Mindshift

Impulses for change – TUM Campus Heilbronn

Digital twins

Venturing into a new era | Page 12

Content

Issue No. 6

Dear Readers,

Hand in hand into a new era – with the image of a human and a digital runner gracing the cover of this sixth issue of Mindshift, I invite you to discover fascinating insights into the groundbreaking research being conducted at TUM Campus Heilbronn.

Against the background of the founding of the TUM Heilbronn Data Science Center, in this issue the spotlight is on data science and artificial intelligence. The two fields are closely linked and are rapidly gaining importance in society, the corporate sector, and science. Research at TUM Campus Heilbronn includes investigating how digital twins can help optimize supply chains in the future. Digital twinning and data science offer huge potential in medicine and healthcare as well, for example, when developing new medical and biotechnological processes or determining how healthcare can benefit from data analyses, forecast models for machine learning, and data-driven optimization methods.

Analogously to digital twins, which are not static elements, TUM Campus Heilbronn, founded in 2018, increasingly is turning into a powerhouse for designing digital transformation. By extending our program to include ten new professorships in data science and artificial intelligence and by fostering internationalization, we are signaling that we will keep our focus on the global impact of our research. We are interested in using data science for the really big issues, and currently are establishing new forms of cross-discipline collaboration.

In this issue, Prof. Luise Pufahl, who recently joined us at TUM Campus Heilbronn, discusses the treasure trove that data can be, the characteristics of process mining, and where her research comes in. Our scientists not only speak up in Mindshift, they also are sought out by top-tier media to share their findings. You can read about the publications from page 24 onward. The third edition of the webinar series hosted by TUM Campus Heilbronn and the University of Oxford dealt with the development of social media and its potential threat to democracy. The webinars are designed to bring knowledge from discussions on global research to the general public.

We hope you enjoy the read and gain fascinating and inspiring insight from this issue of Mindshift.

Prof. Helmut Krcmar
Founding dean (2018–2020) and representative of the president
for TUM Campus Heilbronn
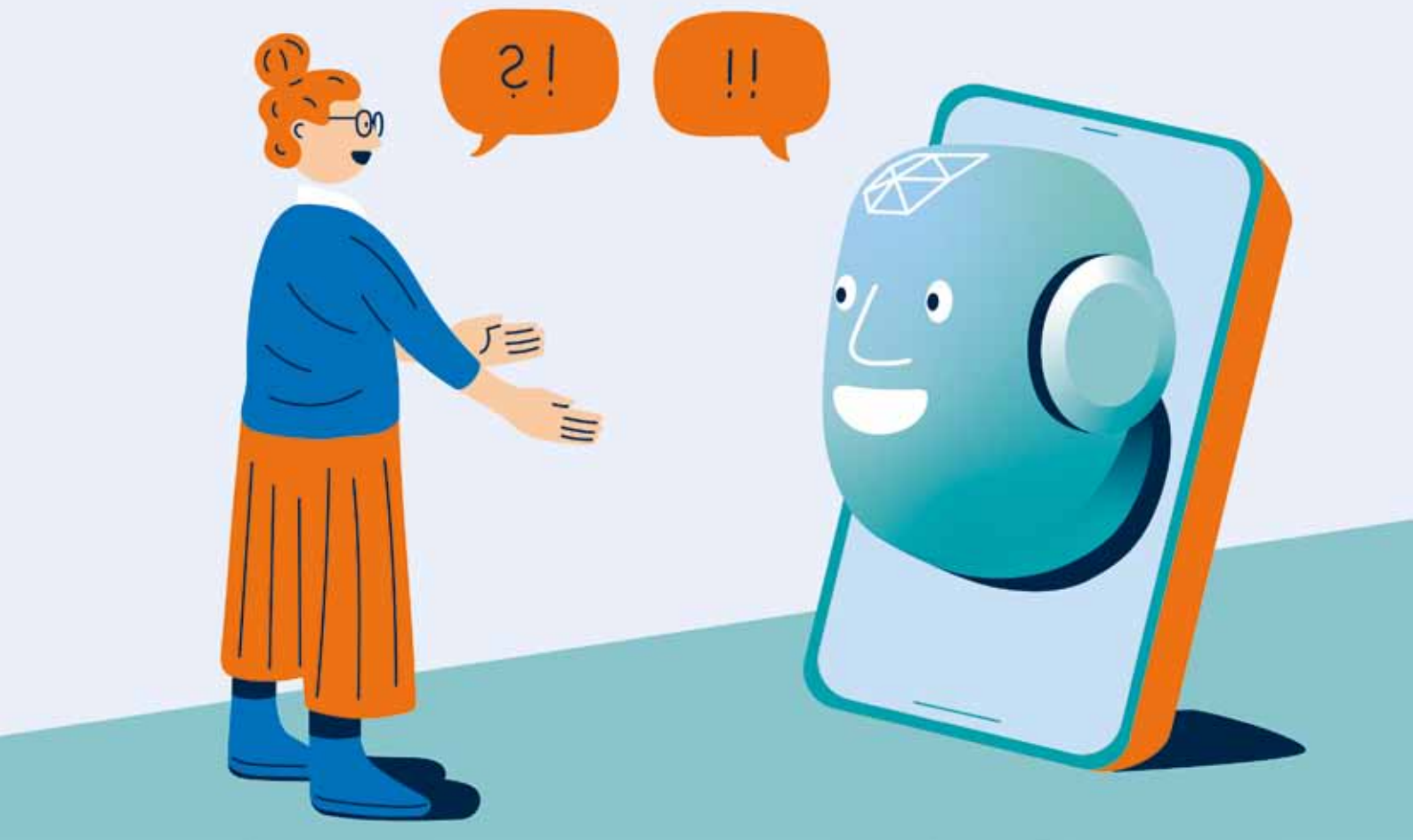
AI in the midst of society

With the founding of the new Data Science Center, TUM at Campus Heilbronn underscores its focus on data science and artificial intelligence (AI). For a long time, AI has been considered a projection surface for people's expectations and wishes. The most recent hype about AI-based language programs such as ChatGPT is cause for both hope and concern. At the end of the day, it is all about responsible use.

British fantasy author Sir Terry Pratchett has been quoted as saying, "real stupidity beats artificial intelligence every time." Or is it the other way around? Remember when in 2015 the AlphaGo computer program brought multiple European Champion Fan Hui to his knees a total of five times in the highly complex game of Go?

The relevance of AI has increased substantially. That holds true in the realms of society, the corporate sector, and science. While AI is connected closely with data science, there are differences between the two disciplines. Prof. Stephan Krusche of the TUM School of Computation, Information and Technology (CIT) at

Campus Heilbronn explains: "Data science focuses on analyzing data, and AI is about ways to use data to create intelligent systems that can make decisions autonomously. AI uses data science to train models and enhance the quality of forecasts."

ChatGPT – is that a human speaking?

AI is about technical systems carrying out tasks which normally require (human) intelligence. One example is ChatGPT, the AI-based chatbot launched in November 2022 by start-up and Microsoft partner OpenAI of the U.S.A. as part of the Generative Pre-trained Transformer (GPT) series. Machine learning models and text generating technologies will enable ChatGPT to have human-like conversations. Prof. Krusche says: "ChatGPT uses a neural network trained in the reinforcement learning from human feedback method so it can respond to queries in natural language." This means the bot draws on a gigantic database of texts to generate context-related answers, and learns constantly by interacting with humans. ChatGPT can answer questions (referred to as prompts), make small talk, and solve problems.

The quality of the questions and tasks is crucial, as Prof. Krusche emphasizes: "To achieve the best results when interacting with ChatGPT, users should pose clear, specific, and precise questions, avoid ambiguities, provide sufficient context, hold off on the use of technical terms, use keywords, pose questions one at a time, and stay away from questions with yes or no answers."

