DRIVEN

by maxon motor

Silent revolution

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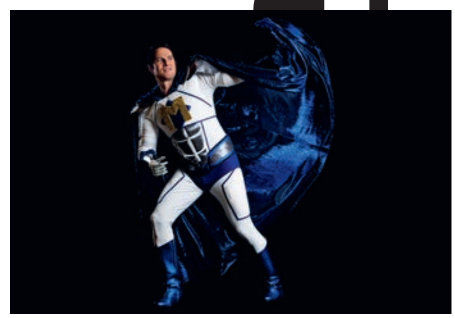

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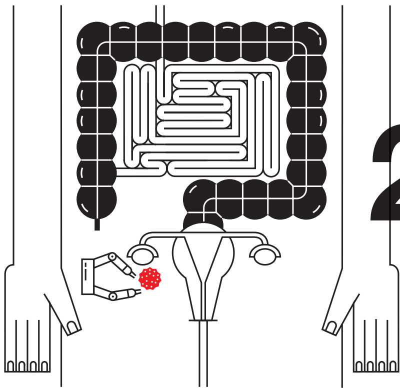


Eugen Elmiger,
CEO maxon Group

Driving the future

Fifty years ago, who would have thought that a family can go on a holiday trip in their car without burning a drop of gasoline? Or that even untrained cyclists could tour the mountains? Or that pulling weeds could be a task for robots, not people? These are only three of many examples that show the influence of electric drive systems on our daily lives and our mobility. Dear "driven" readers, in the new issue we present new developments and trends related to the subject of e-mobility.

And you can read about the wide variety of applications for maxon drive systems. We'll also let you have a peek into our battery production, as well as our new cleanrooms. For the curious of mind, there is an in-depth technical article about inductance in iron-core DC motors.

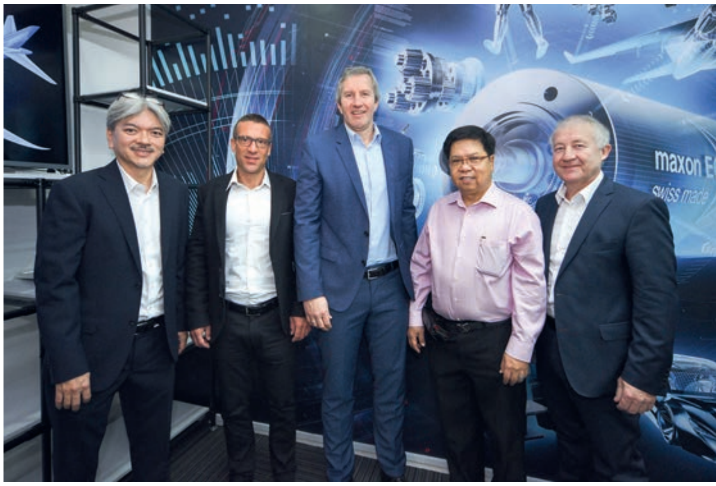
Happy reading!

Photo: Gregory Bull/Keystone

maxon joins Team Emirates

maxon motor will be an Official Supplier to Emirates Team New Zealand for the 36th America's Cup Defence, including the America's Cup World Series events and Christmas Race. Three times winner of the America's Cup, Emirates Team New Zealand were the first non-American competitor to successfully defend the trophy. Their vigorous defence of the 36th Americas Cup will be assisted with the support of maxon DC motors in Auckland from 6-21 March 2021. The America's Cup AC75 Class Rule allows the use of electric motors to operate hydraulic valves, drive clutches, rudders and foils. Teams may also use motors for driving simulator platforms and numerous test jigs.


OMEGA



UK

maxon motor acquires motor manufacturer Parvalux

The maxon motor group continues to grow. In December 2018, it acquired the British drive motor manufacturer Parvalux Electric Motors Ltd. Parvalux has more than 70 years of experience in the development and production of brushless and brushed DC motors, AC motors, and gearheads. The company has 185 employees at three production sites in Bournemouth and generates revenues of GBP 23 million annually.
With the integration of Parvalux, the maxon motor group is expanding its portfolio and takes another important step toward becoming a provider of complete systems. In addition, the acquisition opens interesting new markets in medical technology (stair lifts, electric wheelchairs, etc.) and industry (robotics and transport systems). "We want to be the long-term number one player in the drives market and offer our customers the best service possible," says maxon CEO Eugen Elmiger. Dr. Karl-Walter Braun, chairman of the board of directors, adds: "I'm confident that Parvalux will contribute to this goal with its know-how and high quality products, and that the company will prove to be an outstanding addition to the maxon world."

The end of the Martian adventure

Farewell, Opportunity

90 days—this was the planned life span for NASA's Opportunity rover on Mars. In the end, the rover kept going on Mars for 15 years, covering 45 kilometers and sending a large amount of scientific data back to Earth before a sand storm spelled its demise. Contact was lost in the Summer of 2018. Now NASA officially announced the end of the mission. The engineers at maxon are a little sad, but also proud. After all, Opportunity was equipped with 35 DC motors, which performed their task flawlessly.

New sales companies

Direct support in Israel and South-East Asia

maxon motor expands its worldwide sales network with two new sales companies. One covers the SEA region, where maxon has been represented in Singapore since the early 1990s by its exclusive sales partner Servo Dynamics Pte Ltd. This partnership has now been taken to another level. The parties have jointly founded the sales company maxon South East Asia, which means that maxon can now directly serve its customers in Singapore, Malaysia, Indonesia, Thailand, Vietnam, Hong Kong, and the Philippines. Another sales company was founded in Israel, with a new site in Caesarea, north of Tel Aviv. Before, Israeli customers had already been able to obtain maxon products through local partners. Now, Israeli customers are also supported by maxon specialists and benefit from the worldwide network of the maxon group, with eight production sites and several R&D centers.

Figure 1897

122 years ago, a machine for making cotton candy was invented and registered for a patent—by a dentist, of all people. Since that day, people have been enjoying this treat at fairs and in theme parks all over the world. A cotton candy machine heats sugar, liquefies it, and cools it down using centrifugal force while spinning it into hair-thin filaments. Many of these machines have drives made by the British company Parvalux, which has been part of the maxon group since 2019.

Photos: maxon motor; Choe Hyeonsu/shutterstock

NASA/DLR

InSight hammers

For once, it's not a rover but a stationary probe that is getting all the attention on Mars: NASA's InSight robot touched down on the Red Planet on November 26, 2018. A short time after, DC motors from maxon unfolded the two solar panels. This secured the energy supply, and the probe was ready for operation. InSight has two main instruments, a seismometer to measure potential quakes on Mars, and a heat sensor designed to penetrate up to five meters deep into the ground. The sensor was developed by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR). Its rod burrows into the Martian soil using a hammer mechanism, driven by a DCX motor from maxon. The rate of penetration strongly depends on the composition of the soil, which apparently isn't ideal: The rod hit an obstacle in the very first hammering cycle. However, the engineers at DLR are confident that these difficulties can be overcome and that the sensor will reach the projected depth.

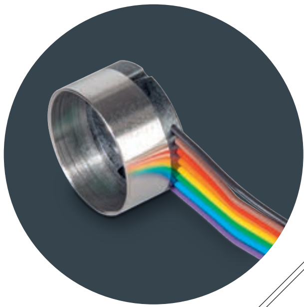
New products

EC 60 flat Power up
Ø 60 mm, 200 W, brushless

EC 60 and EC 90 flat Power up

Vastly more power due to air supply

The popular brushless flat motors with diameters of 60 and 90 millimeters have a new design. Their power has been increased by up to 100 percent. Both the EC 60 flat and the EC 90 flat are now available as Power up versions, either with an open rotor or with an attached fan. As a result of optimized motor cooling, the EC 60 flat now delivers 200 W, while the EC 90 flat even achieves 600 W. The flat motors are particularly suitable for applications where space is limited but high drive power is needed nonetheless, for example in logistics applications like belt drives or autonomous vehicles.



ENX EASY XT
Ø 10 and 16 mm

ENX EASY XT

The encoder for extreme conditions

The family of ENX encoders is joined by three versions of the ENX EASY XT with diameters of 10 and 16 millimeters. In addition, the ENX 16 EASY XT is also available as a single-turn absolute encoder. Originally, the new encoder versions were developed for the high requirements of aerospace applications and are now available to all customers. They have an expanded temperature range from –55 to +125 degrees Celsius. In addition, the insulated single-stranded wire cables of these encoders are perfect for routing cables in situations where space is at a premium. The magnetic ENX encoders from maxon motor stand out for their durable construction and high signal quality, which makes them highly suitable for positioning tasks. In the online shop, they can be combined with the brushed DC motors from the DCX series, as well as the brushless EC-4pole and EC-i motors, and configured as desired.

The maxon online shop has more than 5,000 products, selection aids, combination tools, and comprehensive product information:

shop.maxonmotor.com

Photos: NASA/JPL; maxon motor

Left: More motion: Robots serve food at a Pakistani restaurant. A gimmick that gets a lot of attention.
Right: New e-skates that were first presented in 2018. Time will tell whether they will establish themselves as a means of urban transportation.

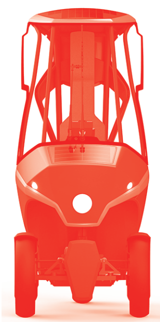
Photos: MIRZA/AFP/Getty Images; Krisztian Bocsi/Bloomberg via Getty Images

Silent revolution

People are increasingly using electrical power for personal transportation and for moving goods. There is no question: E-mobility is here to stay and will change our lives in a number of ways.

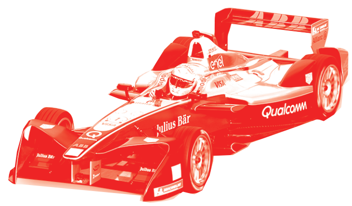
Photos: Jeffrey Greenberg/UIG via Getty Images; STR/AFP/Getty Images

Left: Everything gets electrified: Applications that required muscle power before are being taken over by electrical drives. This includes e-skateboards, which are experiencing a veritable boom, especially in the USA.
Right: Segway-like devices, on the other hand, can already be found all over the world—for example in China, where security officers use them on patrols.



