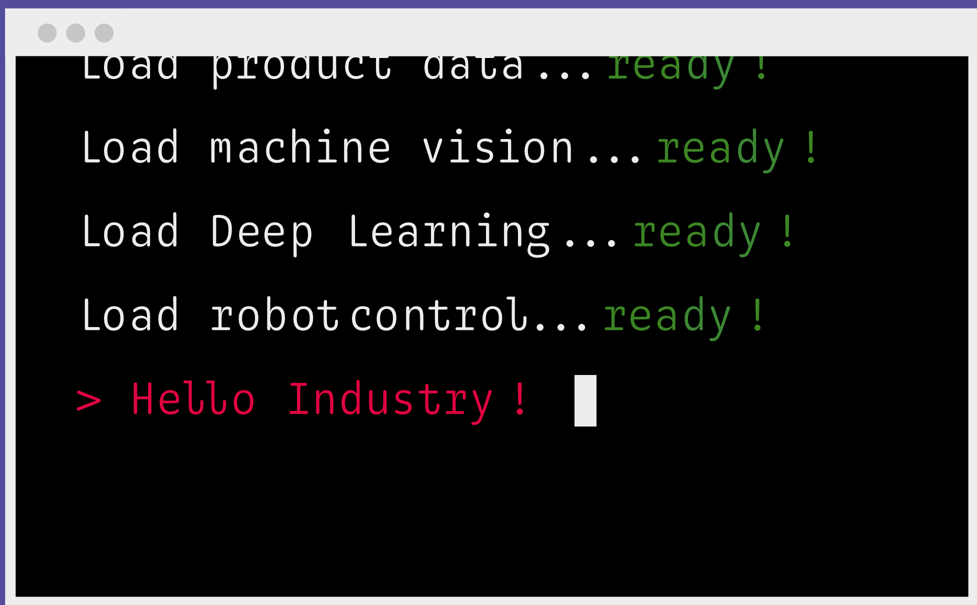
THE MAGAZINE OF THE **PRODUCTION TECHNOLOGY CENTER BERLIN**

futur

VISION | INNOVATION | REALIZATION



ARTIFICIAL INTELLIGENCE

Smaller Effort, Big Effect
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INSTITUTE
PRODUCTION SYSTEMS AND
DESIGN TECHNOLOGY

INSTITUTE MACHINE TOOLS
AND FACTORY MANAGEMENT
TECHNISCHE UNIVERSITÄT BERLIN

These beauties are helping scientists train artificial neural networks.

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Production Technology Center (PTZ) Berlin

PROFILE The Production Technology Center (PTZ) Berlin houses two research institutes: the Institute for Machine Tools and Factory Management IWF of the TU Berlin and the Fraunhofer Institute for Production Systems and Design Technology IPK. As production-related research and development partners with a distinctive IT competence, both institutes are in international demand. Their close cooperation in the PTZ puts them in the unique position of being able to completely cover the scientific innovation chain from fundamental research to application-oriented expertise and readiness for use.

We provide comprehensive support to companies along the entire process of value creation: Together with industrial customers and public-sector clients, we develop system solutions, individual technologies and services for the process chain of manufacturing companies – from product development, planning and control of machines and systems, including technologies for parts manufacturing, to comprehensive automation and management of factory operations. We also transfer production engineering solutions to areas of application outside industry, such as traffic and safety.

DEAR READERS,

what ideas or images does the phrase »artificial intelligence« evoke? Does it make you think of the voice-controlled digital assistants that you use to control your cell phone or your home? Of Deep Blue, the chess computer that defeated world chess champion Gary Kasparov back in 1997? Or of autonomous vehicles that, unlike navigation systems, not only show you the way, but also take you to your destination without any intervention on your part?

AI conjures up very different associations – and emotions. This is due, on the one hand, to the mostly vague definitions of the term in public discourse, and on the other hand to a usually very simplistic presentation of this highly complex topic. Hope and curiosity, but also skepticism and concern have therefore accompanied this technology since its scientific inception in the 1960s.

In the meantime, AI systems are shaping not only our everyday lives, but also business and industry. Reason enough for us to introduce you to our human-centric understanding of AI in this issue of our FUTUR magazine. Let us show you how machine learning and computer vision technologies are used in production.

One example is reverse engineering, where nowadays a lot of manual work is required to get from a physical object to a point cloud to an eventual CAD model. Researchers at Fraunhofer IPK have developed an AI-based solution that automates large parts of the process, saving developers and engineers a lot of time.

For AI to develop its full potential in industry, experts from different domains, such as materials science or production engineering, must work closely with AI specialists. Sven Hamann, managing director of Bosch Connected Industry, describes how this can be achieved in our interview on AI in production.

The fact that cooperation across domain boundaries is also Fraunhofer's strength is demonstrated by our scientists in numerous industrial projects. Together with a software provider, they are developing mobile assistance systems for maintenance, repair and overhaul. They enable tool manufacturers to detect errors in production planning at the design stage with the help of digital twins. And they are providing solutions for complex manufacturing and assembly tasks for an engine manufacturer using intelligent data evaluation methods.

In this issue of our magazine, you can find out exactly how our researchers are achieving all this and how artificial intelligence plays a key role in their endeavors.

Wishing you an enjoyable read

Yours

Eckart Uhlmann

Eckart Uhlmann

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In addition to AI expertise, domain knowledge is becoming increasingly important.
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© Bosch

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© Rolls Royce plc

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»We tap into novel savings potential by adjusting aspects that were previously fixed.«

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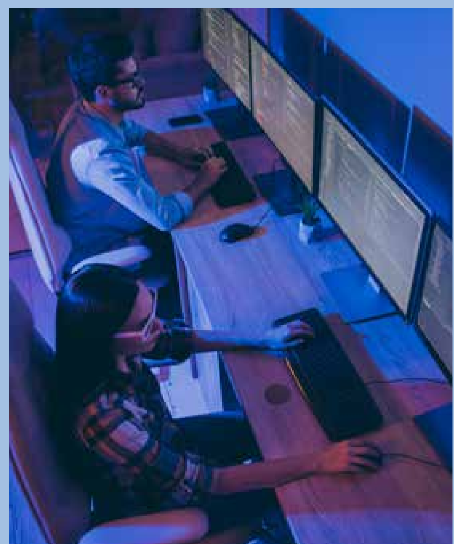
SHORTCUTS | futur

TAKE PART!



Digital Transformation Assessment
Digital transformation is a multi-faceted issue that goes far beyond mere automation or the implementation of modern technologies. Value creation structures will change massively within a very short time. Companies are therefore called upon to put to the test previous business practices and strategies as well as their own processes, structures and products.

Scientists at Fraunhofer IPK are now conducting a study in which companies can determine the progress of their digital transformation status. Participation is free of charge.

↳ **Complete the online self-test conveniently in just a few minutes at** www.ipk.fraunhofer.de/digital-transformation-assessment-en

WELL SAID

»The idea that you can do things entirely on your own has become outdated and is no longer realistic, especially in light of the complexity of the topics.«

Sven Hamann, Managing Director Bosch Connected Industry, in our interview on AI in production

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IN DETAIL

Find out **what you are seeing here** and what exactly it has to do with AI

↳ on page 50.

NUMBER OF THE ISSUE

30 watt

is the power of a regular light bulb. Find out how our brain manages to consume less energy than said light bulb in a column by our alumna Prof. Katrin Amunts, MD.

↳ more on page 36

STANDARDIZING KNOWLEDGE MANAGEMENT IN SME

DIN SPEC
Heute Idee.
Morgen Standard.

Guidelines for knowledge management specifically tailored to SMEs – that is the aim of DIN SPEC 91443 »Systematic knowledge management for SMEs – tools and procedures«.

Bringing knowledge management into small and medium-sized enterprises has been a central concern of Fraunhofer IPK for years. Scientists of the institute have therefore significantly supported the development of the SPEC.

↳ **Find out more at** www.ipk.fraunhofer.de/DIN-Spec-SME

Digital (T)Wins

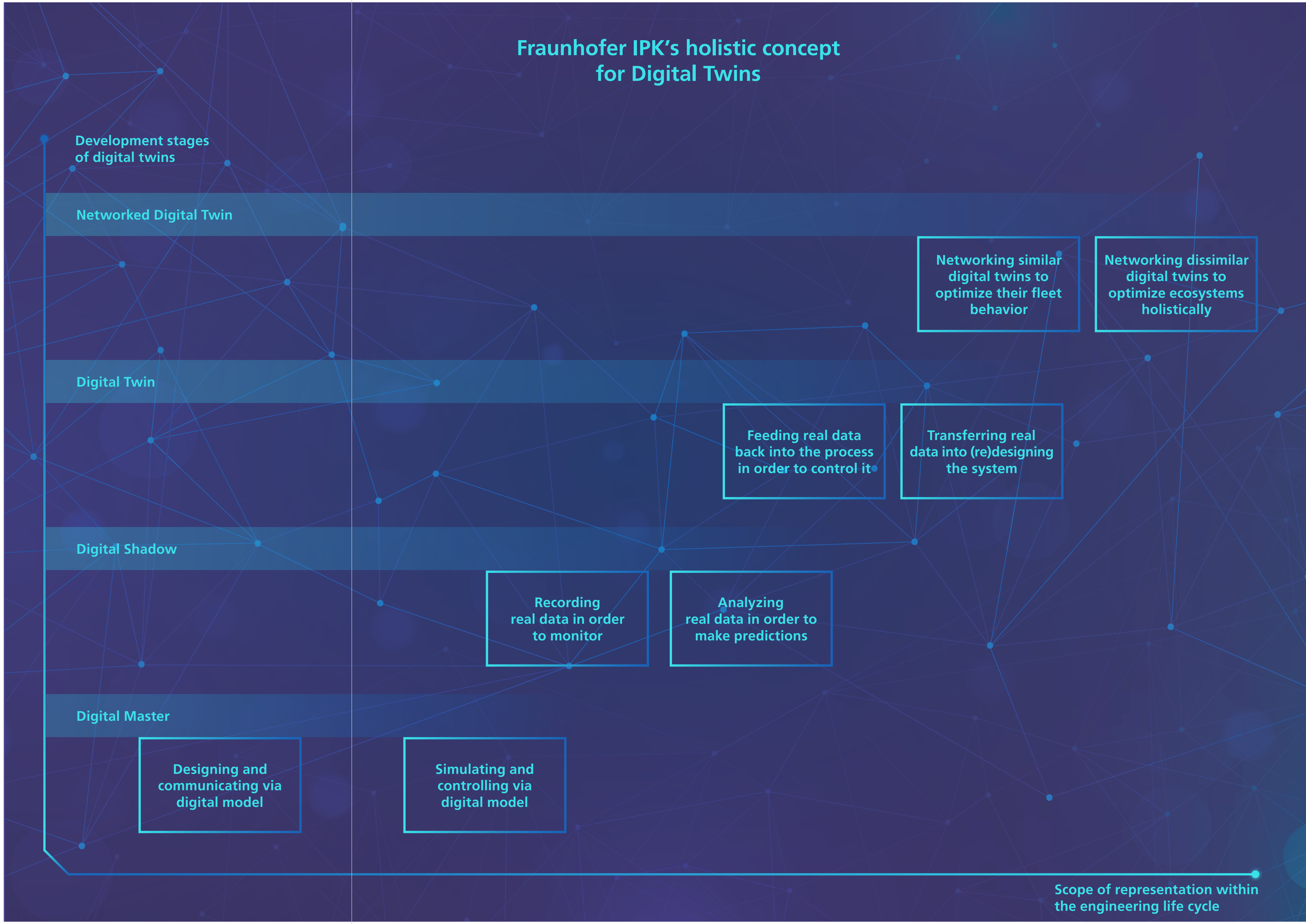
To use digital twins profitably, manufacturing companies need to know how to network them.

Planning highly flexible factories, realizing intelligent products and designing process parameters in machine tools – at first glance, these tasks do not have much in common. Yet they are all performed in order to engineer highly complex systems. To master them, companies are already using digital twins in many cases. They are the digital images of specific products, production plants or entire factories, and make it possible to record, predict and control their properties, status and behavior by using models, information, and data.

The basis for all this is a digital master. It holds reference models and information from the development phase of products and processes, laying the foundation for their modeling or simulation. Such a digital master can be used, for example, to define the function and design of a product or to safeguard and optimize manufacturing processes in advance.

The digital shadow, which continuously records the real-time status data of a production system, goes one step further. To this end, operational data from the shop floor is recorded, stored and made available. The behavior of a system can be observed in order to identify inaccuracies in the digital master model and correct them manually. The real data of a digital shadow thus serves as an additional basis for simulation-based investigations and helps to predict, for example, how a tool will wear out and when it will have to be replaced.

The digital twin itself is created by intelligently linking the digital master with the digital shadow. Today, for instance, vibration data can already be recorded in real time in machining processes, enabling quick adjustment of process parameters as required. Data on environmental influences such as temperature and humidity, which could negatively affect the process, are also sometimes included in order to flexibly and adaptively control the process. Typical tool vibrations during machining, which can lead to shorter tool life or even damage the workpiece, tool or machine, can thus be avoided.



AI solutions are the key to highly flexible end-to-end networking of digital twins.

THE VALUE OF NETWORKING

The manufacturing industry has recognized the potential of digital twins as a future technology. According to a Gartner study, only 13 percent of all large companies with ongoing IoT projects in the major industrialized nations are currently using digital twins. For 62 percent of those surveyed, such projects are at least in the planning phase.

But in those companies where digital twins are already in use, they are far from being optimally utilized. So far, they have mostly functioned as data-provisioning systems, or they are used for backup and error analysis. This is the conclusion of the »Digital Twin Readiness Assessment« study conducted by Fraunhofer IPK and msg in 2020. Offerings such as automated value-added services and the design as autonomous or adaptive systems have so far been considered in only a few concepts.

If companies want to use digital twins profitably in their production, it is not enough to use them singularly. They only develop real potential when they are combined with each other – in other words, when they are networked twice. Not only between digital masters and shadows, but also between individual product, process or factory twins, either among themselves or with each other. In highly volatile production environments, however, this can only succeed, if this networking is used in a highly flexible and continuous manner throughout the lifecycle of production, its processes and products. The key to these so-called networked digital twins are AI solutions.

WHEN MACHINES HELP EACH OTHER OUT

Industry and research are already working on AI algorithms that are designed to continuously and automatically optimize the control model of a machine tool. Based on empirical data from past machining processes, the algorithms learn which settings on the control model lead to optimum machining results along various boundary conditions. If the learning process is successful, the adjustment of the control model is only a formality.

If the control model, and thus also the digital twin of a machine tool, is modified in this way, the same mechanisms can be transferred to other similar machines so that they can be optimized for execution in a task-specific manner, ensuring that the entire fleet of machine tools can work in perfect harmony. To this end, solutions of agent-based self-organization are applied, which make it possible to ensure that production does not come to a standstill even in the event of deviations from the original production plan. Resulting reduced process times create new opportunities in factory design or cost advantages for the product. Linking disparate master and shadow models of an overall system in the form of such a networked digital twin therefore makes sense. This way, one does not have to go to the trouble of transforming data and exchanging it between heterogeneous software systems in the production environment.

In addition, companies can apply previously simulated controls to machines and plants at distributed locations simultaneously. Or they can use the data to implement new business models or even establish cross-company collaborations via functioning information flows.

THE TRANSPARENT FUEL CELL – CRADLE TO CRADLE

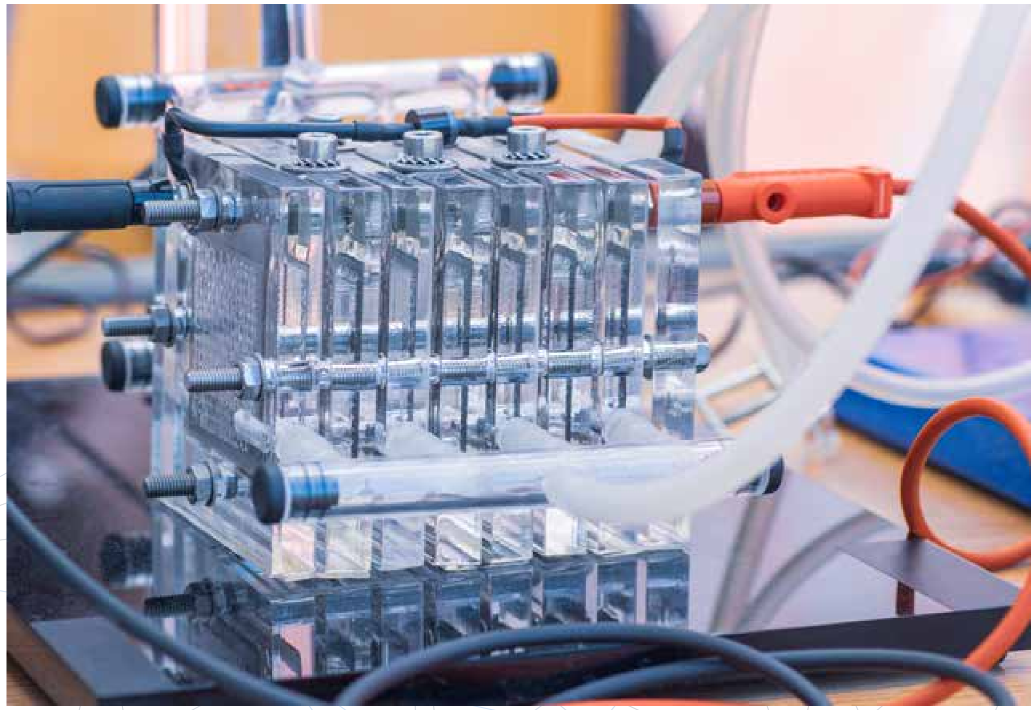
Whether for providing energy to power electric vehicles or stationary at home, the fuel cell technology is an essential part of energy transition toward decarbonization. However, the technology is still expensive and risky: investment costs for the infrastructure are high, the diversity of variants is immense (there are six different basic types alone) and the empirical values are insufficient.

For this reason, Fraunhofer IPK is developing an intelligent workshop-oriented production environment that can be used to economically manufacture very small quantities on an order-by-order basis. Each single fuel cell is to be tracked in a targeted and individualized manner with the help of its digital twin, so that meaningful decisions can be made along its entire product life cycle. It will be possible, for instance, to decide when the optimum time for reprocessing has come from an economic point of view, and how this can be implemented with as little risk as possible from a technical point of view.

For this purpose, the digital product twins of the fuel cells are for the first time being networked with the factory twin in such a way that the effects of changes from both the engineering of the respective digital master and the real data of the production and application can be considered together directly. The digital masters are used to network all relevant objects and processes, creating comprehensive transparency across the entire value chain in real time. Deviations from the planned production process due to disruptions are ideally detected in advance, so that appropriate countermeasures can be initiated at an early stage. The information collected and provided by the digital twins of the production systems for each process step also serves as the basis for the digital product twin of each manufactured fuel cell.

If this information is linked with that from the fuel cell's utilization phase, new insights can be gained, for example, to optimize the fuel cell on a utilization-specific basis. Such an optimization specification can then be automatically incorporated into the configuration of processes within the factory to prepare the fuel cell for its »second life«. In this way, networked digital twins are helping to recycle products economically – for an optimized circular economy. ◆

Image:
Digital twins accompany this fuel cell along its entire product life cycle.



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Glossary //

Breaking down **artificial intelligence** is no mean feat. Put very simply, it is the attempt to transfer human ways of learning and thinking to computers and machines. With this glossary, we want to delve a little deeper into the subject and show you how we interpret the most important concepts from the broad field of AI at the Production Technology Center Berlin.

Artificial Intelligence

According to Prof. John McCarthy (1955, Stanford), artificial intelligence (AI) encompasses the science and engineering of intelligent machines. The intelligence of an agent is measured by its ability to independently solve previously unknown tasks based on prior knowledge. In practice, the focus of AI is on emulating typical human cognitive abilities, such as natural understanding of language and images. The technologies used to map these abilities onto computers fall under the field of machine learning. The field is currently experiencing a renaissance due to breakthroughs in deep learning.

Data Analytics

describes the collection, organization, storage and processing of data with the aim of extracting and using the underlying information to gain in-depth knowledge about a process or procedure. The focus is often on the optimization of processes and procedures in production systems as well as the optimization of design decisions. Another major application area for data analytics at Fraunhofer IPK is estimating the service life of a component for predictive maintenance.

Machine Learning (ML)

refers to software methods that can derive the best possible behavior based on sample data without having to explicitly program each individual case. Different principles of learning can be distinguished: supervised learning, unsupervised learning and reinforcement learning.