AI-based chatbots have their limitations

Dr. Andreas Braun, former CTO of Microsoft Germany, is convinced that ChatGPT makes AI fit for use by the masses and, most of all, simplifies its use. "AI has reached the midst of society. That means ChatGPT may be as significant a breakthrough for AI as the World Wide Web was for the internet."

Although the bot has users in awe, it does have its limitations. Prof. Krusche points out: "Because it lacks expert knowledge, ChatGPT may not be able to provide quali-

„„

We set up best practices for integrating AI into the education system and for limiting the challenges we have identified and are developing applications based on ChatGPT.

Prof. Stephan Krusche, TUM School of Computation, Information and Technology

fied answers in complex or specialized areas and it does not fully understand human emotions and nuances. So far, ChatGPT delivers bibliographical information and references, can map trains of thought, and can draw on extended and reliable sources of knowledge."

Meanwhile, everyone's attention was on a test conducted by Prof. Christian Terwiesch. He had ChatGPT take the final MBA exam at elite university Wharton School in the U.S. ChatGPT passed. Do universities have to start worrying about students having their exams taken by AI? Does ChatGPT need to be blacklisted?

"

AI has reached
the midst of society.

Dr. Andreas Braun, former CTO
of Microsoft Germany

No prohibition, but responsible use

"We believe that despite its current limitations, prohibiting the use of this technology, as has been done in western Australia and at a Paris university, does not make sense," says Prof. Krusche, referring to the position paper he and his colleague Prof. Enkelejda Kasneci published jointly with scientists from TUM and Ludwig-Maximilians-Universität in Munich. "Instead, we should see ChatGPT as a promising tool that helps students improve their learning experience and provides support to teachers so they can become more productive and offer better, more targeted teaching."

According to Prof. Krusche, it is crucial that institutions use AI technologies in an ethical and responsible manner. Clear guidelines, instructions, and codes of conduct regulating the employment of AI-based bots to ensure

that they are not misused for manipulation or fraudulent purposes could help strengthen trust in these technologies for academic settings. "In addition to setting up best practices for integrating AI technologies into the education system and for limiting the challenges we have identified, we are developing applications based on ChatGPT," says Prof. Krusche, who is a member of the new Generative AI Task Force of the TUM Think Tank.

AI can generate added value for companies

Either way, AI-based bots have a lot of potential – including beyond the university context. Companies can use them in multiple ways to automate processes, increase efficiency, and enhance the customer experience. For example, chatbots can help automate responses to customers' inquiries, process purchase orders, and optimize marketing campaigns. Other fields of application include data analysis, employee training via e-learning, and incorporation into websites.

Prof. Krusche warns: "Companies have to evaluate carefully whether the use of bots actually adds the value they were hoping for, and whether ethical and privacy aspects are being considered."

Identifying relevant applications

From the General Data Protection Regulation (GDPR) to the principles of ethical and responsible use of AI, legal obstacles should not be underestimated. On the contrary says Dr. Braun: "The EU AI Act is waiting in the wings and it is not likely to make things easier in this field. Another important factor is that companies implement the two GDPR core principles of 'by design' and 'by default' – and not only with a view to privacy."

German companies have been rather reticent when it comes to employing AI. For most of them, the biggest hurdle is defining an application case. Dr. Braun remarks: "Use case catalogs can help. I categorize them by four dimensions: bottom line, which includes cost savings or increases in productivity; regulatory, meaning monitoring and controlling regulations including AI self-monitoring of solutions such as ChatGPT; top line, which encompasses growth drivers such as new markets or services; and moon shots, that is, entirely new business models." The AI periodic table (see info box on page 8) can help identify relevant AI technologies and models. That makes sense because ethical and privacy issues always follow use cases as well.

> "
> **While language assistants Siri and Alexa are able to respond to specific questions, chatbots such as ChatGPT which are based on far larger language models can answer almost any question and can be used for longer conversations.**
>
> Prof. Sebastian Müller,
> TUM School of Management

Using NLP for text data clustering

More and more discussions about ChatGPT include mention of a new natural language processing (NLP) era. Generally, the term NLP refers to the processing of human language. The word-based methods are complemented by more advanced, context-based methods which have come along more recently. Categorically, they are suitable for applications with many unstructured text documents or language data which other-

wise would require a great deal of time and money to be processed manually. "We have seen great advances in this field in the past few years. While language assistants Siri and Alexa are able to respond to specific questions, chatbots such as ChatGPT which are based on far larger language models can answer almost any question and can be used for longer conversations," says Prof. Sebastian Müller of the TUM School of Management at Campus Heilbronn.

Prof. Müller gives an example of an application: the customer service center of a major car manufacturer. "Specially trained models can help convert thousands of recorded discussions with customers into text documents automatically," Prof. Müller explains. "Then, the company uses large language models to identify discussions with similar content and to conduct analyses, for example, of complaints, buying interest, or satisfaction rates." The valuable information so obtained can be applied, for example, towards increasing customer loyalty.

According to Prof. Müller, AI-based financial consulting is another potential field of application. "Imagine a conversation in which a person describes his or her current financial situation and long-term goals. Based on this information, the language model makes suggestions, for example, regarding the purchase of financial products." Prof. Müller narrows it down by saying that to meet this purpose, language models – Large Language Models (LLMs), to be precise – must be able to understand highly complex business relationships and to differentiate between true and false because in the end, financial consulting, which in Germany must be authorized by the Federal Financial Supervisory Authority, revolves around the question of who assumes liability for inadequate consulting. "Expenses for models must be made plausible – keyword: explainable AI – and the costs of large language models must be reduced, for example, through more efficient model architectures," Prof. Müller emphasizes.

Taking context into account

Automated evaluation of information is and will remain a hot topic – including at TUM Campus Heilbronn. In their latest research project, Prof. Müller and his doctoral student, Christian Breitung, set out to define a global network of companies based on similarities in business

models. To this end, pre-trained language models evaluate standardized company descriptions to identify potential competitors, suppliers, and clients.

"We use large language models to design a highly dimensional matrix of similarities and for each company we identify businesses that work with a sufficiently similar business model or maintain a direct business relationship. This approach facilitates the automated identification of new relationships among companies, relationships that cannot be detected based on the companies' alliance with a specific industry or with traditional, word-based methods," Prof. Müller explains.

Humans vs. AI?

So, is AI better than the human brain? Can this technology replace people and/or jobs? Dr. Braun has a clear opinion: "We bank on humans plus AI. In almost all cases there is 'a human in the loop,' as we call it – or perhaps there is 'AI in the human loop,' and AI essentially makes work easier and helps increase efficiency and/or quality." According to Dr. Braun, AI processes could be fully automated but he believes they will always be carried out in controlled environments, for example, as part of quality management in manufacturing where rejected products are sorted out automatically and the risks are limited clearly. ●

GLOSSARY

Data science
Methods and techniques used to extract knowledge from data, including processing, analyzing, and visualizing data. The objective is to identify patterns and interrelationships in the data to generate insights and to forecast and support decision-making.

Artificial intelligence (AI)
Technologies that enable computers and machines to exhibit humanlike behavior such as learning, solving problems, and making decisions.

Natural language processing (NLP)
A subarea of AI that attempts to capture natural language and process it in a computer-based manner through the use of rules and algorithms. The objective is to facilitate direct communication between humans and computers.

Explainable artificial intelligence
The objective is to explain how dynamic and nonlinearly programmed systems achieve results. It includes artificial neural networks, deep-learning systems, and genetic algorithms.

ChatGPT
An AI-based chatbot developed by OpenAI as part of the Generative Pre-trained Transformer (GPT) series. The objective is to have humanlike conversations through the use of machine learning models and text generation technologies.