The single-person car

It's quite possible that the mobility solution of the future is a blend of car and bicycle. At any rate, this is what the Swiss developers of the BiCar believe. The three-wheeled electric vehicle protects the driver against the weather, is fast enough for city traffic at 45 km/h, and can be parked almost anywhere, like a small motorcycle. A small batch of 50 units will be on the road starting in the summer of 2019. Mass production is scheduled to begin one year later. The BiCar has solar panels, which means that it doesn't constantly have to get hooked up to a power outlet. Several cities have already expressed interest in offering the BiCar as a sharing vehicle. An app displays the nearest location. This creates a flexible mobility system, and large cars with only a single person at the wheel may become a thing of the past.



Getting all charged up

Speed doesn't need a combustion engine. The Formula E has been proving this since 2014. Even though still overshadowed by the Formula 1, the Formula E is gaining in popularity, not least due to attractive race tracks in metropolises like Hong Kong, Paris, Berlin, or New York. The race cars reach top speeds of up to 225 km/h. However, speed alone does not decide who wins: Driving in an energy-efficient way is equally important, else the battery will be drained before reaching the finish line. The organizers host the races in order to call attention to the benefits of e-mobility.

Electric kickboards

Electric kickboards are all the rage these days, especially in cities. Various companies, such as the start-up Lime, are offering them for rent. Commuters in particular take advantage of the offer to get from the train station to the office. Tourists are another group of frequent e-scooter users, as the rental price is relatively cheap. Pedestrians, on the other hand, are often annoyed by parked scooters congesting the sidewalks. In addition, the batteries and robustness can certainly still be improved. However, one thing is certain: It's an interesting development that merits future attention.

Robotic dogs bring the mail

The growing market for last-mile logistics is highly competitive. A number of start-ups and major companies alike are currently testing a variety of robots that deliver goods directly to the end customer's door. Amazon and Starship Technologies are using vehicles with three axles. Continental on the other hand are trying out four-legged robotic dogs. The machines are carried to a neighborhood in an autonomous vehicle before dispersing in all directions. There are still some technological obstacles to overcome. However, delivery robots might be part of our everyday lives soon.

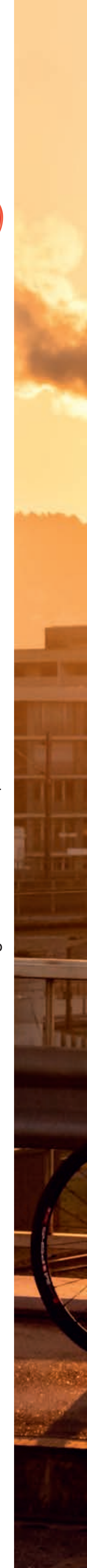
Hello, minibar!

Why does a hotel need a minibar in every single room? This is a question that the German company Robotise asked itself. The answer: Jeeves, a mobile service robot that delivers drinks, snacks, and other products to the hotel room door. The various drawers in the robot are designed for cold or hot food and beverages. Jeeves independently navigates hotel corridors and is even able to ride elevators. Since the elevator feature doesn t work everywhere due to missing interfaces, the robot may soon be equipped with a hand. Apart from that, Robotise's motto is: "Simplicity is the key."

Power and pedals

E-bikes are making inroads, despite the initial skepticism of many cyclists who prefer to rely on muscle power. The technology develops rapidly, and an increasing number of people is using e-bikes for commuting or in their spare time. In Germany, more than 700,000 e-bikes were sold in 2017. That's an increase by 19 percent from the year before. In Switzerland, one in four bikes sold in 2017 was an e-bike. It's entirely possible that e-bikes are the vehicle of the future—at least in cities. Paris is a great example. The city's traffic authority is planning to purchase 20,000 e-bike this year and offer them for rent. The goal is to fight air pollution—while giving Parisians a little bit of exercise.

Photos: ShareyourBiCar; Fabrizio Russo/Unsplash; PRESSLAB/ Shutterstock; Continental AG; Robotise; maxon motor



E-bikes can be used to get to work fast. However, the motor needs to be light. Fortunately, the maxon BIKEDRIVE weighs only three kilograms. Together with a battery and the PowerGrip, the rear motor is part of a retrofitting kit for easily turning a regular bicycle into a powerful e-bike. maxon is already planning other products for the electric bicycle market.

Precision braking

Photos: TUfast

It was a beautiful moment for the TUfast team. At the 2018 Shell Eco-marathon, they had to prove that their autonomous vehicle is able to brake safely and reliably. Like all the other teams, the students at the Technical University of Munich took on a challenge: Their car had the task of autonomously navigating to a parking bay and stopping as close as possible to a blue block placed in front of it. As an additional difficulty, the parking bay was on a downward incline. TUfast succeeded anyway—as the only team in the competition. For their motor-powered brake, developers used a maxon DC motor with a built-in ceramic gearhead. An ESCON controller provided precise speed control.

Efficiency above all

At the Shell Eco-marathon, more than 100 teams compete to create the most efficient vehicle possible and to win in a number of different disciplines. In the Urban Concept category, in which the 40 students of the TU Munich are taking part, the car needs to be suitable for cities. This means, for example: It needs to offer space for cargo, be equipped with lighting, and offer an upright seating position for the driver.

The TUfast team spent a year to develop its first autonomous vehicle and tried to get the best out of the car. Benedikt Köberlein, in charge of the drive: “Efficiency is the main criterion. Every single component needs to be lightweight and have minimal losses.” Because the development time is very short, the team relied on the principle “keep it simple” and the experience of its sponsors that stand ready to assist with know-how. “It wouldn’t have been possible without.” In the end, the team won in its discipline and took home the Vehicle Design Award.

TUfast Eco Team

The TUfast Eco Team offers students of the Technical University of Munich practical experience in the realm of electric mobility. Every year, the members design and build a highly efficient electric car. In 2016, the team set a world record for the most efficient electric car, at 1232 km/kWh.

Higher requirements to the drive

TUfast is taking part in this year’s Shell Eco-marathon in London. The bar is high: The team is going for the title in both the efficiency category “Urban Concept Battery Electric” and the autonomous vehicle category. Again, drives from maxon are being used, for the steering as well as the brakes. “The requirements in terms of precision are even higher here. In addition, the motor is exposed to continuous loads,” says Köberlein. As a solution, he and his colleagues selected a brushless DC motor with a spindle drive and matching controller.

The young developers are convinced that they can exceed the autonomous performance of 2018 in this year’s competition. Until then, there will be lots of hard work at the computer screen and in the workshop. However, the effort pays off, says Benedikt Köberlein: “In the end, we’re all having a lot of fun.”

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On track for an e-mobility

At one time, the universe of maxon motor consisted of small motors. These days, the component portfolio not only includes DC motors, but also gearheads, motor controllers, master controllers, and sensors. They are the basis for the integration of complex systems in a wide variety of applications. This is the future of the drive specialist.

Motor
The motor is the centerpiece of any drive system. Small or large, short or long, brushed or brushless, ironless or with iron windings: maxon offers an immense variety of motors, and the engineers always have an open ear for special requests. Especially in e-mobility, custom solutions are common.

Sensors
supply the controller with data on the motor speed and the position of the motor shaft. The high signal resolution enables motion control with extreme precision.

Precision gearheads
multiply the motor's force again by a large factor. In e-mobility applications, gearheads need to be durable, quiet, and robust. maxon is the perfect choice for fulfilling these demands.

Controller
A controller supplies current and voltage to a motor. The current, speed, and positioning controllers from maxon are optimized for a wide variety of DC and EC motors. Reliable networking is possible via CANopen or EtherCAT.

Master controllers
are the overall "brain" of a drive system. Precisely and with lightning speed, they send commands to individual motor controllers and process their data. Numerous connection and configuration options leave nothing to be desired.

Batteries/ battery management system
E-mobility and power outlets don't match well. This is why maxon is offering its own batteries (see the article on page 20) and has even developed a battery management system (BMS).

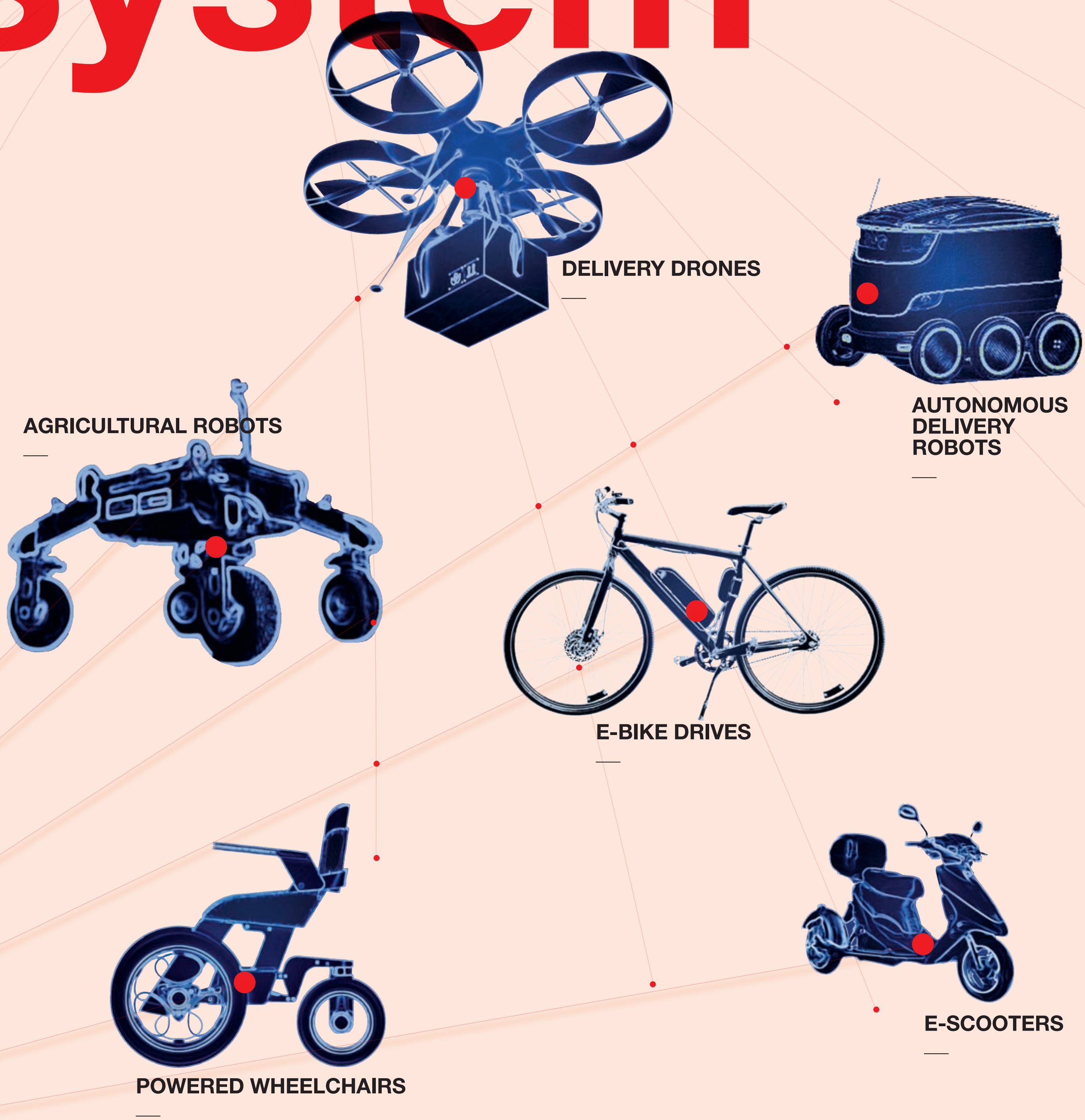
Apps
As was already done for the BIKEDRIVE, the retrofitting kit for bicycles, maxon is planning to design more smartphone apps in the future. This will make controlling drive systems for e-mobility extremely easy.