Supervised Learning

In supervised learning, the computer learns a behavior from a set of given input and output examples, a so-called training dataset.

Reinforcement Learning

In reinforcement learning, the computer attempts to replicate learning processes in nature by inferring optimal action strategies based on a reward signal to be maximized. Unlike supervised learning, the software agent is not shown the correct actions at any point in time, but only whether the task was successfully completed or not. This gives the agent great autonomy in finding a solution. Thus, reinforcement learning holds great potentials e.g. for programming robots in uncontrolled, dynamic environments.

Unsupervised Learning

In unsupervised learning, the expected outputs are not specified in training examples. The computer recognizes regularities or anomalies in the input data on its own.

Computer Vision

deals with the perception and interpretation of images and videos by computers. Among the most prominent applications are face recognition, autonomous driving and object recognition. Applications in the industrial environment such as image-based quality inspection and visually controlled execution of robot movements (visual servoing) are summarized under the field of machine vision.

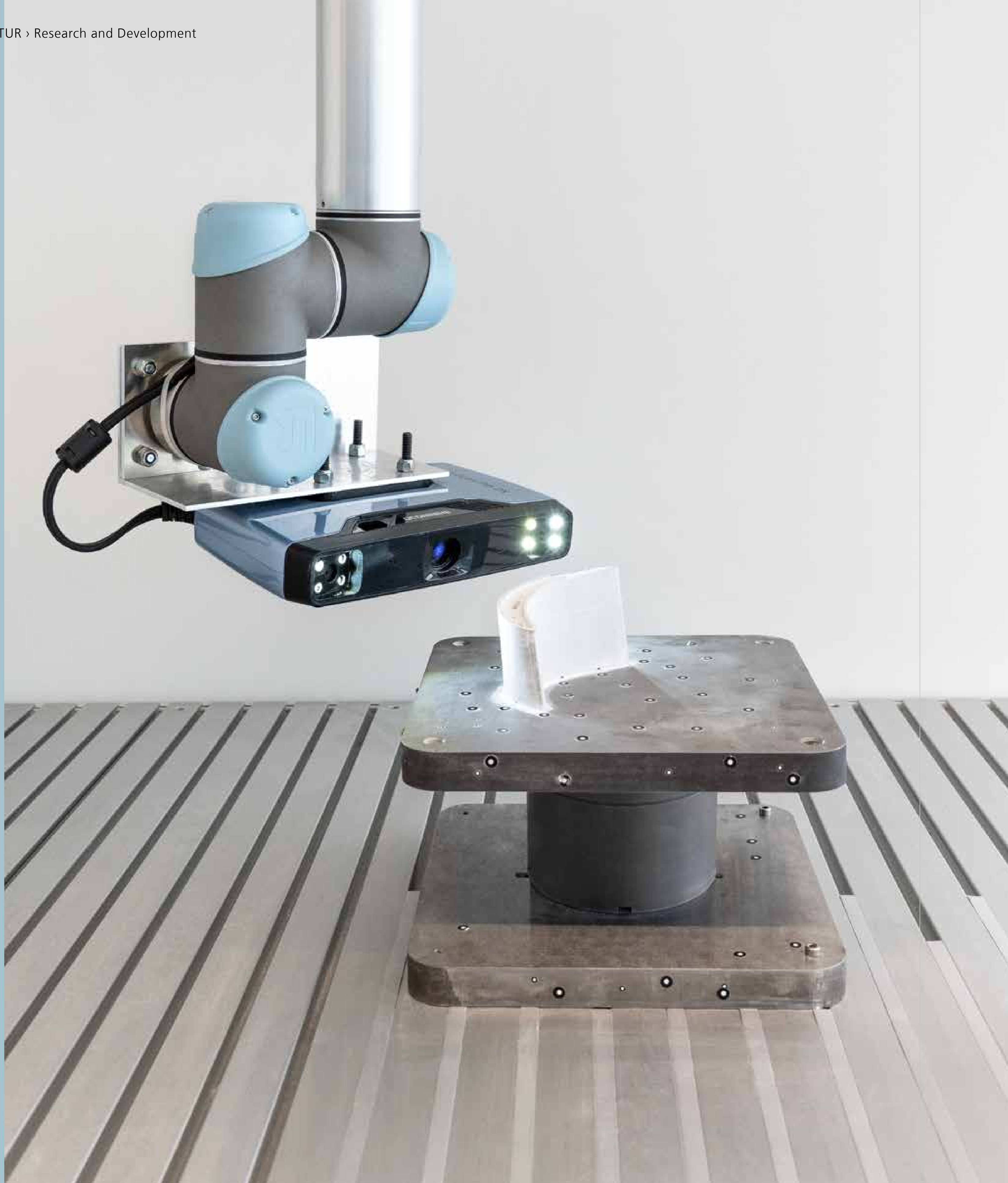
Deep Learning (DL)

is currently the most successful machine learning method. Inspired by information processing in the brain, DL employs artificial neural networks. Due to their high capacity, modern neural networks are particularly efficient in analyzing large amounts of data, resulting in a high robustness of the solutions they generate. In some specific scenarios, such as image recognition and natural language processing tasks, DL methods have already been able to significantly outperform a human being.

Artificial Neural Networks

are information processing structures inspired by their biological counterparts. They currently consist of up to several 100 million processing units (neurons) that are arranged in layers and interconnected with each other. The sensitivity of each neuron to incoming information, i.e. whether this information is passed on to the next neuron or not, is regulated by a variable weight. These weights determine the overall functionality of the network and are computed using complex optimization methods such as gradient descent.

Find more definitions in the publications of the German Academic Association for Production Technology (WGP):

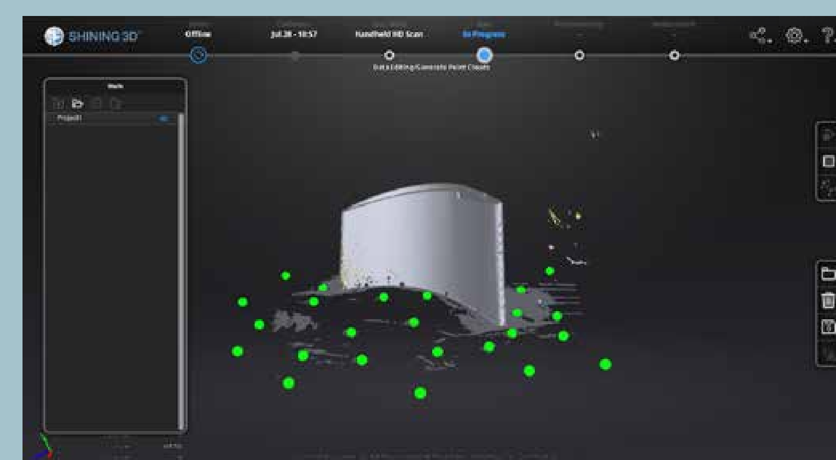


1

Scanning + Reverse Engineering = Scangineering

From the physical object to the point cloud and finally the CAD model – reverse engineering means a great deal of work. A team from Fraunhofer IPK aims to change that with an AI solution.

Images:
1
Using open communication standards, 3D scans can be performed with simple and inexpensive components.
2
Raw data of the data acquisition within the manufacturer software



2

What do a municipal employee who surveys land parcels and buildings, a manufacturing manager who wants to determine the current state of plant construction, and an engineer who analyzes component geometries in parts and tools have in common? All of them engage in reverse engineering.

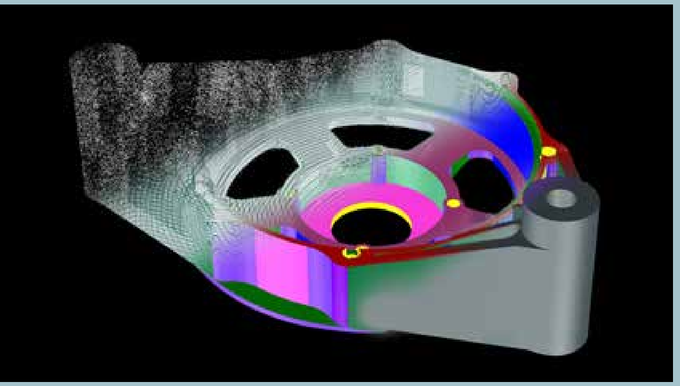
To do so, they usually use techniques such as laser scanning or photogrammetry to record various data on the objects they wish to capture. So far, so good. But a huge quantity of data is not particularly informative by itself. It first needs to be transformed into a meaningful, parameterized 3D model. The creation of such manipulatable CAD models is the goal of reverse engineering.

The compilation of optical measurement data in the form of point clouds is now technically easy to implement using modern methods such as laser scanning. The subsequent processing of the data into parameterized 3D models, on the other hand, is still performed manually. This requires trained specialists and a lot of time. Hence, this task is currently still often outsourced to service provider companies in low-wage countries. In an era of high-level automation, the question arises: »Why can't this be done at the push of a button?«

NOT JUST VIRTUALIZED, BUT PARAMETERIZED

To extract useful CAD models from the large amounts of virtual point cloud data, certain requirements need to be met. The models not only need to be able to map geometric and structural information, but also metadata, such as on materials, identification numbers, or access rights. These must be accessible in parameterized form and easy to process with other programs.

1



Classically, data points – sometimes up to several million of them – are pre-processed before model reconstruction can begin at all. Incorrectly detected points are discarded, the entire point cloud is divided up into subsections, and the point density is reduced.

Subsequently, the actual model reconstruction begins with segmentation, in which geometric properties of the point cloud are determined and combined into clusters. This is followed by the classification of these clusters into features – design elements of CAD authoring systems. Finally, these are then reassembled into a parameterized 3D model, as if following a blueprint.

AUTOMATED ASSISTANCE

To be able to carry out this complex process in a fully automated fashion, researchers at Fraunhofer IPK have developed what they call »Scangineering«. In this procedure, the parameterized 3D models are generated algorithmically using artificial intelligence.

Scangineering is based on the reverse engineering process chain and can roughly be divided into the two software components main module and framework.

- The main module contains functions for visualization (GUI), interaction options for users, and is used to display the results.
- The framework, which is invisible to users, contains the algorithms for processing the point clouds and meshes, such as functions for segmenting, registering, and filtering. Furthermore, the framework contains support functions and tools for manipulating the input data and determining object instances. Finally, it also provides functions for data analysis and the graphical evaluation of the results.

Compared to classical reverse engineering methods, Scangineering relies on a high degree of automation. Humans remain a part of the beginning and end of the process as input providers and analysts of the results. However, the repetitive work steps in the middle of the process no longer need to be performed manually.

2

Images:
1
Stages of reverse engineering – from point cloud to CAD model
2
Demonstration of the automated process chain

Scangineering therefore helps to make objects, buildings, machines and components usable easily and quickly as virtual models. In this manner, the process also contributes to long-term sustainable value creation. After all, virtualizing physical objects using 3D scanning also makes it easier to reuse, refurbish, and recycle products.

DISRUPTION IN THE CONSTRUCTION SECTOR

In multiple research and industry projects, experts from Fraunhofer IPK have successfully demonstrated that their technology is suitable for automated reverse engineering of fully automated 3D models. To meet individual requirements of the respective use cases, only the software parameters need to be adapted.

Scangineering is about to take the next big step: Via the internal Fraunhofer funding program AHEAD, two scientists are collaborating with the company pointreef – Digital Reality on a joint spin-off. By the end of 2021, an initial version of the software is expected to revolutionize the market for modeling of physical objects in the building and construction sector. ◆

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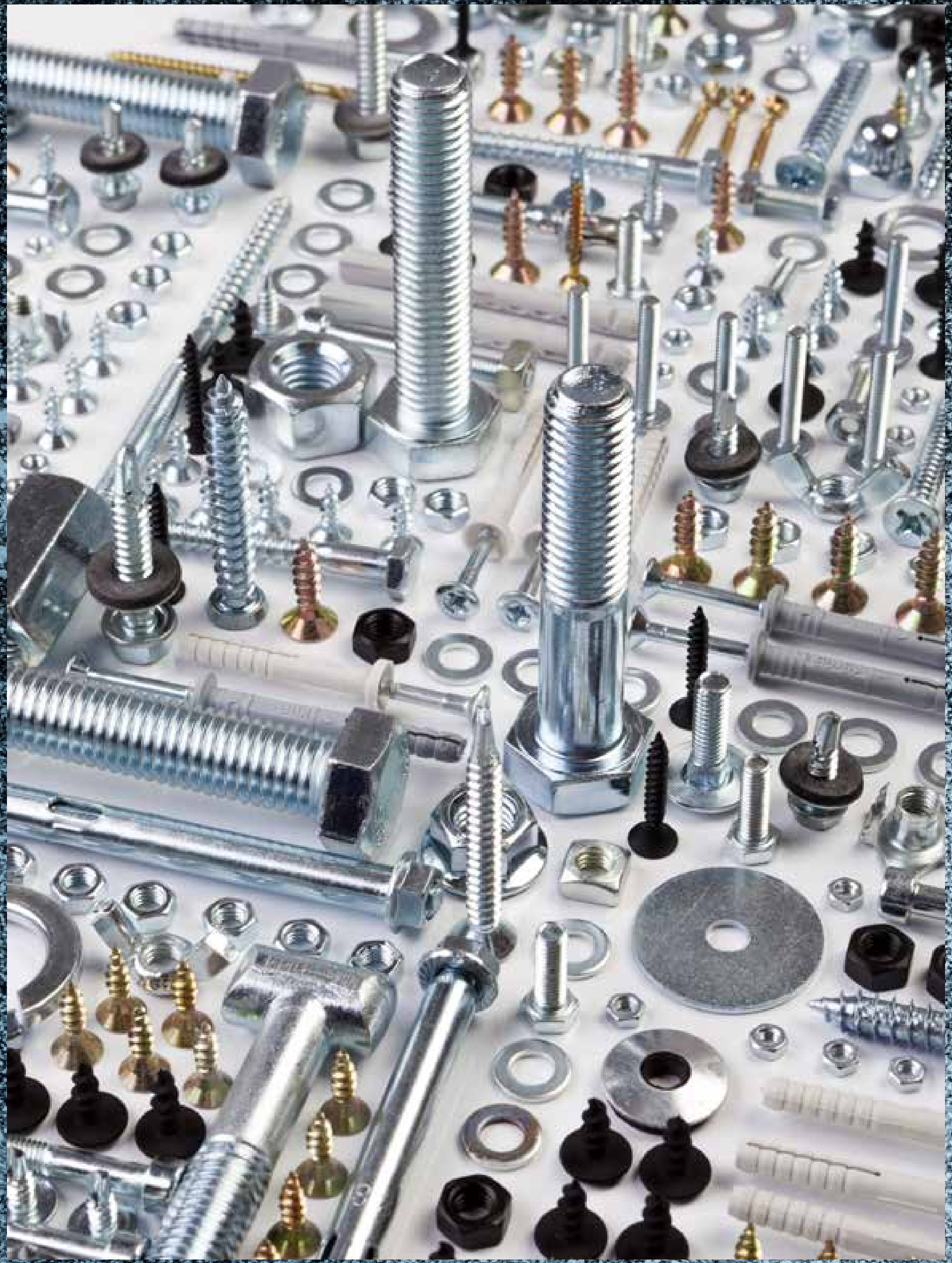
Smaller Effort, Big Effect

Artificial intelligence requires large quantities of data? Not necessarily, say scientists at Fraunhofer IPK. They use visual quality control for industrial goods to show how it can work.



From A for aluminum components to Z for zinc plating – by the end of the production line, industrial goods must meet certain predefined surface quality requirements. Inspection workflows must deliver compelling test results quickly and reliably, particularly when large quantities are produced and the requirements for surface quality are extremely strict. Choosing the right inspection methodology can therefore be a decision of enormous economic relevance.

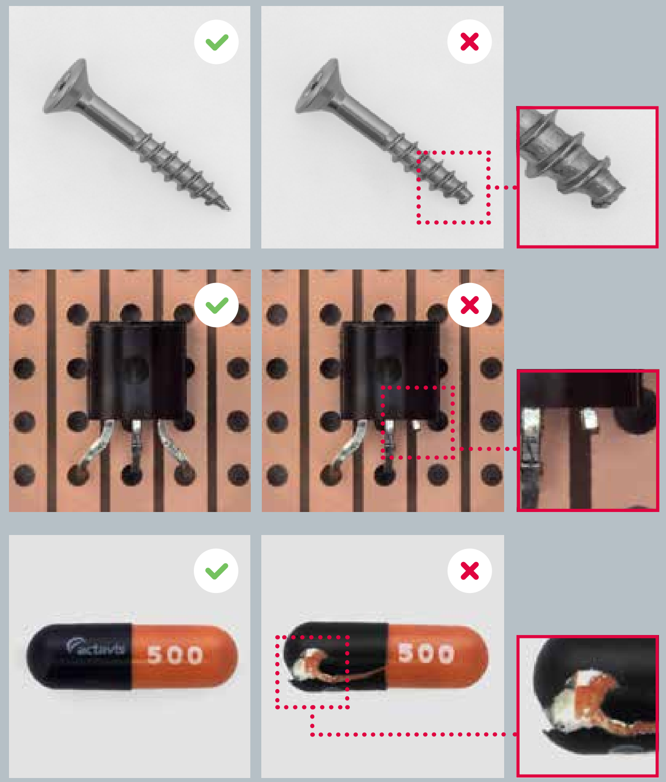
To date, small and medium-sized companies in particular have carried out quality assurance by means of sample checks. In this process, a component is picked at random from a production batch. An employee then checks whether or not the component's surface exhibits any defects, either by hand or using expensive and slow high-precision scanners. Depending on the batch size, this means that only a fraction of the manufactured components are inspected. 100 percent inspection of the parts does not take place. Another disadvantage is that manual inspection can be highly inaccurate, depending on the qualifications and capabilities of the employees.

Modern AI-assisted image processing methods, on the other hand, have the potential to recognize objects and possible defects with greater accuracy than humans. Such AI systems typically use supervised learning methods. This assumes that all potential defects that can occur in a component are known in advance – and have been captured in an image. Depending on the application, hundreds to thousands of images are needed to train the AI appropriately. To do so, each individual defect must be marked by hand – precise down to the last pixel – on each image (AI experts call this process annotation). For industrial applications in particular, collecting and labeling such large quantities of data results in high costs, and the manpower required is staggering. For SMEs in particular, this is a hurdle to unlocking and exploiting the benefits and potential of AI methods.

The goal of the project »VIADUCT – Effort Reduction for AI Applications in Industry by Reducing Training Data« is therefore to develop AI methods that require very little training data for visual inspection. Working with their Armenian technology partner Ngene LLC, researchers at Fraunhofer IPK are first undergoing a paradigm shift and reformulating the inspection task: Instead of looking for familiar defects, they are searching for any deviations (anomalies) from a predefined quality standard. The AI now no longer functions according to the principles of supervised learning, but instead uses unsupervised learning.

Conversely, this means that exclusively defect-free components are used to define the quality standard and train the AI processes. They are generally available in significantly larger quantities than defective parts, and are more quickly available. Although these flawless parts will still need to be captured in images, the highly time-consuming pixel-by-pixel annotation of defects is no longer necessary. The Fraunhofer team has already been able to demonstrate that this can save up to 97 percent of the effort required for data collection.

Visual quality control is then performed using what is called anomaly detection, which identifies all deviations from the target quality. Artificial intelligence thereby assists inspection staff and supports them not only with detecting defects, but also with evaluating the images of defects. For example, visually similar images of defects are automatically collated for staff to classify them into meaningful defect categories (e.g. critical/non-critical defects).



Images: Detection of defective screws, transistors and encapsulations © *MVTec Software GmbH*

The technology for image-based anomaly detection offers great potential for application in the automated visual inspection of industrial goods. Jan Lehr, project manager at Fraunhofer IPK, is certain of this: »Not only can we keep the effort for data collection as low as possible, but also the effort for implementing AI-based visual inspection procedures. This makes such methods especially interesting for small and medium-sized companies.« He and his team are already looking for application partners who wish to test the possibilities of AI-based image processing in their inspection processes without having to dedicate a great deal of effort to integration. ◆

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Join in and Benefit

We would like to explore how AI technology can add value to your quality control. We need your support and your products!
Send us your products by December 31, 2021 and you will receive your potential analysis free of charge by the end of June 2022. We will then return the objects back to you.

More information:
www.ipk.fraunhofer.de/optical-ai-testing

The VIADUCT project is funded by the German Federal Ministry of Education and Research as part of its strategies for artificial intelligence and for the integration of the Eastern Partnership countries into the European Research Area since September 2020.

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AI in Production

Artificial intelligence is considered a key technology for industrial applications. Sven Hamann, Managing Director of Bosch Connected Industry explains the concrete benefits for manufacturing companies.

