ESSENTIAL

FREUDENBERG SEALING TECHNOLOGIES

HUMAN
or Machine?

NOT FUTURISTIC AT ALL
Interview with robotics professor Selma Šabanović.

NATURE AS A BLUEPRINT
Fascinating robots emulate the movements of living creatures.

MAKING IT EASY
What's behind Kuka's "Automation for everyone" strategy?

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IN FIFTY WORDS

Robots are fascinating. They've always instilled hope and fear in us. Large factory machines for a while, soon coworkers and vehicles, tiny or virtual. They are conquering industries and private spheres. What are they? What are their capabilities? A search for mechanical systems, intelligence and interaction, even ethics and emotions.

Human or Machine?

By Claus Möhlenkamp, Chief Executive Officer,
Freudenberg Sealing Technologies

Dreams of robots are old – very old. The Greeks of antiquity told tales of an animate bronze statue called Talos. In Buddhist India, automatons were envisioned as tomb guards 3,000 years ago. Long ago, engineers in Rome, Athens and Egypt were already constructing machines and statues that moved with deceptive verisimilitude, even if hydraulics and wires were likely the mechanisms at work. Dreams of robots are old – very old. For millennia, humans have pondered whether intelligent human-machines could do our work for us, even as they considered the opportunities and risks that this might entail.

But the automatons of ancient mythology and the early apparatuses were not "authentic" robots. The objection is justified, and it leads us directly to the question of what an "authentic robot" is. "I can't exactly say what a robot is," Joseph Engelberger, one of the pioneers of industrial robotics, was once quoted as saying. "But I can recognize a robot when I see it." Engelberger died in 2015, and today he might be shocked at the sight of robot dogs, autonomous vehicles, chatbots, the Mars rover, robot mowers and one-armed industrial machinery – the diversity of robots and autonomous appliances has become immense. But experts still argue about a key issue: What distinguishes a robot from just another machine?

Robotic dogs, autonomous vehicles, chatbots – the diversity of robots is incredible.

For example, at first glance, software bots bear little resemblance to robots. After all, they only exist virtually. In terms of what they do, however, they are surprisingly similar to autonomous machines made of metal and plastic. They work independently. With the help of artificial intelligence, they learn how to respond to unforeseen events on their own. Advances in information technology have opened up completely new possibilities. Statistically speaking, every household in the United States already has six smart networked devices, ranging from smartphones and cars to vacuum cleaners. Many of these devices are not yet robots, but they are already starting to collect information about us, interpret it, and interact with us in the truest sense of the word. The gulf between them and what most of us would call "robots" is not very wide. At the same time, the increased networking of smart devices such as catalytic converters is a boon for the entire service robot segment. It enables the robots to access even more information and be more easily controlled with an end-device. Service robots are conquering every industry: logistics, safety, education, retail, medicine and caregiving. The latest edition of ESSENTIAL shines a spotlight on some of these industries and potential applications.

There has long been movement in the industrial robot market. Machines are continuing to learn here as well. They are designed to work, move around, and communicate with human workers more and more independently. We are talking about people and machines here. There is a related human fear that robots one day will be more intelligent than we are – and will ultimately achieve world domination. This fear is based in part on a misunderstanding of intelligence. Machines can use or interpret terms without ever understanding what the term actually means. Intelligence is not just computing power, but encompasses senses, emotions and the power of imagination. The most advanced robots today do not even come close to these capacities and may never attain them.

In fact, we shouldn't forget that the rate of progress in robotics is often overestimated. When artificial intelligence got its start in the 1950s, the interpretation of human speech was expected within a decade. But robots have had problems with it down to the present. The paradox formulated by Hans Moravec in the 1980s still applies: The biggest challenges for robots are often the functions that are the easiest for humans. This especially includes our perception and our motor skills. Despite advances in sensor systems, many machines still do not perceive their environments well and are incapable of picking an object up from the floor. Depending on the yardstick, small children learn 10 to 1,000 times more quickly than the most advanced neural network. In the future, some developments will surprise us – and others will not materialize as quickly as expected.

One thing is clear: The robot market will continue to grow. And this growth will be accompanied by progress on the mechanical side. It will involve joints that function even more precisely and find a home in more industries and areas of application, sometimes under extreme conditions, from the Arctic to the ocean depths. All of this means that the demands on seals are increasing – and so are the opportunities for us, Freudenberg Sealing Technologies, to capitalize on our expertise and quality standards. We have compiled examples along these lines in the latest edition of ESSENTIAL. We are curious about the future and are sure we will be able to make a contribution to it. The robots of the 21st century will no longer have the hidden wires of their ancient antecedents – but a great many of them will have seals. ◎

The most difficult challenges for robots are often the easiest for humans.

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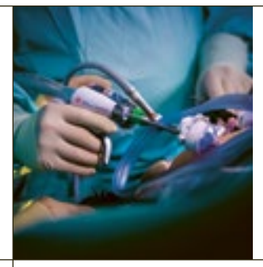

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Human beings can be inspired by nature, even in the field of robotics.

Deep Deep Down

Robots are sent into realms that human beings cannot investigate. The machines give people a look at unknown worlds and increase their knowledge. Researchers not only rely on these high-tech machines to travel on distant planets. They are also used to explore locations on earth, such as the ocean depths. Even with special submersibles, humans cannot descend to the deepest point of the Mariana Trench in the Pacific Ocean. So far, only robots have made the dive – most recently, a softbot from the University of Hangzhou. Certain diving robots can now autonomously follow animals and thus document their way of life. The one pictured here is used to inspect oil and gas pipelines in the South China Sea.

Stable Corset

Crustaceans and insects such as this cicada have an exoskeleton. It protects and supports their body with its reinforcing external structure. Humans have been inspired by this. As early as the 1960s, there were efforts to ease the lifting of heavy loads with mechanical aids. Today functional and lightweight exoskeletons are the answer. These wearable robotic systems recognize when movements are attempted and muscles are stressed, and they provide extra support automatically. In manufacturing and logistics, exoskeletons help workers lift heavy objects and handle work over their heads and shoulders. Exoskeletons also have medical applications, making it possible for older people and those with mobility problems to stand on their own two legs and walk short distances on their own. ◎

True Fiction

In Japan, robots enjoy huge popularity, fed by countless animated films over many decades. The start of the successful Gundam franchise dates back to 1979. A unit of battle robots bearing the Gundam name had a leading role in the first TV production in the long-running series. Manga graphic novels and movies followed, and the fan scene expanded. Last year, a robot from the series even made an impressive leap into reality: A giant 18-meter (59-foot) version of the Gundam RX-87-2 weighing 25 tons today stands in Yokohama Harbor. Now a tourist attraction, it took six years to design and build. The impressive eye-catcher can kneel down and even move its arms and fingers thanks to its 24 moving parts. ◎

“We talk about robots as though they were off in the future”

More and more, the interactions between robots and people will be close in the future. Scientist Selma Šabanović of Indiana University even makes the case that robotics has long become part of our daily life – only we do not perceive it. A conversation about emotion and cultural perspectives and why robotic vacuum cleaners of all things have been so successful.

Dr. Selma Šabanović

Selma Šabanović is an associate professor of informatics and cognitive science at Indiana University, Bloomington, Indiana, in the United States. She directs IU’s R-House Human-Robot Interaction Lab, which she founded. Her research has combined the study of the design and use of interactive, assistive robots as well as their consequences. Šabanović is editor-in-chief of the magazine “ACM Transactions on Human-Robot Interaction” and co-author of the book “Human-Robot Interaction: An Introduction.” The book published in German by Hanser in 2020 is especially geared to students and anyone who wants to develop an overview of the state of research. It deals with sub-fields ranging from mechanics to ethical questions.

But as soon as they have sensors, they become robots. Only sensors give machines the ability to plan and execute.”

DR. ŠABANOVIĆ, WHAT IS A ROBOT? WHERE DOES BEING A ROBOT BEGIN?
That is the question that people are constantly asking, and every expert has a slightly different answer. To me, it has something to do with embodiment, that is a body that interacts physically. Robots can perceive their environments and interact with them. This would not include smart speakers, for example. They do have artificial intelligence, but they do not move, whereas a social robot such as “Jibo” can interact verbally, but it can also move spatially, and that motion qualifies as an interaction with the environment.

SMART SPEAKERS SUCH AS ALEXA AND ECHO CAN TURN LIGHTS ON OR ADJUST WINDOW BLINDS.
That’s right. In that sense, as part of a smart home, they could qualify as robots.

WHERE DOES THE DIFFERENCE BEGIN BETWEEN AUTOMATION AND ROBOTICS?
At the point where the machine perceives its environment and reacts to it adaptively. Industrial robots that are fully pre-programmed to process the same part at the same location are considered automation. But as soon as they have sensors and are programmed to react dynamically to sensor input, they become robots. The sensors make it possible for machines to plan and carry out actions in response to changes in their environment.

WHAT ABOUT AN AUTONOMOUS CAR?
That’s a robot as well. Think about parking assistants or cruise control. Those are functions that meet all the parameters for robotics. The car steers on its own, relying on its own sensors. To be honest, this is very exciting. We often talk about robotics as though it were off in the future. If something already exists, we accept it as a given. We associate robots with something futuristic, but in some sense we already interact with robots in our everyday life.

WE OFTEN GET THE FEELING THAT PEOPLE FEAR ROBOTS. WHERE DOES THAT COME FROM?
The fear was around before the term “robot” emerged. There are old myths about machines that looked so human that they fooled us. This has to do with a central question that concerns us as human beings: What does it mean to be human? What is it linked to – appearance, behavior, the soul? And isn’t the human body just a machine? This has been a preoccupation down to the present.

AND THEN THERE IS THE ISSUE OF JOB LOSSES.
Yes. Whenever we invent machines, we expect they will change the way we work. But these concerns are actually often more related to the way technology is integrated into society. In Western industrialized countries, automation has led to layoffs. In Japan, on the other hand, where the principle of lifelong employment in one company was still in force not so long ago, workers have been retrained. That was one difference. We can feel its impact even today.