Illustrations: Meike Herkersdorf Photo: maxon motor

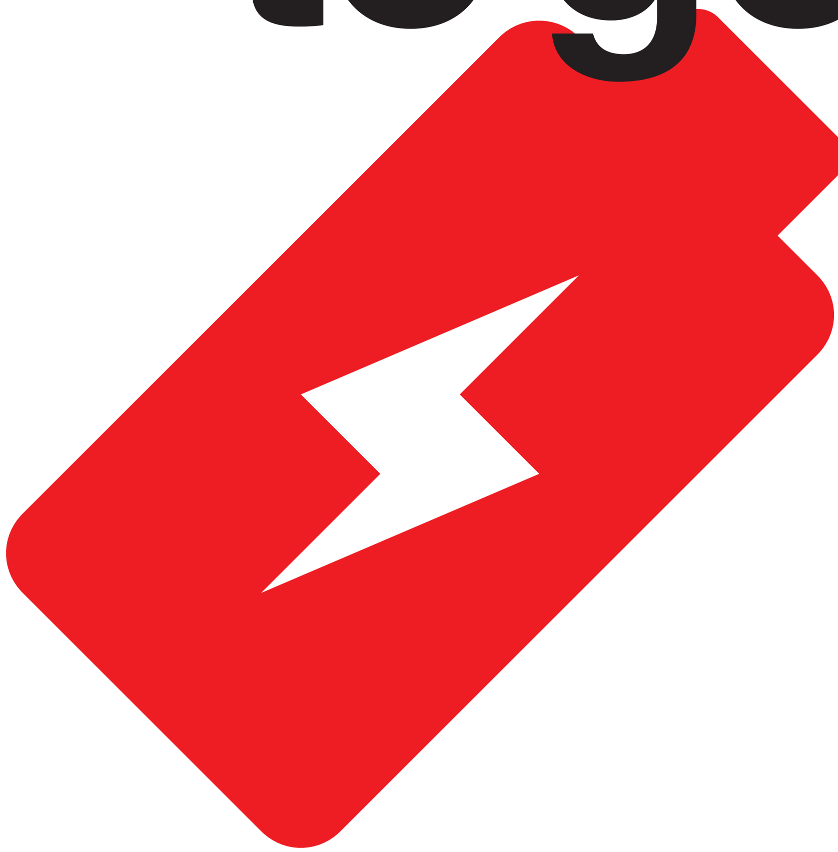
system

For more information about maxon systems see

systems.maxonmotor.com



energy to go



No matter if it's a flashlight or a Tesla: They don't work without a battery. maxon recently started a small but excellent workshop for manufacturing lithium-ion battery packs.

In e-mobility, all is nothing without them: batteries. They deliver the "juice" for countless vehicles and applications that are exciting precisely because they don't need to be connected to a power outlet all the time. Yet even though the technology has made great progress over the past decades, batteries still seem a little old-school compared with state-of-the-art high-tech electronics. For example, the microprocessor of a smartphone is able to perform billions of operations within seconds. However, charging the battery takes hours. In addition, batteries are the heaviest of all the installed components. Consumers might find this annoying, but it is simply in the nature of things that energy storage devices and the chemical reactions inside them can't be miniaturized to the same extent as is customary in the semiconductor industry. In our daily lives, we encounter a number of different battery types:

Photos: maxon motor / Adrian Venetz

- Cheap alkaline batteries, for example in remote controls and watches
- Nickel-cadmium batteries, with similar uses as alkaline batteries, but rechargeable
- Lithium-ion batteries, for example in cameras, power drills, and electric cars
- Lithium-polymer batteries, for example in smartphones and tablets. Lithium polymer batteries are a special type of lithium-ion battery that can be built very flat, since a gel electrolyte is used instead of a liquid one. However, they are more sensitive than lithium-ion batteries.

Even though lithium batteries are the gold standard today, they have certain downsides that can't be overlooked. Most people have seen pictures of smartphones or electric cars whose batteries caught fire or even exploded—a horror scenario. This is why researchers all over the world are looking for new battery types and technologies. The goal: Lowering the size, weight, charging time, and price of batteries while increasing their safety. In addition, the elements of lithium and cobalt (the main components of many batteries) are not available in unlimited quantities.

Magnesium batteries could be a potential successor. This technology is at the focus of a research project by the Karlsruhe Institute of Technology (KIT) and the Helmholtz Institute in Ulm. "A magnesium battery would offer decisive advantages over conventional lithium-ion batteries," the KIT writes in a press release. "As an anode material, magnesium enables much higher energy densities and would be much safer." Another benefit: Magnesium is about 3000 times more common than lithium and easier to recycle. "If Europe makes good progress with the development, then magnesium batteries might also help to reduce the dominance of Asian battery manufacturers and establish a competitive battery industry in Europe," the KIT also writes.

Another candidate for what is known as a solid-state battery is, surprisingly, glass. The sodium contained in glass is one of the most common elements. Such batteries with a special glass electrolyte are potentially capable of being charged within minutes, while offering better safety than flammable lithium-ion batteries. However, some time is going to pass before such a battery technology will be ready for the market and will be able to replace lithium-ion batteries.

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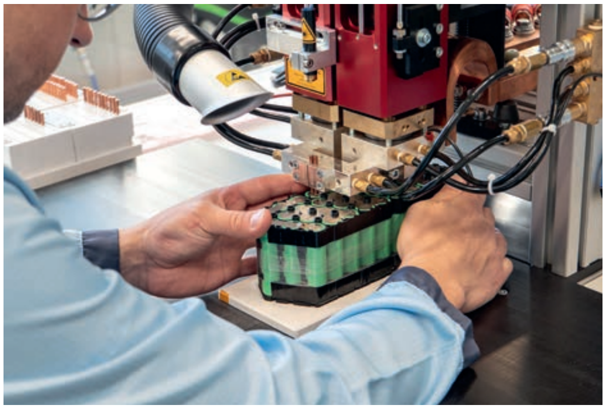
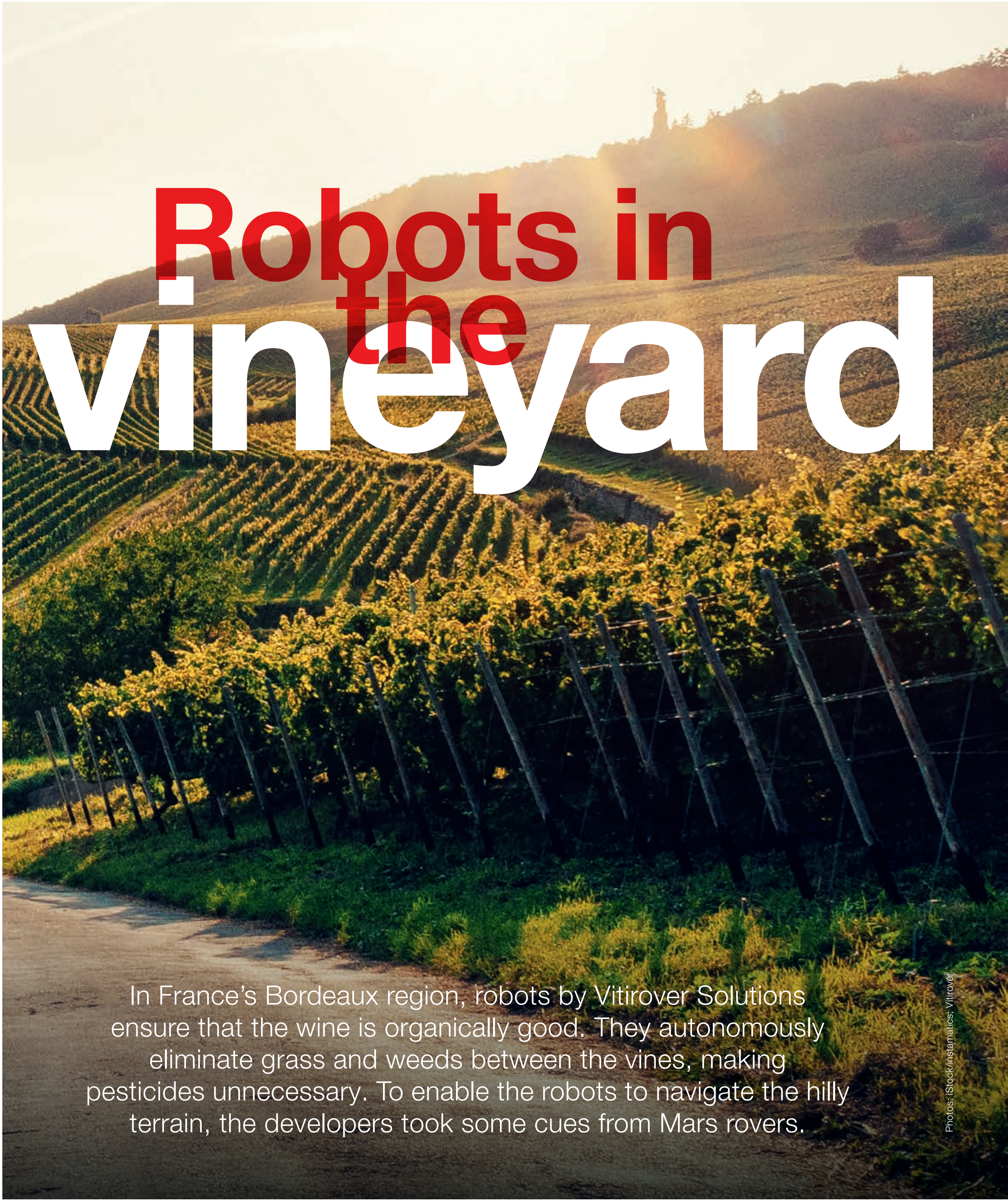