Interview with Sven Hamann,
Managing Director at Bosch Connected Industry

© Bosch

| futur | A Germany-wide survey by Bosch indicates that AI is highly popular as a key technology for industrial applications. What hopes do people associate with it?

/ Hamann / We do indeed sense that the industrial application of AI is currently gaining momentum. There is a great deal of curiosity and openness towards trying out AI. Many are hoping for greater efficiency, better work results, or greater safety in the operation of plants. Others see the technology as a driver of complexity and are concerned about a loss of control. That is why I am convinced that AI has to prove how it can be beneficial. We see this in products in the consumer segment: In this area, AI has now reached a level of maturity that provides a high level of benefit, and where I, as a user, tend to experience a reduction in complexity, such as in speech recognition. I believe that AI will also gain a lot of momentum in industrial production. In our plants, where we integrated AI solutions into specific use cases at a very early stage, we now see that we can leverage enormous potential. We are talking about savings amounting to several million euros per plant. These are pivotal aspects that will profoundly accelerate the introduction of AI in companies.

| futur | Which specific AI applications are already being used at Bosch?

/ Hamann / In manufacturing, we are already employing AI in a number of places. The classic example is certainly predictive maintenance. In this scenario, the current condition of the machine is monitored via sensor data. We use the data to detect malfunctions even before a production standstill can occur. By analyzing data from our manufacturing processes, we can gain new knowledge regarding the production processes. We then use this knowledge to optimize production parameters or cycle times. We also use AI in intralogistics. In a pilot project, we are currently optimizing the material supply dynamically during on-

SVEN HAMANN

MANAGING DIRECTOR AT BOSCH CONNECTED INDUSTRY, ROBERT BOSCH MANUFACTURING SOLUTIONS GMBH

Sven Hamann has headed the Bosch Connected Industry business unit since July 1, 2019. Before that, he was responsible for the central research area for manufacturing automation and metal and plastics technology at Bosch. He has broad international experience in production and mechanical engineering and holds a Diploma degree in engineering from the Technical University of Berlin with a focus on information technology in mechanical engineering.

going operation, thereby constantly adapting it to current conditions.

| futur | Despite its many advantages companies often still find it difficult to use AI technology. In your view, what are the biggest obstacles?

/ Hamann / One obstacle is in fact the degree of digitalization itself, which still varies greatly from one industry and company to another. The very first step is the availability of data throughout the entire life cycle of a product, i.e., starting with the product creation process, design, development, production, and ultimately its operation. This data must be prepared in such a way that makes it meaningful. If it is enriched with semantic data structures, for example, companies can tap its potential in two directions. For one, the feedback loop can be used to optimize the next generation of products, or to adapt products to specific user behavior. The second is to tap into business models. This constitutes the foundation. Before that, it is quite difficult to use methods like AI. This groundwork is at different stages of completion in various companies.

Another obstacle is the availability of expertise. Artificial intelligence, as previously mentioned, carries a very high potential. However, its benefits only emerge in the domain. This means that companies need to bring together domain experts such as materials scientists or production engineers with AI experts. I think it is key to actually view this digital transformation as being a transformational project. It starts with creating transparency – concerning the goals I am pursuing, about planning and implementation – and giving employees the opportunity to get involved, help shape things, and further develop themselves. The key aspect here being lifelong learning.

Image:
Industrie 4.0 is coming of age – thanks in part to Bosch's pioneering work in AI.
© Bosch

»Our goal is that by 2025, all Bosch products will contain AI or at least be developed and produced using AI.«

Sven Hamann

| futur | How does Bosch succeed in combining its own domain know-how with AI expertise?

/ Hamann / We try to do this deliberately in our Bosch Center for Artificial Intelligence. Here, we bundle the AI expertise of almost 300 people from different locations in seven countries. This allows us to involve AI experts at a very early stage of product or process development. The advantage for us, of course, is that the robots and machines are in the labs just next door. This means we have a very rapid feedback loop and can quickly identify what benefits an application will bring. Naturally, this is highly attractive for someone who wants to see the effects they are achieving with their work.

| futur | How important are partnerships in building such expertise?

/ Hamann / Extremely. The idea that you can do things entirely on your own has become outdated and is no longer realistic, especially in light of the complexity of the topics. We therefore make it a point to establish partnerships.

One such example is Cyber Valley in Tübingen, where we are conducting joint research with partners from the academic field and the private sector in the areas of AI, machine learning, robotics, and computer vision. On the one hand, we are faced with the challenge of applying the technologies to concrete use cases and generating benefits. But on the other hand, there are fundamental questions that have not yet been solved. One example is »Understandable AI«: How can I verify AI-based systems? How can I reduce the number of training cycles for my algorithms and still achieve a high-quality result? This is relevant in, e.g., potentially critical use cases such as autonomous driving.

In production, it is all about quality, which is of course also a valuable commodity for us suppliers. Manufacturers require an intelligent system the most when they introduce a new product. In order to start using the appropriate production processes, they need quality assurance. However, they do not yet have any training data at all to do so. This is a basic problem that we are very much concerned with. Furthermore, the robustness and transferability of the AI models to different machines and plants is also another issue. These are all fundamental challenges that cannot be solved by a company working on its own. That is why collaborative research work is necessary.

| futur | How long do you think it will take for AI to become a standard tool in companies?

/ Hamann / That is difficult to answer in such general terms. But I can tell you very specifically what we have set out to do: Our goal is that by 2025, all Bosch products, across the entire range and spectrum, will contain AI or at least be developed and produced using AI. We are implementing this step by step, and are well on our way. ◆

All Eyes on Recycling Management

Each year, up to seven percent of all end-of-life parts are discarded instead of being reprocessed for remanufacturing. An AI-based decision support system aims to make the identification of end-of-life parts more robust and profitable.

One thing is certain: Economy and ecology will need to become the best of friends in the coming years. In light of the Paris Climate Agreement, it is obvious that, particularly in a country with a strong economy such as Germany, strategies for emissions reduction, climate neutrality and sustainability in the manufacturing sector need to be expanded further – and quickly. In many respects, the course for this has already been set. For example, concepts for recycling products and components help to conserve resources while also reducing the amount of waste.

One way of doing this is remanufacturing, a process for restoring used equipment to make it as good as new. Combined with subsequent reuse, this can extend the service life of products. For this reason, the Circular Economy Act also assigns a high priority to remanufacturing, as it holds both ecological and economic potential. For example, a life cycle assessment of end-of-life automotive parts calculated that the refurbishment of an exhaust gas turbocharger can reduce emissions of CO_2 equivalents by 37 percent as compared to producing new ones. The process of collecting and sorting end-of-life parts involves identifying and assessing the condition of each individual part.

But how do you identify a component that is past its prime? Because of the large variety and sometimes soiled and deformed products, this sorting process is often difficult and needs to be handled individually as well as manually. Furthermore, the only reliable visual identification feature is the part number, which is often no longer legible. It is therefore not surprising that many end-of-life parts are mistakenly discarded – simply because it is not possible to identify them. As a result, only their raw materials are recycled, instead of directing them to be maintained. A large portion of the original value of the product is thus lost.

Image:
AI-supported decision support system for semi-automated sorting of used components

But challenges are always accompanied by opportunity and this case is no exception: In the EIBA project, a team of researchers is developing an AI-assisted system for the semi-automated sorting of used parts. Based on the two-man rule, it aims to assist employees in production with sorting in the future, thereby allowing more end-of-life parts to be sent for remanufacturing. As part of a holistic concept, it aims to help make the sorting process more robust, better defined, and more profitable. For this purpose, all available data from the sorting process will be used and analyzed with regard to their added value in order to develop a decision support system that will facilitate the work of employees.

DIVIDE AND CONQUER

In the project, researchers at Fraunhofer IPK are investigating a range of parts comprising around 120,000 different variants in widely varying conditions. To simplify the complexity involved, the familiar »divide and conquer« approach from computer science is being applied. Process knowledge concerning the composition of the range of parts is used in order to divide a problem into less complex sub-problems. Hence, at the beginning of a selection process, image-based processing of the end-of-life part takes place. During this procedure, the packaging of the end-of-life part is first

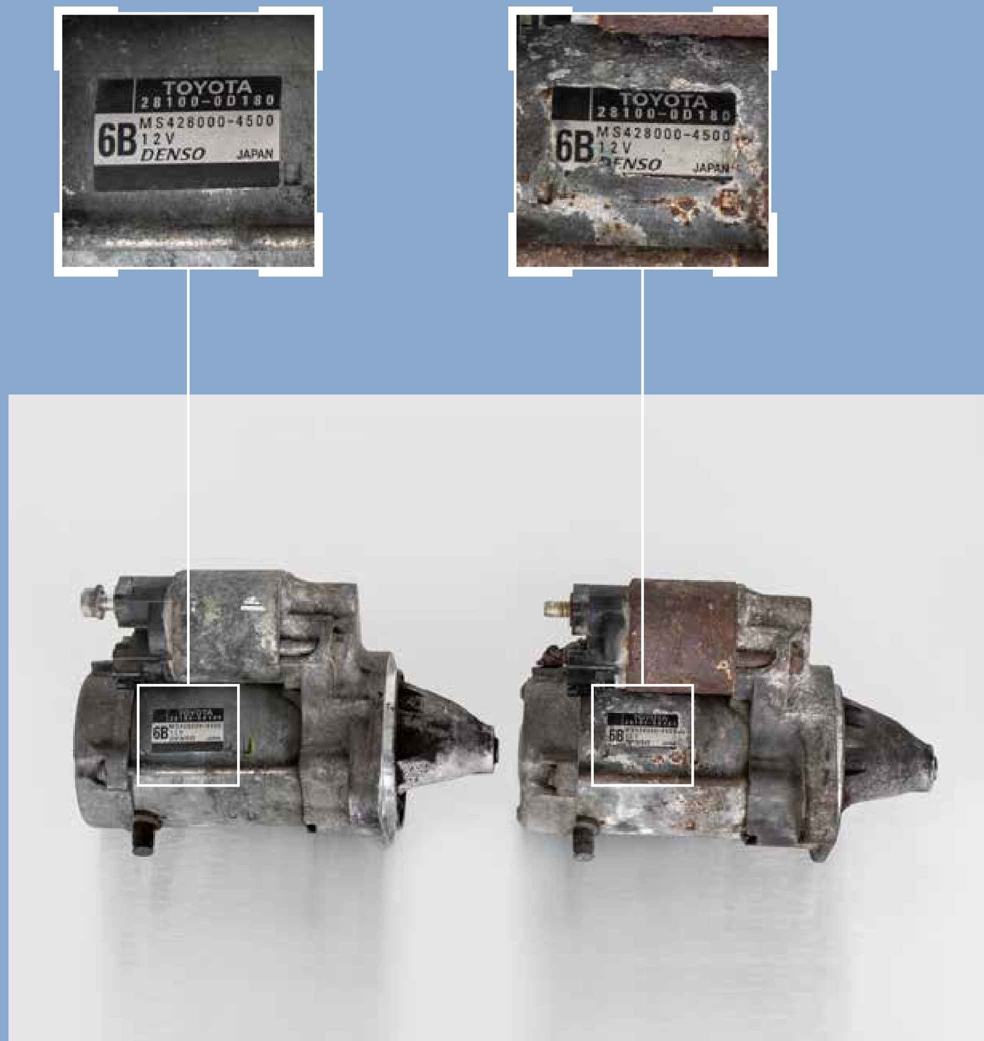


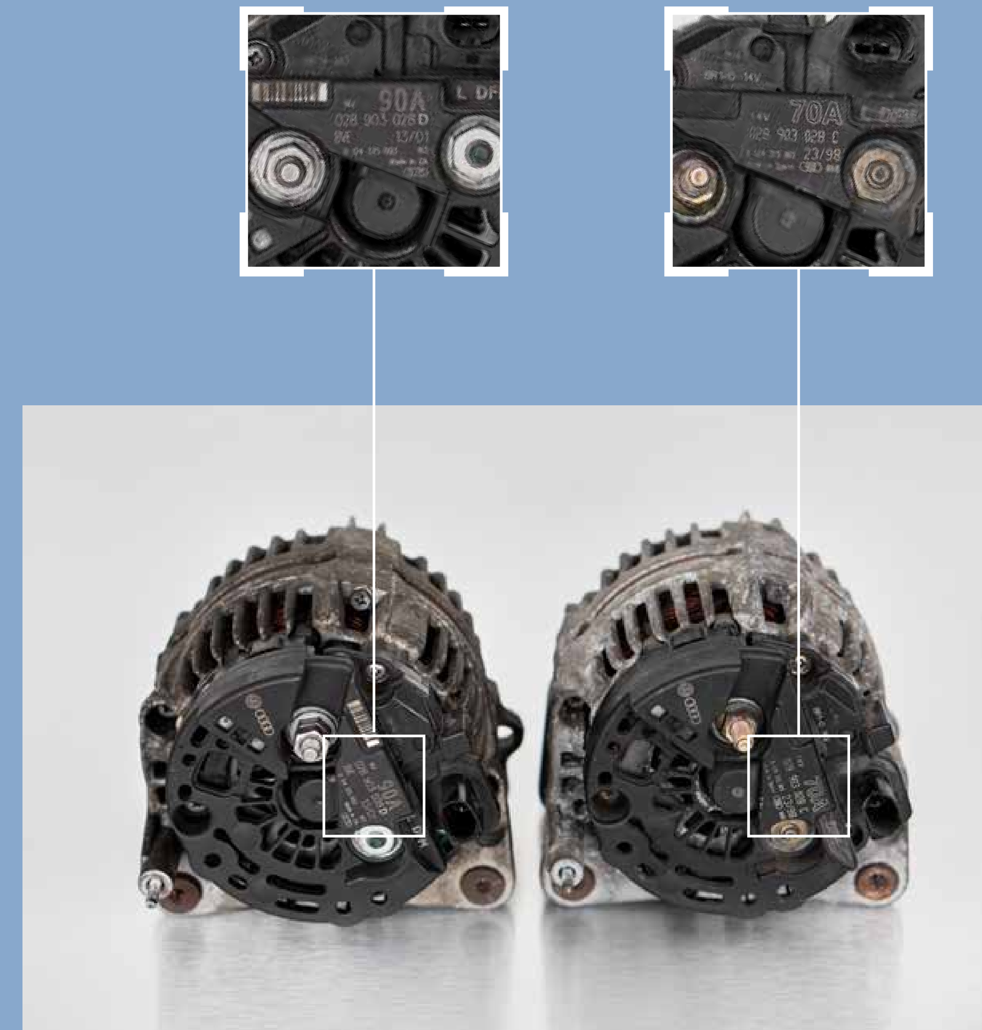
Image:
Condition variance – two starters with identical part number differ visually due to signs of wear.

scanned to obtain information about the product group. This approach reduces the identification of the part from 1:120,000 in the application scenario to 1:5000.

Following the image-based processing, the results obtained are combined with the analysis of part-specific business data in order to perform reliable and valid identification. To increase the robustness of the identification process, text recognition (OCR – Optical Character Recognition) is being developed in addition to feature-based identification. This technology attempts to recognize labels on the images captured and evaluate them. Although the information extracted may be incomplete due to wear and tear, it is suitable for verifying the results of the image-based evaluation.

The identification of an end-of-life part is performed primarily using what are called Convolutional Neural Networks (CNN). These are machine learning algorithms which specialize in the extraction of features from image data. The approach described not only simplifies identification, but also enables the use of more compact network architectures, thereby significantly reducing computation times when training and applying the algorithms. Over the course of this process, the knowledge gained is also used to continuously refine the algorithms and hence augment their performance.

Image:
Product variance – two generators with different part numbers are visually similar.



AI MEANS TEAMWORK

In Germany, around five to seven percent of one million end-of-life parts, i.e. up to 70,000, are discarded each year because they cannot be identified. An initial study in the project yielded a recognition accuracy of around 96 percent using image-based identification alone. In terms of the 70,000 discarded old parts, AI-based identification is expected to enable 67,200 more end-of-life parts to be correctly returned to the materials cycle than before.

This combination of human know-how and AI-based evaluation of images, components, and business data has resulted in a new, innovative and holistic approach to remanufacturing. The two-man rule consisting of humans and AI decision support systems helps to make objectively reproducible decisions, thus creating more transparent and economical work processes. ◆

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Transforming Job Profiles with Algorithms

Digitalization is transforming job profiles and production requirements. An AI-based role navigator is supposed to help industrial companies prepare their employees for the networked production.

Digital transformation means more than just selecting digital tools and processes and introducing them to a company. A successful digitalization strategy also involves training employees for new types of tasks in a digital, networked production system. But how do you decide which employees are best suited for which new roles? What further training do they need to acquire the necessary know-how for their new duties? And how can one find suitable learning opportunities in the scattered market of advanced vocational training?

Small and medium-sized enterprises (SMEs) in particular – the core target group of the KIRA Pro project – face major challenges when answering these questions. They rarely have sufficient resources to systematically manage skills. Many companies have not yet developed a mature strategic orientation with regard to digital transformation. This makes it difficult to evaluate and weigh up the specific areas in which expertise needs to be built up and expanded in the medium term.

KIRA Pro approaches the problem by assisting companies facing these decisions with the help of artificial intelligence. A »role navigator« is used to identify suitable offerings which serve the company's goal out of a large number of advanced training courses. It can create an individual and industry-specific learning path for any particular employee.

Let us play this through using an example: Based on its transformation strategy, a company has determined

> KIRA Pro generates learning paths with different training courses, which in total make you fit for a new role.

that the job profile of the multi-machine operator will become more important in the future. The necessary expertise for this target role is to be cultivated among existing personnel. To this end, employees who possess suitable prior knowledge are to be provided with targeted training. The existing qualifications of employees are fed into the role navigator. It then checks which training courses can take the various employees from the level of their current know-how and skills to the necessary qualification for the target role. A learning path is thus created for each employee with various tailored qualification modules that would, in total, make them suitable for the target role.

Since employees will have different levels of prior knowledge, the role navigator determines that the learning paths of the various colleagues would be very heterogeneous in terms of their length and complexity. This can be seen in the sample diagram: Sabine, a programmer, would have to complete a learning path with detours and side branches to qualify as a multi-machine operator. The mechatronics engineer Peter, on the other hand, could be trained for the target role along a straightforward learning path with significantly fewer stations.

Such matching between corporate strategy, existing competencies, and available training opportunities makes it easier to navigate the continuing education market and eliminates the need for users to develop manual search strategies. The algorithm that emerges in KIRA Pro will take into account preferences and the learning strategies of trainees when selecting offerings. For example, training courses, coaching, e-learning, or practical units can be incorporated. The project thus also takes into consideration the trend toward smaller learning units and new learning formats. Continuing education offerings sourced from various renowned learning partners are fed into the system. One future goal is the user-friendly integration of the 3000 professions and 12,000 skills of the European ESCO framework into the software.