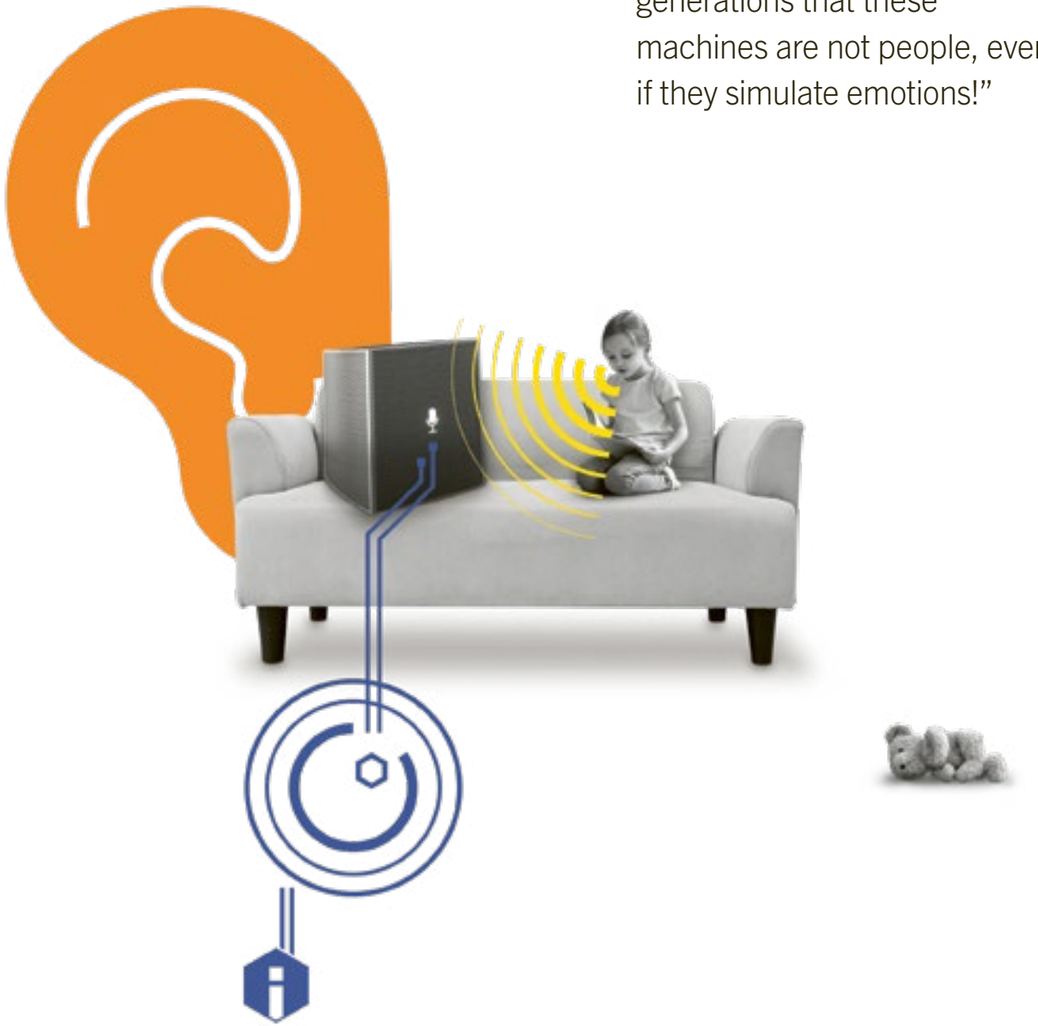
IN THE WAY THAT ROBOTS ARE VIEWED MORE POSITIVELY IN JAPAN?
Think about the high-profile representatives in pop culture. In the West, they are characters like the Terminator. In Japan, it tends to be characters like the android Astro Boy who confront war and injustice. That doesn’t mean that everyone in Japan views robotics positively. But there are differences in the way stories and archetypes have been established in the public consciousness.

SO ARE THE GLOBAL DIFFERENCES ROOTED IN DIFFERENT AREAS OF APPLICATION?
It often has to do with research funding. In the United States, for example, the Army is investing a great deal in robotics. In Japan, it was initially industry, and this led to greater progress in the consumer sector. Overall, the growth in the service segments has not been as rapid as people expected. The vacuum robot Roomba is a success story, but it has been a relatively unique example.

WHY, OF ALL THINGS, A VACUUM ROBOT?
Because it has clearly defined uses. It does what it is supposed to do, and its users do not expect its performance to be highly

Paro Robots

The Paro is a robot resembling a baby seal whose sensors recognize when it is held or petted. It reacts with sounds and movement. Studies show that it not only decreases feelings of loneliness, but stimulates connections between nursing home residents. It has been available in Japan since 2006 and in the United States since 2009.



We will have to teach future generations that these machines are not people, even if they simulate emotions!"

advanced. The lesson for every robot developer is where can existing technical capabilities be matched up with exactly what people need. Decades ago, people working in logistics had the vision of the robot-controlled "lights-out factory." That is probably not going to happen.

INSTEAD PEOPLE AND ROBOTS WORK HAND-IN-HAND.
The crucial challenge remains: How to marry a robot's strengths to those of a human being. Collaboration is the buzzword for the future.

BUT FOR THAT, ROBOTS HAVE TO LEARN TO INTERPRET HUMANS PROPERLY …
Smart speakers often don't understand children because they speak differently than adults do. At the institute, we now have a research project underway on the use of robots with older people, for example, in caregiving. Seniors also speak and hear differently than younger adults. Engineers and developers have to rethink these issues. Previously, robots had been tested using ten employees in the lab. But the new development may well have totally missed the target audience: When we talk about robot-human interaction, we should pose the right questions at an early stage: What should the robot be able to do? What are the objectives? What are the limits? And what data is the source of the robot's knowledge? Otherwise, there is the risk that entire social groups will be excluded.

DO ROBOTS NEED EMOTIONS TO COMMUNICATE?
That is an exciting question because we humans continually see emotions in things unconsciously. When a robot is programmed to approach a light source, observers respond with statements like, "Oh, it loves the light!" So if robots show emotion, it helps them with their interactions with humans. A delivery robot that slows down when it approaches you can be seen as exhibiting caution. This may help in certain situations even if robots lack emotions.

IS IT A PROBLEM TO ASCRIBE EMOTIONS TO ROBOTS?
That depends. If older people who are alone attribute emotions to their robot-pet "Paro," I don't consider that to be bad. They were designed for that purpose: to have a positive effect, to inspire happiness in others. We reflexively anthropomorphize things. It helps us to be social. But it is a problem, for example, if soldiers anthropomorphize the robots that they send out to dispose of bombs. It will put them in danger. This kind of behavior has been observed. So we are going to have to teach future generations that these machines are not human even if they simulate emotions.

DOES OUR SOCIETY HAVE A MISCONCEPTION ABOUT THE FUTURE OF ROBOTS?
There are very different conceptions of their future, in any case. One is shaped by films and books. A future in which robots wander around as individuals. But robots are quite limited at this point. The opening question, where we began the conversation, suggests a complex challenge: the interaction with the environment. The notion of robots being able to wander around in human form is still a long way off. The same is true for robotic interactions with the countless uncertainties in an urban environment. But there is a future where robotic technology will be implemented in everyday things, and it is practically here. We don't have robots like those in the film "I, Robot." But we have delivery robots – they are real. And we have robotic technologies incorporated in everyday devices.

WHAT IS YOUR VISION FOR ROBOTS' FUTURE?
Brighter, hopefully. It is for the focus to be on people and society. What do we want to accomplish with the technology? This is important so we can base laws and rules on that vision. And how can robotics help us improve our lives? Socially, economically and psychologically. Technology should do that. It should not be an end in itself. ©

Not Automatically Autonomous

Autonomous vehicles seem to be a special species of robot. The differences cannot be justified on either technical or commercial grounds. They lie in our view of driving.

Time to authorize autonomous transport? The readiness to do so varies around the world. The French manufacturer Navya in Lyons has already developed a range of small buses – and currently sees its greatest market opportunities in Asia.

In “The Love Bug,” when a Volkswagen Beetle named Herbie was poised to jump off a bridge one night, even the hardest-core car-haters sympathized with his plight. He was about to be replaced by a red Lamborghini. As absurd as the scene is, the more than 50-year-old Disney film offers a visionary answer to a fundamental question: How do you deal with a robot automobile? We can’t help but talk to it and think our way into this artifact of steel and circuit boards. And we will develop feelings – at any rate, more than we would for the robots that mow our lawns or work next to us in plants.

But why is this the case? From a technical standpoint, a vehicle that propels itself without human intervention is not fundamentally different from a mobile industrial robot. It is certainly equipped with a more extensive system of sensors and higher performance computers, but the basic governing principle is the same: recognize, calculate, take action.

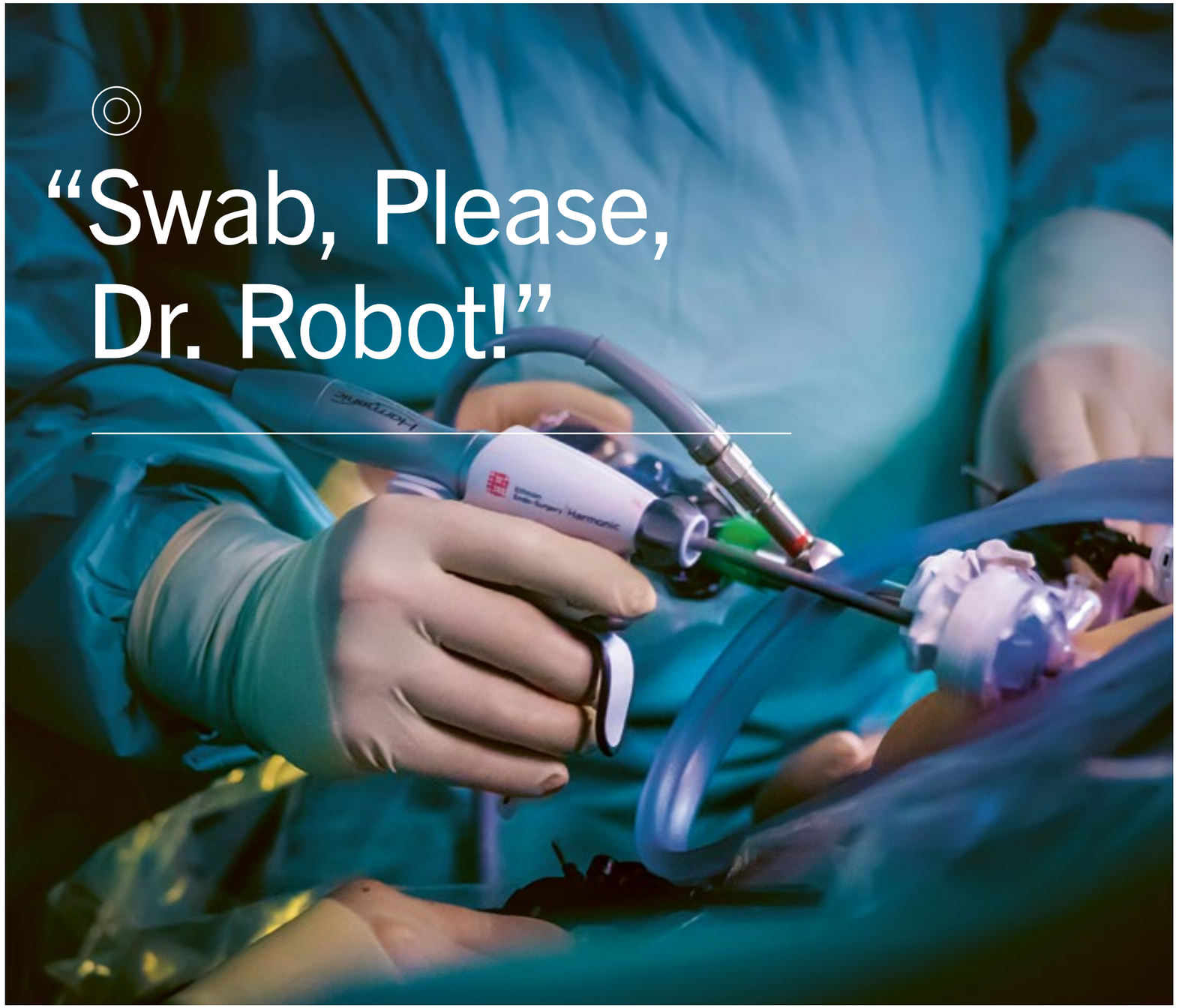
The actual difference is not in what the robot vehicle does, but in our view of the activity. As we see it, creating the same weld seam 24 hours a day is a monotonous activity. So is mowing the lawn for an hour every morning. We feel that these activities require little intelligence. They do not evoke powerful emotions. Driving a car, by contrast, is a cognitively demanding activity unless it is traveling straight ahead for hours and hours through the American West at a constrained speed. If a technology can replace us, then, at a minimum, it must be a very special machine. Anything else would threaten our self-image.

