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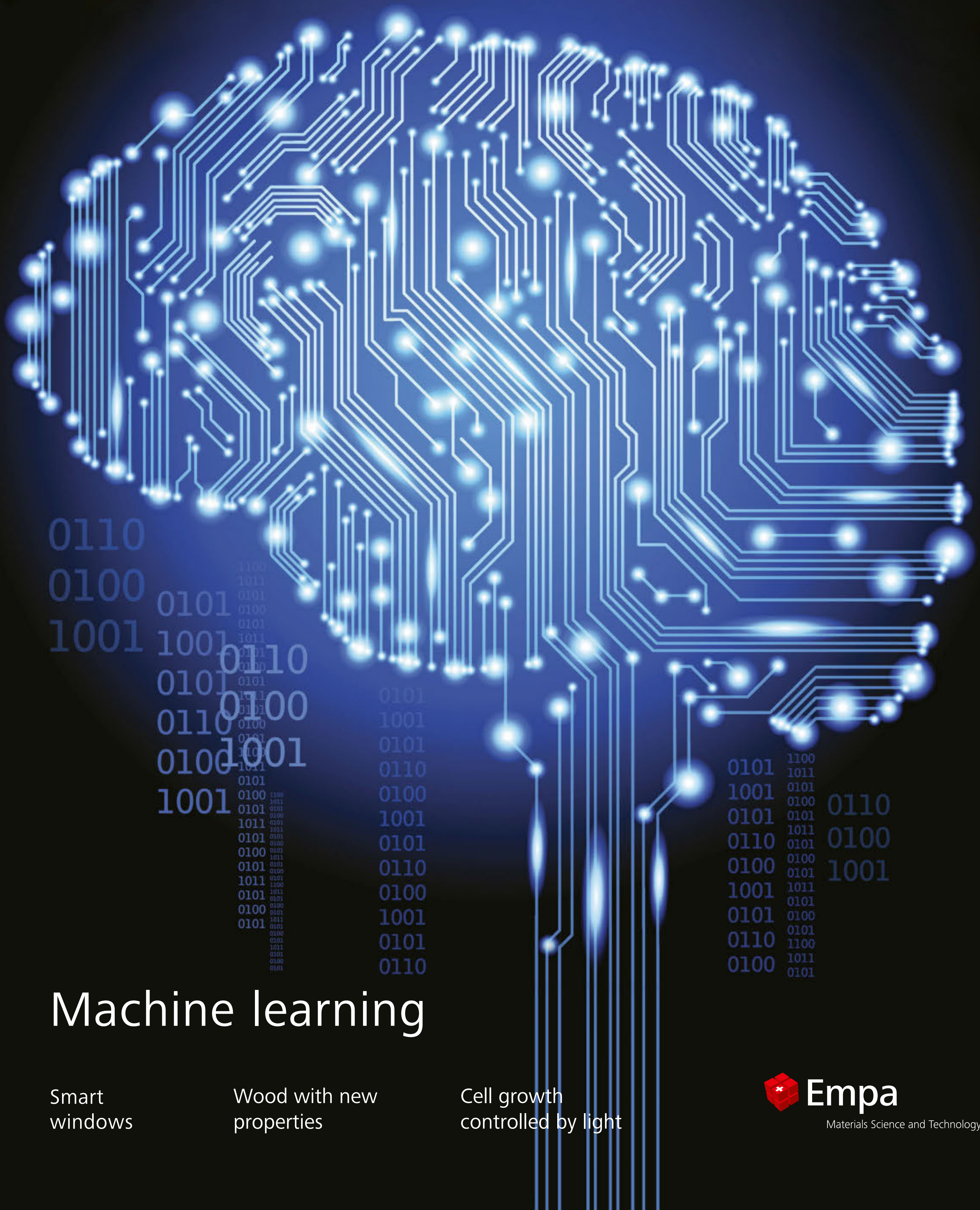


Machine learning

Smart windows

Wood with new properties

Cell growth controlled by light

Empa
Materials Science and Technology

MICHAEL HAGMANN Head of Communications

In love with my operating system

Dear readers

One man's meat is another man's poison: While technophiles struggle to keep their mouths from watering at all the juicy treats that artificial intelligence (AI) is supposed to offer, the skeptics among us remain jittery – enter Terminator, HAL and other computer dystopias. These days you would be hard-pushed to find a more controversial scientific topic than AI.