The periodic table of artificial intelligence

The AI periodic table project is directed by the Bitkom industry association. The dedicated website illustrates fields of AI application in corporate settings. A total of 28 elements have been identified and categorized in a manner reminiscent of the periodic table of chemical elements. Among the 28 elements are language and image recognition, relationship learning, and the control of robots or autonomous vehicles. The website shows what each element can accomplish, how it can be employed in companies, and what suppliers deliver the respective technologies and solutions.

Every AI element in the periodic table is allocated to one of three groups: Assess, Infer, Respond. To optimize an application case using AI, at least one element must be selected from each group. Take autonomous driving, for example: A self-driving vehicle speeds towards the back end of a traffic jam. Within seconds, the car has to capture the traffic situation (Assess), calculate the probability of collision (Infer), and initiate an adequate brake or swerve process (Respond).

DeepL – not only correct, but stylistically confident

DeepL is known for its translator tool developed to help convert text from one language into another. In January 2023, the Cologne-based company launched the beta version of DeepL Write, an AI-based writing assistant. We interviewed DeepL CEO Dr. Jaroslaw Kutylowski.

For us laypersons – how does DeepL Write work?

Dr. Jaroslaw Kutylowski: For now, DeepL Write is available in English and in German. The program is based on neural networks similar to DeepL Translator which are trained purposefully using diverse machine learning techniques. You can compare them to the human brain. We all have been there, sitting for what feels like an eternity working on the same sentence. We know it is not quite right yet and we also know the solution is somewhere in the inner regions of our brain. We just have to dig long enough.

Is this where the AI-based writing tool takes over and starts digging?

Dr. Jaroslaw Kutylowski: Exactly. AI digs and delivers sensible alternatives in real time. Personally, I use DeepL Write a lot in communications for work. I trust that my ideas and thoughts are expressed precisely and accurately and I finish my e-mails in no time.

In what areas can companies use DeepL Write?

Dr. Jaroslaw Kutylowski: There are a number of applications. In principle, DeepL Write supports anyone looking to communicate in any type or form – be it writing e-mails, drawing up reports, or formulating sales pitches. DeepL Write can streamline these processes. Especially when international teams collaborate, DeepL Write can lend a helping hand. Take users in Japan, for example: Even though they invest a lot of time and effort into learning English, many feel insecure in global communications. DeepL Write helps them express themselves with stylistic confidence.

Knowledge
for the digital age

New technical data processing and analysis opportunities have taken center stage. TUM bundles its competences in data science at the Munich Data Science Institute and the TUM Heilbronn Data Science Center.

Data science encompasses much more than algorithm research for data processing. The term refers to a bandwidth of scientific disciplines and activities which in their entirety address the use of data to answer relevant questions and to solve problems. The spectrum ranges from fundamental research to domain-specific applications and technology transfer, that is, the transfer of novel algorithmic solutions to applications in the field.

A major contributor to successful outcomes in data science is the collaboration between researchers in the field of fundamentals and application disciplines. Without constant information exchange and close cooperation, the algorithms could not be employed for their intended purposes.

Cross-discipline cooperation wanted

Due to the increasing importance of data and data processing, the collection, management, and analysis of data have become major assets for researchers. In addition, the need for inter- and trans-discipline cooperation has increased. The goal is to raise awareness of the cross-discipline nature of data science.

To be able to implement data science in practice successfully, first a number of challenges must be addressed. The long-term goal of development and use of data science first and foremost is conditional upon sensitizing people to the potential impact of decisions. For example, the decision to develop elements of algorithms can lead to distortions (referred to as biases) in the results. However, such effects cannot always be predicted directly and may not be identified until a later date. Therefore, the application of data science requires a critical eye to pinpoint and address adverse effects. Despite the potential repercussions, the enormous opportunities that data science provides prevail. Balancing these opportunities with certain risks is a responsibility that necessitates academic research across multiple disciplines.

Munich Data Science Institute

To tap the potential of data science, in 2020 TUM founded an interdisciplinary institute, the Munich Data Science Institute (MDSI), which offers a joint home to data science, machine learning, and artificial intelligence. The MDSI is a research center, a service institu-

tion for scientific projects, and a training facility for the next generation of data scientists.

Close to 60 professors of computer, engineering, natural, life and social sciences, and medicine make up the core members of the MDSI. In addition to the focal topics with their strong practical relevance, the MDSI promotes fundamental research on AI and data science. By collaborating closely with institutions in the field of entrepreneurship, the MDSI strives to make current developments available to society quickly.

"Conducting research with large amounts of data has its challenges, and not all of them are connected directly to the field of research," says Prof. Stephan Günnemann of the TUM School of Computation, Information and Technology. Be it proteome research, social media analysis, or inorganic catalysis, selecting suitable data structures and analysis methods is crucial to every practical application. Prof. Günnemann adds: "The MDSI provides consulting services to researchers at TUM as early as the planning stage and assists them during the entire course of their projects."

Data science and machine learning also play important roles in teaching at TUM. The MDSI contributes actively, and for many years jointly with the Data Innovation Lab has been offering a research internship operated in cooperation with the private sector. Here, students in all disciplines are given the opportunity to work on data science projects.

A joint initiative of the MDSI and Ludwig-Maximilians-Universität in Munich, the Konrad Zuse School of Excellence in Reliable AI is a trailblazing project regarding the teaching of AI. Throughout Germany, the Federal Ministry of Education and Research and the German Academic Exchange Service finance three Zuse Schools which attract young people from around the world who are talented in the field of AI. "Every year, master and doctoral students can apply to Konrad Zuse School," says Prof. Günnemann. The teaching content complements the participants' studies or doctoral programs. "As the name implies, focus is on reliable AI, that is, the question of how we can ensure that machine learning algorithms do what they were programed to do," Prof. Günnemann explains. Members also have access to internships, sojourns abroad, and courses in science communication and other fields.

Prof. Günnemann outlines the program: "Over the next few months we will kick off a lot of new research projects. In addition, we are offering workshops on diverse data science topics, certification programs, and hackathons – there is something for everybody." The first research projects will be evaluated soon.

TUM Heilbronn Data Science Center

Even though data and ideas can be shared over long distances, spatial proximity fosters collaboration and cooperation. The expansion of TUM Campus Heilbronn will include the founding of the TUM Heilbronn Data Science Center (TUM HDSC) which will provide a home to data science. Prof. Dr. Helmut Krcmar, founding dean and representative of the president for the development of TUM Campus Heilbronn, explains: "The TUM HDSC is designed to be the thematic bracket that links diverse disciplines – mainly computer and business sciences – to foster progress in data science." Analogously to the goals set for the MDSI, focus will be on, "tasks that prioritize interdisciplinary and cross-faculty work in the field of data science," says Prof. Krcmar.

As a complement to the MDSI, the main task of the TUM HDSC will be to conduct coordinated, cross-discipline research in data science on the continuum of the development of fundamental principles, all the way to practical applications. Prof. Krcmar states: "That includes cooperative research with external business and science units as well as raising funds externally. Also, the TUM HDSC will offer internal and external workshops as well as the interdisciplinary promotion of young talent, for example, in formats that meet the needs of doctoral candidates."

All the activities will focus primarily on the profile of TUM Campus Heilbronn "for the digital age" and on the resulting interweaving of business administration and computer science aspects. Connecting factors can be found primarily in the areas of digital transformation and family businesses.

Close collaboration with the MDSI is supported by a pool of positions on joint projects, among other things. "Researchers at the TUM HDSC and the MDSI can submit joint project applications and obtain additional tandem positions for the duration of their projects. In this way, the TUM HDSC will not only link computer sciences and business administration studies, but also the TUM sites in Heilbronn and Munich," Prof. Krcmar explains. ●

A twin of zeros and ones

Digital twins are virtual images of reality fed with vast amounts of data and equipped with artificial intelligence. The market for digital twins is growing rapidly, as are the fields in which they are used – everything from planning products and processes through optimizing supply chains and on to mapping entire cities digitally. TUM Campus Heilbronn drives research in this field.