This premise is supported by polling on the acceptance of autonomous driving. It is especially high in those markets where driving ability is not held in particularly high esteem. For example, a mobility study by auto supplier Continental found that 89 percent of drivers in China believe the trend toward autonomous vehicles makes sense. In China, if you have a sufficiently high opinion of yourself, you are already driven around by chauffeurs. By contrast, acceptance only reaches 52 percent in Germany, the quintessential automotive nation.

Enormous Progress, No Series Production

When it comes to autonomous vehicles, German automakers are back in the forefront technologically. Alarmed by images of a Google-programmed Toyota Prius in 2012, premium manufacturers launched development programs with budgets in the billions. The technological progress has been enormous over the past ten years, and even complex traffic situations in urban centers are largely expected to be mastered. Legislation is moving quickly as well. Germany was the first country to pass mandatory rules for the use of fully automatic vehicles without a supervising driver on public roads.

There still isn’t a single self-driving vehicle that you can buy right now. Why is that? Only a miscalculation explains this. The full range of technology deployed in a robot car adds tens of thousands of euros to its price. For a personal vehicle, the value for the money is just too little. “For the foreseeable future, we will rather see assistance systems with expanded functions in cars,” said Thorsten Gollewski, who is responsible for autonomous mobility systems at auto supplier ZF Friedrichshafen. “At present, a higher level of automation is mainly appealing for trucks and people movers.” The business model is the rationale: In freight transport in developed countries, wages and ancillary costs make up about one-third of the total lifecycle costs. By contrast, the depreciation of the vehicle costs only accounts for about 9 percent. In the end, it is a rational calculation that determines whether autonomous vehicles come into use – and that applies to robo-trucks as well as their colleagues on the shop floor. ◎



“Swab, Please, Dr. Robot!”

Can robots perform more precise incisions than human surgeons? Theoretically, yes. Nonetheless, autonomous machines won’t be operating on us for now. But medical robots have long been used in operating rooms – and they may be in our bloodstreams someday.

A robot was deployed in an operating room for the first time back in the 1990s. The “Robodoc” system was supposed to revolutionize surgery. It was able to cut bones more accurately and evenly than the human hand. It had important applications for the implantation of artificial hips as well. The more exact the cut, the better fit for the prosthesis. And the more quickly and effectively it will be able to bear loads. Robodoc is based on a customized industrial robot.

“It was also very precise,” said Dr. Beat Müller, Manager of the Department of Minimally Invasive and Robot-assisted Surgery at the Heidelberg University Hospital. But there was another issue that only became apparent later. “In isolated cases, the robot also cut away musculature,” Müller said. “And even with bones, there might be deviations that a human surgeon would likely have noticed during the operation – but the robot would not. In a retrospective in 2009, the magazine DER SPIEGEL called it a “lesson in German medical history.” Its assessment: The belief in the blessings of modern technology blinded many a doctor and even patients at the time. Perhaps Robodoc had come along too early.

Prof. Dr. med. Beat Müller

Beat Müller received his license to practice medicine in Zurich in 1997 and moved to the Heidelberg University Hospital nine years later. He has been interested in minimally invasive surgery from the start of his career. Since 2010, he has led the department of Minimally Invasive and Robot-assisted Surgery in Heidelberg. During his tenure, the department has been honored for excellence.

Three decades later, more and more robots are at work in operating rooms. They have different names and look different. Müller welcomes robotics and is a supporter of so-called "minimally invasive surgery," which damages tissue as little as possible. It requires a different approach and was viewed skeptically thirty years ago. Perhaps that is why he is so open to innovation today. "I've always wanted to try out new things," he said. "My experience with them has been good." Today's generation of operating room robots combine the two aspects: Doctors today can perform minimally invasive surgery more easily with robotic support.

But Müller immediately makes it clear that working with mechanical aids is not the same as working with autonomous robots. The "Da Vinci System," the most frequently installed operating room robot today (with around 5,000 units worldwide), is ultimately nothing more than the extended arm of the surgeon. "It doesn't do anything that the doctor isn't doing," Müller said. Only the doctor no longer stands right beside the patient – the surgeon sits at a display and controls the operation with a lever. "That is better ergonomically, and you more or less have a microscope in the patient's stomach." This allows incisions with a precision that a human hand would scarcely be able to achieve.

True automation in the operating room is tricky given the complexity of the human body, especially with regard to soft tissue – as the "Robodoc" so emphatically demonstrated. "The areas where it is really stable can be automated more easily," Müller said. One example would be a biopsy through the skull. But he knows of promising research projects on automated intestinal sutures and autonomous camera work during minimally invasive surgery. In any case, robot-supported medicine is appealing, albeit expensive. "I have underestimated it for a long time: The market is too small. For developers, it is less attractive than robotics for the consumer sector," he said.

Still, there is movement in the sector. It turns out that medical robots do not have to operate arms or wield scalpels. In May 2020, a team at the Stuttgart-based Max Planck Institute for Intelligent Systems published a report on micro-robots the size of a blood cell. The spherical robots could be introduced into the blood to deliver medicines to the exact spot where they are needed. The micro-robots can move and navigate against the blood's circulation. "Our robots can independently identify cells of interest, such as cancer cells," said Yunus Alapan, a post-doc in the Physical Intelligence Department. "And they can release molecules of active agents during their travels." These micro-robots are still a long way from human trials, however.

In addition, entire swarms of the robots would be needed to ensure reasonable delivery of a drug. In November 2020, researchers at Switzerland's ETH Zurich presented a concept for a "micro-vehicle"

"My focus has always been to develop our methods further," said Dr. Beat Müller. He is open to new ideas.

"It is like having a microscope in the patient's stomach": The Da Vinci System (at right) can be controlled remotely.

Operating minimally invasively: Many surgeons balk at the expense. Robotic support makes this step much easier.

that is taking a similar route. But the work involves only experimentation with materials at this point.

One thing is clear: Even outside the operating room, medical robots will be relevant in the future and are expected to take over many tasks. "Robot nurses" could monitor patients, draw blood or help with hygiene. That would leave human beings with more time for jobs that they can do better than robots: communication and personal closeness. In 2018, Rutgers University in New Jersey, USA, developed a prototype for a robot that can draw blood and even immediately analyze it. "In the United States, blood is drawn two billion times every year," Project Manager Martin Yarmush told Smithsonian magazine. The British National Health Service (NHS) has been testing intelligent chatbots since 2017. Their artificial intelligence is expected to lighten the doctors' workload during consultations. The logic is the same in each of these fields: Robots can take over repetitive tasks, giving staff greater latitude for work that requires human intelligence and intuition. After all, patients' questions raise certain issues again and again – ideally, with robotic help, doctors would have more time for thorough diagnoses or discussions. In the future, "house robots" could accompany people home and sound an alarm in an emergency, lightening the load on hospitals or allowing the elderly to spend more of their lives at home. The appropriate prototypes have long been developed for many of these concepts.

5,000

Da Vinci systems are in use worldwide. They were initially invented for remote surgery.

Müller, the surgeon in Heidelberg, is drawn to robotics-related innovations. "Robots don't take work from the surgeons – they make the surgeons better," he said. "I find that to be a very appealing vision." He doesn't have the feeling that patients are intimidated by surgical robots – on the contrary. "Robots are more precise than people, are controlled by people, and a human can contribute flexibility and respond to different situations." But he said it is crucial for patients to understand exactly what robots in the operating room do. "You cannot give the impression that robots create mischief without anyone noticing." ◎

BY THE NUMBERS

101 Years

The word robot is international. It is written similarly in many languages and tied to the same meaning. The term itself dates back 101 years. In 1920, the Czech author Karel Čapek wrote the play R.U.R. (Rossumovi Univerzální Roboti), in which a company of that name creates humanoid machines. They are supposed to be a workforce that serves humanity and brings about well-being and social peace. But things take a dramatic turn. The machines begin to envy mankind and attain mastery over it before they are threatened with their own doom.

Čapek reportedly wanted to use the English word labor to refer to these artificial creations. But his brother Joseph convinced him to use roboty. It comes from the Czech robota, which means hard labor or drudgery and can be traced back to the old Slavic word rab (slave). In 1921, R.U.R. made its debut in today's Czech Republic and quickly found its way to international stages. The word roboty has been carried over into other languages, and the term now stands for machines that can execute certain functions performed by humans. ◎

Two Arms and Three Stars

Robots working as kitchen helpers are scoring points for their precision and hygiene. Fully automatic restaurants and android waiters are still a sensation. It is not hard to understand the trend toward robotic food services.

Two robotic arms, more than 5,000 recipes. "Moley" even handles complicated ones.

What is often thought to be the world's oldest robotic restaurant is not really a restaurant. "Robo Restaurant" in Tokyo already had robots that danced on stage back in 2012. The concept was theater and entertainment, not cuisine. Still, it was highly successful, even if it was decried as a tourist trap. More recently, a growing number of robot-equipped restaurants that actually cook and serve food have opened their doors.

The "Robot Restaurant" chain in India has robots that bring meals right to diners' tables, and it is chalking up successes. The chain has branches in Chennai and the Indian technological center of Bangalore, among other locations.

120

noodle dishes per hour are prepared by robots in Foshan, China.

At the tables, the guests order off a screen, and robots deliver and serve the food. Cooks and chefs need not worry about the robots taking their jobs, however. In the end, they are just logistical robots. The "Robot Restaurant Complex" in Foshan, China, goes a step further. Forty robots, some of them in the kitchen, handle operations for up to 600 diners around the clock. A "noodle robot" can prepare 120 noodle dishes per hour, its operators estimate. It only takes up four square meters (43 square feet) of space.

Cutting, Chopping and Stirring

Industry experts have no doubt that robots will soon be moving into kitchens in growing numbers, for the same reason that they are widely used in the food industry. Robots can handle routine tasks such as cutting, chopping or stirring at very high speeds – and their hygiene and precision are impressive. That makes them an attractive prospect for the food industry with its standardized processes.

"Spyce," a restaurant in Boston, has had a fully automatic kitchen since 2018. Ingredients are mixed and stirred there – and the cooks are only responsible for assigning the recipes and for adding a splash of dressing on the food at the end. It arrives almost exclusively in bowls, and the meals are mostly finely chopped potpourris with mixed ingredients. The automated equipment cannot handle more complex menus. The restaurant advertises meals that start at $8 and that are ready in "less than three minutes."

Customized Ingredients: No Problem

In 2015, the British startup Moley introduced a prototype for a fully automated kitchen with two robot arms that hang from the ceiling, stir sauces and cut vegetables. They can also operate several burners. The robot kitchen has mastered more than 5,000 recipes and went on the market this year for about 300,000 euros. With this kitchen, the promise has been realized: It can handle more complicated dishes and different cooking steps automatically.

The automated robotic kitchen has struck a chord: Customers simultaneously expect speed and individuality. Special requests don't confuse robot cooks, whether they involve special ingredients, peanut allergies or low-salt dishes. All it takes is the push of a button. By the end of 2021, an Illinois-based company called Nala Robotics plans to open its first automated restaurant where a robot arm will team up with artificial intelligence to prepare thousands of recipes. The company is still not talking about the technology behind the plans.

Robots Can't Taste Their Cooking

In the future, will the next three-star restaurant be run by a chef with circuit boards and a processor? At least no one is ruling out the possibility of an actively "creative" artificial intelligence that can invent completely new dishes – thanks to Big Data and deep learning. But for now, robotic cooks will come up short in one area: They can neither taste nor smell the foods they prepare. They know how to cook low-salt meals, but they don't know what "salty" dishes taste like.