The project brings together a consortium of training providers and SMEs with transformational ambitions. Peers Solutions GmbH combines HR expertise and further education with AI experience in the manufacturing sector. FBT Feinblechtechnik GmbH and Harms & Wende GmbH & Co. KG possess innovative strength and years of experience in mechanical engineering. In collaboration with providers of continuing education platforms, the Fraunhofer IPK project team aims to enable the industrial partners to devise strategies for operational transformation and expertise development and to implement them in the real world. ◆

More information:
www.ipk.fraunhofer.de/kira-pro-en

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AI-based role navigator

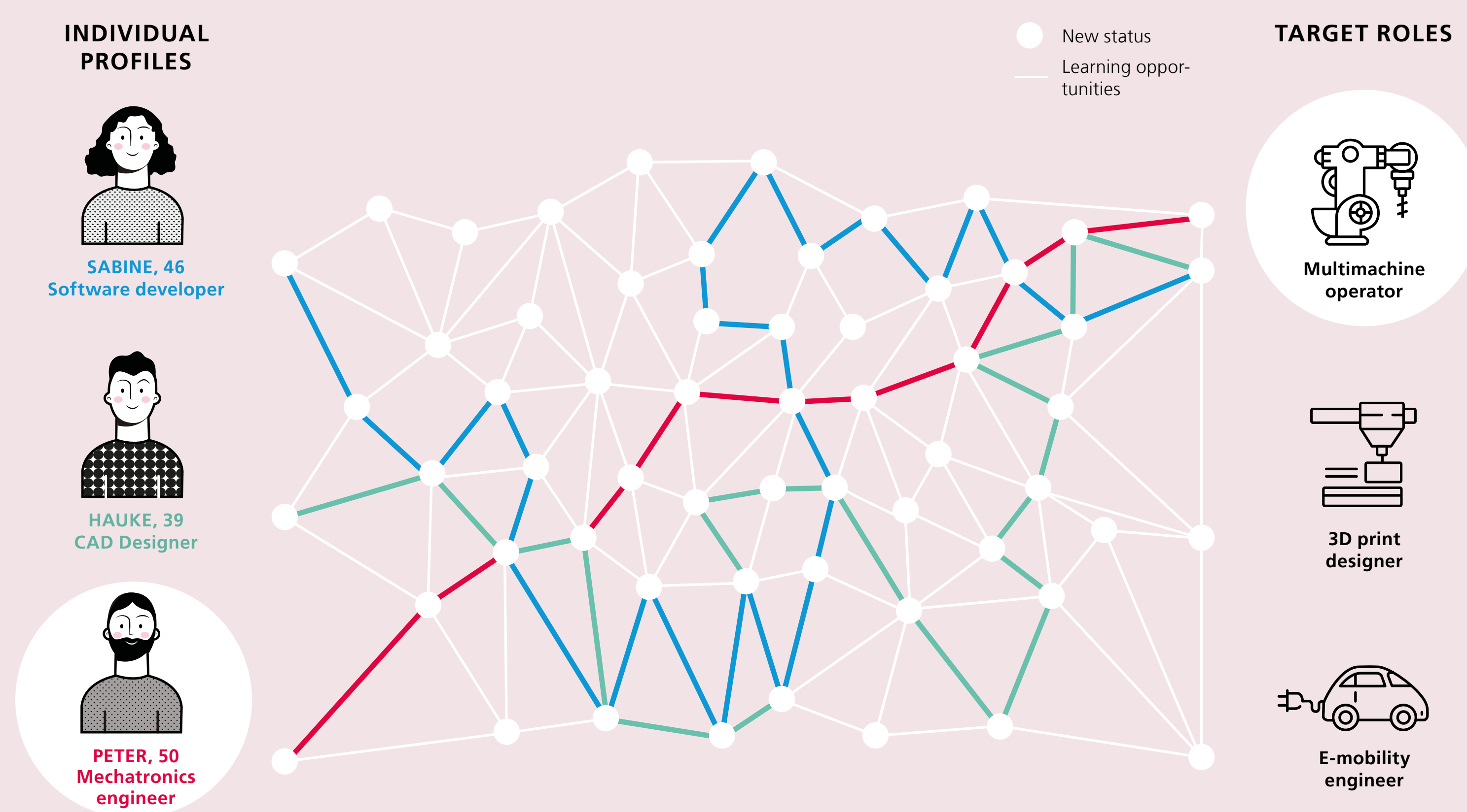


Illustration: pikisuperstar / Freepik | Pictograms: Flaticon.com

Welding Technology Meets Artificial Intelligence

Modern additive processes require highly efficient quality assurance methods. Could neural networks be the key?

Pores, fine holes, poor bonding, spatter, microcracks in a layer – all these are typical defects that can occur during laser powder directed energy deposition (DED). Considering the multilayer structure of this additive process, these defects can lead to deviations in shape and irreparable damage, thereby making life difficult for manufacturing companies and end users. In a process that is used for repairing turbine components or applying wear layers, such defects can have fatal consequences for critical components.

At the same time, this manufacturing process has numerous benefits: In addition to a very high process speed, comparatively high deposition rates are achieved with a relatively low energy input. Not only does this minimize distortion, it furthermore preserves the microstructure of the base material. It is therefore a worthwhile investment for manufacturing companies to use the DED process – provided the required quality of the end products can be guaranteed.

ASSURING QUALITY – BUT HOW?

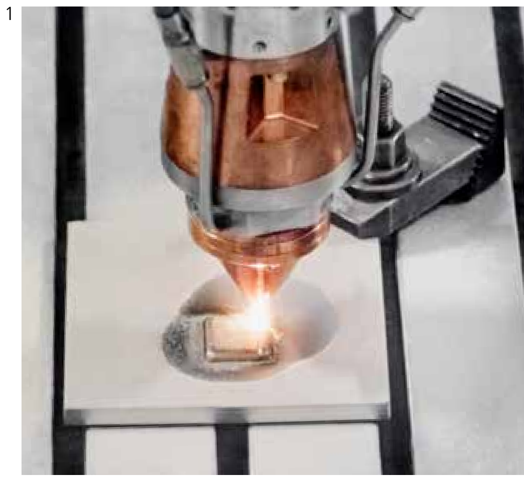
Quality assurance in laser powder DED is complicated due to the influence of several parameters, such as the laser power, feed rate, powder mass flow, and laser spot diameter. That is why various sensors are used to monitor the process.

The challenge is now to draw conclusions about the qualitative properties of the component from the measurement data acquired by the sensors. Ideally, the data can also be used to predict process parameters and to document process quality. However, such conclusions are only possible, if large amounts of data are collected over a longer observation period and with high resolution. Suitable algorithms will be required to efficiently evaluate this data. Researchers at Fraunhofer IPK set out to work on this problem.

NEURONALLY NETWORKED

The team uses artificial neural networks to map complex processes such as laser powder DED. In the application, learning or training phases are carried out first. Due to the iterative design of the network, knowledge gained from previous phases is used to optimize the network itself. After successful validation, the developed neural network serves as a tool for the researchers to analyze data: On the one hand, it is able to respond to previously recorded input data with the corresponding outputs (association). On the other hand, it can map

1



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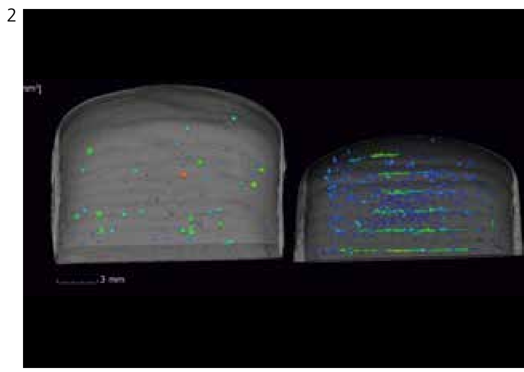
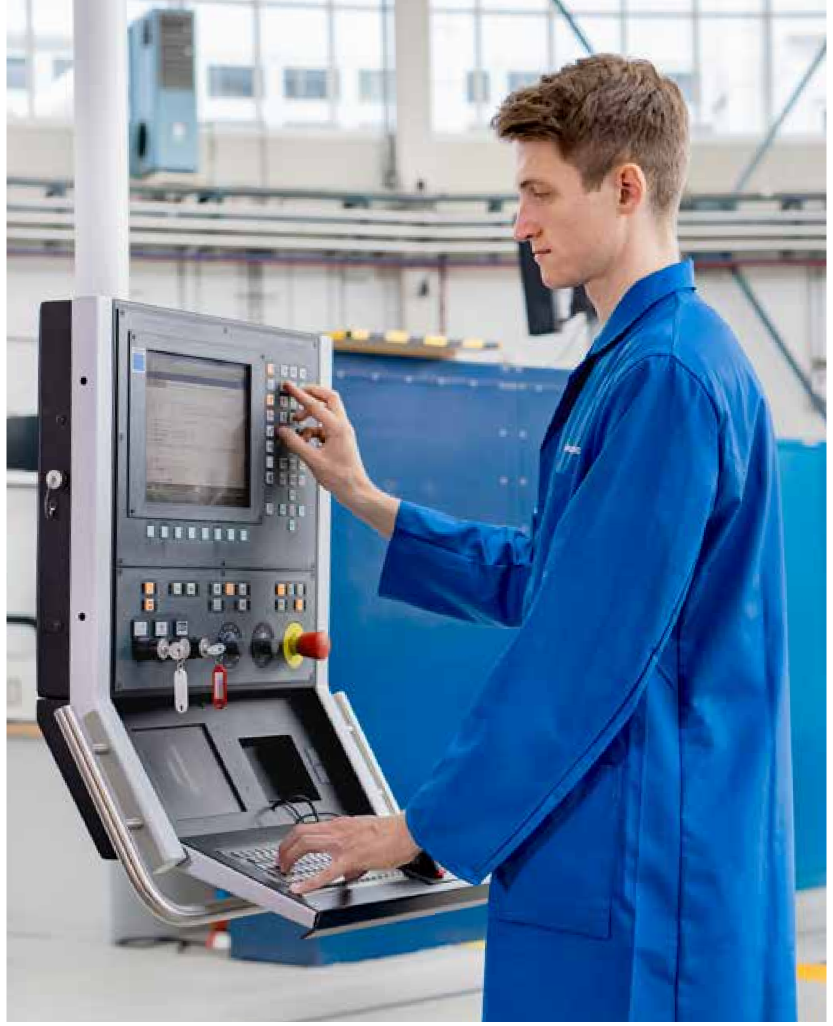


Images:
1
Laser powder directed energy deposition (DED) is used to produce samples.
2
Defects in built-up volumes can be predicted using neural networks.

statements to patterns that have not yet been learned (abstraction). This allows for the description of complex interactions between process variables and quality characteristics.

The scientists are currently investigating how different sensors can be combined in order to record certain measurement data during the DED process which is particularly suited for applying AI methods to quality assurance. For this purpose, pyrometers, laser scanners, melt pool cameras, and laser intensity measurement sensors are used.

Once the measurement data from the various sensors has been obtained, it needs to be cleaned up and processed. Only then can the researchers use it as input for an artificial neural network, in addition



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2

to the process parameters. To this end, the team needs to find a way to determine the key statistical parameters, such as mean values, maxima, or minima. Furthermore, abstract mathematical quantities, such as Fourier constants, can be extracted. Typical measurement data series yield approximately 1000 of such computable features. Using suitable algorithms, these are prioritized and greatly reduced, creating a solid database for artificial neural networks.

TANGIBLE RESULTS

The research findings to date show that defects can be avoided and quality characteristics predicted by employing AI for welding technology. The project team was

Image:
1
Man, machine and AI work closely together.
2
In the DED process, samples of different quality are built up by varying process parameters.
3
Sensory mapping of the samples creates the data basis for training the AI.

Quality assurance in welding technology can be revolutionized on the basis of artificial intelligence.

able to correctly predict the density of additively manufactured components with 97 percent certainty by using AI methods.

Based on such information, users can make decisions as to whether a component is suitable for a particular task or whether it should be classified as scrap. This will allow costs and lead time for downstream testing to be reduced in the future. The researchers are confident that companies will soon be able to benefit from the gained knowledge. For one, quality assurance in welding technology could be revolutionized with artificial intelligence. What is still missing is more empirical data from real-world applications, which will be collected in upcoming projects with industrial companies. ◆

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3

The Brain as a Model

Brain research and technological development are driving each other forward. With the help of neuro-inspired technologies, supercomputers, and artificial intelligence, we can continuously deepen our understanding of the complexity of the human brain.

A guest article by Prof. Dr. med. Katrin Amunts, director of the Institute of Neuroscience and Medicine at Forschungszentrum Jülich

Neuro-inspired technologies mimic certain principles of the structure and functioning of the human brain, and have led to breakthroughs in the fields of supercomputing, data science, and machine learning. Conversely, neuro-inspired technologies can also help us learn a great deal about how the brain works.

One example is the European Human Brain Project (HBP). In this project, researchers from more than 122 research institutions from 17 countries are working together to link brain research and information technology. We want to understand the human brain in its multi-level complexity in time and space down to the smallest detail, and put this knowledge to use in medicine, computer science, and technology. Supercomputers and artificial intelligence help the project's neuroscientists analyze the massive amounts of data required for this purpose. For example, we were able to create an anatomical model of the human brain with a resolution of 20 micrometers from thousands of digitized histological sections of the brain. The model provides valuable insight into the architecture of the brain and enables us to better understand diseases and treat them in a more targeted fashion. But new insights from brain research not only advance medicine – they also contribute significantly to the development of new, powerful, and energy-efficient AI and computing technologies.

For example, when it comes to learning something quickly (»single shot learning«) or constantly refining what was previously learned (»life-long learning«), artificial intelligence still lags significantly behind human intelligence. Furthermore, the brain is extremely space- and energy-efficient as compared to powerful computers – properties that are particularly important for the use of artificial intelligence in mobile applications. For example, our brain requires less energy than a 30-watt light bulb for highly complex information transfer and processing. It thus consumes only in a range of one millionth of the energy a supercomputer does. This is due to the fact that nerve cells communicate with each other particularly efficiently using electro-chemical transmission. They do so by using these electrical impulses, known as spikes, extremely sparingly. On the other hand, there are many types of calculations where supercomputers perform many times faster. Better understanding these functional differences is a matter of interest for both computer science and brain research.

Researchers at the Human Brain Project at Graz University of Technology have drawn inspiration from findings in brain research to develop a new learning algorithm for artificial intelligence. Similar to the brain, the individual cells of the artificial neural network are only activated when their impulses are actually needed to process information. In future, the learning algorithm will be integrated into a chip by the manufacturer Intel as well as into the SpiNNaker system, the world's largest neuromorphic computer architecture.

Our brain requires less energy than a 30-watt light bulb for highly complex information transfer and processing.

SpiNNaker was developed by scientists at the University of Manchester. The system's structure is based on that of a biological nervous system and comprises one million processor cores. This means it has the capacity to simulate the neuronal activities of a mouse brain. The system is openly available to researchers worldwide via the EBRAINS digital infrastructure, which was developed as part of the Human Brain Project, and holds enormous potential for brain research, computer science, and robotics.

Working with a research group at Dresden University of Technology, the Manchester team recently developed an AI chip called SpiNNaker2 as part of the Human Brain Project. The chip exhibits unparalleled efficiency and sub-millisecond latency for event-based systems. It is to be installed in a computer system with 10 million processor cores at TU Dresden. There, it will be tested in applications for autonomous driving, data traffic in smart cities, tactile Internet applications, and biomedicine. Furthermore, the chip will soon be commercialized via the Dresden-based startup SpiNNcloud Systems.

Prof. Dr. med. Katrin Amunts

was elected as scientific leader of the European flagship Human Brain Project (HBP) and became scientific research director in 2016. She is professor for brain research at the C. and O. Vogt Institute for Brain Research at Heinrich Heine University in Düsseldorf, Germany, as well as director of the Institute of Neuroscience and Medicine at Forschungszentrum Jülich, Germany. Her research focuses on organizational principles of the human brain and how its structure relates to function and behavior. At the beginning of her career, Katrin Amunts worked as a research assistant in the Machine Vision department under the leadership of Dr. Bertram Nickolay at Fraunhofer IPK in Berlin in the early 1990s. »I was able to draw a great deal of useful information for applications in brain research from the methods of image analysis and the various industry approaches that I became acquainted with at Fraunhofer IPK. Even in my latest research, I am using a method that I learned during my time in Bertram Nickolay's department.«

Machine Learning Three Ways

Data evaluation methods are omnipresent in our daily lives. They also provide compelling solutions to problems during manufacturing and assembly, as demonstrated by a pilot project with Rolls Royce in Germany.

Even when dozing off, we are still able to mumble »Set the alarm for 6.30 am« in the direction of our smartphone. The response from the calmingly electronic voice gives us the certainty we need to fall asleep peacefully. Hidden behind the scenes of this everyday exchange are complex data analysis methods. A combination of natural language generation (NLG), natural language processing (NLP), and machine learning (ML) conjures up an intelligent assistance for all occasions.

Today, we benefit from data analysis methods in almost all areas of life – not just in our private lives, but also in industry. For example, when a new product is to be launched on the market, a great deal of data with important, mostly implicit insights into the product itself along with the associated manufacturing processes is being generated from the very beginning of its life cycle. Having employees in product development evaluate it would be a daunting task. This is where machine learning methods come into picture. Such methods evaluate the existing data automatically. Employees can use the resulting findings to optimize manufacturing processes, solve problems more quickly, as well as improve overall product quality. The possibilities are practically endless.

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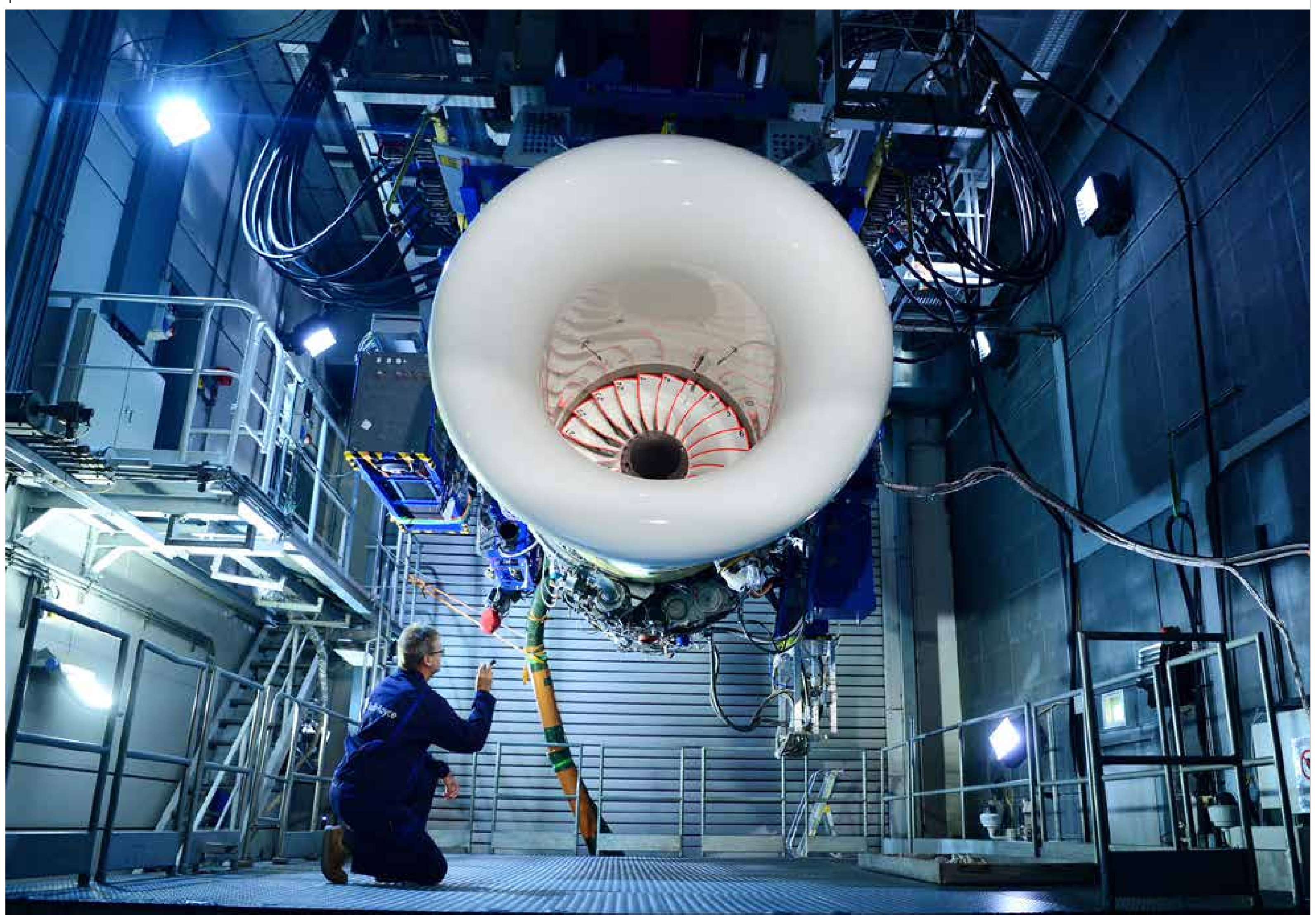

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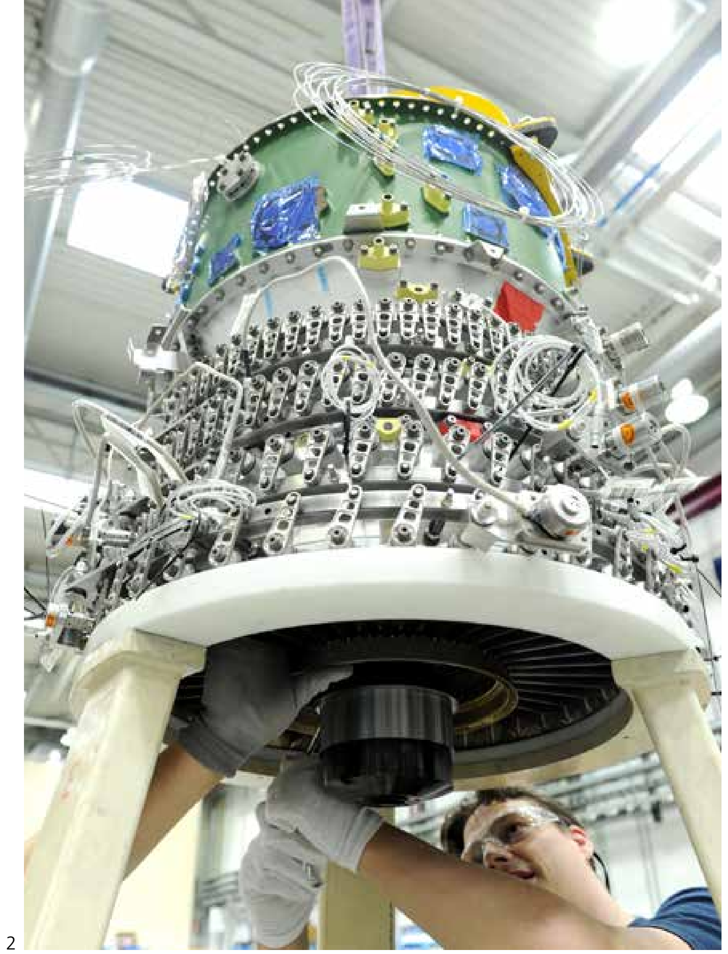


The possibilities of machine learning for manufacturing and assembly problems are practically endless.