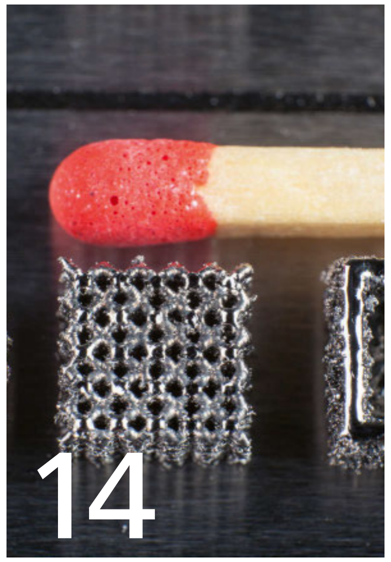
What the latest supercomputers can achieve with a little help from smart algorithms and machine learning is indeed staggering. Garry Kasparov's chess defeat to IBM's Deep Blue almost pales into insignificance by comparison; meanwhile, humans no longer stand a chance against computers in the Asian board game Go, either. The next target was poker, which at least involves the very human element of bluffing – and only recently an AI program called Project Debater (also developed by IBM) beat humans at debating, i.e. in a battle of words and arguments. From there it seems only a short leap to sci-fi films like Her, where Joaquin Phoenix falls in love with his new operating system (with the seductive voice of Scarlett Johansson).

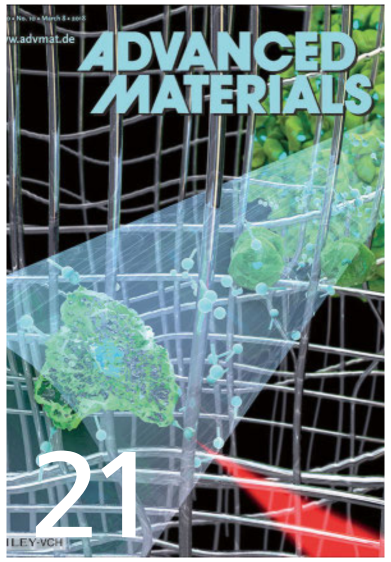
Are these prospects encouraging or alarming? For sure, the potential of using AI to, say, diagnose cancer more rapidly and treat it more effectively in future is huge. And self-driving cars and other gadgets will certainly make our lives more comfortable and straightforward. At the same time, however, an increasing malaise in the face of "all-knowing" machines is also to be expected – along with the necessity to monitor technological developments with accompanying research and use them for the good of everyone. Clearly, this is easier said than done. Nevertheless, we have to rise to the challenge.

Happy reading and until the next issue!

Focus

Machine learning





Cover
Machine-learning is a sub-area of artificial intelligence that can be used effectively in materials science. A computer can routinely obtain valuable information from large quantities of data that initially seem unclear or even worthless. This enables production processes to be monitored in real time, for instance. ***Page 09–19.***
Photo: iStockphoto.

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Heat islands in the water tunnel

Heat waves are increasing worldwide. Cities in particular suffer as a result. A new water tunnel at Empa could help to alleviate these urban heat islands in the future.

TEXT: Karin Weinmann / PICTURE: Empa

Year after year the heat records are being broken. Cities suffer much more from the heat waves than the surrounding countryside: the temperature differences between urban zones and the surrounding green areas can be as high as several degrees. The phenomenon is known as urban heat islands. There are several reasons for the temperature differences: The dark surfaces of pavements and rooftops absorb more sunlight during the day– and retain it better. Additional heat is generated in the city by traffic and industry. Furthermore, there is usually a lack of vegetation that could reduce the temperature by evaporation.

Cities and research groups around the world are working on ways to alleviate this urban heat island effect. Special attention is paid to the wind: it could dissipate the heat from the cities, bring cooler air from surrounding lakes and forests and additionally cool the surfaces by convection. During heat waves with little wind, the buoyancy effect plays an important role: when hot air rises above the city, cooler air can flow up below. In addition, areas with cooler air can be created: For example, parks with vegetation, lighter surfaces that absorb less solar radiation or surfaces where water evaporates – for example, artificial lakes or wet materials. The wind can distribute this cooler air in areas where the heat island effect cannot be fought locally.

In order for the wind to dissipate the heat from the cities, however, the city must be built in such a way that air masses can flow relatively easily around the buildings. This is anything but trivial: there has not yet been enough research into how urban structures influence local wind conditions. How does the wind flow and swirl on buildings and over heated roads? And how does this change the temperature distribution?

A matter of scale

Answering these questions is the aim of the new water tunnel at Empa, which was officially inaugurated in June 2018. But why does it take a water tunnel to better understand wind movements? It is a matter of scaling: Since the models of urban structures are only a fraction of the size of real buildings and roads, water behaves exactly like wind in a real city at suitable flow speeds. The water tunnel has two clear advantages over a wind tunnel, which is also suitable for studying wind flows in cities: On the one hand, smaller models can be used, i.e. a larger area of the city can be examined. On the other hand, the flow field and the temperature distribution in the water can be measured simultaneously.