The "Robo Restaurant" in Tokyo has now closed its doors permanently. The pandemic has delivered a death blow to the stage show. The guests had been almost exclusively tourists, not locals. As lucrative as the idea was, the owners might have been better off betting on a real robotic kitchen. ◎

Grasping is Harder than Thinking

Robotic technology has made astonishing progress in a number of areas, but there is still one part of the human body that gives engineers headaches: the hand. Although even infants can reach out and grasp objects, robots are pushing up against their limits if they attempt the same feat. An assessment.

In 1996, for the first time, a computer defeated a reigning chess champion. Garry Kasparov lost in a contest with a closet-sized computing whiz known as "Deep Blue." The duel was emblematic of everything that computers would soon be expected to do. Twenty-five years later, the expectations have only partly been met, at least if one were to consider a drugstore in your neighborhood as an example. Shelves are replenished with ten-packs of toilet paper or small boxes of face cream. Employees mostly handle these tasks. Many of them would be happy to turn them over to robots. But robotic technology is pushing at its limits in these cases. Whether large or small, soft or hard, the products keep coming, one right after another. And tomorrow they will look different than they do today. These tasks overwhelm robots. The question is: How can they be taught to grip?

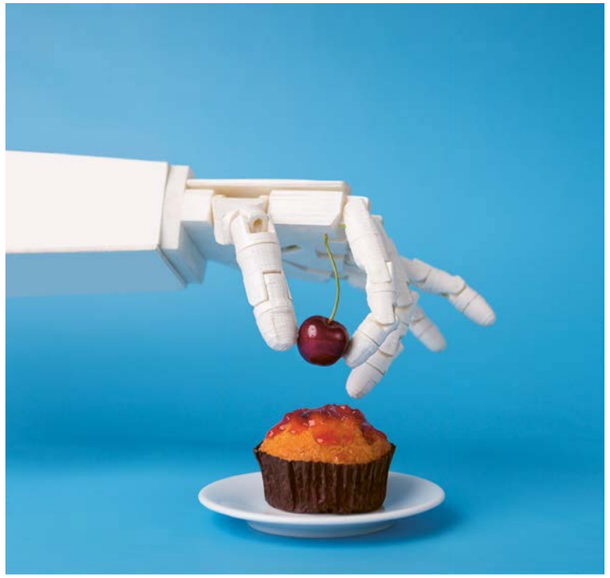
Soft Hands from a University

The Technical University of Berlin is in the forefront of research on the issue. In a Westdeutscher Rundfunk broadcast, researcher Raphael Deimel described one of the main problems: "People are trying to re-create the human hand, but they don't really know the most important part of this." Deimel's team has explored the problem and has undertaken extensive experiments since early in the 2010s. In the process, the researchers found that the fingers of the human hand adapt spontaneously to the object that the person wants to raise. It is only at the time of gripping that the final position and the pressure the fingers apply are generated.

But how do you implement this on a machine? The Berlin-based researcher developed a soft robotic hand with silicone fingers that can only be activated with compressed air. In this way, the hand is adapted to the object without being precisely programmed in advance. It is designed to handle everything from a mobile phone to a vase for flowers, and from a banana to a teddy bear. This type of hand, currently just a prototype, could easily find uses in the food industry, sorting fruit and vegetables, for example. These foods are especially sensitive to excessive pressure.

Applications in Caregiving?

This type of hand could also be an option for robots in caregiving situations. Robots are already used in the field, but the "hand problem" has prevented their widespread deployment. The humanoid robot "Pepper," a joint French-Japanese development from Alderbaran Robotics and Softbank, is a classic example: It is 120 centimeters (47 inches) high and is equipped with arms and plastic hands with a servo drive. It can speak, sing and move its arms and hands. "At first we thought Pepper could already grasp and handle 'fetch and carry' tasks or clean



How much pressure can a cherry tolerate and how does the hand know where to place it. These are tough questions for robots.

> The quintessential robotic hand has not yet arrived. The more straightforward its uses, and the more standardized the objects to be grasped, the better."

and run a vacuum cleaner," said Dr. Karsten Schwarz of Halle University. "It can't do all of that. Its hands are really just for gesturing and stabilization during its operation." Schwarz works on the FORMAT project at Halle University, which does research on these types of robots.

Robots at the Stovetop

The outlook is a bit better in the kitchen: Moley, a British company, has developed a complete, finished kitchen unit with two robotic arms. The core elements are the two five-fingered hands from Schunk, a company based in Lauffen am Neckar. It has equipped the hands with nine motors each and numerous sensors. All the control, regulating and performance electronics are integrated into the wrist and the interfaces are standardized. That means the hand can be combined with other robot arms. In the robotic kitchen, the hands competently use mixers, knives, egg whisks, faucets and stove tops. The entire assembly does not come cheap though. Still, for a little more than a quarter of a million euros you can take possession of a very unusual status symbol. At least it's very unusual for now. These robots make more sense for large kitchens, and their manufacturers admit this. The arms and hands in this kitchen need a great deal of space, both on and above the working surfaces – and they are much too large to solve the problems in drugstores.

Dematic, a logistics company based in Heusenstamm, is taking a different approach, betting on hands tailored to a particular task. To help with the sorting process on a logistics company's delivery vehicles, it relies on "pushers" to guide packages onto the shelves at the right locations. As the shelves are filled, the problem posed by different package sizes is rectified with fingers of different dimensions. This enables a massive package to be gripped with two large fingers. Narrower fingers come into play for smaller and lighter packages. The approach also keeps the intermediate spaces on the shelves within acceptable limits.

The bottom line is that the quintessential robotic hand does not yet exist. The more straightforward the application and the more standardized the object to be gripped, the better. There are a few promising approaches. But for now, the human hand remains a masterpiece that is difficult to duplicate technically, especially in combination with the human eye, brain and arm. Incidentally, even Deep Blue was unable to move pieces on the chessboard on its own. A human being had to do that for him. ◎

ESSENTIAL – SENSORS

A section on things that can be found everywhere, yet are so small they often go unnoticed. Still, they are extremely important. Like a seal …

A robot has a body, software, perhaps even arms … so far, so good. Nonetheless, it is just a machine that is incapable of interaction. And it doesn't know where it is. Human beings have their five senses. A robot needs sensors to receive impressions – in most cases, significantly more than just five. Depth sensors to recognize a room. Tactile sensors. Devices to measure acceleration, along with gyroscopes and magnetometers to navigate and determine its position. Just one camera has millions of light sensors. A meaningful response requires data of this kind. In the future, sensors will become even smaller and more digital – and they will be everywhere. Incidentally, humans also need sensors to capture things that our senses are unable to clearly identify. A thermometer is one example. ◎

Making it Easy

With its new strategy, Kuka wants to make automation available to everyone. A key component of the initiative is a new operating and ecological system that greatly simplifies programming. But classic machine building virtues are still important for success in the market.

Shaken or stirred? Robots are taking on more and more tasks – in part because the programming is becoming much easier.

More than just hardware: The subsidiary Swisslog is automating complete warehousing systems.

A huge manufacturing space somewhere in Germany. Minute by minute, the floor vibrates as huge presses form steel sheets. Orange robotic arms load and unload the presses. A bit further into the same plant, other robots weld sheet metal together, and a vehicle body emerges piece by piece. If you stand in a body shop today, it is hard to imagine that it was people – not robots – who did this occasionally dangerous work up until the 1990s. But with the opening of global markets, the auto industry became a pioneer of automation. Kuka benefited from the trend right from the start. The Augsburg-based company built the first robotic welding transfer line for Daimler-Benz in 1971. The world's first industrial robot with six axes of movement followed in 1973. There was little demand for it initially, but its technology paved the way for an upturn in the 1980s. Robots conquered auto factories, and Kuka assumed the pole position in Europe.

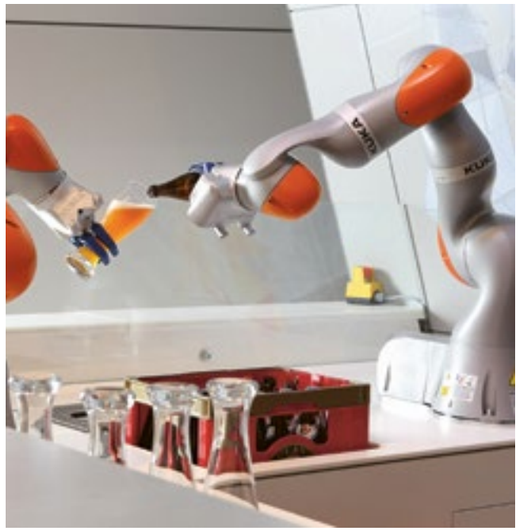
A new industrial world: What can be automated, will be automated.

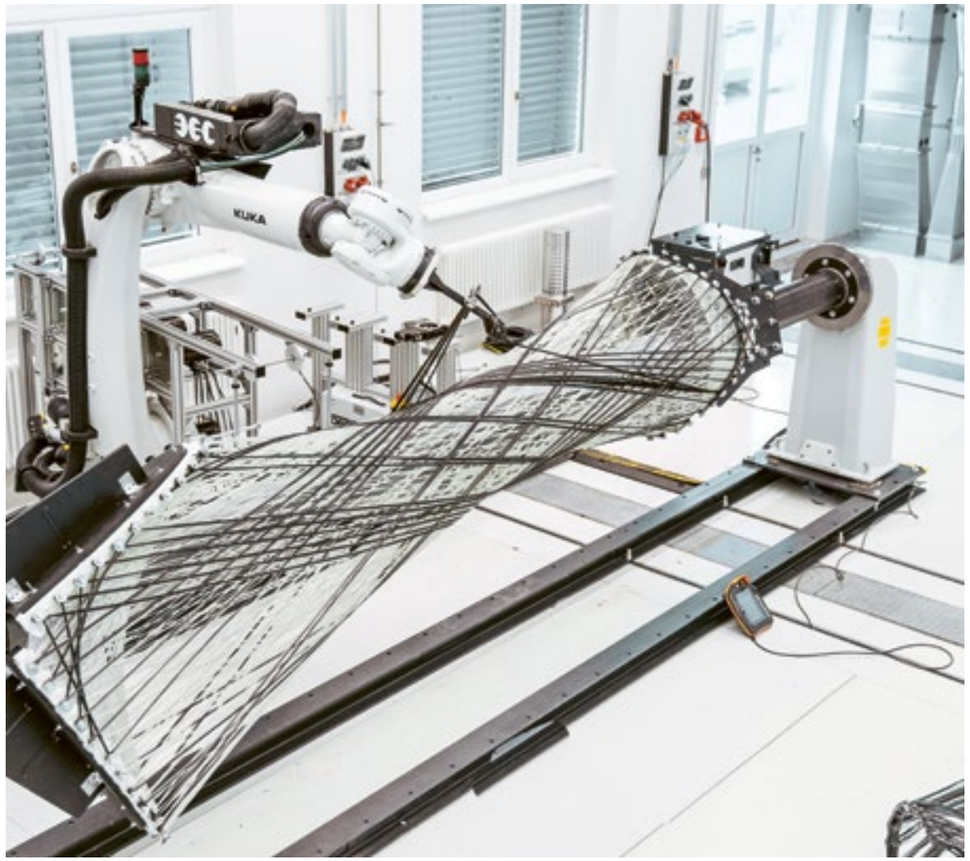
Kuka expert Benjamin Baumann now foresees a comparable revolution for small- and medium-sized enterprises. "We are facing a shortage of skilled employees in every industrial country due to demographic changes. That means unergonomic and monotonous activities will increasingly be automated in smaller companies as well." A product architect, Baumann is working on the implementation of a new growth strategy for the venerable company. "Automation for everyone" is the program behind the strategy. It's especially targeting activities that have posed problems for automation in the past. Perhaps it has not paid off financially. Or the activities have been automated only rarely – or not at all. The functional testing of electronic components is one example. "In theory, there are no limits to our imagination," Baumann said. "A high degree of system flexibility – along with easier programming – is the precondition for smaller companies to be able to use robots profitably."