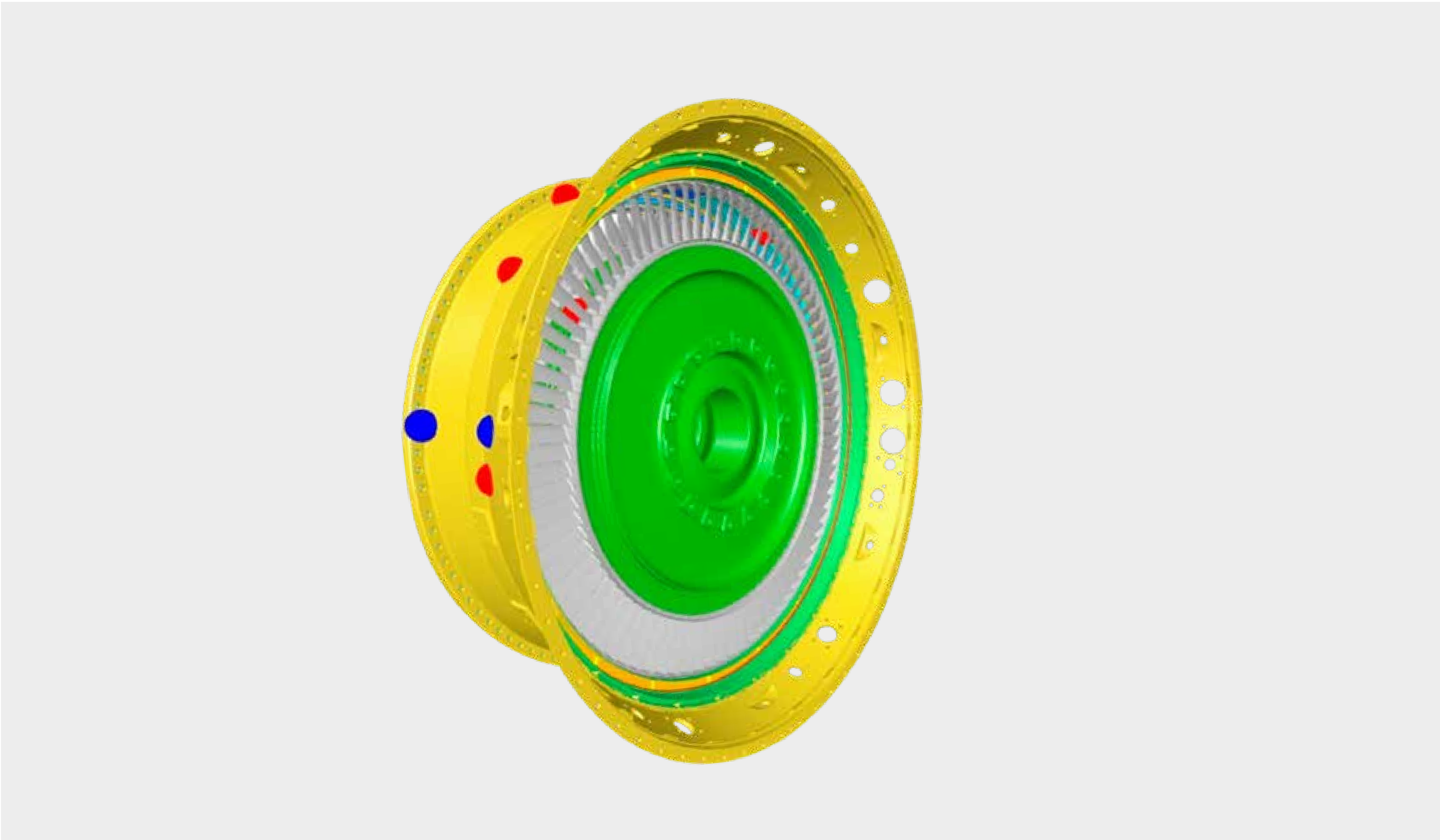
Images:
1
A Rolls Royce Pearl 15 turbine on the test bench
© Rolls Royce plc
2
Assembly of the Pearl 15
© Rolls Royce plc

A POWERFUL TRIO

In Cockpit 4.0, a collaborative project with Rolls Royce Germany, researchers at the Fraunhofer Institute for Production Systems and Design Technology IPK developed a virtual decision support system that uses ML methods to derive useful insights for solving manufacturing and assembly problems. For example, if a turbine part is missing during the assembly process, a team can be tasked with locating it. This prevents delays in the assembly process. For this purpose, three ML approaches were tested using the available data:

1. Natural Language Processing
Natural Language Processing (NLP) is a machine learning method for processing natural language. In the project, NLP was used to identify matches with previous descriptions of problems in order to allow inferences to be drawn about current cases. A distinction is made between automatically and self-trained models, whereby the latter are trained independently by the researchers using specific vocabulary.

Three different NLP algorithms were used: a bag-of-words model, a self-trained Word2Vec model, and an automatically trained Word2Vec model. In the bag-of-words model, the individual terms of previous problem descriptions were evaluated without taking grammar into consideration, and compared against terms from current cases. The Jaccard coefficient was used to measure similarity. The second NLP algorithm was trained by the researchers themselves. It is based on a Word2Vec



1

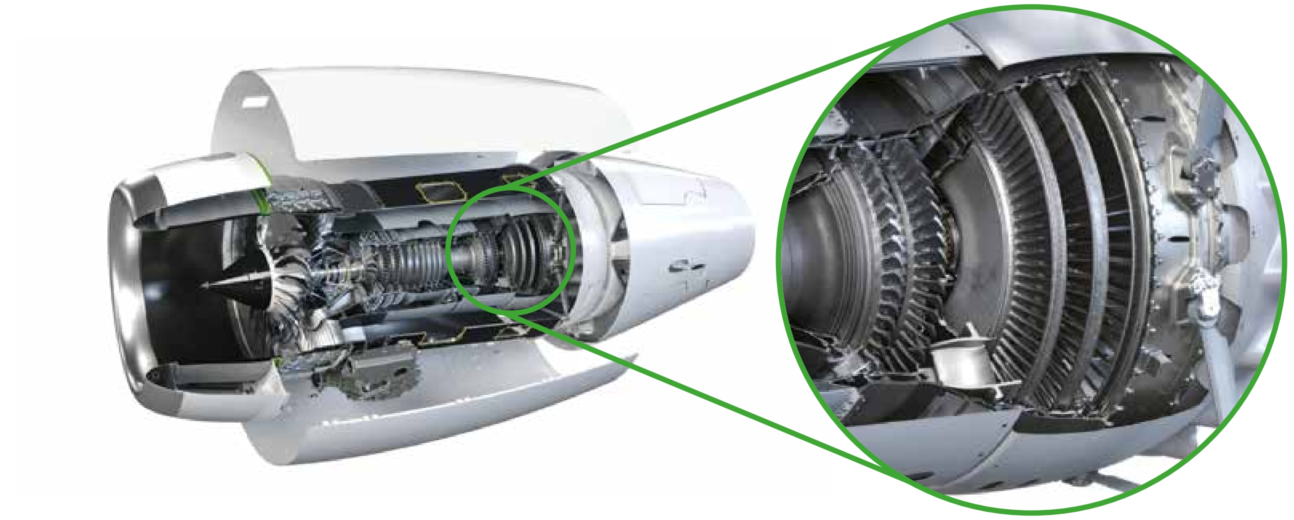
model that vectorizes terms, i.e., classifies them according to previous occurrences. The second Word2Vec model was trained automatically with the aid of Google News. For both Word2Vec models, Word Mover’s Distance was used to measure similarity. In the evaluation, the self-trained model showed the best performance, while the model trained using Google News exhibited the lowest accuracy. This is due to the fact that independent training, i.e., entering industry-specific terms and abbreviations in the model, leads to more precise results. The results clearly demonstrate that training the models independently is beneficial for accurate matches.

2. Regression-based Approach

The regression-based approach is frequently used to predict results based on variables. In Cockpit 4.0, it was adapted to generate a model that can predict the processing time required for an incoming case or problem.

This information can help in prioritizing problems. In the event of time-consuming cases, appropriate measures can be taken to shorten the period of time until the problem is resolved. The start and end dates of cases are generated to determine the duration of each case using supervised learning, i.e., data processing with predefined parameters. Four types of regression models were trained, namely linear regression, lasso regression, a support vector regression model (SVM), and a model tree with SVM. The model tree with support vector regression models achieved the lowest error rate.

Images:
1
In the demonstrator, the 3D model of a turbine part shows open and closed assembly problems.
2
The installed turbine part
© Rolls Royce plc



2

Clusters can provide the user with similar cases, which then serve as the starting point in solving the current problem.

3. Clustering

Clustering is another machine learning method which can be used to assign different data points to specific groups. In the project, the clustering approach was used to subdivide the data sets into clusters in order to identify similarity patterns. The clusters can provide the user with similar cases via unsupervised learning, which then serve as the starting point for their research in solving the current problem. Three types of clustering algorithms were used, namely DBSCAN, HDBSCAN, and k-means. k-means clustering achieved the best qualitative results.

TECHNOLOGY IN SEARCH OF USERS

With the solution developed at Fraunhofer IPK, the researchers succeeded in demonstrating that companies can use data sets for the long-term improvement of development and production processes through machine learning approaches. At the end of the Cockpit 4.0 project, a prototype was created employing these three methods, and was extensively tested and evaluated by end users at Rolls Royce. Above all, they cited the time saved when solving assembly problems as the main benefit. At the same time, it also became clear that the virtual decision support system still needs to be further developed and refined in order to be seamlessly integrated into daily work processes. Such improvements could be subjects of future research projects, which could also benefit other partner companies in the industry. ◆

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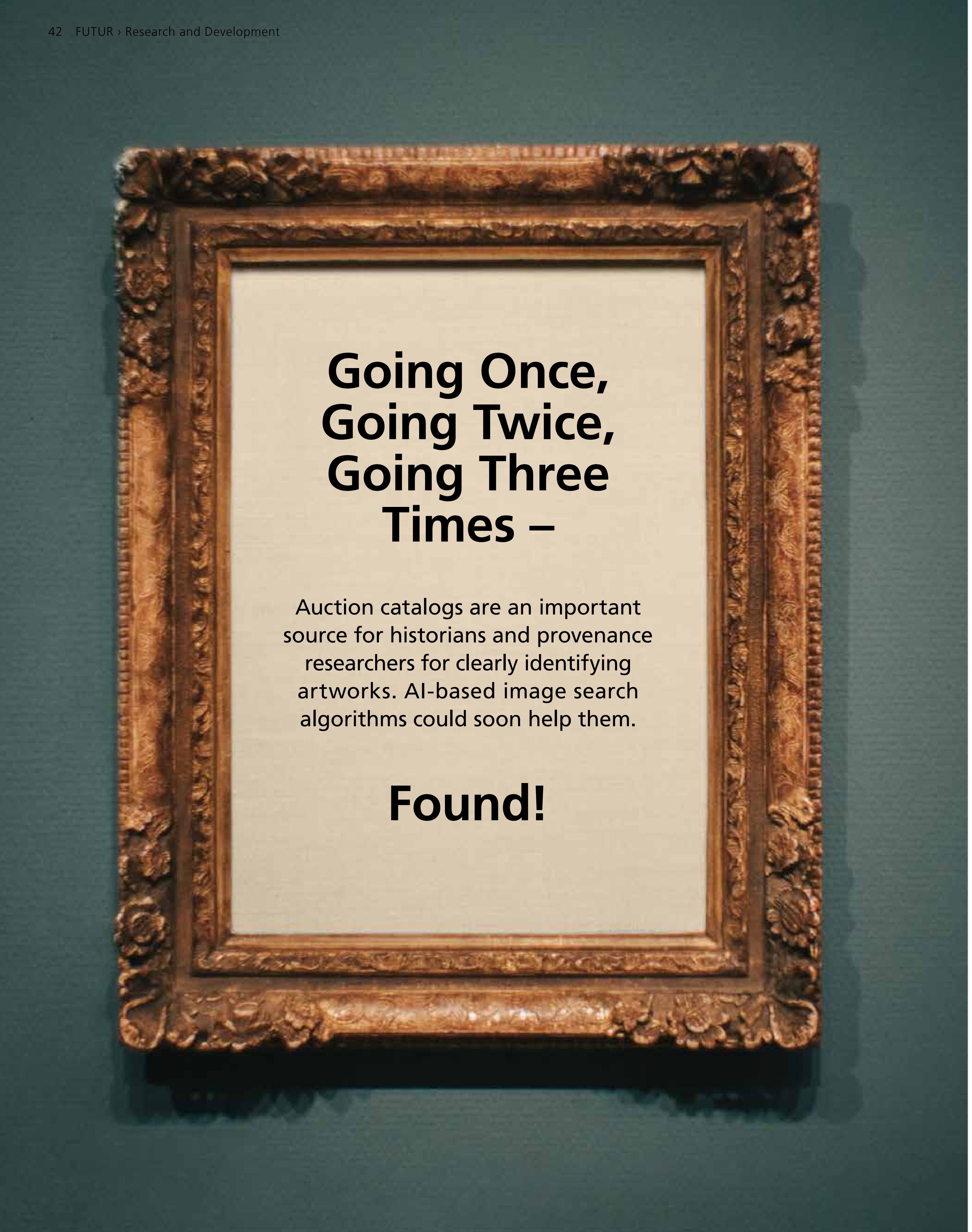


Going Once, Going Twice, Going Three Times – Found!

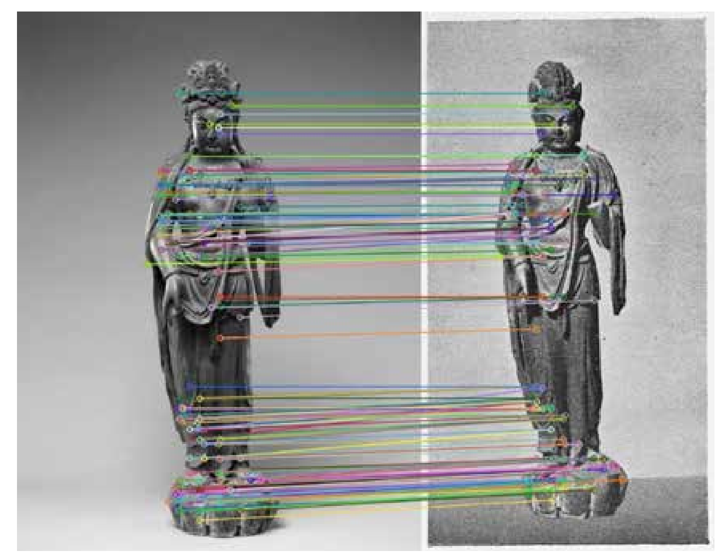
Auction catalogs are an important source for historians and provenance researchers for clearly identifying artworks. AI-based image search algorithms could soon help them.

Bodhisattva Mahasthamaprapta (Dashizhi)
13th century

If one wants to research the art market of the first half of the 20th century, there is no getting around auction catalogs. They are an indispensable research tool, especially for provenance researchers: They document where a work of art came from, who it once belonged to, and where and when it changed hands, often over several centuries. »German Sales« is a database that has been growing for around ten years. It digitally records and centrally collects information on the historical art market in Germany, Austria, and Switzerland. It was launched as a collaborative project between Heidelberg University Library, the Kunstbibliothek of the Staatliche Museen zu Berlin, and the Getty Research Institute in Los Angeles. Around 11,000 auction catalogs along with gallery, storage, and antiquarian catalogs are now available online and via open access.

On behalf of the Rhineland Regional Council (Landschaftsverband Rheinland, LVR), researchers at Fraunhofer IPK have investigated the extent to which modern computer vision methods can help with researching works of art in such digital auction catalogs. Guido Kohlenbach, head of the Department of Culture at LVR, explains: »Automated identification of cultural assets or art objects in online catalogs would make it easier to research the whereabouts of objects at specific times as well as stored data in the publications and thus obtain valuable information about owners.«

1



2

As part of a feasibility study, the Fraunhofer researchers developed AI-based image search methods that can reliably match images or art objects. The methods were validated using pairs of images, each representing matches between auction catalogs and other digital image collections. The researchers were confronted with the challenge that images of one and the same art object can vary greatly depending on the date and

Images:
With the help of AI-based methods, current and historical images of art objects can be compared with each other.
1
Original
© *The Metropolitan Museum of Art*
2
(left) Public Domain, The Metropolitan Museum of Art; (right) German Sales, University Library Heidelberg
© *Fraunhofer IPK*

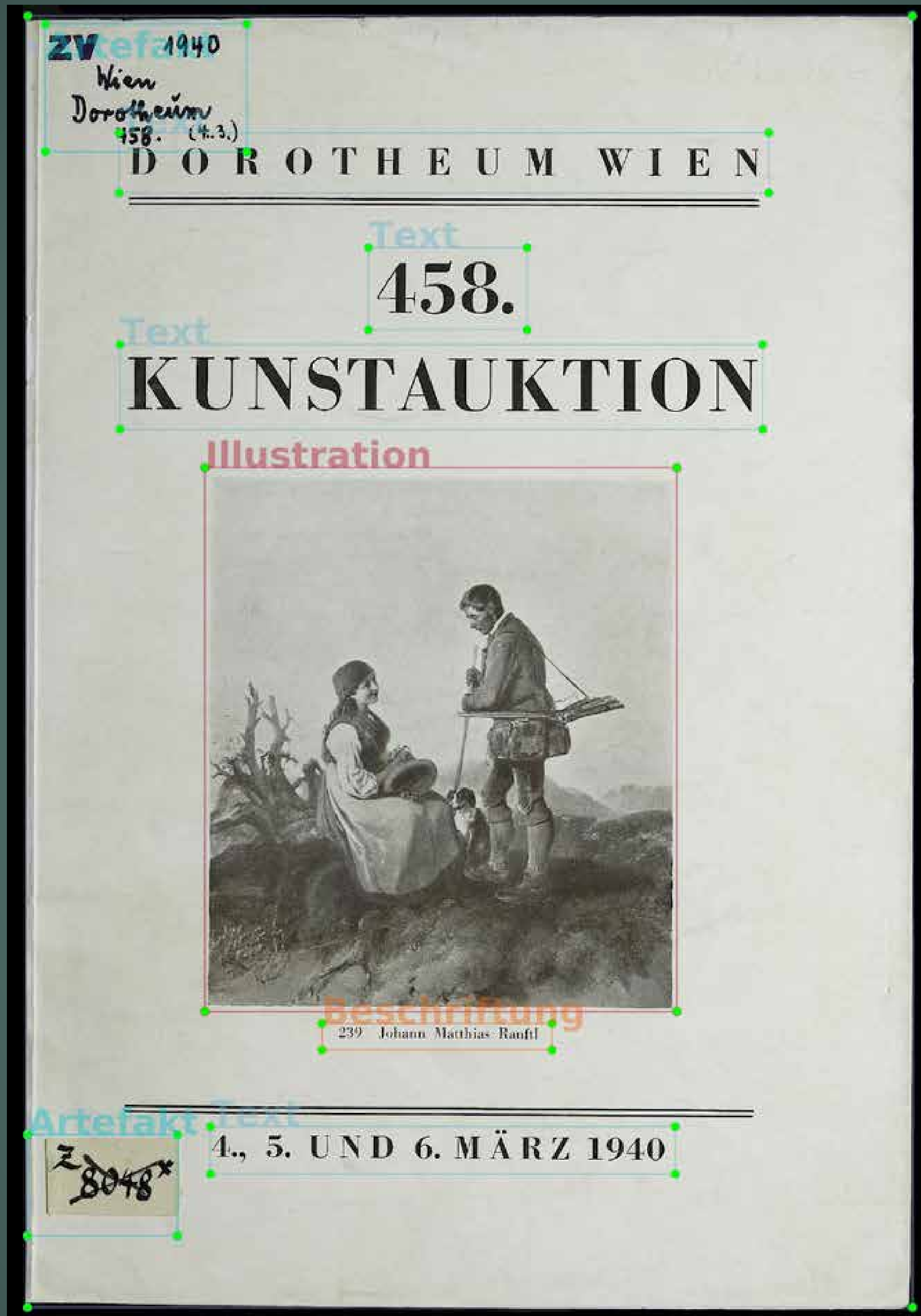


Image:
Results of the automatic segmentation of a page from an auction catalog

1

2

Lidded vase, Cornelius Funcke
around 1710

technique of image acquisition, image quality, perspective, or even the type of object itself (2D or 3D).