"Houston, we've had a problem!" This radio message reached NASA's mission control center in Texas in the evening on April 13, 1970. The Apollo 13 crew was half way to the moon when an oxygen tank exploded. Everybody realized there would not be a moon landing; the big question was, how will the three astronauts on board manage to return to earth alive? NASA updated its flight simulators, fed them all the information available about the spacecraft's situation, and simulated safe ways for the astronauts to return unharmed. As Prof. Helmut Krcmar, representative of the president for TUM Campus Heilbronn, explained in a presentation, this was history's first successful deployment of a digital twin.

What was a giant leap for aerospace back in the day now, more than 50 years later, has penetrated almost all industries. Just as digital twins can be found in the industrial sector and in logistics, they also are in development for urban planning, medicine, and healthcare. A digital twin is a virtual image of a physical object or system. It offers a snapshot of the moment and also depicts an entire lifecycle based on both existing data and real-time data delivered by sensors. This combination of data, algorithms, and artificial intelligence makes it possible to conduct complex simulations, analyze past errors, and plan for the future. In this way, products and processes can be tested in virtual spaces before they become reality.

Making supply chains more resilient

Digital twinning is a growth market valued at 3.1 billion US dollars in 2020. According to the IT company IBM, some industry analysts estimate that the value of digital twinning will expand to as much as 48.2 billion US dollars by 2026 at least. Why this is so can be explained at TUM.

At Campus Heilbronn, Prof. David Wuttke focuses his research on modeling optimization processes with the support of algorithms and machines. Moving forward, digital twins can help enhance supply chains. They can emulate actual supply chains or individual logistics systems or warehouses virtually. The real-time data obtained is used to analyze and forecast, identify hidden risks, and prevent mistakes. Likewise, digital twins can help simulate a supply chain's level of resilience. "Digital twins identify and eliminate a lot of errors because machines or algorithms that are able to process and visualize large volumes of data allow us to see the big picture," says Prof. Wuttke. "Managers or staff members can engage digital twins to analyze specific areas, dive inside the machine, and draw conclusions."

Opting for the safest alternative

The City of Munich currently is testing ways to create a virtual image of the entire city. The digital twin of the metropolis will be applied in a variety of areas: It will help city administration to digitize its processes and ensure

vehicles handled by the department of waste management are set into motion at the precise moment the sensors on old clothes containers report that the bins are full. TUM's Department of Traffic Engineering and Control has been awarded a contract to provide scientific support for the project. The department's responsibilities include collecting traffic data and simulating traffic situations. New bicycle paths, for example, can be tried out in digital Munich first – and the real city can decide which option is the safest and provides for the best flow of traffic.

Digital twins also are beneficial in battery cell research. High-performance battery cells are essential to electromobility and thus a crucial lever for the turnaround in energy policy. Virtual images can point out weaknesses in production processes and optimize them quickly. The team from the Fraunhofer Research Institution for Battery Cell Production is cooperating with other research institutions to design a digital twin of an entire battery cell production line that will map the factory, the machines used in manufacturing, and the product.

Digital twinning also opens up new opportunities in medicine and healthcare. While it will be some time before we can send our virtual twins to a doctor's appointment, the results of research conducted by TUM's Prof. Jingui Xie (p. 14) and Dr. Tobias Köppl (p. 17) show that this future may not be too far distant. ●

Making healthcare more resilient

The COVID-19 pandemic has made one thing very clear: Our healthcare system is not adequately prepared for exponentially increasing outbreaks of disease. At TUM Campus Heilbronn, Prof. Jingui Xie is conducting research on how data science and analytics can help hospitals improve their planning and their allocation of resources and capacities.

Overburdened ICUs, nurses at the brink of burning out, and emergency physicians fighting to find hospital beds for their patients were the order of the day during the pandemic. Municipal departments of health often found

Prof. Jingui Xie hosted a workshop in Heilbronn.

themselves in difficult situations and were compelled to rely on the Federal Armed Forces to keep up with the recording of infection reports. Some health departments resorted to methods that were unsuitable for the enormous amounts of data accumulated during a global crisis. This healthcare situation was not limited to Germany; it could be observed in many countries around the world.

Equipping hospitals for global crises

The main element that led the healthcare system to the verge of collapse was the dynamic development of the pandemic. Along with the strong fluctuation in demand for staff and free beds, the uncertainty in the forecasting of developments made the efficient use of available capacities extremely challenging for all those involved.

Conventional models of machine learning used for capacity planning typically deliver an average figure for resource requirements. However, they seldom provide reliable forecasts or estimates that consider fluctuations in demand and, thus, are inadequate for needs-based planning.

This is where Prof. Jingui Xie and his research at TUM Campus Heilbronn come in: He has set out to investi-

gate how healthcare can benefit from data analyses, forecasting models for machine learning, and data-driven optimization methods and thus become more resilient when faced with global crises – and in everyday life. Prof. Xie is convinced that efficient hospital resource management can reduce the adverse effects of pandemics such as COVID-19 on public health.

"Hospitals can use data and forecasting models to estimate the number of incoming patients, optimize their headcount through cross-department training and flexible schedules, and allocate resources based on patients' needs," he explains. "By implementing these measures, hospitals ensure that they have enough personnel, equipment, and materials to satisfy demand and to provide adequate patient care while minimizing the risk of burnout and exposure."
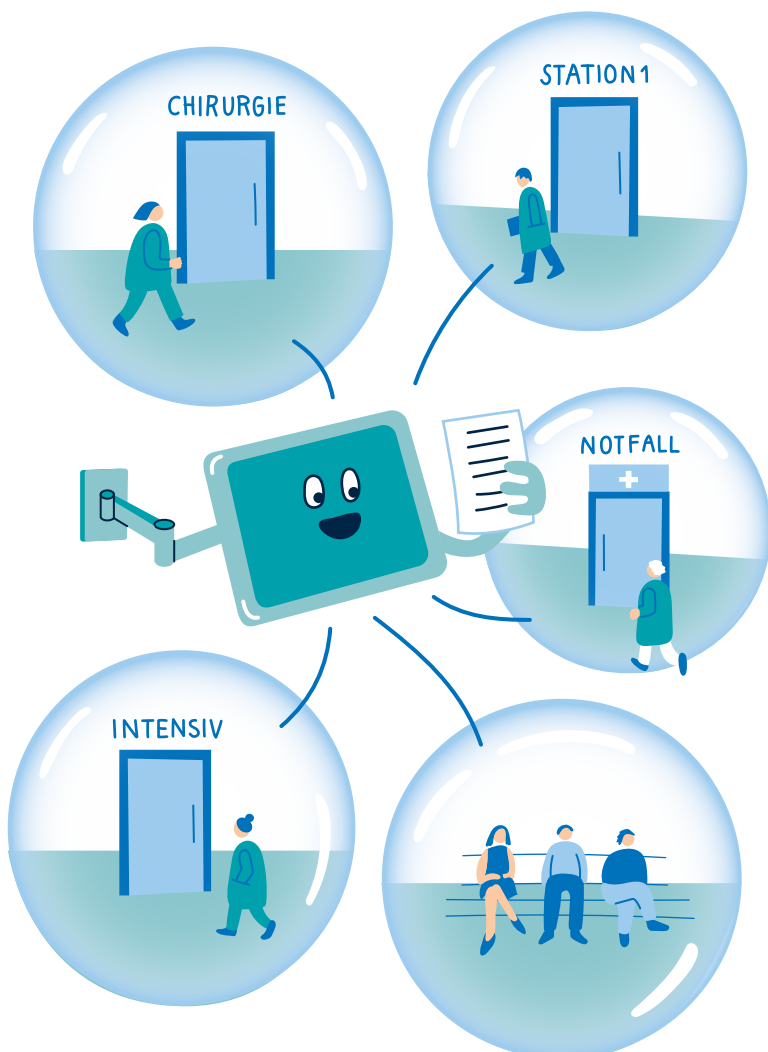
Researchers from around the world came together to discuss one topic: preparing healthcare for crises.