This is done with a laser measuring system: the research team mixes tiny particles and a fluorescent dye into the water. The particles are illuminated with a pulsating laser beam extended to a plane. During such a laser pulse, a camera takes two images in rapid succession. The measuring system can now evaluate how far and in which direction the particles have moved. Thanks to the fluorescent dye, the researchers can determine the temperature distribution: It absorbs green laser light and emits light of a different colour – the warmer the water, the brighter the light.

The determination of the cool and warm flow structures allows researchers to gain new insights into how heat can be removed from cities. These results could help planners, architects and governments in the future to develop cities more resistant against heat waves. //

An unlikely marriage among oxides

Sebastian Siol is looking for new materials with unusual properties that were so far not accessible in experiments. To do this, he connects partners who don't really fit together: Siol also makes sure that the crystal bonds last in everyday life. Only then are they interesting for industrial applications.

TEXT: Rainer Klose / PICTURE: Empa

The term alloy usually refers to a mixture of several metals. However, other materials can also be alloyed. In the semiconductor industry, for instance, oxide and nitride alloys have long been used successfully to tune the material's functional properties. Usually these changes occur gradually and the properties of the base materials are still easy to recognize.

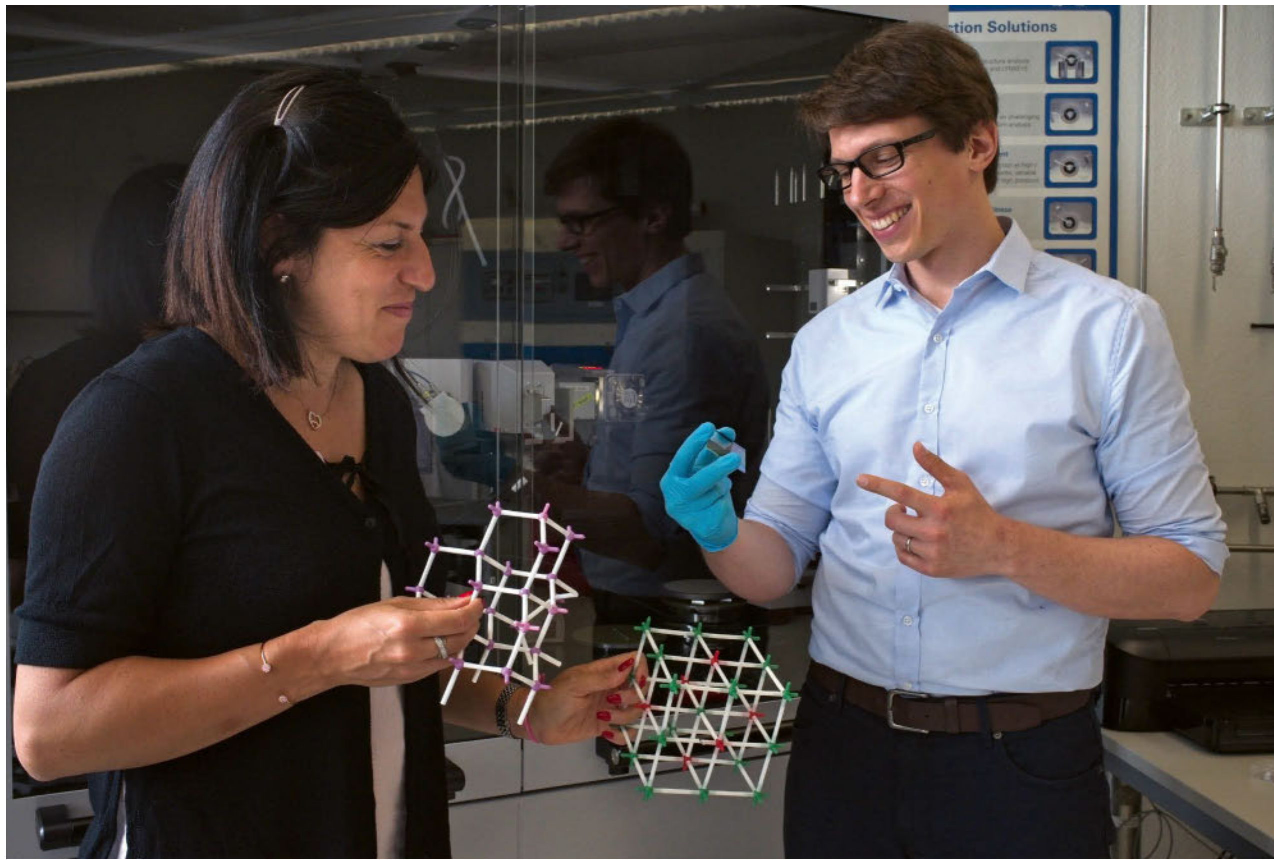
However, if compounds are mixed whose crystal structures do not match at all, "heterostructural alloys" are formed. In these alloys, the structure changes depending on the mixing ratio of the components. Sometimes, this yields surprising properties, which differ remarkably from those of the base materials. It is these very oxide alloys that Empa researcher Sebastian Siol is interested in. He not only wants to discover them, but make them usable for everyday life. In his quest to find the desired material, he has to keep an eye on several materials properties at once, such as the structure, the electronic properties – and the long-term stability.