maxon explores the world of batteries

Batteries manufactured by drive specialist maxon? What may sound like a plan for the future is already reality. maxon began its journey into the world of power storage with the development of the BIKEDRIVE, a retrofitting kit that turns a regular bicycle into an e-bike. After some difficulties with the battery supplier, maxon decided to build its own batteries. However, this is easier said than done. Manufacturing batteries requires engineering creativity, technical knowledge, and specialized equipment. "For us, this is a relatively new, but exciting field," says Benny Keller of maxon advanced robotics & systems (mars).

A battery pack consists of several individual cells that typically deliver a voltage of 3.7 V. Depending on how these individual cells are wired, the battery pack has different specifications. If the cells are wired in series, their voltage are added. Wiring cells in parallel increases the battery capacity. Creating an optimal combination of such individual cells requires skill and technical knowledge. "In addition, there are many safety standards that need to be met," Benny Keller explains. A battery pack isn't finished after the cells have been professionally glued and wired. A battery management system (BMS) is also needed. The electronics are usually installed on a PCB in the battery casing. The specialists at maxon have developed and produced their own BMS. The BMS ensures that the cells are charged and discharged evenly. This is critical for the battery's service life. There are also safety aspects to a BMS. For example, it prevents that a battery is charged or subjected to load at excessively low or high temperatures.

It's clear that, as a newcomer to the scene, maxon can't start mass-producing batteries from one day to the next. However, the workshop in Giswil is very well equipped for the production of prototypes and small output quantities. For larger quantities, maxon relies on the assistance of renowned manufacturers in southern Germany. Naturally, maxon batteries are designed for e-mobility and robotics applications.



Robots in the vineyard

In France's Bordeaux region, robots by Vitirover Solutions ensure that the wine is organically good. They autonomously eliminate grass and weeds between the vines, making pesticides unnecessary. To enable the robots to navigate the hilly terrain, the developers took some cues from Mars rovers.

Photos: iStock/instamatics; Vitirover

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The Vitirover is only 70 centimeters long and weighs slightly under 20 kilograms. It cuts grass and weeds at a rate of 300 meters per hour.

The wine region around Saint-Emilion in France is world famous and steeped in tradition. Winemaking here goes back to the Roman age. However, the Romans could only dream of the agricultural tools available today: These days, robots help with the laborious care of the vines. The Vitirover, developed by the eponymous company in Saint-Emilion, is one of these robots. It is a fully autonomous lawnmower powered by solar energy. About twenty of these robotic mowers are in use in the vineyards. This year, Vitirover will deliver 200 more robots, for example for use along railway tracks or in photovoltaics plants. The main benefit of the robot is that it is environmentally friendly and helps to make organic wine. The use of the robot in the vineyards makes pesticides like glyphosate unnecessary. In addition, the robot protects the soil by avoiding the compaction that may be caused by tractors or horses.

Close collaboration with ESA

The development of the robot, which is able to mow more than two hectares of land, wasn't an easy task. As it turned out, the unstable soil in the vineyards is quite similar to the surface of Mars. This is why, when drafting the first design specifications, Vitirover collaborated with the European Space Agency (ESA) to review the designs of all of the robots that were developed for Mars missions. "This really helped us, because we couldn't find any terrestrial robots that came as close to our specifications," says Xavier David Beaulieu, CTO at Vitirover. He started the company in 2010, together with Arnaud de la Fouchardière. After taking over the family business, the Château Coutet winery in Saint-Emilion, he faced the challenge of controlling the growth of grass and weeds between the vines. Today, Vitirover is a globally leading innovator in high-precision winery applications. The company has ten employees.

The robot negotiates rocky, often steep terrain and is exposed to mechanical stresses every 12 seconds, on average. The requirements for its motorization were accordingly high. The mechatronic solutions are the result of a partnership between Vitirover and mdp—maxon France—that goes back more than eight years. The robot is driven by four DC motors, one per wheel. They are brushed DCX 22 L drives that offer maximum power density in a very small installation space. They are highly efficient, which is important in battery operation. Combined with a GP 32 C gearhead, this solution enables the mower to absorb the load on the wheels and deliver the torque required for traction. "In terms of the drive, the problem of the radial load on the wheel axle wasn't an easy one to solve. However, in the end we did it," says Xavier David Beaulieu.

Encapsulated in an aluminum bell housing

The greatest challenge however was elsewhere, namely the three blades that are driven by DCX 32 L series DC motors. The high load tended to damage the ball bearings of the motors, which led to failures. The engineers at maxon finally developed an aluminum bell housing for sustainable protection. Kevin Schwartz, in charge of the Vitirover project at MDP: "Our role is not limited to delivering electric motors. Instead, we supply complete solutions that fulfill the needs of the customer."

The super hand!

Photo: Philipp Schmidli/maxon motor

Bionicman is a different kind of superhero. His futuristic prosthetic hand lends him superhuman powers. He uses these powers to give children with disabilities more confidence—and cool, 3D-printed hands.

When Michel Fornasier dons his sparkling blue cape, he ceases to be a normal human with everyday problems and limitations. He transforms into his alter ego, Bionicman, has unlimited powers, is able to fly, and even to turn back time.

Yes, it's really him. Bionicman! "The costume creates this special kind of magic. When I'm standing in front of school kids, they actually believe that they're looking at the real Bionicman. That's just an amazing feeling."

However, Michel Fornasier isn't wearing his superhero costume just to make himself feel good. He's on a mission. He works to strengthen the confidence of children and show them that having a physical disability does not make them better or worse than other children. Bionicman fights for tolerance and against mobbing. Fornasier was born without a right hand and knows what he is talking about. He never let things slow him down, learned early how to tie his shoelaces, and has even run a marathon. After all, why not?

Michel Fornasier has been wearing a bionic hand prosthesis for slightly over four years. The man from Switzerland has set himself the goal of introducing children to the topic of "people with physical disabilities." He uses his alter ego Bionicman to do so.

From Spider-Man to Bionicman

Fornasier has been using a myoelectric hand prosthesis made by Touch Bionics, a high-tech device with six integrated maxon motors that provides 25 motion patterns. "This prosthesis has made my life much easier in many respects, even though it can replace only 15 percent of the human hand's functions. I can use it to ride a bicycle or scooter and am able to type on a keyboard using both hands. Also, simply being able to hold a smartphone in my right hand feels great."

Children used to ask: Does the hand give you superpowers? Initially, Fornasier denied the question. However, after a while he began to say: Who knows? That's how the idea of Bionicman was born. Fornasier contacted the artist David Boller, who had worked for Marvel and DC in the USA and had even drawn Spider-Man comics in the past. Together, they created the first stories about Bionicman, who comes to people's aid in various situations. Physical handicaps play a role in many stories. "What I want to do is to point out in a playful way that there are people with disabilities, and that they would like to be treated just like anyone else." The first comic anthology is out now. A second volume is planned for late 2019.

3D-printed prostheses for children

While Bionicman provides the moral support, Fornasier helps out with state-of-the-art technology. In 2016, he started the charity organization "Give Children a Hand," to which he devotes a lot of energy. A cooperation with ETH Zurich and the Wyss Institute has been set up to develop affordable prosthetic hands whose components come from a 3D printer. At the time of this writing, 25 children are wearing prototypes and continually

Excerpt from the first volume of Bionicman comics. More information on:

bionicman-official.com

provide feedback for improvements. “To children, the look is often more important than the functionality,” says Michel Fornasier and laughs. “First and foremost, the prosthesis has to look cool.”

Ambassador of the Cybathlon

There is still a lot to do: Engineers have to keep developing prosthetics, and society needs to treat people with disabilities as equals. This is what Bionicman fights for. These goals are also shared by the Cybathlon event, which was first held in 2016 and will take place again in 2020 in Zurich (see box). It comes as no surprise that Michel Fornasier is an ambassador of the Cybathlon. “I mainly try out new tasks for the prosthetic hand race and provide feedback to the organizers: What’s difficult, and what could be improved?” In addition, he advertises a lot for the Cybathlon. “It’s a great event, because it’s about people, not about disabilities.” Fornasier is impressed by the ambition shown by both engineers and pilots. “The resulting developments benefit users in the end.”
Michel Fornasier will definitely be in a ringside seat at the Cybathlon in 2020. Together, the Cybathlon and Bionicman are a unique team that overcomes social taboos and builds bridges between people with and without disabilities.

maxon supports the 2020 Cybathlon

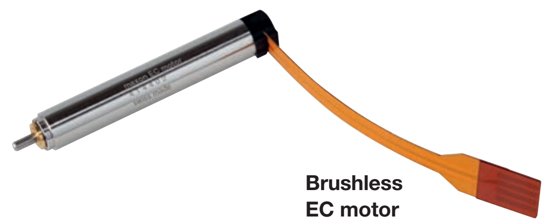
In the Cybathlon, people with physical disabilities compete against each other in obstacle races—supported by state-of-the-art technical assistance systems. The second installment of the event takes place in Zurich on May 2–3, 2020. The teams and pilots compete in six disciplines: Virtual racing using thought control, bicycle racing with electrical muscle stimulation (FES), dexterity challenge with prosthetic arms, obstacle race with prosthetic legs, obstacle race with robotic exoskeletons, obstacle race for powered wheelchairs.
The Cybathlon is hosted by the Swiss Federal Institute of Technology in Zurich (ETH). With this event, the institute provides a platform for exchange between technology developers, people with disabilities, and the public. maxon motor again supports the event—this time as Presenting Partner.
More information on: **cybathlon.com**

Starring

maxon
BIKEDRIVE
retrofitting kit

Rear motor, 50 Nm
Battery, max. 500 Wh
PowerGrip, 3 stages

⟶ E-mobility, p. 15



Brushless
EC motor
EC 4

⟶ Surgical robot, p. 28

maxon DC motor
DCX 22 L

⟶ Robots in the vineyard, p. 22

Current and
speed controller
ESCON

⟶ Precision braking, p. 16

Photos: maxon motor

Through thick and thin with feeling

The start-up company NISI Limited is currently developing a miniature surgical robot that can be inserted though natural openings in the body and only unfolds inside the abdomen. To achieve this goal, the engineers are pushing components to their limits and beyond.