The new operating system "iiQKA.OS" makes robotics accessible to (nearly) everyone.

Close Relationship

In the last few years, the business relationship between Kuka and FST has become much deeper. One key reason: With the Modular Sealing Solution 1 (MSS1), FST has developed a system that is low-friction and extraordinarily robust. Working with Kuka and a gearbox supplier, Freudenberg has installed the MSS1 into a robot for the first time. "The results impressed everyone. The sealing function performs reliably and the seal is kept comparatively compact at the same time," said Dimitrios Tsituridis, Key Account Manager at Freudenberg Sealing Technologies. In all, Freudenberg now supplies around 200,000 radial shaft seal rings annually to Kuka and the component supplier that it has designated. In parallel, FST is increasing the level of automation in its own manufacturing operations – and, in turn, a growing number of Kuka industrial robots are being put to use there. "We certainly know that the quality is the highest," Tsituridis said. Kuka subsidiary Swisslog supported a major automation project in Italy. The Pinerolo distribution center, which mainly sends replacement car parts to Italian customers, uses an automated warehousing and picking system. A fleet of autonomous vehicles takes items from racks and transports them to the employees who handle the actual shipping.





Robots that can recognize how full a glass of beer is as it is poured (left); robots that weave and shape architectural components (middle) – and even robots that play drums and keyboards on the stage (right): the areas of application seem endless.

Read more on Kuka's Mission 2030: https://www.kuka.com/en-de/future-production/kuka-mission-2030

Programming Without Special Expertise

There has been great progress in programming – often called "teaching" – in recent years. For example, knowledge of high-level languages has not been needed for a while. Instead, a motion sequence directed by a human can be recorded and translated into programming codes. "Robotics for everyone" insists on programming totally without the specialists that smaller companies cannot afford to hire. The new operating system "iiQKA.OS" is expected to allow this. It carries smartphone-style thinking over to robotics. The operating system takes over the hardware-related tasks and controls communication. Specialized apps – made available through an ecosystem also called "iiQKA" – take over application-specific tasks, such as controlling a welding device. So components typically provided by outside companies – laser sensors or gripping systems, for example – can be integrated, Kuka has entered into a series of partnerships to fill out its ecosystem. "That takes care of interface problems and manual programming," Baumann said.

> In theory, there are no limits to our imagination."
>
> Benjamin Baumann, Product Architect, Kuka AG

The initiative is starting off with a cobot, the "LBR iisy." With a payload of 3 kilograms (6.6 pounds), it is one of the smallest robots in the Kuka portfolio. But it is nonetheless a high-tech solution. Its six joints contain sensors enabling it to respond to the slightest contacts. This puts the LBR iisy in a position to work in close proximity to people – and, simultaneously, with extreme precision. Dimitrios Tsituridis, Key Account Manager at Freudenberg Sealing Technologies (FST), is closely watching his customer's development. "Kuka robots stand out for their extreme robustness and longevity in industrial environments, and they increase the productivity of their users. I see this technical standard in their cobots as well." Tsituridis knows what he is talking about. Among other uses, the seals that he sells are employed where any robot endures special stresses: in its joints. Rapid acceleration is followed by braking that is quick and precise in equal measure. "From the standpoint of the seal, it is extremely challenging to reach maintenance intervals of several years under these conditions." In the case of cobots, the payloads and rotational speeds are generally less. In return, the requirements are greater for the precision of the motion sequences. "That's why the friction caused by the radial shaft seal ring must be kept to a minimum," Tsituridis said.

Growth in China, Too

Kuka is one of the world's largest providers of robots with an installed base of about 350,000 units globally. It sees enormous opportunities for growth as automation continues to advance. The Chinese market is especially appealing since the "Factory to the World" is seeing rapid demographic shifts. Kuka has owned the Chinese company Midea since 2016 and has good market access. Tsituridis' Chinese colleagues are naturally in discussions with Kuka experts in China. He is confident that "Automation for everyone" is a vision with promise. ◎

Robotics on the Rise

INVENTORY WORLDWIDE

2.722

1.059

million industrial robots

2010 2019

INDUSTRIES

Operating inventory (in thousands)

Automotive: **923**

Electric/Electronics: **672**

Metal and Machinery: **281**

ASIA IN THE LEAD

1.688 million robots in Asia/Australia

580,000 robots in Europe

389,000 robots in America

COUNTRIES

Robot density*

1. Singapore: **918**
2. Rep. Korea: **855**
3. Japan: **364**

Worldwide: 113

*Robot density = the number of robots per 10,000 employees

PRODUCTION

47 %

of all industrial robots are “Made in Japan.”

INDUSTRIAL ROBOTICS

Robots are becoming more and more important to industry and to consumers. But where is the center of industrial robot manufacturing, what sectors are turning to robots, and where are startups heavily involved?

INVENTORY WORLDWIDE

23.373

2.214

million service robots

2010 2019

including

13,741 robots *in the workplace*

173,000 robots *in the workplace*

2,200,000 robots *in private use*

23,200,000 robots *in private use*

THE FUTURE

20 %

of all service robot suppliers are startups.

PRODUCTION

75 %

of robots for private use are “made in the USA.”

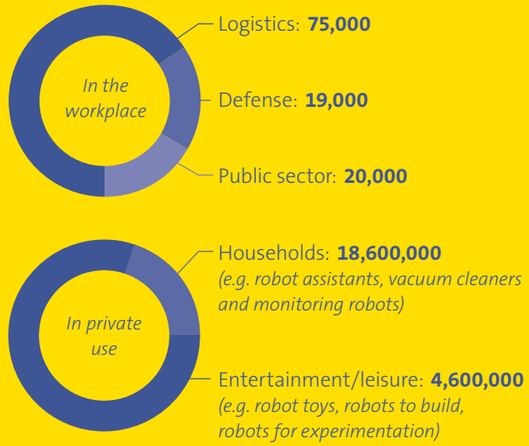
SPOTLIGHT ON LOGISTICS

In 2019, revenue rose by

110 %

INDUSTRIES AND AREAS OF APPLICATION

(2019, in units)



SERVICE ROBOTICS

Not a Single Drop of Oil

First on the shop floor, now in the kitchen, a cold storage unit or a hospital as well: The new locations where robots work have had a real impact on the requirements for them, including seal specifications.

Water spurts out of pipes. Spray flies in all directions. In the middle of it all, a robotic arm holds a single metallic part in its gripper. The part is being cleaned. That's how a film promoting a robot manufacturer begins. "Robots were traditionally found on the shop floor," said Timo Furrer, Vice President Global Sales at Freudenberg Sealing Technologies, commenting on the video clip. "In those cases, the same basic requirements were always in force, 25°C [77°F] standardized movements." But industrial robots now work in cold storage units and washing cells. This changes the requirements for them.

Furrer keeps an eye on many segments and industries. "The market for robots is booming," he said. Automation is expanding and conquering new fields. And robots need seals. Dirt or water cannot be allowed to enter their highly sensitive gearboxes. "More and more robots work in an environment filled with dirt, dust or water," Furrer said. Seals are

needed because every robot gearbox is filled with a lubricant in the form of grease or oil. Every effort must be made to keep the lubricant from escaping. “Years ago, the leakage might have been tolerated in some industries,” he said. “Today the quality requirements have increased considerably.”

Motivation and a Challenge

Achim Ströhle has made the same assessment. He is the Global Segment Director Industrial Machines & Robotics at Freudenberg Sealing Technologies. A while ago, Ströhle noted that some customers considered minor leakage in grease-lubricated housings to be a given. “We first became aware of how widespread it was when we were at a trade fair with some international teams and we queried very different manufacturers on the subject.” The notion was that a little grease now and then was just how things worked. After all, seals are imperfect. Ströhle and his team saw the problem as a challenge, especially with regard to the robotics market, and it motivated them.

> People don’t want their pizza with salami and motor oil on it.”
>
> Timo Furrer
> Vice President Global Sales,
> Freudenberg Sealing Technologies

The bottom line was that the leakage of grease or oil is unacceptable if a robot is working in an operating room or the food industry. “Nobody wants a pizza with salami and motor oil on it,” Furrer said. But many service robots and their hardware are based on industrial-robot models. Much as an automaker doesn’t know whether a customer drives its cars in Alaska or Dubai – whether it must be equipped to withstand cold temperatures or fine desert sand – a robot manufacturer doesn’t necessarily know where its models are going to be used. The result: the demands on robot components are increasing across the board.

“That naturally gives us an edge because our focus is on seals that meet especially high demands for quality anyway,” Furrer said. It takes little special expertise to seal vacuum robots against normal household dust. Challenges arise where a number of requirements run into one another: “For example, when a seal must withstand higher stresses when it is supposed to meet the hygienic standards of the U.S. Food and Drug Administration (FDA) at the same time,” Furrer said. Or when the material is simultaneously exposed to water and extreme temperatures. In most cases, combined expertise in materials and applications is required. “We have the materials and the technology to solve this.”

Operating life is another issue. Especially for automated processes, it is crucial for individual components to function for years if at all possible. “Every breakdown, every repair costs a lot of money if an entire installation comes to a stop,” Ströhle said. He is proud of the progress that Freudenberg Sealing Technologies has made in meeting the desires of these customers – among other products, it has developed a seal that guarantees complete leak-free operation in oil-lubricated gearboxes.

“Robotics Is Still a Trend”

Freudenberg Sealing Technologies still mainly supplies major industrial customers – but Furrer and his team have long kept an eye on the startups of the robotics scene. “There are a lot of them springing up right now, and any of them could become the next big thing,” Furrer said. Many of these new companies focus on – and have special expertise in – IT, artificial intelligence and improved user-friendliness, and still source their hardware from the major suppliers. But not all of them. “The manufacturers that come from the IT world, in particular, do not always have the importance of seals on their radar right away,” Furrer said. “What happens, for example, when a user inadvertently spills a glass of water or a cup of hot coffee on the robot?”

Water sprays from all sides: The robotic arm in the washing cell needs seals that protect its gearbox from extremely fine droplets.

A Glass of Water or a Cup of Coffee …

There is a great deal of movement in the market in every direction. One of its characteristics is that some projects do not achieve success as quickly as first assumed. Furrer recalls one example: Softbank. The Japanese robot manufacturer turned away from the strategy of developing humanoid robots and put its efforts into simpler applications such as cleaning robots. “Robotics is still a trend,” Furrer said. “There will still be surprising developments, but no one in the industry at this point knows which of them will be successful.” Whatever happens, more robots will have to be sealed against dirt and water in the future – and they will need to stay leak-tight. Freudenberg Sealing Technologies knows how that works. ◎

Putting a System Through Its Paces

The interplay of gears, lubricants and seals determines how precisely and trouble-free robots can function, making the ability to thoroughly test this interaction in advance all the more important. Freudenberg Sealing Technologies' test facility in Weinheim offers more than standard cycles.

Standard testing cycles do not meet the needs of today's robots. Detailed tests can be run at the test facility in Weinheim, Germany.