Siol joined Empa last year. Previously, he conducted research at the National Renewable Energy Research Laboratory (NREL) in Golden, Colorado, where he left behind a notable publication: alloys with "negative pressure". Together with his colleagues, he mixed manganese selenide and manganese telluride using a coldsteam technique (magnetron sputtering). At certain ratios, the base materials merged to form a crystal lattice that was 'uncomfortable' for both components. Neither of the partners could force its favorite crystal structure, which it prefers in a pure state, upon the other.

The resulting compromise was a new phase, which normally would only form at 'negative pressure' – i.e. when the material is permanently exposed to tension. These materials are extremely difficult to produce under normal conditions. Siol and his colleagues at NREL have managed to overcome this difficulty. The new material, now accessible thanks to this method, displays many useful properties. For instance, it is piezoelectric. In other words, it can be used to generate electricity, produce detectors – or conduct semiconductor experiments, which would not have been possible with the pure base materials.

Researching stable systems

At Empa, Siol will bring his experience in making 'impossible' oxide alloys to the table. He aims to discover oxide mixtures with a variable structure and thus stabilize them to such an extent that they become fit for everyday use. The Laboratory for Joining Technologies & Corrosion headed by Lars Jeurgens has plenty of experience in practical applications for stable oxide layers and alloys. The initial focus is on mixed oxides made of titanium and tungsten oxide, which could be of interest for window coatings, semiconductor technology or sensor technology. Siol's colleague Claudia Cancellieri has been researching the electronic properties of oxide interfaces for several years and contributes her expertise to the project.



Claudia Cancellieri and Sebastian Siol study heterostructure alloys. These materials could be just the ticket for intelligent window coatings.

"What we make from these components will often be metastable"

"The material combination is very exciting," explains Siol. Titanium oxides are extremely stable and used in solar cells, wall paints and toothpaste. Tungsten oxides, on the other hand, are comparatively unstable and are used for smart windows, gas sensors or as catalytic converters in petrochemistry. "In the past, research often focused solely on optimizing material properties," says Siol. "It is crucial, however, that the material can be used for several years in the respective field of application." For instance, this would be important for semiconductor coatings in electrochromic windows, which have to last for decades in aggressive environments, exposed to sunlight and temperature fluctuations. The Empa researchers are seeking this longterm stability.

To produce these oxide phases Siol and his colleagues use different industrially scalable techniques: controlled oxidation of thin metal films in a tube furnace or electrolyte solution, as well as reactive sputtering, where the metals are oxidized directly during the deposition process. "Impossible" oxide alloys, the subject of fundamental research until now, are thus gradually becoming tangible for industrial applications. //

Pitted against an invisible opponent: the 19-year-old Chinese Go player Ke Jie ponders his next move against the self-learning software program Alpha Go.

When machines learn

Artificial intelligence will change our lives in the coming years – just as dramatically as the triumphant advance of smartphones. New opportunities are also opening up in materials research. On the following 10 pages you will learn how "machine learning" works and what it can do.

TEXT: Rainer Klose / PICTURE: AFP/STR

Alexa, when is the next train to Paris?" "Siri, what will the weather be like tomorrow?" Artificial intelligence (AI) is part of our everyday lives for quite a while now. Modern computers can make do without precise key entries and are fault-tolerant: They listen and learn to understand us – even if we have just woken up, are chewing gum or the background noise while driving drowns out our voice.

We will encounter self-learning systems ever more frequently in years to come: They steer cars autonomously, provide ever better online translation programs and give consumers of YouTube videos hot tips on what is worth watching next. All by themselves.

The fact that these self-learning systems will soon be able to crack hard nuts, too, is already clear: A team from the Swiss AI Lab (IDSIA) in Manno (Ticino) has succeeded in developing voice recognition for Farsi and character recognition for Chinese, even though nobody in the team can speak either of these languages.

The AI scene is also famous for the victory of computers over humans in the Asian board game Go. The game is considerably more complex and has many more variants than chess – so much so that a pure computer, such as a chess computer, would not be able to win. You have to learn the game.

Which is precisely what the software Alpha Go, developed by Google's Deep Mind research center in London, managed to do March 2016. The machine analyzed 30 million human moves from a database and gained so much experience as a result that it beat Korean world champion Lee Sedol in four out of five games. For the first time in history, a computer had beaten a Go pro.

Better than any human

By October 2017, however, Alpha Go had already met its match: The successor software Alpha Go Zero played without any human instructors, only against itself, after it had been shown the basic rules of the game.