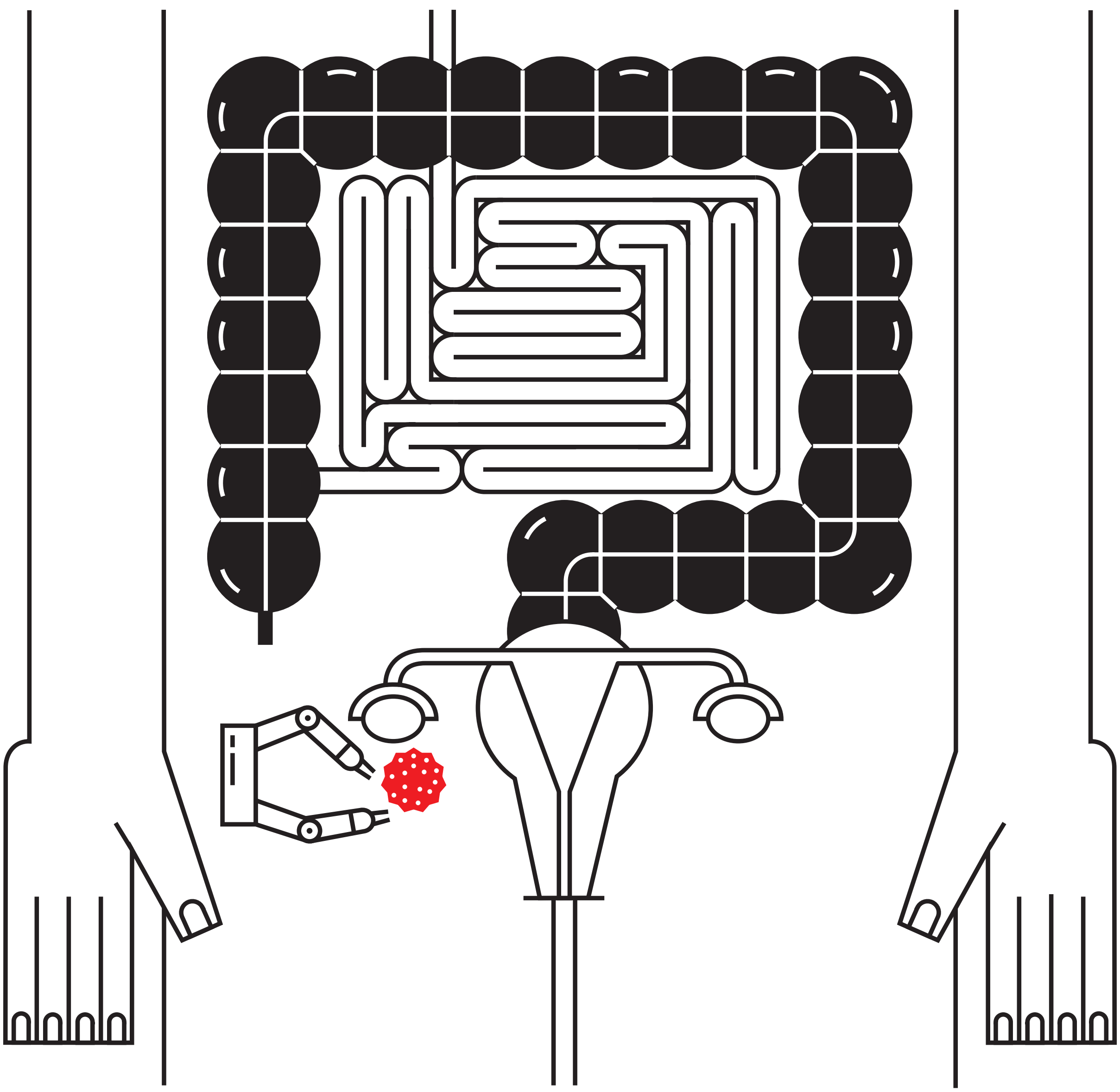


Illustration: Anita Allemann Photos: NISI robotics

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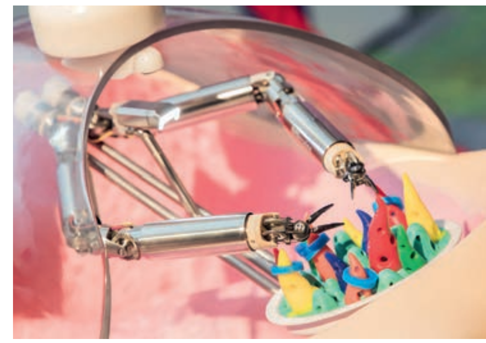


The NISI surgical robot was used successfully on animals in the summer of 2018.

In the world of medtech, there are many astonishing new developments these days. The world of surgical robots could be turned on its head soon: In summer 2018, the Hong Kong-based startup NISI announced that it had successfully performed a series of gynecological operations on live pigs. This may not sound like anything special at first, however: For the operation, the surgeons used a small robot that had been inserted rectally. This is a world's first, according to the company.

NISI was founded in 2012 and works with the universities of Hong Kong and Cambridge to develop a robotic system that enables complex, minimal-invasive surgeries in the abdominal and pelvic area without leaving visible scars. “We want to become the world's leading expert in non-invasive robot technology,” says Corinna Ockenfeld at NISI. The successful surgeries in the summer of 2018 have given the medtech start-up a lot of momentum. Initial surgeries on humans are planned for 2021.

The idea behind the NISI surgical system is as follows: The surgical robot is inserted through a natural orifice, usually the anus or the vagina. This way, only a small cut inside the body is necessary to introduce several surgical tools into the abdomen. Current systems require several incisions, one for each instrument. The new technology has a number of benefits: Less blood loss during surgery, fewer wound complications, shorter recovery time for the patient, and no visible scars.

The robot itself has two small arms that unfold inside the body and can be controlled by the surgeon on a control panel. The two robotic arms are powered by micromotors from maxon and have up to ten degrees of freedom. The system also has high-resolution 2D and 3D cameras and delivers haptic feedback, so that the surgeon is able to feel what is happening at the other end and can work with the greatest precision.

Bringing surgical robots to the next level requires more than outstanding technicians and engineers: Quality components are a key element. NISI is therefore testing various concepts and combinations of components. “We want to push the envelope in medical and robot technology,” says Dr. Corinna Ockenfeld. With regard to the motors, this requires an extremely small size and extremely high power density. “We are working closely with maxon and have a weekly exchange of information. We really appreciate the support we've received over the past years. The collaboration with maxon is highly productive and extremely valuable for both sides.”

The prototypes of the surgical robot currently use various brushless DC motors from the EC series, with diameters from 4 to 8 millimeters, complemented by matching planetary gearheads. Both partners are pushing the precision drives to their limits, sometimes running them outside the nominal specifications. However, the BLDC motors are customized for the specific needs. They require high power density, must fulfill extremely strict quality standards and be sealed against body fluids. In the future, the drives will also need to be biocompatible.

The next steps are to make the entire system even smaller, to make the motors even more dynamic, and to expand the working range of the robot. “We take care of every little detail and take innovative approaches to solving problems,” says Dr. Corinna Ockenfeld. Step by step, NISI is coming closer to its vision of making non-invasive surgery without scars something that can be taken for granted.

Spotless

The new certified cleanrooms at the maxon headquarters in Switzerland, before and after setting up the first assembly stations.

Medical technology has no tolerance for error. This is why maxon micromotors are made in certified cleanrooms. This kind of special facility takes significant effort to build.

Cleanrooms are needed in all kinds of industries—e.g., medicine, food technology, and the semiconductor industry. Using cleanrooms to make electric motors seems a little odd at first. However, that's exactly what maxon has been doing since early 2019 in its new Innovation Center in Switzerland. In more than 1200 square meters of cleanrooms, drives can be made under strict hygiene standards. However, to what end?

Making a powerful motor, for example to be used in industrial automation, takes engineering skill, good workmanship, and a clean environment—but not a cleanroom. The new cleanrooms are used for making maxon's miniature drives: Motors with diameters of only a few millimeters. This type of drive is used especially in medical technology. maxon is already a strong partner when it comes to drives for medical applications, such as insulin pumps or hand-held surgical tools. With the new cleanrooms however, the Swiss drive specialist is getting ready for even more finicky and delicate applications, such as implantable drive systems for heart pumps.

Months of planning

"Planning a certified cleanroom was a new and exciting challenge for us," says Christian Kunde, project manager at maxon medical. It was a lot of effort. "The planning took about 15 months and was done in cooperation with external experts." Indeed: At first glance, it's just a series of clean areas with lots of assembly stations and microscopes, separated by glass windows. The technology is literally hidden behind the scenes: In the partitions and in the ceiling, there are whole arrays of pipes and kilometers of cables.