For capacity planning, moving forward hospitals could employ a digital twin that also knows how to make the best use of limited resources. In this way, hospitals would be equipped to handle pandemics and other unpredictable situations appropriately.

Cross-border cooperation is essential

The COVID-19 pandemic also brought to light the fact that no country can master a global crisis on its own. Cross-border cooperation and knowledge-sharing between scientists are key.

To stimulate knowledge-sharing, Prof. Xie hosted a two-day workshop at the Center for Digital Transformation. Twenty participants from internationally renowned institutions of higher education including the University of Cambridge, London Business School, Rotterdam School of Management, Zurich University, and École des Mines de Saint-Étienne accepted the professor's invitation and came to TUM Campus Heilbronn. The researchers shared their expertise on using real-time forecasts to assign free hospital beds to COVID-19 patients in one region or across regions in the best manner possible and to allocate treatment so as to make optimal use of capacities and at the same time keep waiting time acceptable to patients.

"The workshop was a great opportunity to share ideas and trigger joint research activities," said Prof. Nadia Lahrichi of Polytechnique Montréal. In her presentation she introduced a new approach to integrating the use of beds and the selection of patients into overall surgical

Prof. Nadia Lahrichi, Polytechnique Montréal

Models that can be transferred to other industries

Workshop participants also discussed the challenges of health analyses based on big data. "These include data quality, privacy concerns, interpretability, and ethical considerations," said Prof. Xie. "We have to face these challenges to ensure exact and fair results while respecting patients' privacy and ethical concerns." These models will help increase the resilience of health-care systems significantly.

Prof. Xie highlighted: "Thanks to improvements in medical resource management, these models can benefit patients, nurses, and the economy as a whole." In addition, they can be transferred to other industries, especially those affected by volatile demand. "Sturdy, data-driven solutions for optimization can help reduce the wasting of energy or perishable products because they facilitate the dynamic and precise alignment of capacities and demand." ●

planning for operating rooms (ORs). The concept starts with the selection of patients to be on the OR list for a specific period of time and the allocation of a date, an OR, and a time window for every medical specialty. The goal is to better predict the probability of downtime taking into consideration relevant factors so every OR can be at optimum capacity.

Prof. Jean Pauphilet of London Business School focuses his research on discharge management. In cooperation with two U.S. hospital networks, Prof. Pauphilet has developed innovative machine learning models intended to use real-time data to make precise forecasts about the lengths of stays of in-patients. "Updates in real time can help physicians and nursing staff identify medical risks or obstacles that impede a patient's discharge and improve the quality of care," he explained.

Prof. Jean Pauphilet, London Business School

A good run for
new health data

Dr. Tobias Köppl is a mathematician at the service of health. He uses scientific computing methods to support the development of new medical and biotechnological processes in individualized medicine. His numeric models of the cardiovascular system, for example, help improve movement therapy. For this project, Dr. Köppl works with ultramarathon runner Jürgen Mennel from Neckarsulm and others.

So far, Jürgen Mennel has run 480,000 kilometers in his lifetime. "My overarching goal is to reach 500,000," he says with a smile. Jürgen Mennel started training at the age of eight and in 1988 he became vice world champion over 100 kilometers. As a sports therapist, Jürgen Mennel knows from experience that "moving is curative."

He carried this message with him when he ran the 2,200 kilometers from Heilbronn to Athens on the 2500th anniversary of the Athens Marathon in 2010. At about the same time, scientists published new research findings about the positive effects of sports on our health. This was to become the starting point for the development of the Digitale Laufbandplattform (Digital Treadmill Platform) on which Jürgen Mennel is working in cooperation with TUM, Fraunhofer IAO in Stuttgart, Fraunhofer Kodis in Heilbronn and other research institutions and universities.

"We wanted to find out how we can use data collected from people on the treadmill to draw a virtual map of what exactly goes on in the body," Jürgen Mennel explains. The data ranges from image material for visualizing blood vessels and bones to pulse and blood pressure curve measurements. "What is even more important: How do we benefit from this insight, for example, to improve movement therapies?"

Jürgen Mennel, initiator of the Digital Treadmill Platform

However, simulating body processes is anything but easy. The virtual visualization of the blood system and blood flow results in huge amounts of data. In addition, the simulations require complex calculations. This is the area of expertise of Dr. Tobias Köppl who taught at TUM

Campus Heilbronn until April 2023. He says: "Simulating blood flow in major vessels has been a crucial part of my research for many years. This is why Mr. Mennel contacted me and asked me for support with his project."

The precursor of the digital twin

To be relevant, a blood flow simulation must be based on a number of parameters including the length of the vessels and the thickness and elasticity of the vessel walls. Because some of them, e.g. elasticity, are very difficult to gauge, these parameters are estimated using complex procedures applied in data science. To determine the length or diameter of a vessel, elaborate processes must be used to reconstruct it from image data.

For the Digital Treadmill Platform, Dr. Köppl worked with simplified flow models to identify the distribution of blood volume throughout the body. "The advantage of this approach is that the time it takes to calculate the result is reduced substantially without significantly compromising the accuracy of the target parameters," he explains.

For example, the approach can be applied to determine the effects of a specific therapy on the blood supply to the liver – a crucial parameter, particularly for patients suffering from fatty liver disease which can be the result of excessive weight and a poor diet, as well as diabetes. "One way to prevent fatty liver disease is to improve blood circulation in the organ," says Dr. Köppl. Movement therapy can help.

The better the movement therapy is customized to the individual patient, the better the results. How warm should the water be in which the patient swims? How

Dr. Tobias Köppl translates medical data into digital simulations.

One goal of his research: improving movement therapies

long and intensive should individual treadmill exercise phases be? Personalized answers to these questions should be provided soon by the Digital Treadmill Platform. In addition to simulating blood flow, it can visualize muscle movement. "It can be considered a precursor of a digital twin of each individual patient," Dr. Köppl adds.

Benefits for society

Mathematician Dr. Köppl expects that over the next few years computer models will be able to visualize increasingly larger parts of the human organism – from the grid of blood vessels to a numeric model of the heart. Machine learning techniques help scientists process and harness large amounts of data. Quantum computers could accelerate these processes in the future.

Whether looking at preventive medicine or acute medical care, these developments can benefit all patients.

"Analyzing patients' medical data with methods used in data science, e.g. neural networks, facilitates the automated detection of individual or combined risk factors impacting health including excessive weight, hyperglycemia, and hypertension," says Dr. Köppl. "Depending on the amount of data available, an initial diagnosis may be reached more quickly by a digital twin than the human brain." He adds that reducing the time for diagnosis and treatment could ease the burden on the healthcare sector substantially.

Dr. Köppl also points out that, "the storing of data concerning a person's health must be protected by stringent privacy regulations." For example, if insurance companies could access this type of data, they could assign patients to specific risk groups and increase their premiums. According to Dr. Köppl, handling sensitive patient data is the top priority.   •

"No data in the system, no readable tracks"

Unearthing and interpreting the wealth of data – we interviewed Prof. Luise Pufahl about the attraction of modern businesses to process mining and the challenges she faces in her research.

Prof. Pufahl, what exactly is process mining?