The machine spent three days practicing and, on average, thought about every move for a mere 0.4 seconds. By then Alpha Go Zero had become the best Go player the world has ever seen. In the competition against the previous year's Alpha Go program, the new software won… 100:0. For all this, it only needed a fraction of the computational power of its predecessor and only around four million practice games instead of 30 million. The computer's learning strategy was the key.

Self-learning systems can also be used successfully in materials research, as you can see on the following pages. Empa scientists use them to process the pinpointed chemical modification of wood, blast rocks with electrical charges, solve problems with the power supply and monitor the quality of 3D-printed metallic workpieces while they are being produced. //

Software "Mari/O"
US programmer Seth Bling developed the software MarI/O, which learns and masters the Nintendo game Super Mario World under its own steam. Watch the learning process here.

https://youtu.be/qv6UVOQ0F44

Software "MariFlow"
The software program MariFlow, also by Seth Bling, merely analyzes the screen of the Nintendo game Super Mario Kart and learns to drive around the course with the same strategy as a human player.

https://youtu.be/Ipi40cb_RsI

From computer programs to artificial intelligence

Source for TEXT and GRAFIC: pwc.com/nextintech

How does a machine learn?

Machine learning is probably the term most of us think of when we imagine AI, whether we realize it or not. But it isn't the same as AI, though the terms are often used interchangeably, and machine learning really just refers to a certain way, in which a machine can use large amounts of data to do things we think of as smart.

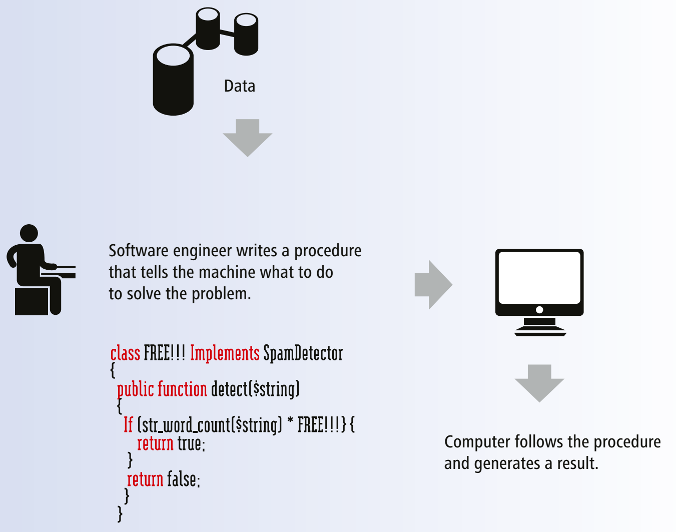
Traditional programming
The intelligence of a basic computer program comes from the programmer who wrote the instructions. It is simply code that a computer runs from start to finish. Whereas with machine learning, a computer is fed data, which is used to train a mathematical model and then produce an outcome, for instance a predictive model.

Supervised learning
A data analyst then verifies the result against more data from the same set. If the machine gets it wrong, adjustments to the model are made and the cycle runs again until the model's results on the training data matches the model's results using the verification data. Once tuned correctly, the machine can then use its predictive modelling on other datasets.

Unsupervised learning
In some instances, computers can teach each other without the need for human intervention. Let's say two computers are given a five dollar note. The first computer tries to reproduce the note, but it does so with different attributes, say initially it produces the right shape, but the wrong color. The second computer assesses this "forgery" against the real note it has, and decides no, these are not the same.
The first computer keeps trying, changing attributes each time until the second computer can't tell the difference between the fake and the real note. In this way the first computer has learnt what makes a note a five dollar note, be it color, shape, content, the number '5' and so on. But no human ever programmed any specific rules to make it understand those facts.

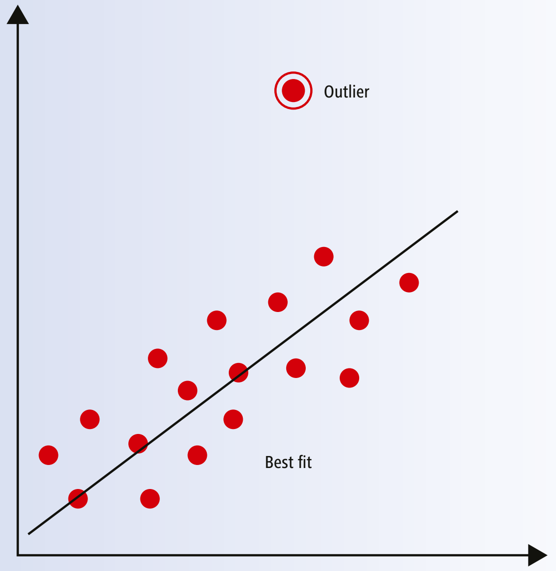
1. Traditional programming

The software engineer writes a program that solves a problem.