The equipment is necessary, among other things, to generate a higher air pressure in the cleanrooms. How does this work? When the airlock to a cleanroom opens, then clean air flows to the outside and prevents contaminated air from coming in. Leaving all the doors open would be the equivalent of a deadly sin. In order to prevent this from happening in the first place, cleanrooms have airlocks in which the air pressure is slightly lower than inside but still higher than normal. Other equipment prevents that the two doors of an airlock are open at the same time. "So you won't be able to shout at me from the other room here," Christian Kunde chuckles.

The particle concentration in the air is measured every minute. In addition to cleanrooms, maxon now also has what's called a GMP area (good manufacturing practice). In this area, not only the particle concentration is measured, but also the microbiological contamination of surfaces and the air with germs, bacteria, and fungi—again with an eye on future applications in medical technology with implantable micro drives.

Air is "diluted" continuously

Cleanrooms come in several certification classes. The maxon cleanrooms are among the more "pleasant" ones. While the employees need to take a variety of measures before and during work, such as wearing a hair net and special clothes, they are not in a completely different world. This is different in nanotechnology, the pharmaceutical industry, or semiconductor production. Workers in these industries sometimes look like they're on a different planet. The equipment for keeping the particle concentration low is also different: In the maxon cleanrooms, there is a constant flow of filtered air coming in. This air disturbs the air in the room, which in turn is extracted and filtered. This continuous exchange effectively "dilutes" the air with respect to particle concentration. A different type of technology, one that is used in operating rooms, is called "laminar flow." In this technology, filtered air flows from the ceiling to the floor. The goal is not to disturb the air, but instead to prevent particles from "floating" in the room altogether.

Photos: Adrian Venetz/maxon motor

Series

Brushless motors with slotted windings

Part I

The effect of inductance on high speed behavior

How do motor data of multipole brushless motors with slotted windings (i.e., with iron core)—such as maxon EC-i, ECX TORQUE and EC flat motors—deviate from idealized linear behavior.

Urs Kafader, head of technical training, maxon motor

Photo: maxon motor

In opposition to the classical coreless maxon motors, maxon flat and EC-i motors have windings with slotted iron cores. This results in a stronger magnetic flux of the coils and the motor becomes stronger.
However, the high winding inductance due to the iron core slows down the current reaction. At high speeds, deviations from the linear and simple behavior of motors with coreless windings, e.g., maxon DCX and ECX SPEED motors, can occur.
Part 2 of this article covers the effect of magnetic saturation in the iron core at high currents. The achievable stall torque deviates from simple linear extrapolation.
Both effects are summarized in the schematic diagram of Figure 1 that can be found in the maxon catalog. The purpose of these articles is to better understand these effects and their implications for practice.

Electrical time constant and commutation

The winding is an inductive and resistive load. As you remember, the motor current is built up following an exponential law when applying a voltage. The exponential behavior is characterized by the electrical time constant, τ_el, that is simply the terminal inductance L_{mot} divided by the terminal resistance R_{mot} of the motor τ_el=L_{mot}/R_{mot} The maximum current at the end is given by Ohmic law, $I_{end}=U_{mot}/R_{mot}$.

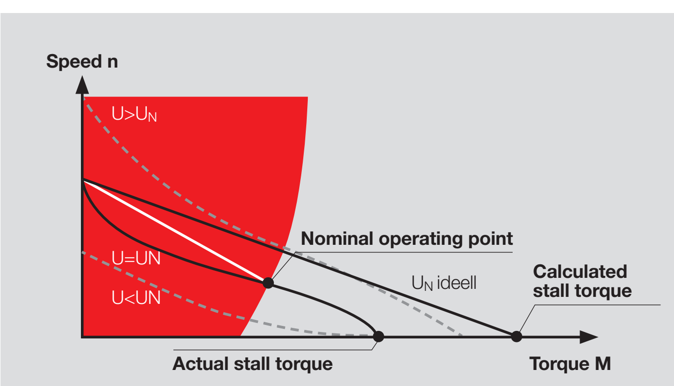


Figure 1: Schematic representation of the effects (from maxon catalog). Part 1 of this article deals with the effects at high speeds on the left. Part 2 covers the effects at high current on the right.

Both effects are summarized in the schematic diagram of **Figure 1** **(p 35)** that can be found in the maxon catalog. The purpose of these articles is to better understand these effects and their implications for practice.

The effect of the inductance is that winding currents cannot change as abruptly as indicated by **Figure 3** **(p 36)**. How much time of each commutation interval is consumed to rise the current?
Let us calculate the duration of a commutation interval and then compare with the electrical time constant. Of course, the faster the motor speed, the shorter the commutation interval. Hence, for the calculations we take as a worst-case scenario the no-load speed at nominal voltage n_0. The number of commutation intervals per motor turn is 6 times the number of pole pairs p. During 1 minute we have $6p\cdot n_0$ commutation steps. Hence, the duration of 1 commutation step is $\Delta t_{comm}=(60\ s/min)/(6p\cdot n_0)$.

The results for different motor designs are summarized in **Table** **(p 36)**.

The first two motors in the table have coreless maxon windings with very low inductance. Accordingly, the electrical time constants are very short and – most importantly – considerably shorter than the commutation interval. This means that the full current can build up almost completely in each commutation step. Of course, the situation of the ECX SPEED motor is not as comfortable as on the EC-max 40 because of the extremely high no-load speed of the former.
The last three motors in the table are multi-pole motors with slotted windings. The iron core increases inductance and hence the electrical time constant to values close to 1ms. On the other hand, the commutation interval becomes very short due to the high number of pole pairs. In fact, the commutation interval is

considerably shorter than the electrical time constant. As a result, the current cannot fully build up and the motor weakens. It is like a non-perfect commutation that will have as an effect a higher no-load speed and a steeper speed-torque gradient. This is indicated in **Figure 1 (p35)** by the dotted lines in the red continuous operation range.
These phenomena will be more pronounced the higher the speed, i.e., the closer to no-load and the higher the supply voltage.

Practical aspects

In the maxon catalog you find three selected points on the speed-torque line: no-load, nominal and stall. These operation points are calculated including the effects described so far. We have seen that the main problem arises when block commutation intervals become very short, i.e. at high motor speeds. Typically, the no-load speed is most affected and shifted to higher values. The specification of the speed-torque line and its gradient a straight line between no-load speed (which is too high) and stall torque is assumed. Hence, the nominal operation point will be lower than this direct line **(see Figures 1 and 4)**.
For most practical applications and motor selection, we can follow the rule stated in the maxon catalog: "Mostly, flat motors are operated in the continuous operation range where the achievable speed-torque gradient at nominal voltage can be approximated by a straight line between no load speed and nominal operating point. The achievable speed-torque gradient is approximately: $\Delta n/\Delta M \approx (n_0-n_N)/M_N$."
Doing the math's for EC-i 40 High Torque 50W motor as an example, we get a speed-torque gradient of approximately 16.2 rpm/mNm which is considerably higher than the catalog value of 6.48 rpm/mNm. Consequently, for reaching 5000 rpm at 100 mNm as an example, approximately 32 V supply voltage is required instead of 27 V when using the ideal catalog value of the speed/torque gradient.

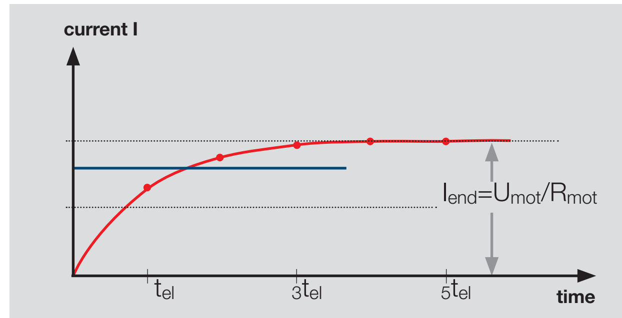


Figure 2: Current versus time in a winding with fixed voltage applied. It takes about 1.5 times the electrical time constant to reach the blue current level.

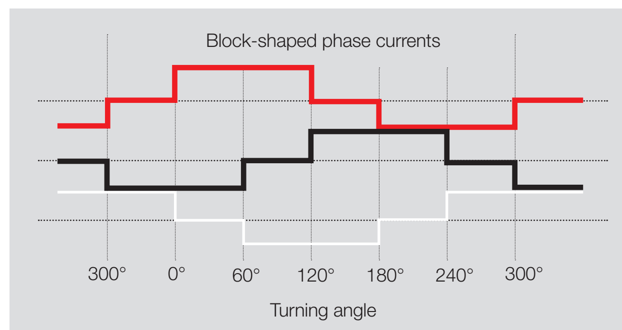


Figure 3: Phase currents for block commutation (from maxon catalog) for a complete commutation sequence.

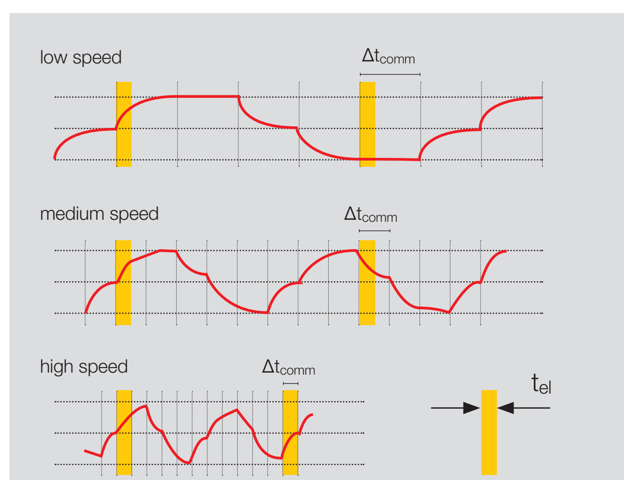


Figure 4: Current in one phase for block commutation at different speeds including the effect of current retardation due to the electrical time constant. The shorter the commutation interval, the lower the average phase current.
Remark: This representation is very schematic assuming a fixed supply voltage and neglecting the effects of a current control loop and a pulsed power stage.

maxon EC motor type	winding, rotor	L_{mot} (mH) R_{mot} (Ω) pole pairs	t_{el} (ms)	Δt_{comm} (n_0)			t_{mech} (ms)
ECX SPEED 22 M HP, 80 W	coreless, internal	0.0133 mH 0.172 Ω 1	0.077 ms	<	0.18 ms (55 $kmin^{-1}$)	<<	2.39 ms
EX-max 40, 70 W	coreless, internal	0.186 mH 1.35 Ω 1	0.13 ms	<<	1.25 ms (8 $kmin^{-1}$)	<<	8.8 ms
EC-i 30, 75 W HT	slotted, internal	0.39 mH 0.38 Ω 4	1 ms	>	0.31 ms (8 $kmin^{-1}$)	<>	0.72 ms
EX-i 40, 70 W HT	slotted, internal	0.512 mH 0.591 Ω 7	0.87 ms	>	0.19 ms (7.5 $kmin^{-1}$)	<>	0.64 ms
EX flat 45, 70 W	slotted, external	0.966 mH 1.74 Ω 8	0.55 ms	>	0.2 ms (6.3 $kmin^{-1}$)	<<	11 ms

Table: Comparison of the electrical and mechanical time constant with the commutation interval duration at no-load speed for brushless maxon EC motors of different design.