The preparation and quality assurance of the image data therefore played a central role in the project, starting with the extraction of images from over 11,000 auction catalogs in the »German Sales« database. »Due to the large number of images, purely manual processing would be very time-consuming and expensive,« explains Raúl Vicente-García, project lead at Fraunhofer IPK. »That's why we are using state-of-the-art computer vision methods that have been proven successful in the automated analysis and segmentation of documents, and adapting them with the help of AI to the special features of historical images.«

The results of the feasibility study are promising: Around 560,000 images of paintings and sculptures, items of art, and even everyday objects such as furniture or cutlery can be searched

Images:
1
Automated matching process of two images of the same object in detail
© Germanisches Nationalmuseum, Nürnberg
2
From a database of almost 600,000 objects, the objects matching the query are output automatically.
© German Sales, Universitätsbibliothek Heidelberg

within just a few seconds using the Fraunhofer methods. During this process, AI-based image features are collected for each individual item so as to achieve a high recognition rate despite the high variability in the type and quality of the images. The image features which are automatically analyzed on different scales range from contours and textures to item details such as the eye of a person depicted in the image. Thanks to the adaptability of the AI-based methods, it is also possible to match current and historical images, which exhibit a much lower image quality.

With their feasibility study, the Fraunhofer experts prove that AI-based image search methods are suitable for provenance research. In the next step, which involves the development of a prototype software solution, the scientists are currently looking for museums, foundations, and libraries that are interested in researching and documenting the provenance and ownership history of their cultural assets more efficiently. ◆

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The feasibility study on the use of AI-based image search methods for provenance research was conducted by Fraunhofer IPK on behalf of the Rhineland Regional Council and with the support of Heidelberg University Library and the international Arbeitskreis for Provenienzforschung e. V. (Research Association for Provenance Research).

Producing the Future

In Berlin's Siemensstadt², researchers are getting tomorrow's production lines off the ground. Spoiler: artificial intelligence will play a key role!

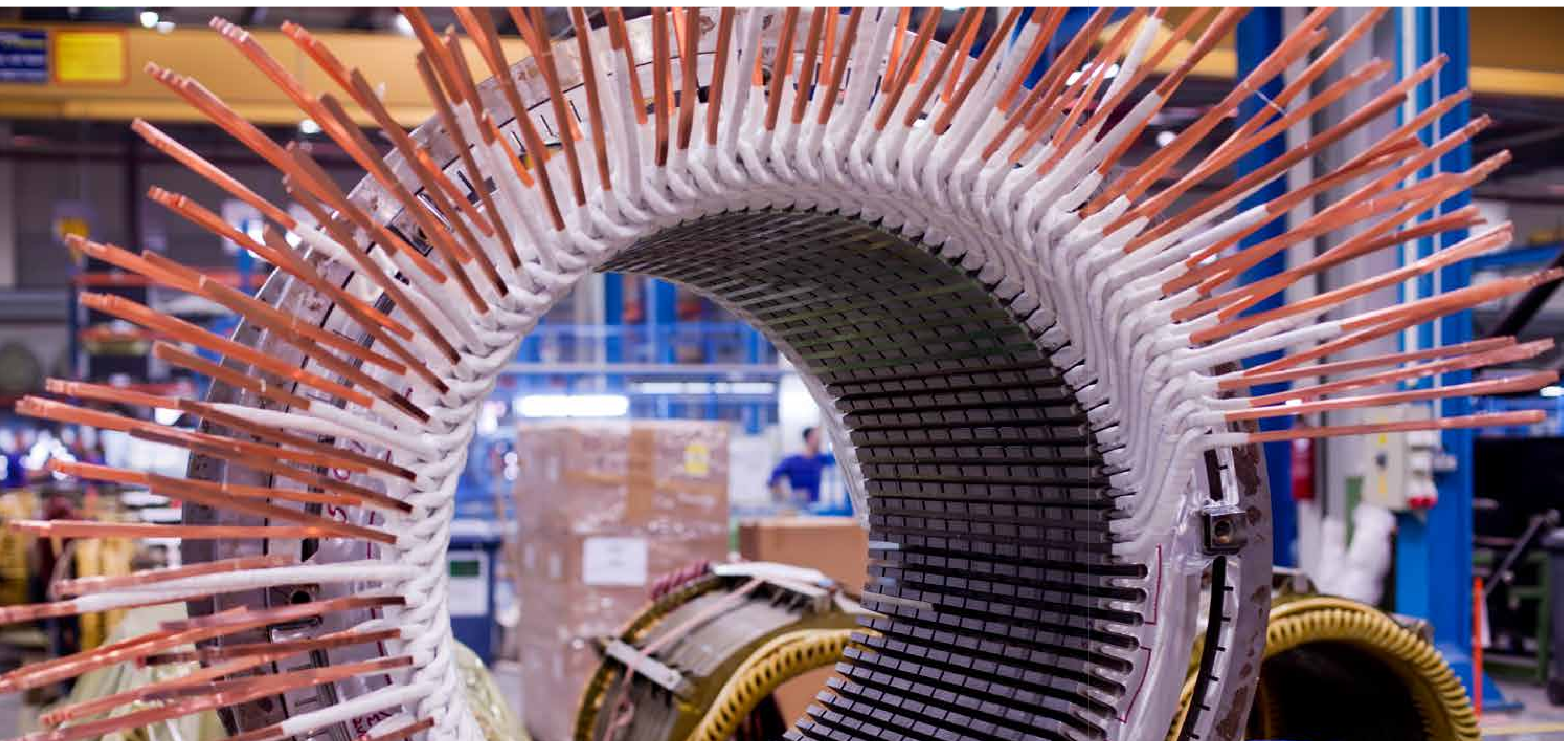


Image: Assembly of the stator of an electric drive

When you imagine the ideal city of the future, what comes to mind? Green spaces between urban canyons, clean air and electric cars, all powered by alternative energy? Nothing less than a paradigm shift is needed to turn this idea into reality, since new types of power plants and electric cars will not produce themselves. Production needs to be resource-conserving and socially responsible in order to ensure high living standards without depleting the earth's resources. The question of how we can shape Berlin's structural transformation from a traditional industrial city to a forward-thinking technological and service hub is the guiding objective of three research projects in which Fraunhofer IPK and TU Berlin are collaborating as part of the Werner-von-Siemens Centre for Industry and Science. The interdisciplinary research teams benefit in particular from their expertise in the fields of digitalization, additive manufacturing, and artificial intelligence.

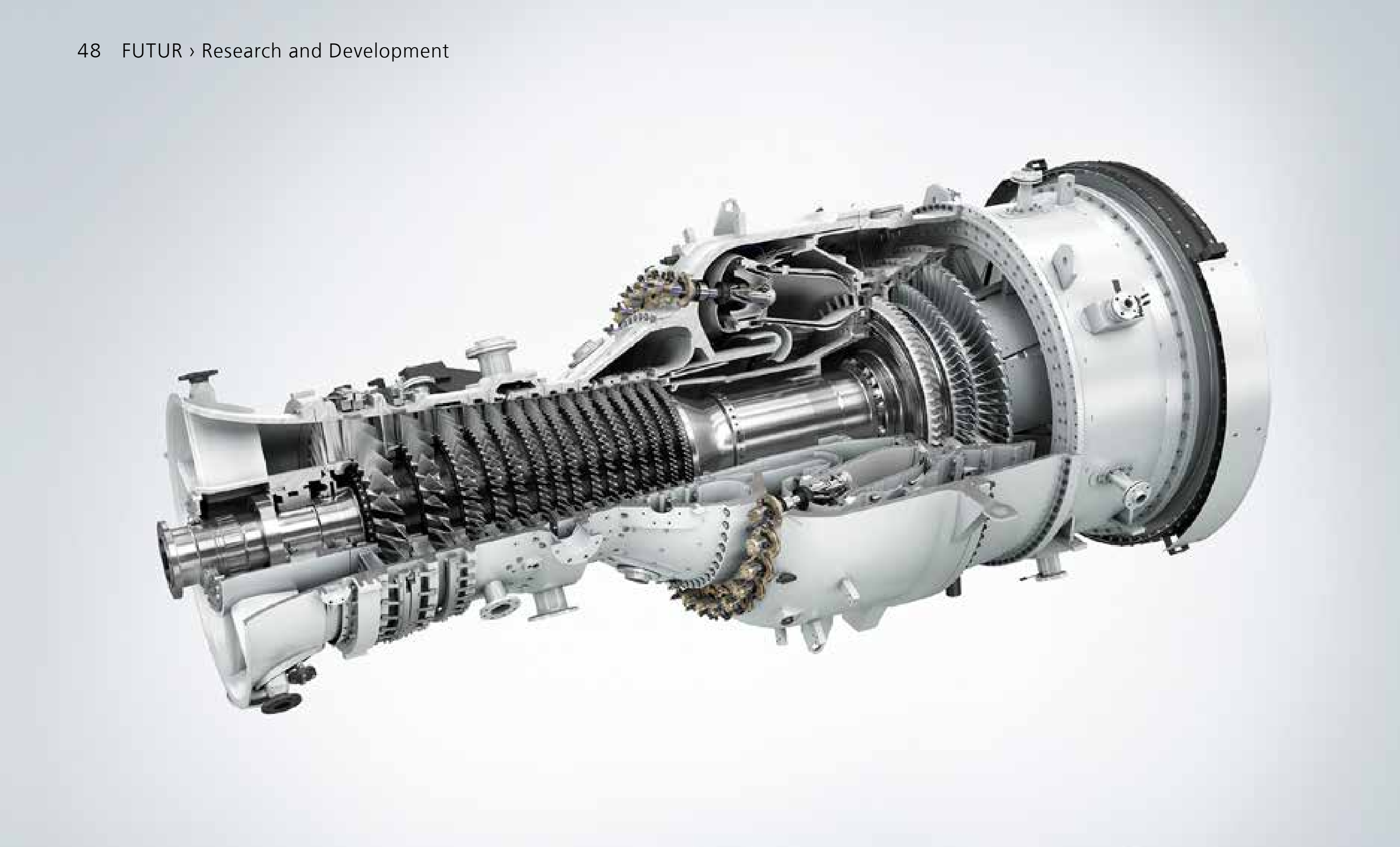
Production needs to be resource-conserving and socially responsible in order to ensure high living standards.

BYE-BYE COMBUSTION ENGINES, HELLO ELECTRICAL DRIVES!

In light of climate change, classic combustion engines are on their way out. They are increasingly being replaced by electrical drives. The 16 partners in the »Electrical Drives« project therefore aim to »develop the competitive electric machine of the future« and apply the research findings to related areas such as railway drives.

In order to not only go along with the transition to e-drives, but to also play a decisive role in shaping it, industrial locations such as Berlin must find disruptive approaches for designing and manufacturing electric machines from scratch. Claudio Geisert, who is working on »Smart Maintenance« in the project, is well aware of the opportunities offered by digitalization: »We see particularly great potential in AI methods. For example, we are using machine learning to turn large electric motors, such as the ones used in gas compressor stations, blast furnace blowers, and rolling mills, into intelligent cyber-physical systems that provide humans with meaningful support in their tasks and prolong the service life of the motors.«

Pascal Lünnemann also works at the interface between real and virtual worlds. In the project, he is responsible for the digital twin architecture and the feedback-to-design system. Above all, he sees digitalization as an advantage for the sustainability of production: »The production of the future will define new priorities for the sustainable use of resources. On the one hand, developers will be empowered to make sustainability-conscious decisions, while on the other, we will achieve deliberately human-centric and resource-conserving cooperation in human-machine collaboration.«



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TAKING ADDITIVE MANUFACTURING TO NEW HEIGHTS: HIGH-TEMPERATURE APPLICATIONS

Some components in modern gas-fired power plants come into contact with temperatures greatly exceeding 1000 degrees Celsius. But that is not the only challenge: If an increasing number of alternative fuels such as green hydrogen or biogas are to be used in the future, the components will have to exhibit entirely new properties that cannot be manufactured using conventional methods. The solution: additive manufacturing methods in combination with novel designs and materials with outstanding thermomechanical properties. With their help, the efficiency of gas turbine power plants is to be significantly increased, thereby also reducing CO_2 emissions.

Dr. Kai Lindow, head of the Virtual Product Creation division at Fraunhofer IPK, describes how researchers are optimizing additive processes along the entire digital process chain: »This digital process chain starts with the digital component in the development department, then moves on to simulation and preparation for production in the 3D printing process, and includes all post-processing steps up to the monitoring of the component while in operation. The objective here is to generate a continuous flow of information. This continuous flow of information is the basis for, e.g., networking product models with simulation models which can depict the real-world behavior of printing processes. It allows the product and the process to be optimized even before the actual printing, which saves time and materials.«

Machine learning plays a key role in the project, says Lindow: »By using learning algorithms, the simulation models can be constantly improved. New products or materials can thus be realistically simulated. The better the algorithms are and the better the available data to feed them with, the closer the product and process simulations are to the actual product and process – hence contributing to time and material efficiency.«

Images:
1
Cross section of an industrial gas turbine
2
Metal is sintered into shape under the action of a laser.

UPGRADES INSTEAD OF REPAIRS: MAINTENANCE, REPAIR, AND OVERHAUL

Maintenance and repair processes have long since exceeded their basic functionalities. The goal of this research project with nine consortium partners is to develop new technologies for maintenance and repair tasks that simultaneously include an upgrade for the serviced component.

For this purpose, new dynamic process chains are being developed in which the individual value creation steps are specified. Each component will pass through a custom repair chain. This development will be demonstrated using gas turbine blades as an example, which can subsequently be operated at higher temperatures or with longer operating intervals after the repair.

Carsten Niebuhr is working on the MRO project: »We at Fraunhofer IPK possess expertise in mechanical processing, for example in the removal of turbine blade coatings using sand or water blasting. To verify whether there is still any residual coating material on the blade, we are developing new machine vision methods. For this purpose, we use hyperspectral imaging in wavelengths that the human eye cannot detect, such as ultraviolet or infrared light.«

For the scientist, the MRO project at the Werner-von-Siemens Centre is a step toward a more sustainable industry: »In future, a fully automated repair or refurbishment line will re-process old parts for operation, allowing the life cycle of many products to be extended.« ◆

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The projects of the Werner-von-Siemens Centre for Industry and Science are co-financed by the European Regional Development Fund (ERDF).

EUROPEAN UNION
European Regional Development Fund

More information
on WvSC via
wvsc.berlin/en/

2

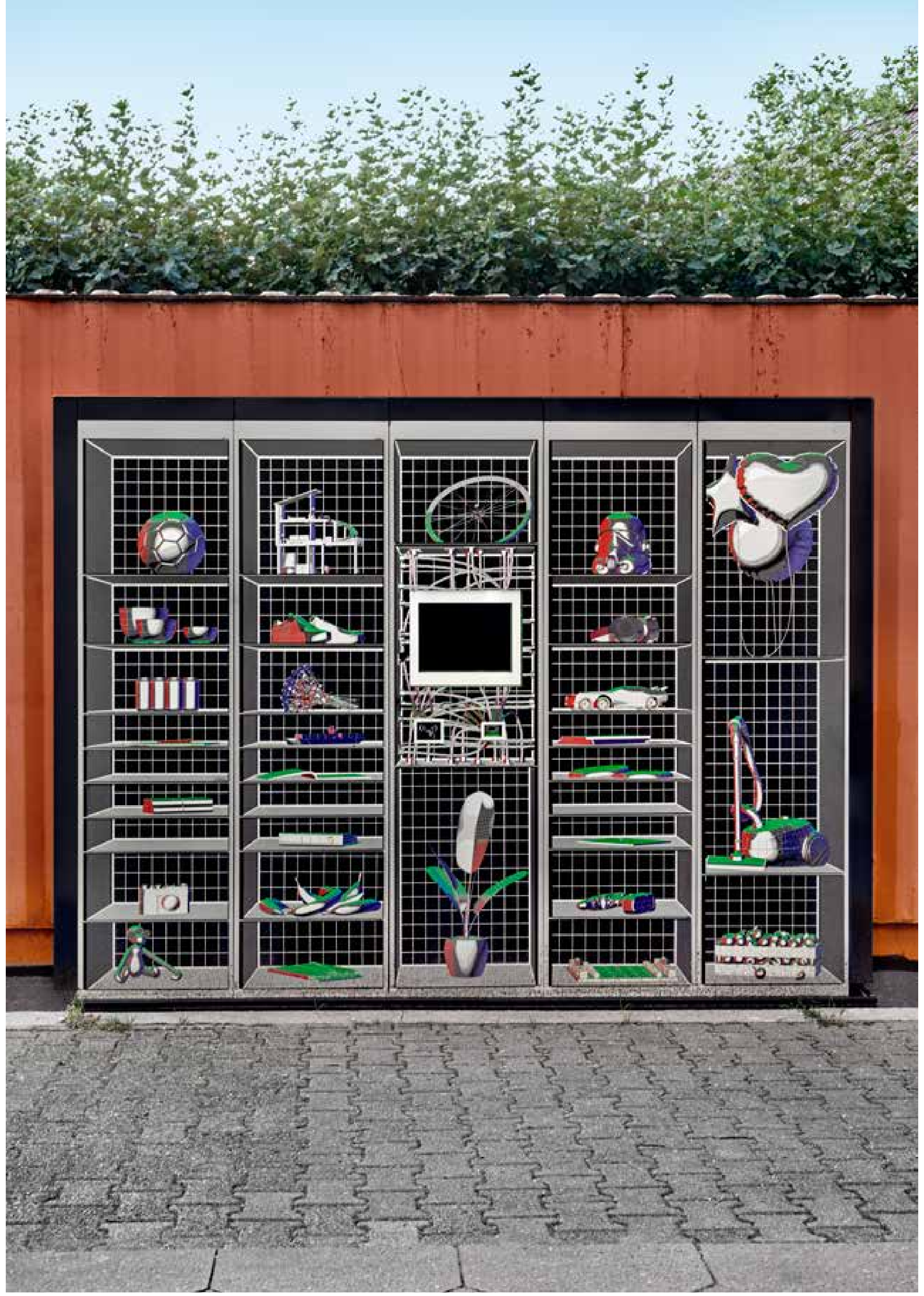
The »Werner-von-Siemens Centre for Industry and Science e.V.« ecosystem is home to a colorful mix of renowned scientific institutions and universities, excellent industry, innovative SMEs, and agile young companies. They have all combined their expertise to establish a future-oriented research collaboration.

- Founding year of the association: 2019
- No. of members: 25
- Partners include: Fraunhofer, Siemens, TU Berlin, BAM, CONTACT Software, T-Systems
- Key issues: production technology transition, mobility transition, energy transition

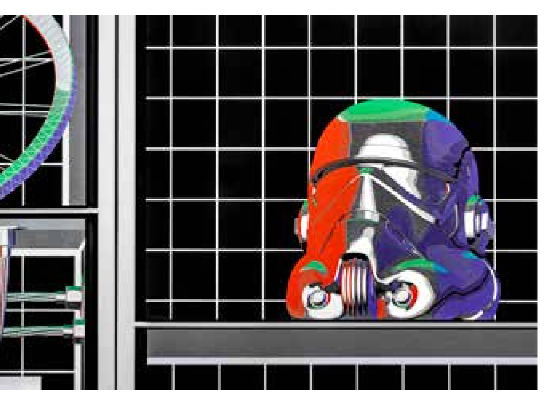
The Werner-von-Siemens Centre for Industry and Science e.V. receives support from federal and state funds within the framework of the joint task »Improvement of the Regional Economic Structure« (Gemeinschaftsaufgabe »Verbesserung der regionalen Wirtschaftsstruktur«, GRW).