Luise Pufahl: Process mining is about observing the development of processes over specific periods of time. The business processes companies carry out, for example, to hire employees or to manufacture products, leave a lot of tracks in IT systems. Process mining opens up opportunities to extract these digital tracks – such as the date and time an order was received – from the companies' operating IT systems and to collect implicit process knowledge. This facilitates insights into the life of a business process in reality and most importantly, its level of compliance with laws and with industry policies. Bottlenecks or challenges can be identified and business processes can be developed continuously.

It sounds as if these digital insights have great potential. What are the limitations of process mining?

Luise Pufahl: An obvious limitation is that the process needs support from an IT system. Similar to data mining techniques, process mining does not work without IT systems – no data in the system, no readable tracks.

Another challenge can be poor quality data. For example, hospitals collect vast amounts of data and document it manually but this data tends to be insufficient. That is because hospital staff members focus on patient care rather than on documentation. If the quality of the data is low, you can analyze as much as you want, you will not get any sustainable results. It comes down to "garbage in, garbage out!"

What is a lucrative way for companies to use data-driven process optimization?

Luise Pufahl: I believe there are three key types of applications for it. It can make the process more transparent. In the past, people were interviewed about their work-styles. Today, the evidence-based approach allows us to determine accurately how a specific process is carried out. The resulting process diagram helps businesses understand what is going on inside their companies.

Process mining also can be used to gauge and assess Key Performance Indicators – KPIs. For example, it helps companies track the period of time between the initial contact with a customer and the signing of an agreement. In what cases is this period short? When does a lot of time pass? Companies can use these indicators to determine whether changes must be made and if yes, what type of changes.

Another important topic is regulations – this is where my research comes in. You can use process mining to verify the compliance of specific processes with laws, rules, or internal guidelines.

What is the most important element?

Luise Pufahl: Process mining encompasses a number of operations. Process discovery focuses on the actual process. Conformance-checking means that ideally the process behaves as intended by the guide-line. When matching the process against the actual

data, you can detect quickly where guidelines have been followed and also where there are deviations and the possible reasons for them. In certain cases, deviations can be helpful; but when it comes to observing privacy regulations or similar policies, taking the correct approach is crucial. However, today matching actual processes against legal stipulations to assess the quality of the processes is not common because process experts still find it challenging to interpret the results of conformance checks.

You conduct research on this topic jointly with a team at Mannheim University as part of a project initiated by German Research Association (DFG). Can you share some insights with us?

Luise Pufahl: Let me break it down: On one side you have the data, on the other you have the regulations. Then, there are the techniques you can apply to match the two. Unfortunately, practice is more difficult than theory. Textually described guidelines must be formalized and translated in a way that they can be handled by an IT system. That is challenging. This is where we come in with our research on novel methods and techniques, for example, with the assistance of natural language processing to facilitate the matching of legal stipulations and industry guidelines against process data. In addition, we are looking into the question of how results can be visualized and processed to allow users to draw sensible conclusions. For this, we also use findings from the field of visual analytics.

Prof. Luise Pufahl

What are the key challenges in these processes?

Luise Pufahl: Companies have a huge influx of rapidly changing rules to which they must adapt. Being able to resort to the process mining techniques I just described makes it easier to decide whether a new rule will be followed or not and what may need to be changed. Despite all the processes and supports available, at the end of the day it is up to the employees responsible to make the decisions. Only humans can interpret things. That also applies to evaluating and categorizing results. This is why including people in analysis processes is so important – we call it "human in the loop". We provide support, but we can't make final decisions for someone else. We are not there yet. And that's a good thing. ●

Fit for leadership

Student Jessica Brügmann and executive Dr. David Kappel are a WoMent tandem, and a well-oiled machine. We met with them to talk about how they benefit from their engagement in the cross-mentoring program.

The slogan "the future is female" has been invading the media landscape and other areas of our lives for quite some time. However, when it comes to their careers, many committed young women no longer want to rely on an unspecific future. They are intent on proving their potential here and now. We were able to experience this type of female empowerment – fittingly on International Women's Day – live and in person. Jessica Brügmann, bachelor student of Management & Technology at TUM Campus Heilbronn, and Dr. David Kappel, Vice President Global Engineering at duagon AG, shared some insight into their mentoring partnership.

"We can't afford to do without well-trained women in leadership positions," says David Kappel, who has a

doctorate in engineering and worked as an electrical engineering lecturer at Heilbronn University of Applied Sciences for twelve years, when asked about the

"

Having mixed teams has its advantages.

Dr. David Kappel

current shortage of skilled workers. "However, some stereotypes persist that give men an upper hand in the professional world. It starts with our education as

children and continues when we elect a study program or a job. Technical study programs in particular are male dominated."

It looks like there is a lot to be done to facilitate new options for action, changes in perspective, encourage-ment, and ambitious target images. These are not the only reasons David Kappel decided to support next-generation female executives as part of the WoMent program. "I want to do my part to help us grow as a society and economically and free ourselves from stereotyped thinking," he explains.

"Someone who has my back"

Jessica Brügmann is David Kappel's third mentee. The young woman with the confident appearance is convinced of the benefits of the concept: "WoMent appealed to me off the bat and I am happy I was chosen for the program after submitting my resumé." Since she entered WoMent, David Kappel has been the experi-enced mentor at her side. "We get together – usually in video calls – once a month and discuss everything that needs managing in my life – from the best way to structure my CV for an application to tips on handling myself in specific situations," she says. Even outside these meetings, Jessica Brügmann's mentor's door is always open. "I like having somebody who supports me and who I can go to – someone who has my back. It encourages me to achieve my goals."

Dialog with experienced professionals

The program offers Jessica Brügmann many advantages in addition to the mentorship. In monthly workshops that build on one another she gets answers to questions there is no opportunity to ask in everyday university life. She has particularly good memories of the session on micro resonance where she learned about the meaning of emotions and how to detect employees' intentions and stress in the work environment.

"Combined, the workshops and my dialog with Mr. Kappel provide me with a sound all-round foundation. I am learning what potential I have and what goals I can set as well as how to behave to be taken seriously in a leadership role."

Respecting each other as equals

All these experiences have helped Jessica Brügmann grow. She summarizes what WoMent means to her: "There are many factors that play into personal maturity but typically are not touched on in university lectures. You have to enter into dialog with experienced people."

Jessica Brügmann and Dr. David Kappel

The interaction with his mentees has helped David Kappel develop new approaches as well. "I am expe-riencing hands-on how the generation of young women ticks, what moves them, and what they expect from future employers and their company's cultures. I take this information into consideration when making deci-sions." He especially appreciates the fact that mentor and mentee see each other as equals and the commit-ment of young women who concern themselves with their careers early on. "They care about what comes next. They show up and say, here I am, let's get to it!"

Jessica Brügmann has not yet decided what she wants to tackle in the future. At the moment she is gaining useful experience during a semester in China. After returning, she wants to focus on graduating. "Mr. Kappel has taught me that sometimes it is better not to stress out but to do the thing for your career that is best in the moment."

WoMent

Initiated by Katharina Rust, financed by the Wissensstadt Heilbronn e.V. Association, and sponsored by the Dieter Schwarz Foundation, WoMent is a cross-institution, cross-mentoring program for female students at all the universities in Heilbronn. At TUM Campus Heilbronn, Prof. Michael Stich helps supervise the program which supports young women attempting to gain a foothold in the professional world quickly. Each participant is paired with a mentor who has a leadership position at a regional company. Over the course of the one-year tandem partnership, mentees gain insight into their mentor's work life and benefit from their experience. The individualized assistance is complemented by an attractive workshop program.

Excellent output

Making relevant research results available to society is one of the main tasks of the scientists at TUM Campus Heilbronn. Sought after by popular, wide-coverage media as contact persons, these experts contextualize questions addressed in current discourse.