The most important lesson to learn

Be careful when selecting motors with slotted windings at high speeds. They might need more voltage.
Don't worry too much if speeds are low; the specified data are just right.
Additional remark: For sinusoidal commutation (FOC or field-oriented control), I expect the high inductance to have a much smaller effect, because the current changes gradually and not abruptly as in block commutation. (However, I've never tested it.)

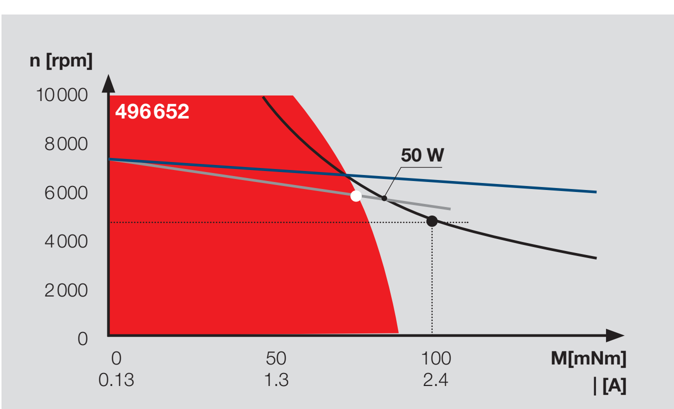


Figure 5: Operation range diagram of the EC-i 40 High Torque motor. Blue line: catalog speed-torque line. Grey line: straight connection between no-load and nominal operation point (dark grey). Green: Operation point at 100 mNm and 5000 rpm.

Motion response – mechanical time constant

The electrical time constant of the classical coreless maxon winding is much shorter than the mechanical reaction of the motors (typically several ms, **Table 1**). For most practical purposes we can argue that the current is instantly there and the motion takes place at the set current. This results in a fast torque generation supporting the high motor dynamics.
The motors with the smallest mechanical time constant can be found in the maxon EC-i High Torque series. The dynamics stems from a combination of high torque – generated by an iron core winding and strong magnets in the rotor – and the low mass inertia of the rotor. Unfortunately, the iron core winding exhibits an electrical time constant of the same order of magnitude as the mechanical time constant. Therefore, the dynamic reaction will be retarded by the time the current needs to build up; it's difficult to get the current into the winding fast enough. Furthermore, saturation effects limit the maximum achievable torque (refer to part 2 of this article) resulting in mechanical time constant that are higher than the ideal values given in the specs.
The second lesson: Don't take mechanical time constants for granted. There might be boundary conditions to account for, the most important being load mass inertia.

It's a can of worms

From a degree thesis to a start-up: Five young engineers want to take a sewer rehabilitation robot to the market—with a new approach, inspired by nature.

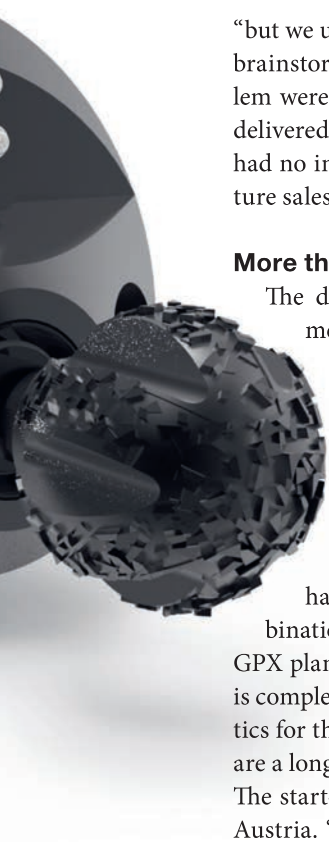
Earthworms have a talent for movement. With their complex circumferential and longitudinal muscles, they are able to crawl forward and backward. It should be possible to apply this perfect natural movement concept in robotics—or that's what a young Austrian engineering student thought when he started his graduate thesis in 2014. In 2016, a team that now numbered five people finally presented the functional prototype of a robot that moved like an earthworm. The construction consisted of several segments of variable diameter. Only the segments that are shrunk, and therefore do not touch the ground, move.

The project won several awards for innovation and gained some media attention. Then the investors started calling. "Launching the company was only a small step afterwards," said Matthias Müller, who is now the CEO of the start-up Foccus Innovation.

Solutions through brainstorming

The young men have come significantly closer to their goal: By now, they have built the first prototype of a pipe rehabilitation robot for commercial applications, such as trenchless rehabilitation of sewers. The product is scheduled to reach the market by the end of 2019. Of course there were technical problems,

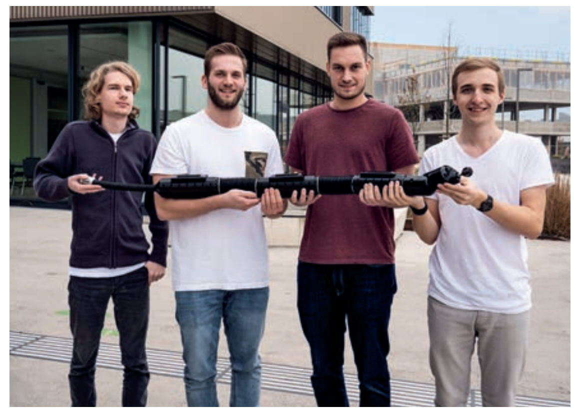
Photos: Foccus Innovation



"but we usually solved them quickly and efficiently in brainstorming sessions," says Müller. A bigger problem were suppliers who promised too much, or even delivered the wrong goods. "Most of the companies had no interest in a start-up with hard-to-predict future sales."

More than 12 drives per robot

The developers found maxon through a recommendation. They applied for the Young Engineers Program (YEP) and were accepted. Now they use exclusively maxon products to drive their robots, combining standard drives and custom units. Matthias Müller says: "The good power-to-size ratio of the electric motors enables us to realize such a small and strong tool." The earthworm robot has more than 12 drives. Most of them are combinations of brushed or brushless DC motors with GPX planetary gearheads and encoders. The package is completed by a few controllers. The key characteristics for the developers of the pipe rehabilitation robot are a long service life, precision, and a compact size.
The start-up received design support from maxon in Austria. "maxon also lent us electric motors for testing. This enabled us to try out a variety of concepts and specify our drives correctly."
The team has already mastered many challenges in innumerable night and weekend shifts. Now the "earthworm" made by Matthias Müller and his colleagues only needs to writhe its way into the market of sewer rehabilitation robots. The engineers are confident that their system has many benefits over existing solutions, for example its low-noise operation. Another advantage is the innovative control unit that delivers vibration feedback and high-resolution 4K images to the user. In the first stage, selected customers will thoroughly test the product. If all goes well, the earthworm robot will wriggle through the sewers in the neighborhood on a regular basis.



The team of the start-up Foccus Innovation with its worm robot.

"maxon lent us electric motors for testing."

Matthias Müller,
CEO of Foccus Innovation

Young Engineers Program

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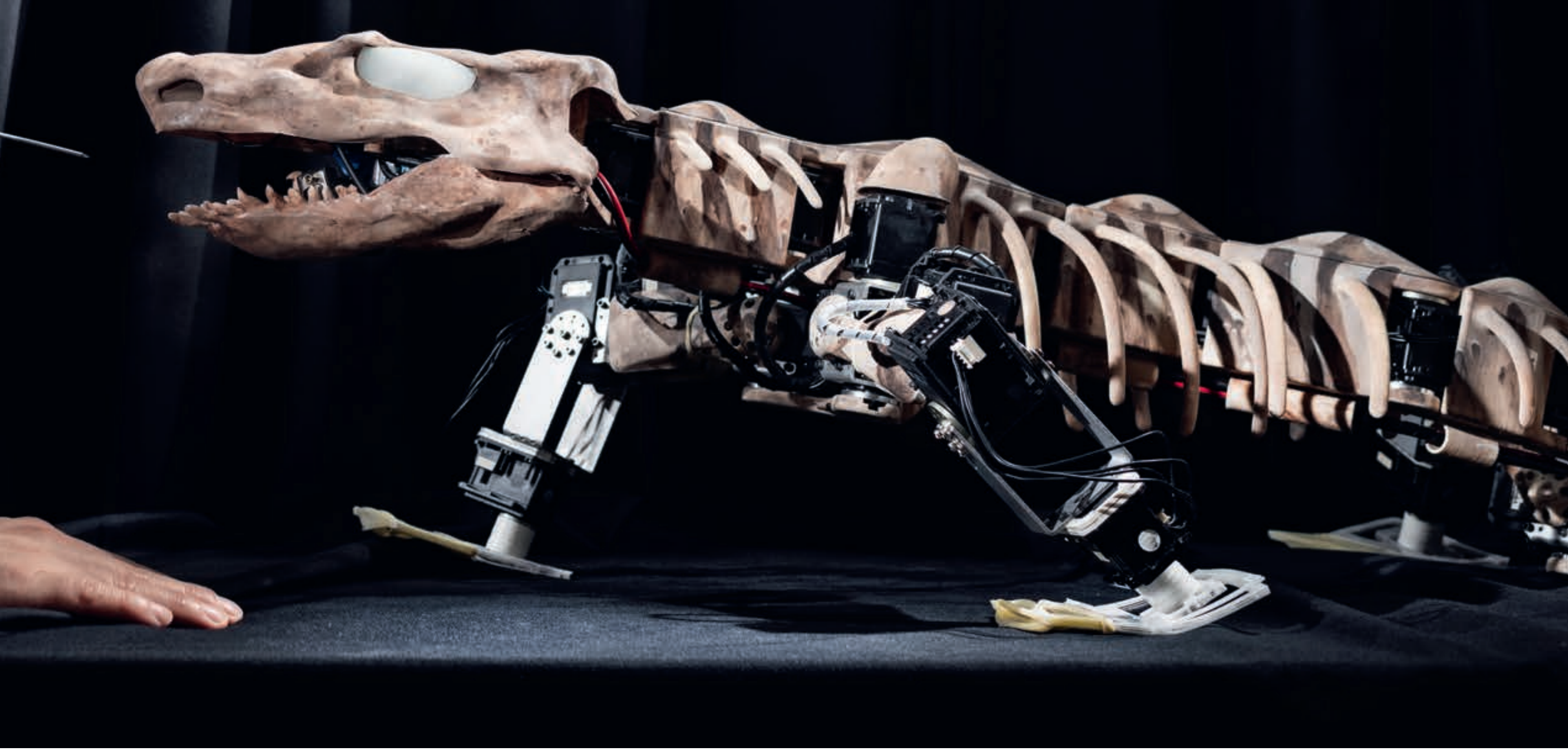
A fossil as a friend

