and highly repetitive work' – which of course cannot be completely avoided; but a redistribution of assignments can help. “Anyone whose work is invariably monotonous will invariably perform less effectively.”

The top reasons for dissatisfaction also included “colleagues who do poor work” and thus have a negative effect in some way on one's own work. When someone says, “I feel inadequate for my job” (No. 5 in frequency), it may mean that superiors are called upon to assign tasks in such a way that those receiving them are competent to carry them out. Together with purely private problems, a category named only occasionally, this was the only other category that was personally related to the developer.

The Artist Engineer

But why should companies find it at all important for software technicians to be contented? In Graziotin's view, developers are creative persons who fall somewhere between artists and engineers. Emotions affect creativity much more strongly than in the case of a skilled tradesman or an industrial worker. It

was also instructive for him to see which factors in the study played no role at all, such as differences in mentality and/or nationality. He also found that demographic factors like company size, professional experience – whether as an employee or an independent business person, and whether the work was full-time or only part-time – were all incidental regarding personal happiness and the impact on work. Even gross earnings played no part in this.

Graziotin noticed as early as 2010 while writing his Master's Thesis at the University of Bolzano and asking why many developers work more productively than others that research on the subject dealt exclusively with technological questions. During a conversation with Pekka Abrahamsson about his Doctoral Thesis, which he began in 2013, Graziotin brought up the problem: "I might have the best tools in the world, be well-trained, and work in a great team, but if I'm in a bad mood on any given day, I'm not going to produce good work. But nobody pays attention to this." His dissertation thus aimed to clarify the connections between happiness and work performance on the part of developers. "What came out was clear as day: happy persons do more, unhappy persons do less. But it's up to science to explain why this is the case." Working with Xiaofeng Wang, his second adviser, Graziotin therefore decided to take psychological theories into account as well. "That was the beginning of this research," which no one had previously done before him. Partly because his results gained widespread attention, the 30-year-old researcher from Austria's Southern Tirol is now continuing his research in Stuttgart with a stipendium from the Alexander-von-Humboldt Foundation.

Employees Want to be Heard

Although happiness is only one factor among many, it has relevance, as Graziotin has been able to show. "What motivates me above all as a person is to improve the working conditions and the sense of well-being of software developers." IT companies profit directly from the work of Graziotin's four-man team, which works with publicly available data. "Any manager of a software company who wants to improve the ability of his employees to perform by improving their emotional well-being can find the our results listed on the Internet." While precise statements are possible only in individual cases, "The answers of our study participants make it clear that the primary problem is a lack of support," says Graziotin. Developers find it essential that colleagues and management really listen to them. "The first important recommendation to companies would be: do an anonymous survey like ours, and make it possible for superiors to give personal support." Strategic decisions are usually made by management, and most persons agree with that. But Graziotin's insights indicate that developers are usually not consulted at all and are often compelled to work with unwanted technological resources. If they were at least to be heard more often, he is convinced, many software developers would be much happier.

Daniel Völpel

The Living University
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Automotive Technology Leaders in Industry Introduce Themselves

Top managers from the automotive world talk about current issues in research, development, production, marketing and sales.

- *Mondays 6:00 p.m. to 7:30 p.m.*

Hörsaal 47.02, Pfaffenwaldring 47,
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- *December 4, 2017*

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Michael Drohlshagen, Dr. Ing. h.c. F. Porsche AG

- *18 December 2017*

Engineering Service Providers – A Field Affected by Electromobility, Connectivity, and Autonomous Driving
Henry Kohlstruck, MBtech Group GmbH & Co. KGaA

- *10 January 2018*

The Bosch World of Innovation: Introductory Lecture by Dr. Volkmar Denner, Chairman of the Board of Robert Bosch GmbH

- *15 January 2018*

Dual Drive Train Strategy – A New Interpretation: Meaningful Co-Existence of Both Systems
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- *29 January 2018*

The G-Class – An Icon In Constant Evolution for 39 Years
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Questions for Science

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MEETING POINT: Rotebühlplatz 28, Stuttgart

- *5 December 2017*

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Prof. Dr. Jens Brockmeyer, University of Stuttgart, Institute for Biochemistry and Technical Biochemistry

- *6 February 2017*

Deciphering the Human Genotype with Nano-Pores
Prof. Dr. Maria Fyta, University of Stuttgart, Institute for Computer Physics

Preview:
Science Day: 30 June 2018

All events:
https://www.uni-stuttgart.de/universitaet/aktuelles/veranstaltung/index.html

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