Facilitating access to early childhood education

The gender pay gap in Germany is 18 percent, seven if you disregard structural differences. Even today, approximately two thirds of mothers in gainful employment work part-time compared to about one in ten fathers. It is an open secret that the rate of mothers who take up gainful employment or take on more hours of work increases exponentially with the availability of daycare options outside the family. For ten years now, every child in Germany aged one or older has been entitled legally to a spot in a daycare facility.

However, responses to surveys show children from less privileged families are less likely to attend daycare facilities. Compared to the number of children attending these facilities whose parents did not graduate from secondary school in Germany (Abitur), the number of

children of parents who do have such qualification is 14 percent higher. Why is that? How can families from lower socioeconomic backgrounds receive support in accessing daycare? Prof. Philipp Lergetporer of TUM Campus Heilbronn and four of his colleagues set out to find answers and conducted a study.

"The application process for daycare facilities in Germany is highly complex," Prof. Lergetporer explained in an interview with "Der Spiegel" magazine. In many cases today, parents have to apply via a centralized online platform. Mothers and fathers with a lower level of education find it difficult to compile the diverse information and certificates they have to submit. For this reason, Prof. Lergetporer and his team included 607 families in a random sample and actively supported nearly half of them with their daycare facility applications. Prof. Lergetporer summarizes the results: "The rate of daycare attendance by socioeconomically disadvantaged families increased by about 16 percent. That is a strong effect. We did not expect it to be this obvious."

Prof. Philipp Lergetporer

Another positive observation was that after 18 months, participation in the labor market by socioeconomically disadvantaged mothers who had received support with their daycare applications was significantly higher than with mothers in the control group who did not have assistance. The supported mothers worked more hours per week, earned more money (plus 22 percent), and thus contributed to higher household incomes (plus ten percent). The results suggest that easier access to early childhood education can be an effective political tool to increase the rate of employment, particularly among mothers from lower socioeconomic strata.

The study has been discussed in "Der Spiegel" magazine, in "Bayerischer Rundfunk" broadcasting network, and other media.

Why do data leaks leave the stock market unmoved?

With the rapidly increasing amount of data being collected today, incidents involving involuntary data disclosure are not uncommon. Especially when sensitive data such as passwords, bank information, and information concerning personal health are in play, people become agitated and tend to bring up security gaps, hacker attacks, phishing attempts, and data leaks.

Many countries have laws in place compelling companies to notify the supervisory authorities and their clients of such privacy breaches as quickly as possible. Although reporting such mishaps can result in a damaged reputation and crashed stock prices for the businesses affected, studies indicate that stock markets handle such news quite calmly. For this reason, Prof. Jens Förderer, Professor of Innovation and Digitization at TUM Campus Heilbronn, jointly with Sebastian Schütz of Florida International University investigated whether the reason for the markets' lack of response is that companies deliberately disclose data loss on days when the headlines are dominated by numerous other market-relevant news. "On hectic days, editorial staff and analysts have to decide what information to

prioritize before publishing," says Prof. Förderer. This causes attention to decrease and softens the markets' reaction.

For the study, the team of professors evaluated reports about more than 8,000 data leaks at listed companies in the U.S.A. between 2008 and 2018. They used information provided by the nonprofit organization Identity Theft Resource Center (ITRC) and compared the timing of data loss disclosures with the dates on which many companies presented their quarterly results in the "Wall Street Journal". What the researchers noticed was that almost 4.5 percent more privacy breaches were published on dates where a higher news volume was expected. "Our results suggest that companies plan disclosures of data leaks strategically and rely on being met with less attention," Prof. Förderer explains. In the case of severe violations of privacy, for example, when particularly sensitive data such as those concerning health or login information are involved, this strategic disclosure timing can be observed even more frequently.

Prof. Jens Förderer

In addition, Prof. Förderer and his colleague reviewed the companies' stock prices after data loss disclosures. In fact, the businesses affected experienced less devaluation on news-heavy days. Because of this, the scientists concluded that the window of time for announcing data loss should be as small as possible. "The longer the reporting deadline, the more time companies have to strategically plan their disclosure and undermine the purpose of such reports," Prof. Förderer adds.

The study was discussed in the "Süddeutsche Zeitung" daily, in "Manager Magazin", in the "Harvard Business Manager", and other media.

When it makes sense to use augmented reality in production

More and more companies rely on augmented reality (AR) to achieve their goals, for example, to enhance productivity. The results of a study directed by David Wuttke, Professor of Supply Chain Management at the Center for Digital Transformation at TUM Campus Heilbronn, show how actual and computer-generated realities can be combined to achieve these goals and in which areas it does not make sense to do so. Prof. Wuttke discussed his findings in interviews with "Deutschlandfunk" and other media.

Jointly with his international team, Prof. Wuttke developed a test setup in which 50 factory employees of a German technology company were given a task that was new to them – the assembly of an electronic product. Half of the randomly selected test persons were given instructions on paper; the others were provided with the complex work steps via AR glasses. "Basically, the information is superimposed on the real information so the test persons do not have to decide which screw is the correct one but know exactly which one needs to go into which bore," Prof. Wuttke explains. The researchers observed that AR applications have a significant influence on productivity: Employees equipped with AR glasses needed almost 44 percent less time to complete the task than those in the control group – 60 minutes for those who were provided with written instructions versus 33 minutes for wearers of AR glasses. Prof. Wuttke summarizes: "We saw that AR increases efficiency and significantly accelerates

While augmented reality in production has positive effects on working hours, it has its disadvantages when it comes to learning.

production." He adds: "A time saving of approximately 40 percent is enormous; when it comes to optimizing production processes, we usually talk about savings of a few percentage points."

In another step, the disadvantages of AR were studied. The test persons carried out their tasks again, but this time from memory only. The people in the AR glasses group scored substantially lower than their colleagues who had been instructed using analog means, apparently because they had internalized the individual work steps to a lesser extent. "If you rely on this technology too heavily, you won't process information as deeply and will achieve fewer lasting learning effects," study director Prof. Wuttke explains. In addition, the virtually supported group found it more difficult to formulate suggestions for optimizing production processes. "The results imply that the AR glasses were a crutch, but did not improve the wearers' understanding of the task at hand. As a result, these individuals had little to contribute to process optimization." The results of the study can help companies tailor AR to their needs and decide between productivity and process optimization. "The results of our study indicate that AR is really, really good for companies looking to accelerate manufacturing and instructing. For those who want sustainable improvements and to make sure their employees think everything through, AR has its weaknesses," says Prof. Wuttke.

He will continue his research on achieving increased efficiency and deeper understanding at the same time – the best of both worlds. He plans to investigate the

Prof. David Wuttke

development of AR applications that ask users targeted questions so what they learn is better embedded in their brains. •

Up close and personal with CEOs

In the 2023 summer semester, students at TUM Campus Heilbronn had the opportunity to gain insight into the work life of successful executives. The CEO Leadership Series was initiated and organized by Prof. Chengguang Li, who holds the Chair of Strategic Management at the TUM School of Management at Campus Heilbronn.

What do BASF, the Berlin International Film Festival, and the Dieter Schwarz Foundation have in common? They are led by people whose work is acknowledged in Germany and beyond.

Among other successful people, we are talking about Dr. Martin Brudermüller, CEO of BASF SE since 2018. As "Manager Magazin" reported when Dr. Brudermüller took office, he is perceived as a down-to-earth man of action who set out to strengthen the global chemical company, mainly in the technical field, in core areas including digitization and innovation. Film producer Mariette Rissenbeek proved her worth in these fields when she successfully steered the Berlinale through two arduous years of pandemic. In 2019, she became the executive director of the internationally renowned film festival which celebrated a comeback this year in local movie theaters.

Since 2016, Prof. Reinhold Geilsdörfer has been at the helm of the Dieter Schwarz Foundation where he is in charge of academia. Under his leadership, the foundation promotes a broad spectrum of future-oriented offerings in education and science, most recently including

ten professorships and funding for top-caliber experts from around the world to conduct research at TUM Campus Heilbronn.