Making a legged robot walk is not as simple as it looks. Coordinating the motion of all its joints to achieve smooth motions, close to those of real animals, requires advanced engineering and careful observation of moving animals. But what if we don't exactly know how the animal looks or moves, as it has been extinct for 300 million years?

Photo: Fred Merz | lundi13

This is the story of *Orobates pabsti*, an early tetrapod that lived millions of years before the dinosaurs existed. Its fossilized bones were recovered in what today is Germany in 2004. The excellent state of preservation of its fossilized bones, nearly complete and articulated, was complemented with fossilized footprints, also found in the region. This helped engineers like me in the Biorobotics laboratory of EPFL (working with Tomislav Horvat and Auke Ijspeert) and a great team of biologists (led by John Nyakatura at the Humboldt University of Berlin) to reconstruct its locomotion using a robot.

But why is the locomotion of Orobates important? Orobates is an ideal candidate for understanding how land vertebrates (including humans like us) evolved. These animals represent the transition from an amphibious lifestyle to land-living vertebrates capable of laying eggs on land. This places them in the evolutionary tree between the amphibians and more evolved animals including reptiles, birds, and mammals. Whether or not Orobates could walk on land seems crucial to be studied. For example, to shed light on debates related to when the dry land was finally colonized by animals. Locomotion experiments with living animals are difficult but with an extinct animal is in fact, impossible. We needed to find a way to reconstruct the locomotion of Orobates objectively. We thought that computer simulation was a good tool to do this but legged locomotion is difficult to simulate. Intermittent impacts of the legs with the ground, contact friction and the overall dynamics of the moving body of Orobates required a real world verification to be valid. That is why we reconstructed the fossil of Orobates with a physical robot. This robot was a scaled version of the fossil, almost doubling its size. The mass distribution and other dynamically relevant parameters, like the speed at which the robot should move, were thoroughly studied to have both biologically and engineering significance. Having this robot built, we were able to test a number of possible gaits that presumably Orobates executed when it was alive. We observed other modern animals whose morphology is similar to Orobates, like a salamander, a caiman, an iguana and a skink. We noticed that their gaits differ in their body height, the spine



Kamilo Melo grew up in Duitama and Bogotá, Colombia and now lives in Renens, Vaud. He studied electrical and mechanical engineering obtaining a PhD in robotics. After working as postdoc at EPFL Lausanne, he now works and research for his own robotics company KM-RoBoTa.

motion range, and their leg rotations as they swing them. These characteristics create a space where the living animals' data and the possible gaits of the robot could be compared. We tested a number of gaits in this space to try to find the most stable, energetically efficient gait, that used force patterns similar to those of the living animals and whose precision matching the footprints was high. We discover that the most likely gaits used by Orobates to walk were quite similar to those of the caiman. This suggested that their locomotion was rather advanced, compared to what was thought of these early tetrapods.

Field test in Africa

Testing with the robot was also a great experience. It looked alive. To control this machine, it was necessary to solve inverse kinematics and dynamics problems, to coordinate the motion of the legs and the spine. To achieve smooth locomotion, the robot's on-board computer sends commands to the motors at rates around 100 times per second. The actuators used are driven by a powerful and efficient maxon DC motor. We used 28 actuators, five per leg and eight in the spine. Few times a robot that complex and close to a real animal has been controlled to execute all these diverse motions.

We built in our experience in designing and controlling sprawling posture robots to make the robot of Orobates. After doing science with the salamander robot Pleurobot (please see Driven magazine in 2018), we also drew inspiration from the gaits and morphologies of Nile crocodiles and monitor lizards to build and test two such robots out in the field. We worked with BBC, filming wildlife documentaries in Africa. The TV series Spy in the Wild features our robots surrounded by wild animals on the banks of the Nile river. These robots survived two intense weeks of filming in extreme environmental conditions, and gave us new insights on robust design for complex real-world scenarios. That is the case with the K-Rock robots intended for disaster scenarios. Because of their posture, they have the ability to walk under tight passages and being amphibious, they can swim and walk in flooded areas filled with debris and obstacles.

Developing these robots, first with the Biorobotics Laboratory of EPFL and now in my private company KM-RoBoTa (part of YEP program of Maxon, and one of the start-ups at the Maxon Innovation Lab in Lausanne), sets the bar for the robust design of animal-like robots that are inspired by real animals and whose mobility capabilities have great potential to be used either for science or for engineering applications.

Actuators of the future

Advances in robotics like these make us think about the actuation mechanisms we currently use. With current technology, we can be fast but we cannot move high inertias quickly and efficiently (allowing impacts, explosive motions, etc). Additionally, to increase the torque, we use gearboxes, which affect the transparency of the motion control by inertia and friction reducing the actuator bandwidth. New avenues of creating better actuators at different scales from soft robotics, to high power proprioceptive actuators often come with the burden of bulky peripheral systems, decreasing the power and torque density, or a high demand in power that overflows the dissipation requirements.

Step by step, like Orobates' robot walked in its footprints, we are designing better actuation technology. But we are still far from providing our robots the desired real animal-like abilities. At least compared to what the animal muscles can do. There is a long, yet exciting research and development path for actuation and robotics design in the following decade worth to be walked.

References

John A. Nyakatura*, Kamilo Melo*, Tomislav Horvat*, Kostas Karakasiliotis, Vivian R. Allen, Amir Andikfar, Emanuel Andrada, Patrick Arnold, Jonas Lauströer, John R. Hutchinson, Martin S. Fischer and Auke J. Ijspeert. Reverse-engineering the locomotion of a stem amniote. Nature 565, 351–355; 2019. *Authors with equal contribution.
DOI: 10.1038/s41586-018-0851-2

Contest

In which city will the 2020 Cybathlon be held?

The prize is a Ninebot e-scooter by Segway that has a top speed of 20 kilometers per hour.

E-mail your answer to:
driven@maxonmotor.com

The deadline for submissions is July 31, 2019.
Winners will be notified. Employees of maxon motor are not eligible to participate.
There will not be any correspondence in regard to the contest. All decisions are final.

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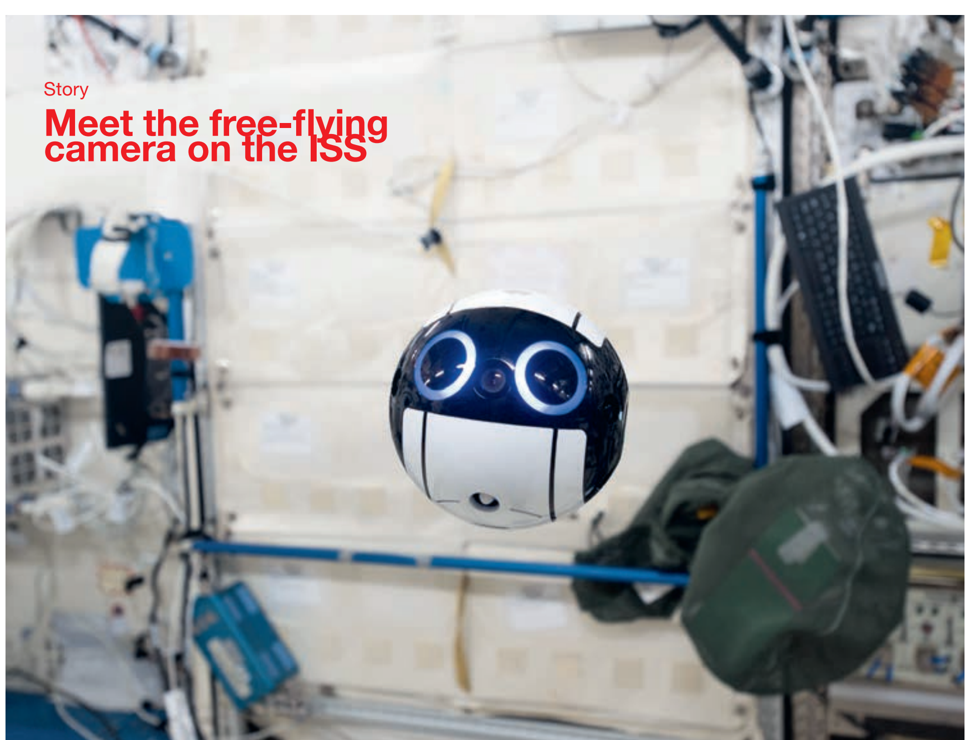
Take this article about a weightless robotic assistant on board the International Space Station (ISS).



Photos: Segway, maxon motor

Rank and file

These windings in the cleanroom of maxon in Sachseln are ready for use. They will soon serve in brushless micromotors with a diameter of 6 millimeters. These midgets are in high demand, especially in medical technology. The enameled copper wire has a diameter of less than 0.07 millimeters, about the thickness of a fine human hair.

Photo: Adrian Venetz/maxon motor