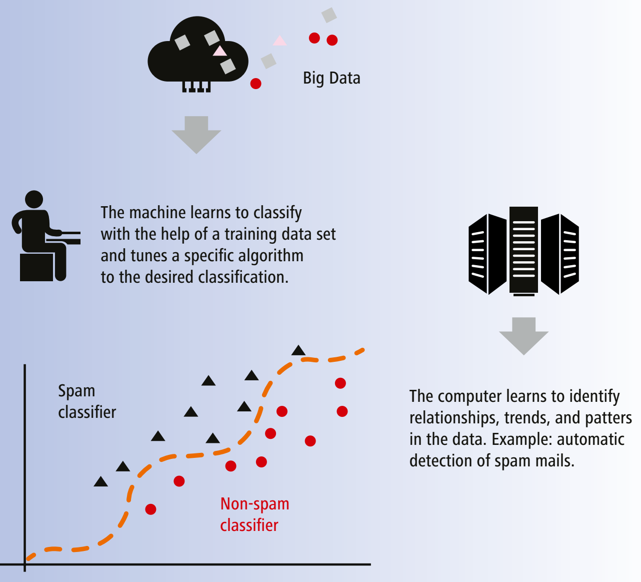
2. Statistics

An analyst compares the relationships of variables.



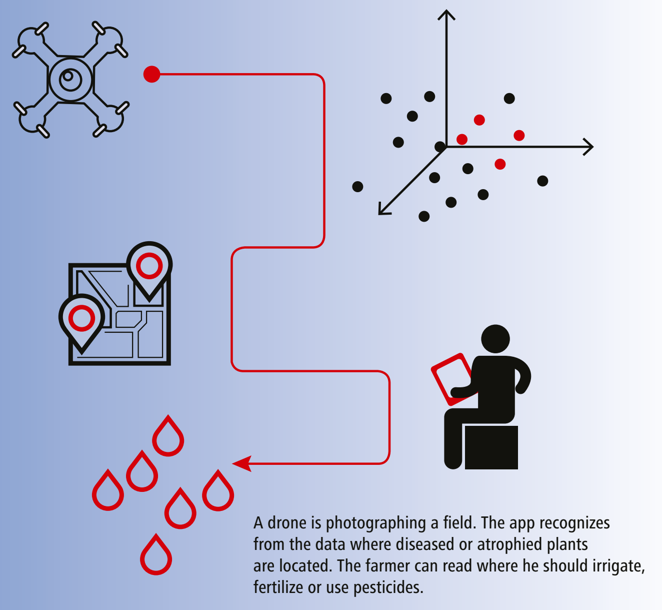
3. Machine learning

A data scientist uses a training data set to teach the computer what to do, and the system carries out the tasks.



4. Intelligent apps

Intelligent apps leverage the outputs of AI, as in this precision farming example that uses drone-based data collection.



Search engine for "smart wood"

Mark Schubert modifies wood properties with the aid of the enzyme laccase. However, the search for suitable ingredients is complex – a bit like trying to find the key to an unknown lock. Instead of long, expensive series of experiments, Schubert uses artificial intelligence as it gets him to the goal more quickly.

Waterproof, electroconductive or magnetic wood can be produced using the enzyme laccase. However, there are different laccases – and they don't all work in every case.

TEXT: Rainer Klose / PICTURE: Thordis Rüggeberg / GRAFIC: Empa

The enzyme laccase is able to alter the chemical structure of wood on its surface and thus facilitate biochemical modifications without changing the structure of the material. By attaching functional molecules, Empa researchers develop waterproof or antimicrobial wood surfaces, for instance. Also it is possible to make adhesive wood fibers, which can be pressed to fiberboards without any chemical binding agents. These solvent-free fiberboards are used for insulation of eco houses.

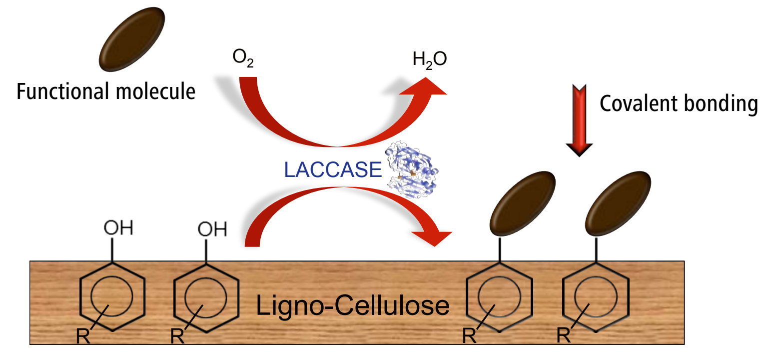
The problem: There are many variants of laccase, which differ in the architecture of the chemically active center, and not all of them react with the desired substrate. As it is extremely difficult to predict whether or not a particular laccase will react with a specific substrate, costly and time-consuming series of experiments are required to identify suitable laccase-substrate pairs. Molecular simulations could solve the problem: You simply need a precise structural analysis of the laccase to simulate the chemical reaction mechanism for every desirable combination on the computer. However, this requires a high computer computing ??? capacity and, even then, would be extremely time-consuming and expensive.