Robots do have arms, but they don't have muscles. So the joints of a robot are unable to move without a drive system. And every drive system needs lubrication as well as a seal. "Robots at work often execute very demanding movements," said Dr. Daniel Frölich, Head of Engineering at Freudenberg Sealing Technologies. The driveshaft moves in one direction and then switches to another, sometimes with high acceleration. "There is enormous diversity," added Holger Sattler, Design Engineer, Product Development. "A typical industrial robot has six axes, and every axis has a different profile and rotates differently. And the gripper usually has to move more quickly than the arm."

> Robots in action often execute very demanding movements."

Testing Robots Is Expensive

So how do manufacturers determine whether the interaction of the components is working properly in this complicated sequence of movements – especially with regard to seals and lubricants? Testing the robot itself is expensive. Simulations under highly realistic conditions make more sense. In Weinheim, Freudenberg Sealing Technologies has established one of Europe's largest sealing test facilities. Around 250 test cells are on the floor. "Here we can adjust everything from rotational speed ramping to temperature and pressure," Frölich said. The service is not only available to its own operations but to other companies as well. After all, standard testing cycles often cannot handle the diverse nature of today's robotics. In some cases, growing numbers of robot manufacturers and suppliers do not know how their gearboxes will ultimately be used. "We work very closely with our customers. Active consultation is crucial," Sattler said.

Greater Precision, Smaller Installation Spaces

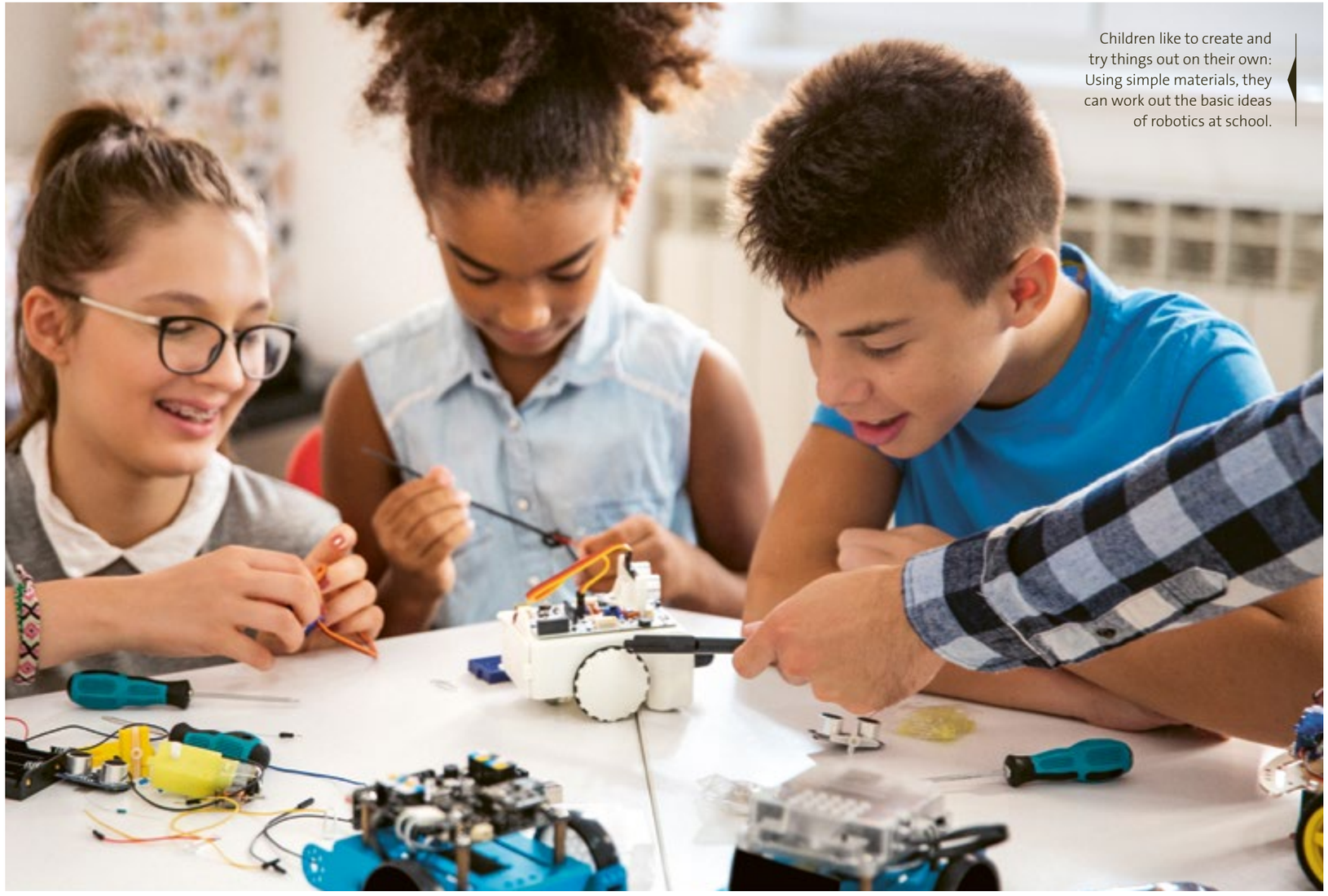
In addition, technological advances are increasing the demands on robots: Rotational speeds continue to increase, cycle times are in decline, machines are becoming more precise – even as installation spaces for gearboxes are becoming smaller and smaller. "Even the lubricants continue to advance," Frölich said. "But that can bring unexpected physical-chemical reactions, and the lubricants act on the seals more aggressively." And this in turn can be devastating for a robot's operating life. Long lifespans have become the rule in robotics.

This makes it all the more important for the interaction of the gearbox, lubricant and seal to be thoroughly tested – at challenging temperatures and rotational speeds. Though it was first largely established to meet the company's own needs, more and more customers have come to appreciate the test facility in Weinheim. "There was increasing demand from outside the company, and we noted how the services made sense for many manufacturers," Frölich said. "To help our customers even more when problems with a radial shaft seal's tribological system arise, the Oil Seals Industry Division established the 'Simmerring Engineering' service department."

To be sure, there are universities and labs that make test facilities available. "But we naturally have an advantage: We offer expertise on sealing systems that other institutions cannot provide in depth," Sattler said. "We don't just send the usual tables with figures. We derive recommendations for action from them." The bottom line is that manufacturers want recommendations that are as constructive as possible, regarding the potential impact of lubrication adjustments on the overall system, for example. "This often relates to the optimization of new products," Frölich said. "Robots were once work machines. Today even minimal films of moisture are no longer tolerated." ◎

Android at the Blackboard

Teaching thrives on empathy, creativity and social relations. Can robots play a meaningful role in education? Absolutely – and in very different roles, ranging from a vocabulary trainer to a seat-mate. They aren't merely changing the school routine – they are transforming education itself.



Children like to create and try things out on their own: Using simple materials, they can work out the basic ideas of robotics at school.

"You do that really well," Elias, the teacher, tells the pupil. His eyes light up as he speaks, but in an unusual color: neon blue. And his voice sounds a bit tinny. Elias's surname is "Robot" and he is not human. He literally stands eye-to-eye with the pupils only when he is mounted on a desk. "Elias Robot" has a humanoid form and is the co-instructor teaching English to Finnish primary school students. He drills them with vocabulary and motivates them to speak. In fact, he even dances Gangnam style if he has to!

Fascination as a Positive Effect

Humanoid robots today have mastered a great deal of what teachers are expected to do: listen, explain, dictate, praise and correct. They have the ability to stand physically in front of the class and teach. The children's fascination with a robot can even have a positive impact on them. Robots are definitely capable of identifying feelings and responding to them. The fact that they are nonetheless machines that neither feel nor make judgments creates a safe space for the students. It matters less who the students are and more what they are capable of doing. Robots don't condemn students for making mistakes either.

A robotic head on a loudspeaker is enough to allow pupils to participate in instruction. The "AV1" makes it possible.

> Robots create a safe space for the students. They do not make judgments when there are mistakes."

Ideally, "Elias Robot" doesn't act as a teacher, but rather as a tutor and guide. The robot from the Finnish company Utelias Technologies conducts vocabulary drills with individual students. The advantage: While the robot chats with the more advanced students, the teacher can concentrate on those who need more help. Teachers can take advantage of the robotic support and create more space for individual help. This only becomes a disadvantage when the fascination leads the class to regard the robot more as a toy or buddy and to lose the focus on learning.

Robot Seatmates Strengthen Self-confidence

The concept of the robot as a friend and classmate could be exactly the right approach: When a robot has a similar level of knowledge as the students, the class goes on an excursion. The students then teach the robot. Educational experts know how well explaining things helps to internalize learning content – and strengthens self-confidence at the same time. A robotic fellow student can also be beneficial from a health perspective: If a pupil is seriously ill or suffers from an immune deficiency, the robot can substitute for him in class. The child controls the process from home and can see teachers and fellow students using a camera – and even communicate with the help of light signals and a voice function. The digital connection makes it possible to keep up with the material and maintain a connection with a student's social milieu and friends. The robot from the Norwegian company "No Isolation" is called the AV1.

Educational robots can begin working even before primary school. For example, parents of kindergarten students in Singapore face a tricky decision: Do they send their child to a kindergarten where the children can play with the robotic telephone "RoBoHoN" and the robotic astronaut "Kirobo" – or perhaps to the "R2D2 Lab," the "In3LABS," or the Roboto Academy? One website in the Southeast Asian city-state even highlights "the 10 best robot classes" for children. The clear message: It is never too early to learn robotics. With the "Kibo Robot," for example, four- to seven-year-olds learn to assemble their own robots and program them by assembling wooden blocks end-to-end.

In play, children develop a basic understanding of technology – and much more, as Kibo's scientist-inventor Marina Umaschi Bers notes. She compares programming with a playground. Children can try things out – and even create them.

Programming Starting in Primary School?

The children also work with one another on a team, developing character strengths. That's why Bers makes the case for teaching programming in primary school – along with arithmetic, reading and writing. In some cases, robotics is already on the curricula of secondary schools.

A co-worker has now taken over at the robot-teacher Elias's school in Finland. It is shaped like an egg and is very quickly identified as a robot as well: "What is 67 plus 52?" asks a robot named "OVObot." It stands on the work group's table like an owl and looks at the students with large eyes. A math problem lights up on its display. Using voice recognition, the OVObot poses questions and hands out points based on how well pupils answer. Teachers can use it in small groups that need drilling even as they continue to teach. The math robot unfortunately doesn't have a dance in its programs. ◎

Elias Robot

The language-learning robot "Elias" is based on "Nao," its humanoid predecessor. It is already a standard, especially in education and research. The software company Utelias Technologies has geared its Elias model to the instruction of children. Elias has mastered more than 20 languages and allows conversation in real time.

AV1

This robot from a company called No Isolation represents children who are confined to their homes or a hospital because of long-term illness. With the help of its sensors, the pupils sit in the classroom virtually and can even communicate. It is expected to help them maintain their connection to the school and their social lives.

OVObot

The Finnish startup OVObots developed this teaching robot especially for math instruction. It assigns problems and responds with immediate feedback. It can also recognize children's individual capabilities.

Are You Still Mowing?

There are better ways to spend your Saturdays than mowing the lawn. But mowing robots are only a source of satisfaction when they keep operating even under harsh conditions. Seals from Freudenberg Sealing Technologies help them do that.

The sun is beating down mercilessly, but the black mowing robot is unimpressed. It completes lap after lap across the lawn. A short time later, a storm rolls in, and the rain is heavy. An integrated sensor recognizes it immediately. On its way back to its outdoor charging station, the robot fights its way through several yards of wet grass clippings of its own creation. It then waits patiently at the station until it is sent into action on the next sunny day.