Mobilizing Neighborhoods

The »Flex Q-Hub« aims to make delivery traffic smarter, more sustainable, and more neighborhood-oriented.

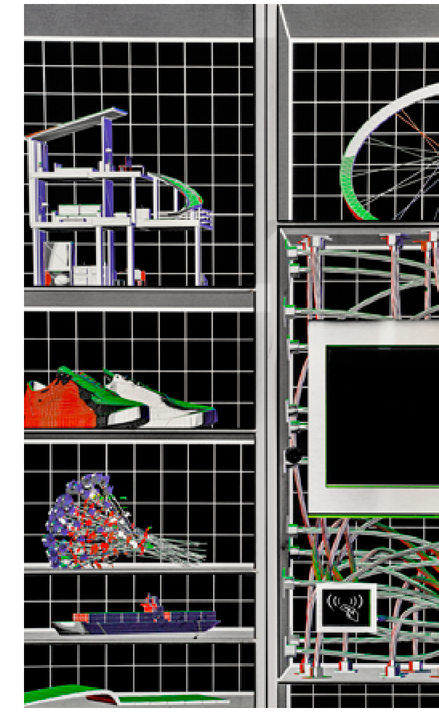


Images
The Flex Q-Hub at Mierendorffplatz grants imaginary insights into its inner workings.



How can quality of life within a neighborhood be increased? The Berlin district of Charlottenburg-Wilmersdorf is breaking new ground around the area of Mierendorffplatz by taking scientifically based model projects one step further.

One important contribution to the sustainable development of the neighborhood is the so-called »flexible neighborhood hub« or »Flex Q-Hub«. It serves as the basis for neighborhood-based logistics, which aim to handle delivery traffic in urban areas in an environmentally friendly and city-friendly manner. The hub, which is a provider-independent parcel station, enables not only parcel delivery and collection by private individuals, but also intermediate storage by courier, express and parcel services. The possibility of tool sharing for residents will also be tested.



The highlight of the Flex Q-Hub is its intelligent compartments. Each compartment pursues its own strategy. They negotiate their offerings among themselves on a virtual market in order to appear as a unified system to the outside world. Manuel Bösing, project manager at Fraunhofer IPK, describes the system as follows: »Each compartment acts as its own agent with individual attributes. Collectively, they operate as a multi-agent system to intelligently process various private and commercial customer requests. This ensures optimal utilization of the capacity of the Flex Q-Hub. Taking individual requests into account fosters greater customer loyalty.« In each case, profiles are created to store the selection history of individual customers. The decisions that are being made in this process are incorporated into the future allocation of compartments. For example, if a person often reserves a certain compartment at a certain fixed time, this behavior pattern can be recorded by a decision support AI. The corresponding compartment or compartments with similar attributes are then kept free for the identified period. This helps ensure that returning customers are always able to find a suitable compartment.

The inception and further development of the multi-agent system with its decision support AI is the purview of the Fraunhofer IPK team. Since June 2021, a prototype of the Flex Q-Hub has been located on Mierendorffplatz, a square in Berlin-Charlottenburg not far from Fraunhofer IPK. Under the name »mieri-mobil«, part of Mierendorffplatz will be used to test forward-looking concepts designed to make the district more sustainable and more social. »People like using the Flex Q-Hub because it is simple and it brings more flexibility into their own lives,« explains Manuel Bösing. In any case, it is already a particular eye-catcher, as the individual compartments are designed with a sensational 3D look from the outside.

The printed images show, as if through X-ray vision, what might be hiding behind the doors: A houseplant, perhaps? A bicycle tube? New sneakers? The design is the result of a competition which architect and designer Klemens Sitzmann won. Regarding the significance of design in the context of the project, Sitzmann comments: »Good ideas need to be brought to the people, and particularly in Berlin, a sensitive approach and successful communication are key for the acceptance of new projects. Innovation must be fun, and progress needs to invigorate.«

The prototype was created as the core element of the »Stadtquartier 4.1« (City District 4.1) research project, in which partners from business and science address the question of what urban logistics could look like in the future. Apart from Fraunhofer IPK, LogisticNetwork Consultants GmbH (LNC), the Leibniz Institute for Research on Society and Space (IRS) and insel-projekt.berlin UG (IPB) are also involved. The German Federal Ministry of Education and Research is funding the »Stadtquartier 4.1« project until April 31, 2022 via the funding measure »Anschlussvorhaben nachhaltige Transformation urbaner Räume« (Follow-up project: Sustainable Transformation of Urban Areas). ◆

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Teaching Machines how to Save Electricity

Our interviewees explore how manufacturing companies can reduce their energy consumption with the aid of machine learning.

PROJECT PROFILE

The goal of the research project »Reinforcement Learning for Complex Automation Technology Applications (ReLKat)« is to develop an AI process to help save energy in the fields of energy supply, building technology and industry. To bridge the gap between research and the world of industrial plants, Berlin-based experts in production science (Fraunhofer IPK), mathematics (Weierstrass Institute for Applied Analysis and Stochastics WIAS Berlin) and artificial intelligence (Signal Cruncher) are working together to make conventional control technology in existing plants fit for the execution of artificial intelligence and, in particular, reinforcement learning (RL). Two Berlin industry giants are involved in the project as application partners: the Mercedes-Benz Plant Berlin and PSI Software AG. ReLKat demonstrates how an interdisciplinary team from the Berlin-Brandenburg metropolitan region can overcome industry and domain-specific challenges – by using artificial intelligence!

| futur | **Mr. Thiele, why is machine learning the way to go in order to operate production plants with greater energy efficiency? Are there no similarly effective, more traditional ways of saving energy?**

/ THIELE / The topic of energy efficiency is much more important today than it was several years ago, especially from an economic perspective. However, increasing energy efficiency in production by means of ongoing adjustments involves manual effort and can rarely be implemented in an economically viable way. This means that we have to depend on automation, but processing the data for real-time control is such a demanding task that our options are limited with conventional automation methods. This is why machine learning comes into play here, because it is able to map complex relationships and make them available for use.

| futur | **Dr. Thess, while prominent voices such as Stephen Hawking and Elon Musk have warned about the pitfalls of artificial intelligence, Signal Cruncher promises »local and safe AI« through embedded machine learning. How does your approach to AI differ from that of other companies?**

/ DR. THESS / We are able to analyze and evaluate data locally. Instead of transmitting the data to the server or to the cloud for centralized evaluation, we perform the evaluation locally, for example in the gateway of the household or the machine. This eliminates certain problems connected with data protection. It also increases reliability because the system continues to function even if the connection fails. This is also in line with the general trend of new technologies first being introduced in a centralized fashion and then decentralized over the course of further development, as is the case with means of transportation, to give an example. First came the railroad, then came the car. Or in the case of computers: First came the mainframe computers, then the personal computers.

| futur | **Can you allay the fears of companies that are hesitant to use AI because of concerns about their data and IP?**

/ DR. THESS / Yes, because the data is no longer transferred to the program that analyzes it. Instead, the program moves to where the data is generated. This means the data no longer leaves its previous territory, and data protection is definitely guaranteed.

/ THIELE / A new discussion between production science and legal science is about the use of operational data. Machine learning can be used to generate knowledge and experience from observing plant operations and make them usable for one's own purposes. If this operational data from one client is then used to teach a procedure which is then applied by a second client, the operating data would also have been transferred indirectly. However, we only train our control algorithms on the system for which they are intended, and discuss transferability between similar plants of the same company with the users. At the same time, of course, such projects underscore that the data generated during operations has a particular value of its own. By making it usable, we see that data is a resource that brings potential added value, and therefore has its own inherent value.

| futur | **Mr. Thiele, you and your team at Fraunhofer IPK have demonstrated several times that you can help companies save energy with the use of intelligent control technology. To what extent does ReLKat take things further than its predecessor projects?**

/ THIELE / Previous projects were still using conventional control technology. At the time, we used empirical data to generate statistical models to map the behavior of the plant at static operating points, but did not yet take into account the plant dynamics themselves. If we wish to map the plant behavior not only at static points, but as dependent on time, this new complexity forces us to use machine learning. By doing so, we tap into a novel solution set and take things up a notch in terms of performance.

/ DR. THESS / We have been working on reinforcement learning for many years, and our aim is to make the core more stable and leaner. To achieve this, a special procedure based on hierarchical tensor networks is being developed over the course of ReLKat. This method will make it possible to keep the technology extremely lean, unlike computationally intensive neural networks, for example. This concerns the algorithmic side of things, the other side is what Mr. Thiele already mentioned: We would like to tackle industrial projects that we have not focused on so far. Fraunhofer IPK possesses a great deal of experience with energy consumption in the industrial sector. From this, we hope to see corresponding potential for sales and marketing in the future.

Gregor Thiele

is deputy head of the Process Automation and Robotics department at Fraunhofer IPK. In several R&D projects, he and his team developed an intelligent, universally applicable framework that automatically increases the energy efficiency of plant operations.

/ THIELE / We at Fraunhofer IPK act as a practical bridge between the experts on the subject matter from manufacturing companies and the machine learning expertise of AI specialists such as Signal Cruncher. We conceptualize industrial manufacturing problems and identify system interrelationships and data in such a way that they can be formulated as a mathematical problem in the first place. It is this interdisciplinary approach between on-site machine experts, AI experts from a dedicated AI company, and Fraunhofer IPK scientists acting as a link between the two that gives a project like ReLKat the opportunity to develop practical solutions within just a few years.

| futur | **You are also collaborating with the Weierstrass Institute for Applied Analysis and Stochastics and with PSI Software AG, a listed company that provides software for utilities and industry. How and why did you bring these interdisciplinary partners on board?**

/ DR. THESS / The connection to WIAS came about through Prof. Reinhold Schneider from TU Berlin, a recognized scientist in the field of tensors. He was able to provide us with the contact to WIAS, which is important for the implementation of tensor networks for reinforcement learning.

/ THIELE / In our search for suitable application partners, we decided to address both discrete component manufacturing and continuous process technology. Hence, our consortium includes not only application partners such as Mercedes-Benz with its Berlin Plant, which has already shown a high level of commitment to energy efficiency optimization for many years, but also PSI Software AG with its pipeline operations division. Doing so allows us to gain project experience in the field of continuous process technology as well as discrete component manufacturing.

| futur | **One hurdle for the use of machine learning in real-world scenarios is that most solutions are highly specialized and must first be »fed« manually at great expense. You are pursuing the goal of developing a generic and flexible solution – how do you intend to achieve this?**

/ DR. THESS / The generic nature lies in the approach itself: By using machine learning, we observe the physical world and ultimately build statistical models. This has the advantage that we do not require much domain knowledge. The traditional way would be via physical modeling using differential equations. This method is costly and also comes with certain limitations. The principle of AI, on the other hand, is to learn about relationships simply by observing the interplay of action and analysis. This black-box character makes the solution inherently highly generic, because it does not really understand what it is actually doing – to put it in »human« terms.

Naturally, this does not mean that specific customizations are not still necessary. The idea of making a solution completely generic seems illusory to me. Of course, we also have to perform a selection of certain parameters and specify trajectories. Nevertheless, the effort required is much less than with manual methods or with a classical physical approach. In this sense, it is true: It is a fairly generic solution for minimizing energy requirements.

/ THIELE / In addition, there is another good argument for the industry that makes our solution attractive: We tap into novel savings potential by adjusting aspects that were previously of a fixed nature. Based on energy efficiency considerations, we can now set a flow temperature to ten or fourteen degrees that had previously been set at twelve degrees for years and never adjusted manually or using conventional controls. This means that we are not replacing a functionality with AI that was previously realized in a different fashion, but instead utilizing the capabilities of AI to add a completely novel functionality – namely, this adjustment of target variables depending on energy efficiency considerations – to the existing automation system. That's why we and our work are perceived as helping and assisting operators, rather than competing with manual labor. ◆

Dr. Michael Thess

is the founder and managing director of the Berlin-based startup Signal Cruncher. The company offers expertise in embedded machine learning for IoT and has made smart energy one of its core topics. With its XONBOT software, Signal Cruncher provides support for B2C and B2B customers in this field.

The Future of Simulation

With simulation models, products can be better analyzed and developments predicted. A research team has developed an AI-based decision support system which increases process efficiency.

When our imagination overwhelms us, we reach for a pen and put down the chaos in our head on paper. By visualizing a complex issue, we keep it manageable – at least for the moment. Today's simulation models in engineering are built on this fundamental concept. The computer-based models are designed to help us understand the properties of products and predict future developments. Various methods can be applied in simulation models, such as finite element analysis (FEA), computational fluid dynamics (CFD), and discrete event simulation methods (DES). FEA is used, for example, to study the stresses and deformations in a component to which force has been applied. On the other hand, CFD methods can be used to position or deform geometries of components for optimal flow around them. And DES simulation can be used to examine entire manufacturing workflows virtually. What these methods have in common is that they do not require physical prototypes, thereby saving time and money.

However, creating such simulations requires a great deal of experience, and usually involves significant effort. Particularly when analyzing different variants or configurations of a product, the effort required for specific use cases is enormous.

INTELLIGENT SIMULATION ...

AI-based decision support systems do an excellent job in assisting engineers with this. With their help, findings from previous simulations can be analyzed and applied to new products with similar configurations. Furthermore, engineers can use similar simulations to perform an intelligent selection of parameters and boundary conditions for a current problem. In addition, substitute models, i.e., reduced digital models, of the simulation can be generated. Researchers at Fraunhofer IPK have recognized the considerable functional possibilities of such intelligent systems and are researching new approaches for assisting engineers even better in their day-to-day work.

In the project, approaches to finding a solution for a use case in product design were researched. Specifically, the project addressed the risk of weakening the material when text is milled into polypropylene components, which may lead to material failure when it is subjected to bending stresses. However, it would have been too time-consuming for the engineers to perform an FE analysis using a simulation model before each milling process, which would have identified weak points in the milling path. Therefore, an assistive system was needed that evaluates the components in advance in terms of their properties so as to avoid time-consuming simulations. The solution was an AI-based decision support system that analyzes the individual components via intelligent image evaluation. A convolutional neural network (CNN), an artificial neural network from the field of machine learning, was used for the decision support system. The CNN was adapted to image recognition for evaluating the image data of the polypropylene components. During this process, the system was trained to determine the different configurations of a component simulation using the resulting image data as well as the corresponding FE results. This resulted in a reduced model, with the help of which the decision

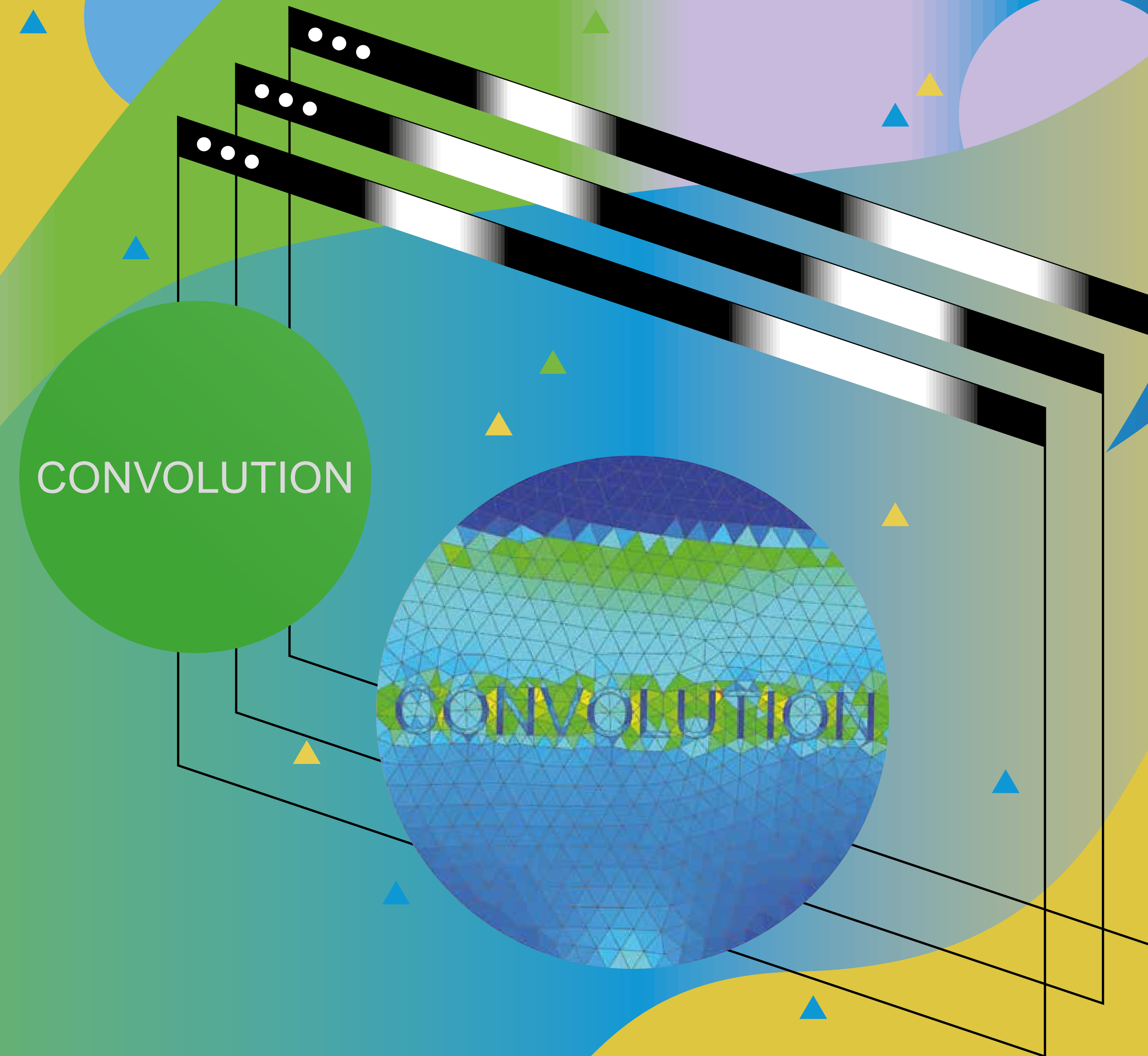

Illustration: The image of the CAD model of a polypropylene component with milled text (left) serves as the basis for the Convolutional Neural Network (CNN). The finite element simulation (right) can be used to train the CNN of the assistance system in order to determine the stress distribution over the component.

support system was subsequently able to recognize – from an image of the component with the text to be milled in – when the component appears robust enough and when it is too fragile for the milling process. The use of AI eliminated the need for a simulation and FE analysis prior to milling. As a result, faulty components could be identified in real time, allowing correspondingly detailed simulations to be initiated for them.

... EXCELLENT RESULTS

The study demonstrates the potential of image recognition as a replacement for time-consuming finite element analysis in simulation models. One thing is clear: The possibilities for decision making with AI and simulations are manifold. In the future, not only will FEA be replaced by the decision support system, but the system's rate of success will also be continuously optimized with the aid of a hybrid substitute model based on real-world data during the milling process. A digital twin, a fully-fledged substitute model, is also being planned. The advantages of AI-based decision support systems cannot be denied: they increase efficiency and significantly reduce costs. ◆

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Context Is Everything

When it comes to maintenance, repair and overhaul (MRO), mobile decision support applications are all the rage. With the help of AI, they are becoming more flexible – and more predictive.

Industrial production is a complex work environment. Workers are constantly confronted with entirely new tasks that sometimes only the most experienced and highly qualified specialists can handle. For example, a milling process that was previously running smoothly may suddenly produce rejects due to wear on the bearing in the milling spindle. Inexperienced workers who are not familiar with the mutual relationships between the machine and the process are quickly overwhelmed when it comes to identifying the cause, which is an essential step. This may pose a threat to the smooth running of production during a time when there is no end in sight to the shortage of skilled workers.

In order to introduce even low-skilled workers to such complex processes, »on-the-job training« can now be carried out with the aid of modern decision support systems. This trend is boosted by the increasing prevalence of intelligent mobile applications based on data glasses, smartwatches or tablets. Specific information and instructions for action related to the respective work step can thus be presented audiovisually in a manner that is easy to comprehend. Specific training videos can also be integrated, which employees can use for ongoing individual training.

A core area of application for such decision support systems is in the field of maintenance, repair and overhaul (MRO). When servicing machines and systems, it is particularly important to transparently document the steps that have been implemented so that other workers know what tasks have been performed. Mobile digital applications therefore support maintenance processes not only operationally, but also facilitate downstream documentation by automating it partially or even entirely.