But there is a shortcut: "deep learning." A computer program is trained to recognize patterns with data from the literature and own experiments: Which laccase oxidizes which substrate? What might be the best conditions for the desired chemical process to take place? The best thing about it: The search works even if not all details about the chemical mechanism are known.

Major progress in the last seven years

The availability of the data in a suitable form and the architecture of the deep-learning network are crucial for this to succeed. Schubert has already been working with neuronal networks for over seven years. His first project on the topic stems from 2012, the latest from 2018. "In the past, we worked with shallow neuronal networks: an input layer, a hidden layer and an output layer. Today, we work with considerably more complex networks. They contain several hidden layers and are so much more powerful."

Schubert trains his algorithms with known datasets and tests them with datasets that the system has never seen before. And his reports on the robustness of his "smart wood search engine" are astonishing: In the past, he was only able to use carefully selected, meaningful data to achieve decent results. Meanwhile, he is also testing his systems with partly unusable data piles. The machine recognizes what it can use and what not.



How laccase alters the surface of the wood: A desired molecule is bound to the cellulose in the wood chemically with the aid of the enzyme.

Industrial application of KI

The system's robustness already enables the deep-learning machine to be used by industry. Self-adhesive insulation boards are produced at the partner company Pavatex, which Schubert has been working with for some time. The production process is full of sensors; enormous amounts of data accumulate that tell us "something" about the quality of the manufactured boards. Only what? Schubert's smart wood search engine finds the connection.

The researcher is currently working on optimizing the production in this way. If something goes awry at one point in the fiber processing, the production should be adjusted before the quality of the final product is affected. This saves costly checks on the end product and can slash the error rate in the production process. //

Tough nuts, cracked intelligently

Welding, printing, crushing concrete – an Empa team monitors noisy processes with the help of artificial intelligence. This way you can literally hear production errors and imminent accidents.

TEXT: Rainer Klose / PICTURES: iStockphoto, Colourbox, Heidelberger Druckmaschinen AG, Empa

Kilian Wasmer from the Empa lab for Advanced Materials Processing in Thun keeps shaking his head while speaking, as if he can't believe the success story himself. Together with his team, he recently patented a system to monitor complex production processes, which can be used in a vast range of situations – even though the prospects of this idea initially did not look particularly good at all. "I told our partners that I rated the chances of success at around 5%. But we'd still give it a go," recalls Wasmer about the project's early days.

Lightning strikes on concrete

The aforementioned partner is Selfrag AG from Kerzers near Bern. The company manufactures high-voltage generators, which can pre-weaken or even break concrete using lightning discharges. In contrast to a sledgehammer, which yields sharp-edged lumps of concrete with split pebbles, this method is able to break down concrete into its basic components of gravel, sand and cement – which enables them to be recycled in full, very much along the lines of a circular economy.

What's more, this method could save a lot of money for the mining industry: The precious mineral ores that are only available in small quantities in the quarries could be ground more easily after being exposed to lightning discharges and separated from the gangue – the worthless rock. Until now, however, there has not been a suitable monitoring option to determine whether the lightning has actually hit the concrete lumps or boulders. Wasmer and his team set about developing one such method.

The Empa scientists started bombarding small test pieces made of Plexiglas with high-voltage lightning bolts. The acoustic signature of every lightning bolt was recorded and the corresponding Plexiglas test piece examined for cracks and surface damage under the microscope. Sergey Shevchik, the team's specialist in artificial intelligence, tested a number of different strategies to recognize revealing patterns from the data. Eventually, not only did he succeed in distinguishing successful lightning strikes from misses, but also in spotting surface hits. For the first time, this gave Selfrag an online monitoring possibility for its lightning technology. Beforehand, the "lightning-struck" concrete lumps and boulders had had to be analyzed in a lab for several days.

A group of welding robots makes a metal component for the automotive industry. The quality of the weld can be monitored in real time. With this in mind, Empa researchers developed a system based on optic fibers and AI.

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When bearings seize up and machines die

The Empa team then tackled another complex problem: the scuffing of roller bearings and other moving metal parts in machines that had not been oiled properly. The problem causes considerable damage worldwide. Unfortunately, temperature sensors integrated in vulnerable components only detect a temperature increase once the scuffing has begun and the parts are already ruined.