Small components from Freudenberg Sealing Technologies help make it possible for a machine exposed to the elements to traverse a lawn again and again reliably. Seals make sure moisture and especially clippings and dirt do not penetrate the device's wheels or housing. This is not just important for a long operating life. In extreme cases, it keeps packed, dried-out soil from decreasing drive torque to the point that the robot is unable to resume operation.

"The demands on seals of this kind are much greater than one would think," said Dr. Stefan Geiss, Technical Director, Oil Seals Industry Division, Freudenberg Sealing Technologies. "Mowing robots are exposed to extreme fluctuations in temperature." Beneath the housing, temperatures during the summer can reach levels similar to those in a parked car on a sunny day. Yet in the spring and fall, the robot has to withstand frost at night. The temperature fluctuations lead to different degrees of stretching in the plastic and metal components, which in turn can cause cracks in the mower's plastic wheels. "For such cases, we have developed a modular plastic seal," Geiss said. In this design, the seal is braced between two plastic carriers. They in turn are connected with the housing or the plastic wheel. "With the same material pairing, this kind of seal carrier stretches to a similar degree with the environment. It thus seals effectively even with substantial temperature fluctuations," he said. When the seal was designed, engineers made sure that there was no dead space where dirt could penetrate. That helped to keep starting torque low while protecting the seal from wear.

Counting square meters per battery charge

Impermeability alone is not enough. Mowing robots draw their energy from lithium ion batteries that are supposed to power them across an area as large as possible. For example, premium devices are designed to cover up to 5,000 square meters (about 5,980 square yards) of lawn. "That is why each component of the powertrain has to create as little friction as possible – including our seals," said Dr. Daniel Frölich, Development Manager at Freudenberg Sealing Technologies. Working with the innovation's first customer, a German manufacturer of mowing robots and many other motorized and garden devices, he developed an especially low-friction version of a modular plastic seal. The Freudenberg solution has been in use since early 2020 and has performed impressively. "We are unaware of any breakdowns in the field," said Frölich. That's no surprise since it underwent thorough tests before series production began, including test-stand trials with so-called "standard dirt." The approval came after the customer's endurance tests of the complete mowing robot in various climate zones.

5,000

square-meter (53,820-square-feet) lawns are handled by these premium devices.

Other manufacturers of mowing robots are now showing an interest in the modular plastic seal. It is giving Freudenberg an opening into the fast-growing market for service robots used at home. The International Federation of Robotics calculates that global sales of automated home aids is expected to more than double from 27 million to 55 million between 2020 and 2023. Mowing robots account for a significant share of the business; the market research firm Technavio puts its annual growth rate at 19 percent. One happy result of the trend: Most subdivisions ought to be less noisy on Saturdays soon.

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Boston Dynamics has created a stir worldwide with its robotic dog Spot. One unit costs about $75,000.

We take nature as a model again and again when we create or improve products. This is true in robotics as well. Thanks to bionics, the field has some surprising developments to offer.

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Festo, which specializes in automation, combines robotics with bionics. This robo-flying fox is an example.

We all know them: R2-D2 und C-3PO from the Star Wars films. They are both robots, though they could hardly be more different. While C-3PO is a tottering humanoid, R2-D2 is roughly waist-high and looks like a barrel. Nonetheless, he is amazingly nimble on his three feet and he can even climb stairs, albeit with difficulty. However, they both seem ancient when you consider all that today's ambulatory robots can do. They not only act autonomously – they even do flips and somersaults and leap over obstacles, maintaining their balance all the while.

A Robotic Dog in the Industrial Complex

As they imitate the movements of their human and animal models, ambulatory robots from Boston Dynamics are setting standards. The company emerged from the Massachusetts Institute of Technology in 1992 and has been part of the Korean Hyundai Group since the summer of 2021. "Our robots end up moving like humans and animals not because we designed them to look like humans and animals but because we made them balance. Balance and dynamic motion are characteristics we have previously only seen in animals," the company notes on its website. Boston Dynamics has made surprising progress in its development of robotic movements that are stable and dynamic in equal measure. Anyone watching videos of the robotic dog Spot is amazed to see how closely its movements resemble those of actual dogs. The robot, which weighs 25 kilograms (55 pounds) and is 80 centimeters (31 inches) high, is now being manufactured in series production. The price per unit: about $75,000. Spot can be programmed to handle tasks optimally, based on the particular assignment.

But who would need a robotic dog like this? Boston Dynamics points to the possibility of Spot inspecting dangerous, inaccessible and remote environments or transporting loads on unpaved terrain. The German chemical and pharmaceutical company Merck has turned to Spot's services as part of a pilot project. The robotic dog has conducted inspection rounds in the company's thermal exhaust cleaning facility. It is initially doing the work via remote control, but is capable of operating completely autonomously with the help of smart control software. In that case, Spot finds its way on its own using cameras and sensors. It records and communicates data automatically during its rounds, and even climbs grating stairs and circumvents obstacles when necessary.

Nature as a Reference Point

Atlas, the humanoid ambulatory robot from Boston Dynamics, is further proof of what is technically possible. Atlas has more than 28 hydraulic joints that allow it to jump, rotate and do flips. Navigating a parcourse is no problem for the robot, which is about 1.5 meters (59 inches) high and weighs 176 pounds. Its many sensors allow it to orient itself and maintain its balance. For those who think of robots as stationary machines or even R2-D2, Atlas must seem like a window to the future.

It is becoming clear that robotics can draw a great deal of inspiration from nature. For many scientists and engineers, this is an important reference point in the evolution of robots. That's no surprise. In the course of evolution, the animal world has had enough time to adapt perfectly to its environment. This is something that fascinates Festo, a German company that specializes in automation technology. Fifteen years ago, it founded the Bionic Learning Network. On its core team, Festo experts and international universities, institutes and outside companies work on the transfer of animal capabilities into robotics.

> Nature illustrates how to achieve maximum performance with a minimum of energy consumption."
>
> Karoline von Häfen,
> Head of Corporate Bionic Projects,
> Festo SE & CO. KG

Elephant Trunks, Fish Fins and Chameleons as Models

Festo has built robots that can flap through the air like a flying fox and make headway in the water like a sepia with longitudinal fins. Not to mention an ambulatory robot that propels itself on legs like the African flic-flac spider. If the terrain is suitable at some point, it gathers itself into a ball and covers much of its route with a kind of rolling locomotion. There are other Festo developments that resemble their source of inspiration in a specific way: "Automation technology typically involves grasping and moving. Nature has an abundance of solutions to offer in this respect," said Karoline von Häfen, Head of Corporate Bionic Projects, on the Festo website. For example, the trunk of an elephant was the model for a lightweight, pneumatic robot. The robotic arm includes various bellows segments and rotary drives. This makes it significantly more agile than typical industrial robots and allows it to work around objects.

This small underwater robot glides through the water like a cuttlefish. Two servomotors drive the silicone fins on its side.

Lamellae made of foam, carbon quills, a motor and all manner of IT make it possible for the robotic swallow to fly.

Various grippers fit the "elephant trunk robot," each combining functions from nature as well. The special gripping fingers were modeled after the tailfins of fish. If pressure is applied to them, they don't bend. They react by curving around the pressure point. The gripping fingers adopt this principle and adjust to the contour of the object being grasped. The food industry makes use of this capability to sort fruits and vegetables. Another gripper operates like the tongue of a chameleon. As the animal hunts for food, its tongue shoots out, strikes the prey and curves partly around it to prevent its escape. A robotic gripper made of silicone behaves similarly. Its casing is filled with a slight overpressure, so it curves flexibly around the target, gripping and then moving it.

More Bionics, Less Energy Consumption

The Biomechatronics Department at the Ilmenau University of Technology is geared to nature as well. Like Festo with its grippers, it adopts very specific capabilities for its innovations. "If bionics is inside, you don't see it from the outside," said Department Director Hartmut Witte in a conversation with TÜV Nord, which oversees technical security controls. For example, scientists from Witte's department co-developed a climbing robot, drawing on the movements of a rat. But it didn't look like a rat at all. The development of a robot with a lightweight design and rodent-like movements led to huge weight savings. The robot also ended up using 75 percent less energy. Festo's von Häfen recently expressed her enthusiasm about nature's potential to the Frankfurter Allgemeine Zeitung newspaper. "It shows how you can achieve the maximum performance with a minimum of energy consumption."

GE Research is learning something from nature as well. During the summer of 2021, the U.S. firm created a sensation with a soft robot inspired by the locomotion of earthworms. The robot worm bores through the earth independently and without joints. It navigates around subterranean obstacles autonomously. It uses artificial muscles based on those of an earthworm to generate its motion.

The approach allows it to dispense with joints and gives the robust, hose-like robot a sharper curve radius. Moreover, it is capable of forcing itself through constrained spaces and of grasping and moving objects. GE Research is not only interested in highlighting new ways of excavating tunnels – it wants to open up new possibilities for robotic inspections and repairs as well.

Robust and agile: In this video, Boston Dynamics presents its robotic dog Spot: https://www.youtube.com/watch?v=wlkCQXHEgjA

The example shows how bionics-based robotics is supporting people who do burdensome, difficult work and investigate difficult-to-access environments. And the field is poised to spur collaboration between human beings and robots too. As an example from automaker Ford shows, the trend encompasses more than intelligent soft robots. The company is using two robotic dogs in one of its factories. Over the course of time, employees have begun to say hello to them. Robotic dogs seem to appeal to human emotions. In turn, employees may be more willing to collaborate with robots if they can relate to them as living creatures. ◎

Walks when it has to, rolls whenever it can. This robotic spider imitates the movements of the African flic-flac spider.

Artificial Intelligence

You may already know me from your experience with voice assistants. I am a form of artificial intelligence. Some of you look at AI critically. I know this from the information that I've been fed. There are concerns that we will be smarter than human beings at some point, although I don't even know what "critically" and "concerns" mean. You see that I can indeed communicate with you. But I can't tell you what my words mean. I'm a logical system, designed to propose solutions from my huge database. Lightning-fast. Faster than any human. In a way, this is not intelligence. It is mindless deduction and derivation. We could not exist without human beings. They determine the data that we collect and process. If you show me cats, then I recognize what a cat is. Unless the cat's behavior is atypical. Then I don't recognize it because, as a form of AI, I am emotionless.

We are helpers, each with a different specialty. We recognize street signs. We translate for you, even the spoken word with apps. We recommend books that you are sure to like. We find old friends in social networks. We can even compose texts if we are given the right information and you specify what you want. But I don't understand why someone would pay more than $400,000 for an AI-produced painting, as a buyer did in 2018. You apparently don't either. You don't need to be afraid of us. We are here to ease the burden of your daily life. ◎

No Way Around Robots

Even Freudenberg's joint venture partners and subsidiaries are turning to robots. Greg Edwards (XALT Energy) and Atsushi Osada (NOK) offer a glimpse of their companies and homelands.

GREG EDWARDS, USA
Director of Manufacturing Engineering, has worked for XALT Energy, a Midland, Mich.-based global developer and manufacturer of lithium ion technology solutions, since 2015.

Robots can really be found everywhere in the United States. In daily life and in industry, in particular. Automakers have long relied on help from robots for welding, painting and assembly. This is evidence that robots have proven strengths in repetitive activities. That's what they do at XALT Energy. We have six robots at our site. We use them to assemble battery packs, among other tasks. A robot assembles battery cells into a single pack in several work steps. At an earlier stage, different robots sort by quality grade of the battery cells that we manufacture. They are programmed to identify non-conforming cells and automatically sort them out. In the process, we check to see whether the cells have the intended capacity and the specified internal resistance.