Kick-off with Christian Wulff

These three were not the only executives who paid TUM Campus Heilbronn a visit between April and July. The CEO Leadership Series was kicked off on April 21 by Christian Wulff, former Federal President and Prime Minister of the state of Lower Saxony, who spoke about his career, his political work, and his goals.

Other participants in the CEO Leadership Series included former TUM President Prof. Wolfgang Herrmann; Prof. Gunther Friedl, Dean of the TUM School of Management; Heinrich Deichmann, CEO of the footwear retail chain which bears his name; Dr. Leonhard Birnbaum of E.ON; Carsten Knop, editor of the "Frankfurter Allgemeine Zeitung" daily, and Ingrid Hofmann, founder of I.K. Hofmann staffing agency.

All these luminaries shared fascinating stories, insights into their careers, and their recipes for success with students who flocked to the auditorium in large numbers
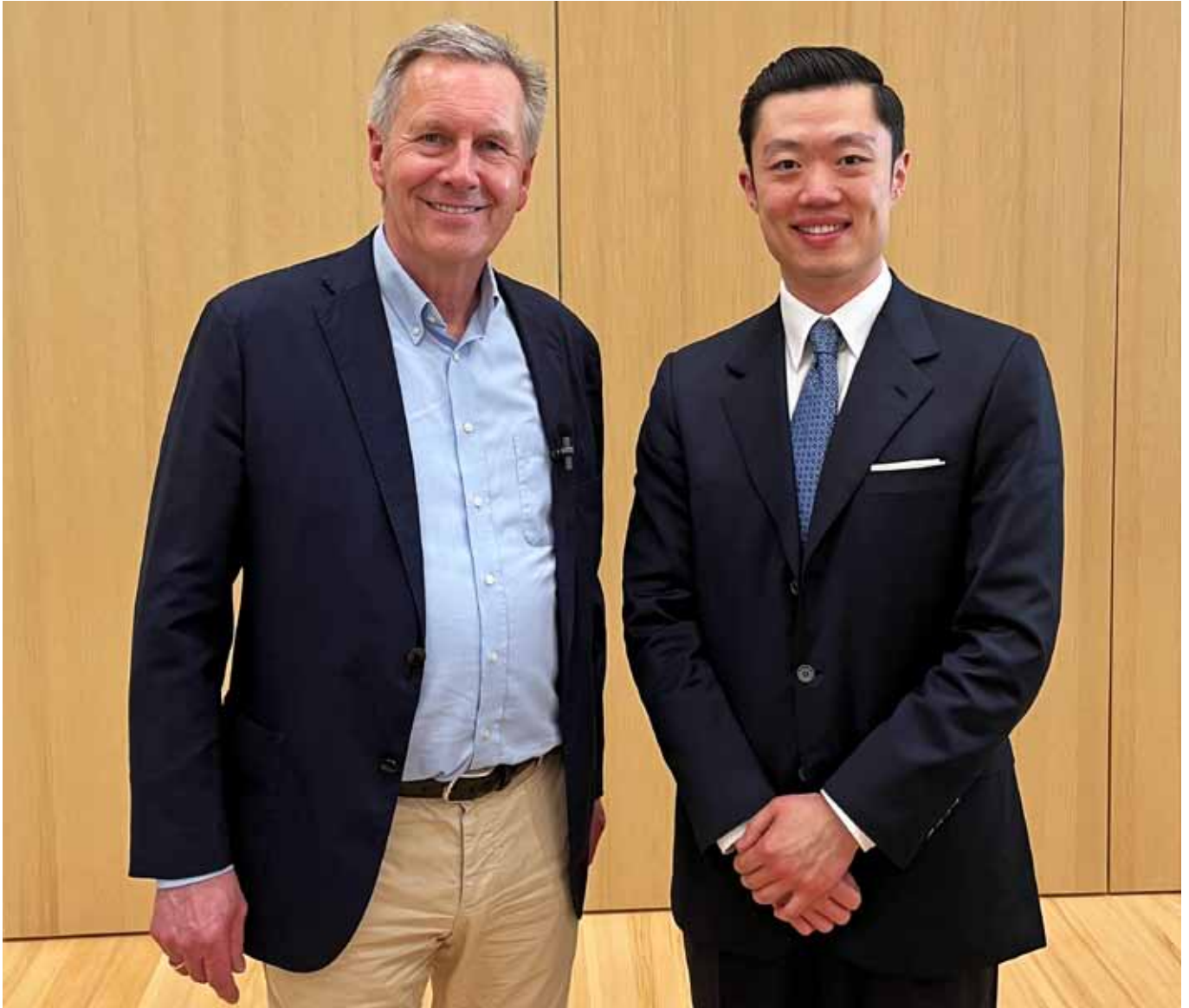
On April 21, Prof. Chengguang Li of the TUM School of Management welcomed former Federal President Christian Wulff to TUM Campus Heilbronn as a guest and speaker of the new CEO Leadership Series.

to interact with the executives on the podium and gain first-hand insights. It was interesting to learn about the career steps the speakers took to reach their current leadership positions, their management styles, their goals, the challenges they face, and the mentors who supported them as they set the course. The discussions also touched on personal life matters including recreational activities, family, and work-life balance.

The CEO Leadership Series will be continued in the 2023/24 winter semester: tumceoseries.de

Social media and democracy

From a freeing power to a potential threat to democracy? The third webinar hosted by TUM Campus Heilbronn and the Oxford Internet Institute was all about the development and the potential (threat) of social media.

TUM Campus Heilbronn and the Oxford Internet Institute (OII) have made it their mission to bring knowledge from discussions on global research results to the general public. Taking into consideration the most recent findings, Mahsa Alimardani and Dr. Aliaksandr Herasimenka of OII joined Michaela Lindenmayr and Prof. Jens Förderer of TUM, Prof. Helmut Krcmar, founding dean and representative of the president for TUM Campus Heilbronn, and Prof. Dr. Maximilian Schreieck of the University of Innsbruck in the webinar to discuss the situation at hand.

The dark side of social media and AI

In the early 2010s, Facebook and other platforms were embraced for their role in the Arab Spring. They made it possible for activists to come together despite censorship and oppression and to stand up to state authority. However, recently the dark side of social media has begun to dominate public discourse. Are social platforms potential central catalysts for populist or radical political views and thus a threat to established democracies?

China, Iran, and Russia are prominent examples of users of modern technologies to manipulate people and opinions – both at home and on the global stage. The results of research conducted by Dr. Aliaksandr Herasimenka, communication scientist at OII, indicate that while activists used to be one step ahead of governments in the use of new technologies such

as messenger platforms and social media, the use of artificial intelligence (AI) has turned the tide. Since AI requires large investments and vast amounts of data, it is employed mainly by governments and large companies, while political opponents have difficulty accessing it. According to Dr. Aliaksandr Herasimenka, this imbalance will be one of the biggest challenges over the next few years and could usher in an era of surveillance.

Followers at any cost?

A different type of challenge, one owed to the manipulative potential of social media, was explained by Prof. Jens Förderer and Michaela Lindenmayr. They are investigating the phenomenon of increasing one's popularity by paying for fake followers.

Social media platforms give companies an opportunity to attract broad attention and boost their success. One of the key questions concerns the extent to which businesses resort to fake followers and how investors react when such fraudulent behavior comes to light. Over two days in 2018, Twitter deleted several million suspicious accounts. Led by Prof. Förderer, the researchers investigated the wipe-out in detail and observed that the companies affected lost an average of 1.2 percent of their followers. The more competitive the industry and the smaller the company, the larger the effects. In addition, the research team found that investors respond negatively to artificially blown-up follower numbers. When followers are exposed as fake, stock prices slump. •