CONTEXT SENSITIVITY AS A GAME CHANGER

Maintenance processes are extremely diverse, making them difficult to automate and therefore requiring regular manual intervention. Service engineering professionals who keep machinery and equipment in good working order possess a large amount of tacit knowledge in order to correctly carry out damage analysis and repair. By using process descriptions, work instructions and checklists, industry and production science have been trying for some time to make this tacit knowledge explicit – and hence transferable.

This transferability reaches its limits in cases where the specific context of the individual process matters. One simple example is the maintenance of a coolant circuit: Depending on the fill level and the condition of other components, such as any impurities in the coolant, different process steps will need to be performed. If the fill level is too high and the coolant is in good condition, coolant must be drained. If it is too low, it needs to be topped up. If everything is OK, this must simply be documented. The fill level and coolant condition can be determined either manually or fully automatically via sensor data.

As part of a collaborative project, researchers at Fraunhofer IPK have therefore joined forces with CONTACT Software to develop a context-sensitive MRO decision support system based on digital twins. Various forms of input are continuously fed into the system, such as sensor values measured at the equipment's location or photos taken by service personnel. A digital product twin of the object to be serviced is enriched with this information and transmits it back to the decision support system in real time. Both historical and current contextual information on the respective product is provided. This allows the condition of the machine or system to be accurately classified, known solution strategies to be selected, and faults to be efficiently rectified. During the MRO process, the system incorporates situation-dependent information into the specific work instructions for maintenance personnel at each work step.

INTELLIGENCE FOR A SUSTAINABLE MAINTENANCE STRATEGY

Context-sensitive decision assistance makes it possible to flexibly adapt maintenance procedures to constantly changing process conditions: The more precisely the condition of the machine or system can be described, the more selectively damage can be analyzed and repaired. Before and after the repair, automated tests can be run to validate the condition of the machine. The results are available in real time and in turn form the basis for subsequent tasks to be carried out.

The ongoing documentation, supported by the context-sensitive decision support system, not only serves to continuously update the digital twin, but also enables the creation of a history of errors and solutions, thus forming the basis for employing machine learning methods. For regularly occurring errors, typical solutions can be identified, which are automatically suggested when the same error occurs again. The intelligent prioritization of promising solutions also incorporates the historical and current context data for the respective problem.

By documenting these solution strategies in the digital twin, intelligent algorithms can not only assist service personnel with mapping solutions to problems in specific use cases. For company management, they also pave the way towards an intelligent, sustainable maintenance strategy, in which faults can be detected at an early stage and ideally be eliminated preventively. Such predictive solution strategies are optimally supported by intelligent mobile decision support systems in the context of what is called »smart maintenance«. ◆

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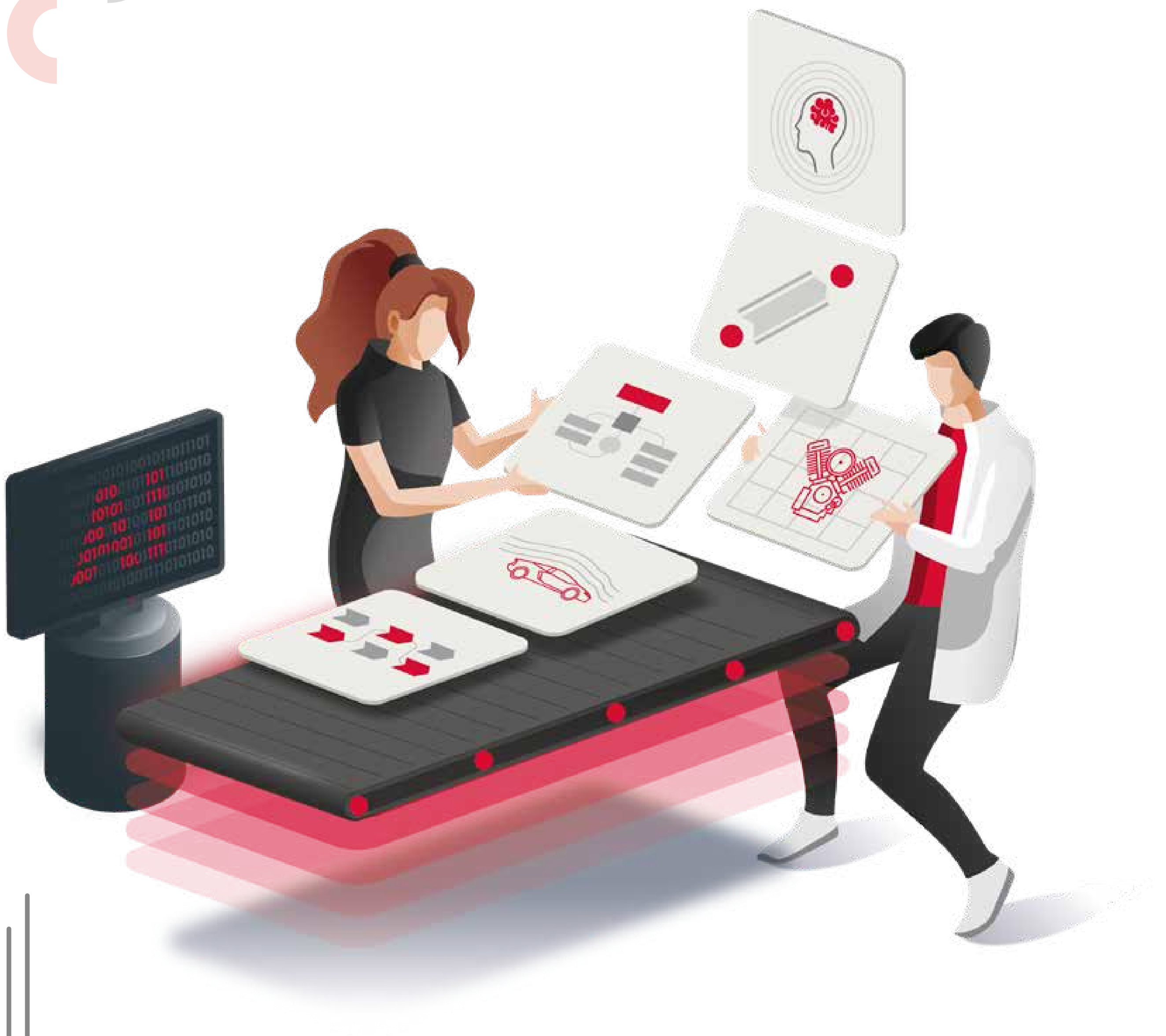
1

2

Images:
1
Mobile maintenance support via smart device
2
Context-sensitive action instruction as step-by-step guide

The AI Marketplace

Artificial intelligence is one of the key drivers in product creation today. A new online platform's claim is to make it more accessible for SMEs.



© it's OWL

The digital transition is changing product creation. Not only is software becoming more and more important – the developed products are also increasingly complex. More than ever, the integrated expertise of various specialist disciplines is in demand. AI applications have an essential role to play here: They can help manufacturing companies increase development capacity, while at the same time cutting down on development times and manufacturing costs. However, many companies lack the AI expertise to leverage this potential. Conversely, providers of AI solutions often lack access to customers or the necessary domain knowledge. A platform is needed in order to bring the two sides of the equation together: the AI Marketplace!

The AI Marketplace creates a unique ecosystem that brings together AI experts, providers and users to exploit the potential of artificial intelligence. Fraunhofer IPK researchers, with their extensive experience in digitalized product creation, act as sources of knowledge and play a key role in shaping the project. In addition to the intelligent matching of service providers and companies, the marketplace also offers a space for the secure exchange of data while maintaining data sovereignty. In future, an app store and a toolbox for AI solutions will expand the range of services offered by the AI Marketplace. Following the »plug and play« principle, small and medium-sized enterprises will be able to put together AI applications on their own and integrate them into their processes without having to hire a service provider.

Companies lack AI expertise, AI providers lack access to customers. The solution: a platform.

PILOT PROJECTS SHOW WHAT THE AI MARKETPLACE CAN DO

Six pilot projects are currently investigating how the marketplace can function best and what it is able to achieve. In these projects, companies and research institutions are working together to develop AI solutions for specific use cases from various domains – from intelligent product monitoring and AI-based vehicle diagnosis to AI-supported manufacturability analysis. Here, initial applications for product creation are developed, tested and implemented, and subsequently made available to users of the AI Marketplace.

One of these pilot projects involves the integration of AI into Computer Aided Design (CAx) at the agricultural machinery company CLAAS. Researchers at Fraunhofer IPK are working with users at CLAAS to design an intelligent carry over parts management system, and are already implementing it as a prototype. Using feature extraction, CAD models are initially classified based on their geometry, and later also in terms of function. Missing master data and additional metadata are added. The objective is to reduce the number of parts in the inventory database. During the design process, potential carry over parts and evolutionary stages can also be suggested to the developers, which can reduce the effort required for the design. In the future, this could reduce costs incurred due to accidental duplicate developments without restricting the necessary creative freedom of the developers. ◆

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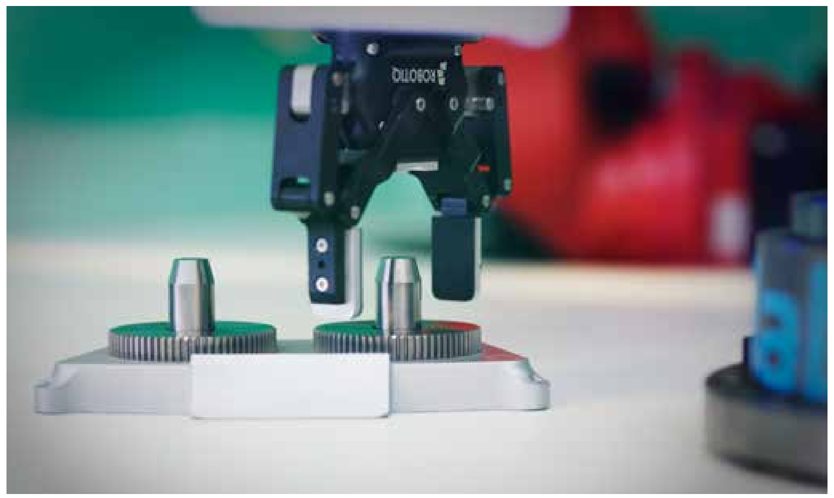
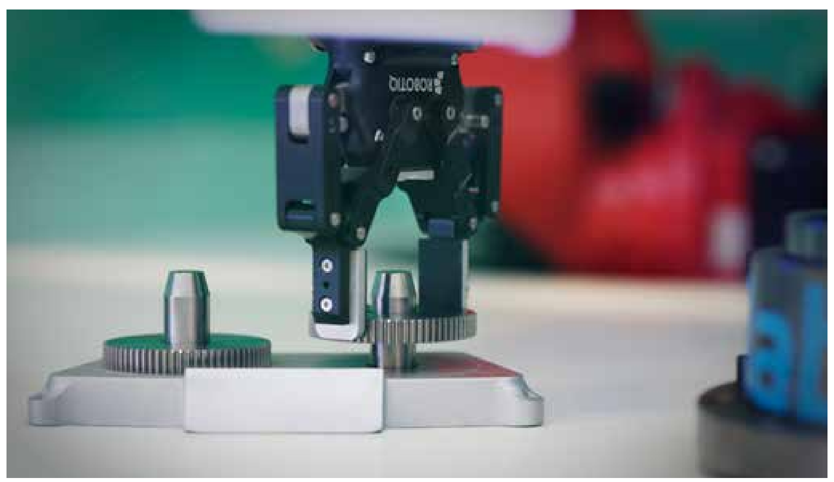
Design Faster with Digital Twins

A new pilot plant allows companies to test complex automation processes safely and cost-effectively.





Images:
Complex automated assembly processes can be piloted more cost-effectively in the future with the help of digital twins.

Find out more about digital twins on our website

A single modular development environment serves as 15 assembly stations.

Images:
The piloting processes can be easily controlled and monitored on the flexible dashboard – whether on the big screen or using a mobile tablet.

The assembly of components is increasingly digitalized and automated. Manufacturing companies invest a great deal of time and money in the automation of entire assembly lines. A large share of this expenditure goes into pilot plants on which the automated processes are designed and tested meticulously. As automation increases, so do the requirements regarding being fault-free – because errors in the design of an automated process often result in considerable additional expense.

Researchers at Fraunhofer IPK have developed an integrated engineering environment for pilots that allows for cost-effective development of interlinked production systems and reliable testing of complex processes. The two six-axis industrial robots in the development environment are equipped with novel component feeding units, force control and flexible interfaces. Any necessary additional sensors can easily be integrated.

So how can an entire interlinked assembly line be mapped with one system? A digital twin of the modular development environment ensures that the two robots are automatically configured for each assembly step. The processes can be controlled and monitored on a versatile dashboard.

The advantages of this robot-based pilot line become clear in direct comparison with traditional ways of piloting. A single modular development environment is required to validate a linked assembly plant with 15 stations, resulting in lower investment costs. The time for setup and reconfiguration is reduced to one third.

Working with our customers, we find the right solution for every use case, whether at our facility in the test field of the Production Technology Center or implemented directly at the company itself. ◆

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Research Needs a Home

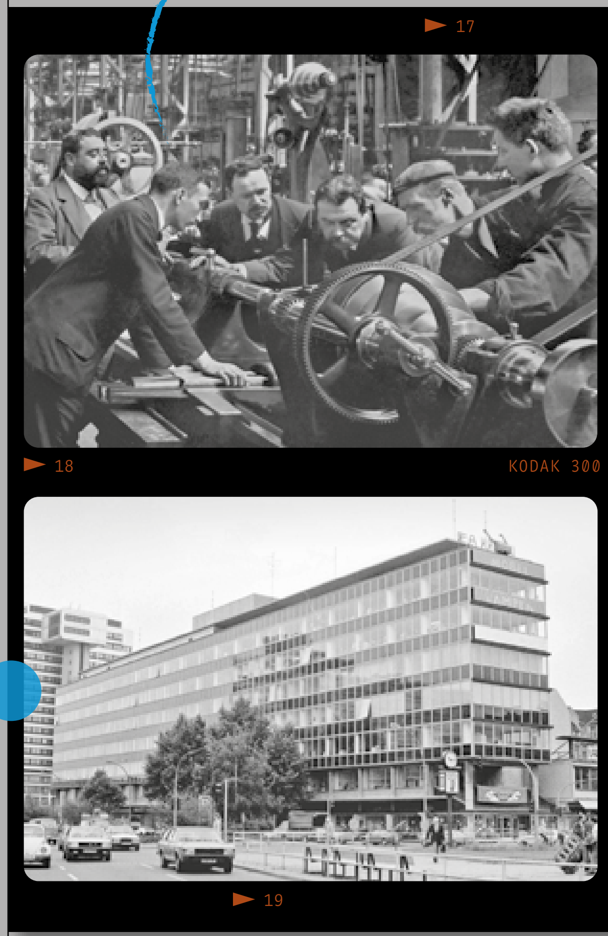
Very quietly, a double anniversary is taking place on the banks of the river Spree this November: The Production Technology Center (PTZ) Berlin is turning 35 years old. Its extension building, the Application Center for Microproduction Technology – AMP celebrates its 10th birthday. An occasion for a look back at the history of a special research venue.

Anyone taking a boat ride on the river Spree during a visit to Berlin will learn interesting facts about a round building on the southern riverbank between Moabit and the confluence of Spree and Landwehrkanal. For example, that a tradition of more than one hundred years of university teaching and research in machine tool construction is cultivated here. That it is also known as »the double institute«. Or that a special powder coating has ensured that the white exterior facade has defied the Berlin city air for over 30 years.

If these walls could talk, they would have a lot to tell. They would tell about visitors from all over the world who have come here to learn about milestones in production research, from Computer Integrated Manufacturing to Industry 4.0. They all came because the PTZ is a special research center. Its six floors house two renowned scientific institutions: The Institute for Machine Tools and Factory Management IWF of the TU Berlin and the Fraunhofer Institute for Production Systems and Design Technology IPK. In addition to a test field with around 3200 square meters, the PTZ also provides them with numerous special laboratories, some of which are equipped with high-performance air-conditioning technology for constant ambient conditions. Nearly 100 test rigs enable practical research and development. Such equipment attracts attention, especially in a political center like Berlin. But let us start at the beginning.

How everything started

Georg Schlesinger



Second domicile of the IPA-Berlin, Kleiststraße, 1979

1904

Georg Schlesinger becomes the first professor for »Machine Tools, Factory Equipment and Factory Operations« at the predecessor of the TU Berlin. He establishes the first production science test field in Germany, cooperates with industrial companies.

1976

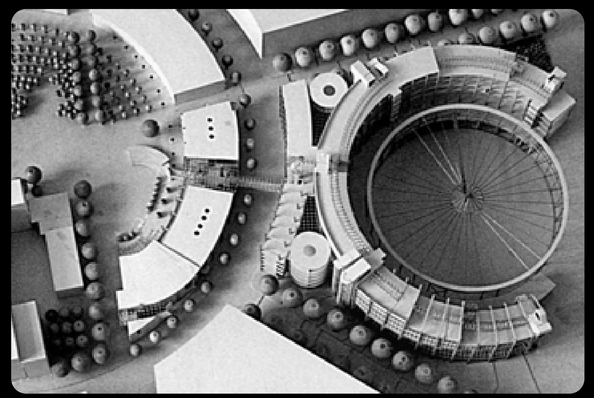
Professor Günter Spur initiates a »Berlin Experimental Institution for Production Technology« to transfer research results into industrial application. Thus the first Berlin Fraunhofer Institute is founded, initially as a branch of the Stuttgart Fraunhofer IPA. In 1979, Fraunhofer IPK becomes independent.

1981

Having started with three employees, just a few years after its founding Fraunhofer IPK is spread across two locations – both of them too small. Long distances also make cooperation with the IWF difficult. A joint building is being considered.

Construction history

Design model, state in 1982



AMP under construction, July 2010

Aerial shot of PTZ and AMP, 2019 © Maedscar

1982

The building concept of architects Gerd Fesel and Peter Bayerer breaks with traditional building forms in industrial and academic construction. The building sections for practical and theoretical work are not placed next to each other, but are closely interlocked in a circular building.

1986

After three years of construction, the building is inaugurated. In 1987 it wins the German Architectural Award. In addition, the powder-coated facade is awarded the European Steel Design Award.

2011

Exactly 25 years after its inauguration, the PTZ receives an annex for precision manufacturing. At the Application Center for Microproduction Technology – AMP, precisely regulated ambient conditions enable accurate production of the smallest structures.

View of the test area, 2019

Federal President von Weizsäcker inaugurates the building, 1986

10.000 sqm
Total floor space

3200 sqm
Test area

18 meters
Test hall height

2350 sqm
Floor space AMP

100
Test rigs

Berlin's Governing Mayor Klaus Wowereit comes for a visit, 2005

Visitors from all across the globe

1986

The 35 years of PTZ are also 35 years in which visits of high-ranking celebrities have repeatedly underscored the relevance of research at the site. This begins with the building's inauguration by German Federal President Richard von Weizsäcker and Berlin's Governing Mayor Eberhard Diepgen on November 25, 1986.

2005

In the years that followed, numerous German and international political leaders visit the PTZ to find out more about the research conducted there. Among them is Klaus Wowereit in 2005, at that time also the Governing Mayor of Berlin. Federal Research Ministers Edelgard Bulmahn and Johanna Wanka even invite guests to their own events in the building. Chinese Vice Premier Ma Kai creates a diplomatic state of exception in 2015. Armenia's President Dr. Armen Sarkissian as well as the Prime Minister of Thailand, H. E. Prayut Chan-o-Cha even honor the PTZ on the same day in 2018. And science ministers from Australia, China, Great Britain, Indonesia, Jordan and Thailand, among others, learn details about the Fraunhofer model.

Save the Date!

We regularly present our research and development results at trade fairs and conferences. Make a note of these dates for 2022 and come and meet our scientists.

More information:
www.ipk.fraunhofer.de/de/veranstaltungen/messen

6. Additive Manufacturing Forum
March 14–15, 2022
Berlin

Hannover Messe
April 25–29, 2022
Hannover

DMEA – Connecting Digital Health
April 26–28, 2022
Berlin

Control – Trade Fair for Quality Assurance
May 3–6, 2022
Stuttgart

Rematec – Remanufacturing Trade Show
June 14–16, 2022
Amsterdam, Netherlands

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Current Events:

Mastering Digital Twins
Online Certification Program

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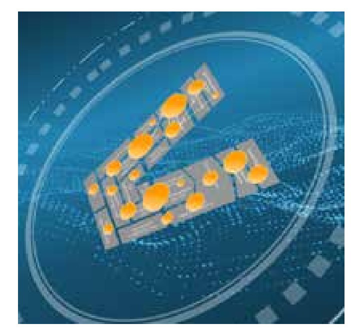

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