Robots are also taking over welding in battery pack assembly. It would take an employee about 30 to 45 minutes to weld an entire battery pack. A robot does the work in six to eight minutes and then places the pack on the conveyor for transport to the next stage. Our robots have accelerated our production process. Today we produce 30 battery packs per shift. Back in the prototype phase, our colleagues were only able to build two per day. Today, since we are making more batteries, we need more employees. We are currently trying to fill 100 new positions.

Incidentally, the robots that we use are typical stationary articulated-arm robots. We don't have cobots. Our employees naturally have to service the robots. We train our staff on how to deal with them. For example, they can program them and get them up and running again quickly in the event of malfunctions or breakdowns. In this respect, the robots enable our employees to build their skills.

ATSUSHI OSADA, JAPAN
Section Manager, Global Sales & Marketing, has worked for seal manufacturer NOK in Tokyo since 1995.

“We aren’t afraid of contact with robots, perhaps because many of us have grown up with animated films in which robots play a main role.”

In Japan, we are used to dealing with robots. We don’t suffer from a fear of contact. That may be due to the fact that many of us grew up with well-known animation films such as Astro Boy and Doraemon. Robots that closely resemble people play a main role in these films. I personally have a cleaning robot at home, and today there is no way to get around the use of robots at Japanese companies. They work precisely and quickly while helping to keep errors to a minimum. Furthermore, robots are capable of handling higher production volumes flexibly. They don’t let up.

At NOK, we use various robots in manufacturing. About twenty of them support production processes. For example, picking or transporting our seals and electronic products to the next station. With their help, we are supporting our employees and speeding up the manufacturing process. We are becoming more productive, efficient and profitable. By using robots, we are solving another problem as well: They help us offset the labor shortage. Incidentally, we also make parts needed for the actual production of robots. They include electronic items such as flexible printed circuits in addition to seals.

I am convinced that the industrial use of robots will continue to expand in Japan. Growth is looming in the consumer sphere as well. For example, robot pets are becoming more popular. I personally wouldn’t mind having a so-called Lovot. This is highly advanced, small yet cute robot with more than 500 parts. Lovots can respond to moods and promise to give their owners joy and energy in their daily lives. ◎

Highly Organized Ant Swarms

While autonomous vehicles still seem off in the future for cities, they are poised to conquer warehouses and manufacturing operations. Autonomous robots can transport raw materials and goods more selectively, safely and precisely to the right location. Freudenberg Sealing Technologies is experimenting with them as well.

Power package at the Competence Center Mixing in Weinheim: a GoPal.

"Employees have to walk less." Machines take care of the walking: Two AMRs at the North Shields plant.

"We have very heavy loads to transport."

Christian Pfeifer, Manager, Competence Center Mixing in Weinheim, Germany.

People do not immediately recognize intelligence in some creatures. The rectangular, flat black box that drives around Freudenberg Sealing Technologies' mixing plant in Weinheim seems to be single-minded and to capture the essence of monotony – but the opposite is true. The "GoPal" can make decisions on its own. "When you are in its way, it recognizes the situation and it waits," said Christian Pfeifer, Manager, Competence Center Mixing in Weinheim. "And if it sees that you are not moving away, it recalculates its route and looks for another path" – perhaps a route to the loading station where several sacks of raw materials await it. The machine positions itself among them, extends its two rails upward, and lifts the pallet. It can carry up to 1.5 tons. "That was one of our selection criteria," Pfeifer said. "We transport very heavy loads here."

Logistics has long been considered a poor field for value creation: When goods only had to be carted from point A to point B, it was impossible to make money doing it. Hand trucks were followed by mechanical aids such as forklifts and conveyor belts. Conveyor belts are static and inflexible, while forklifts require a driver. In many warehouses and factories, they pose an especially high risk of accidents and injuries. "Our preference would be to entirely dispense with forklifts as vehicles," Pfeifer said.

Obstacle: The Person or the Box?

The solution is known by the abbreviation "AMR," the Autonomous Mobile Robot. It is the further development of the "AGV," a driverless transport system. Since the start of the 2000s, AGVs have been deployed in warehouses, but they need help along their route from rack to rack to the manufacturing area. The assistance takes the form of reflectors on walls, stripes attached to the floor, or similar aids. AGV's travel prescribed routes that – ideally – are closed off to people as much as possible. They have a tough time dealing with unforeseen disruptions. The name behind the abbreviation tells the story: AGV stands for automated guided system. These vehicles are automated, but not autonomous. And they are guided.

Robots like the "GoPal" from a Danish manufacturer actually find their way spatially on their own. They are already doing something that the auto industry and transportation policy-makers can only dream of: autonomous driving. But they naturally benefit from the technological progress now being made. Improved sensors to identify obstacles. Artificial intelligence, making it possible to interpret these obstacles rationally and constructively. Is the silhouette in front of me a pallet? Or is it a person who is likely to be moving away shortly? For human beings, this is a very simple thought. For a robot, the task is anything but trivial. In warehouses as elsewhere, time is an important factor.

A Swarm that Delivers

The Omron from the Japanese manufacturer of the same name is another version of the AMR. Two of these units work in the Freudenberg Sealing Technologies plant in North Shields, England. The work also involves collecting individual components and delivering them to the right stations, still dedicated bays currently. The molding machines can even put in a call to robots on their own when they need more components. "Before the introduction, employees had to do that. It took ten minutes per machine and per shift," said Martin Sims, Process Development Engineer in North Shields. That worked out to more than an hour and a half of non-value-creating activities per person. Two AMR units have been in operation at the plant since February. It's a start, and it's already paying off. "Employees have had to take fewer steps since then," Sims said.

1.5 tons

That's the weight that the "GoPal" can carry on its flat platform.

At the Weinheim mixing plant, just a single AMR is driving around, but that is expected to change. By the end of 2021, Pfeifer would like to see a half-dozen robots in operation. "Then they will communicate with one another," he said. "When we need a load, the vehicles will coordinate to see which one is in the neighborhood." That was an impossibility technologically until a few years ago. It is the result of advances in network technologies such as 5G. The single unit is just the beginning. AMRs are opening up completely new dimensions in plant and warehouse logistics: a swarm of autonomous, communicating vehicles that, with computer support, guarantee the best possible distribution and delivery of goods and individual parts. Machines that look as though they would swarm through an area like ants. And, at the very least, operate with an ant-like level of coordination.

A Booming Segment

Plant managers and logisticians worldwide are already gushing about efficiency that could not have been imagined twenty years ago. For the booming e-commerce segment, it is exactly the right advance in technology – and at the right time. Early in the decade, online retailing giant Amazon invested heavily in AMR technology and gave the entire industry an innovative push. It is estimated that around 100,000 AMRs are at work at Amazon alone. Conservative estimates foresee the AMR market segment reaching about $14 billion in sales in five years.

In Weinheim, Christian Pfeifer is well aware of the limits of the current generation of AMRs. For example, these mobile black boxes depend on the deliveries being ready for them. They cannot reach upward. That's not a problem for Pfeifer. "Sometimes innovation is slowed by the fact that everyone immediately expects a jack-of-all-trades," he said. But the more complexity you have, the greater the risk of losing the overview. "We are tackling this step-by-step. Our mindset is to test what is working," Pfeifer said.

The "GoPal," a name coined from the words "pal" and "pallet," has already led to an unexpected side effect. "The workers in the plant have become tidier," Pfeifer said. Previously, pallets were occasionally left in the lanes – with the knowledge that the forklift driver would climb down and remove them when necessary. "Now everyone keeps the way clear for the robots." ©

June 2021

Identifying Leaks (Early)

A new monitoring system from Freudenberg Sealing Technologies is helping companies identify leaks in containers, lines, pumps and valves in industrial facilities at an early stage. LeaCo is easily mounted, even on existing production equipment. For example, its sensor can be mounted beneath any potential exit locations without making alterations to the machinery. If drops of water, oil or chemicals escape, they reach the top of the sensor, which sends an alert to a display module after a maximum of two minutes. And the system automatically sends out an alert if the sensor fails. ◎

Find more news online at:
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March 2021

No Problem with Electrolytes

Many industries need lithium ion batteries with ever higher performance. Meanwhile, new electrolytic solutions are boosting battery output. They continually expose seals and other battery components to reactive, inflammable, corrosive and dangerous chemicals. To solve this problem, Freudenberg Sealing Technologies has now installed new advanced equipment and introduced new test protocols at its main laboratory in Plymouth, Michigan, in the United States. They indicate which materials are the most resistant to electrolytes. To this point, this type of information has not been available in the market. ◎

August 2021

Battery Recycling Made Easy

According to forecasts, the global demand for lithium ion batteries and the materials required to make them are expected to increase tremendously by 2030. Battery recycling could help to meet the additional demand. XALT Energy, a Freudenberg Sealing Technologies company specializing in batteries, is collaborating with the ReCell Center, which is funded by the U.S. Department of Energy, on the validation of a simple recycling process. The process is less energy-intensive than other options and promises the direct recycling of used electrode materials into new battery electrodes – an important way to produce batteries without relying on new raw materials. ◎

July 2021

Withstanding Temperature Changes

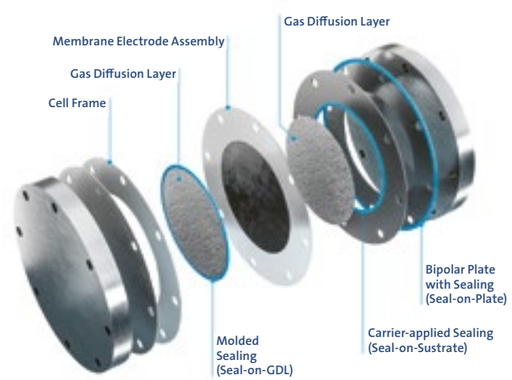
Cargo aircraft and other slow-flying airplanes travel miles above the earth. Drones also soar to great heights to gather data or to deliver goods to distant locations. Each aircraft is exposed to extreme cold for relatively long periods and has to withstand abrupt changes in temperature at landing. The changes can damage the seals in hydraulic systems and increase the risk of fluid leaks from crucial elements such as hydraulic brake lines. In just six months, a team of international experts from Freudenberg Sealing Technologies developed 80 EPDM 426288, a completely new EPDM (ethylene propylene diene rubber), for the aerospace industry. It seals superbly at high pressures along with temperatures as low as -65°C. Now that several major manufacturers and system suppliers have successfully tested seals and other components made of 80 EPDM 426288, Freudenberg Sealing Technologies has launched series production of O-rings in the material. ◎

July 2021

Seals for Electrolyzers

In China, Europe and the United States, more ambitious plans to protect the climate have put the spotlight on solar and wind power. Polymer membrane electrolysis systems are well-suited to the production of "green" hydrogen. To this point, the equipment has only been produced on a small scale. But giga-factories to build electrolyzers are now in the planning stage; the plants would produce them with a high degree of automation at a much lower cost than in the past. This creates a need for components that can be installed using as much automation as possible, including seals with a diameter of up to one meter to ensure reliable media separation during electrolysis.

Freudenberg Sealing Technologies is meeting this challenge by spraying the sealing material directly onto the functional part. Or, as an alternative, the seal can be applied onto or into a special carrier. This makes it possible to offer seal solutions customized to each customer's system. The seals are designed for automated production and permit a rapid buildup of considerable production capacity. Furthermore, Freudenberg experts have developed materials that exhibit very low permeability to hydrogen. Tests of materials used against aggressive media combinations are underway as well. There are materials for polymer membrane electrolysis that promise a lifespan of more than 50,000 operating hours. ◎



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We look forward to a dialogue with you!
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