However, just because something is creaking in a machine does not necessarily mean the machine needs complete revision. Anyone who dismantles and services his or her production machines more frequently than necessary causes unnecessary costs. But those who wait too long run the risk of a moving part scuffing, breaking apart and thus destroying other parts of the machine, which would be disastrous. The goal, therefore, is to hear the "crucial" creak from the cacophony of noises – and to stop the machine just in time before it is damaged.

Wasmer's team allowed a bearing made of hardened steel to rub against a cast-iron base on a tribometer, an instrument for measuring friction, recorded the noises, halted the experiment in different phases and studied the damage under a microscope. Four operating phases could be determined from these tests: firstly, the "running-in" of the parts, during which the surfaces adapt to each other, rough points disappear and the frictional resistance drops. This is followed by a trouble-free operating phase, the "steady state". Then, the friction rises again virtually beyond measure and the first tiny, microscopic damages to the surface occur – this is the "pre-scuffing" phase, the perfect moment to stop and service the machine. If this does not happen, the machine scuffs, spelling a catastrophic end to its operations: The dried-up and locally red-hot surfaces suddenly fuse. Large parts are torn out of the surface and form splinters, which can cause further damage. The component now breaks up rapidly if exposed to further forces.

The Empa researchers even managed to discern the vital clues from this cacophony. They are now able to recognize the jamming with 80% certainty. Even more importantly, however: The crucial pre-scuffing phase can be recognized with 65% certainty – and even predict a few minutes before the catastrophic conclusion comes about. This would be sufficient to halt many industrial machines in time and prevent serious damage.

Quality management in additive manufacturing

Wasmer's latest project is devoted to additive manufacturing (AM) – the production of metallic components made of metal powder, which is melted with a laser beam. This novel manufacturing technique does not use any casting molds and is just the ticket for geometrically complex individual parts. Until today, however, it has been necessary to strictly adhere to the process parameters (e.g. laser power and speed, powder specification etc.) for a particular alloy or application. Any deviation can cause pores, cracks or internal stress in the workpiece, rendering it useless.

The quality control process is also still in its infancy: Manufacturers can use pyrometry or high-resolution cameras to estimate the temperature of the melt surface that the laser creates in the metal powder. What the molten metal looks like deep down inside, however – e.g. whether pores have formed – remains unclear. Another method involves high-resolution images of every lasered powder layer and X-ray images of the final workpiece. However, these methods are time-consuming – and in both cases errors can only be detected afterwards, when material and time have already been spent.

Wasmer and Co. adopted another approach: They combined acoustic sensors with machine learning. Last year, a pilot experiment succeeded in observing the production process in real time on Empa's own ConceptLaser M2 Cusing-type powder bed laser machine. The researchers assembled fiber optic Bragg gating that had been produced in the Empa lab inside the 3D laser printer. The fibers are very sensitive and are able to record acoustic signals. Then, test pieces were produced specifically with different porosities and the acoustic signature of the laser printing process was recorded. For some of the test pieces, the laser passed through the powder too quickly; it failed to fuse completely and pores remained.

For other test pieces, the laser passed through the powder too slowly. The pool with molten metal became too hot and partially evaporated – again, leaving pores in the workpiece. The Empa researchers analyzed the data using an algorithm called SCNN ("Spectral Convolutional Neural Network") and first described in 2016. Using this machine-learning method, they succeeded in distinguishing whether the laser melting process was too hot or too cold with a hit ratio of over 83%. The results were published in Additive Manufacturing in May 2018.

Listening in during laser welding

The researchers are confident that the method can also be applied to things other than laser 3D printers. Other AM techniques such as laser sintering, stereolithography or multi-jet printing are based on similar physical principles. The Empa method for process and quality monitoring in real time could thus be valuable for all these techniques.

Another industrial partner has already benefited from Empa's knowhow: Coherent Switzerland based in Belp has been manufacturing laser sources and tool heads for welding devices for 44 years. Thanks to the Empa results, the company now has a sensor system at its disposal that monitors and documents the welding process optically and acoustically. The data obtained in this way could help optimize future welding processes and maintain the high quality standard that the automotive industry demands from its suppliers.

Strong powers of persuasion required

Kilian Wasmer is visibly proud of "his" researchers from Russia, Iran, Greece, Vietnam, Germany and Switzerland. "If you know how to tackle a problem and have got the right experts on board, you can achieve a lot." However, he is not expecting overnight fame. "The topic we are working on is a very special mixture of complex mathematics, computer science, opto-acoustic sensor technology, laser technology and classic metallurgy. This makes it difficult to write publications that immediately win everyone over – after all, most readers only feel comfortable in one field," he says, adding that some of his publications spent almost a year in the review process.

In order to get their results out faster, the team has now built a demonstrator and installed it in their lab in Thun. The openly accessible machine welds small steel plates and monitors the process in real time. A laptop located two steps away displays what is happening in the laser melt zone. This should help advertise the method.//

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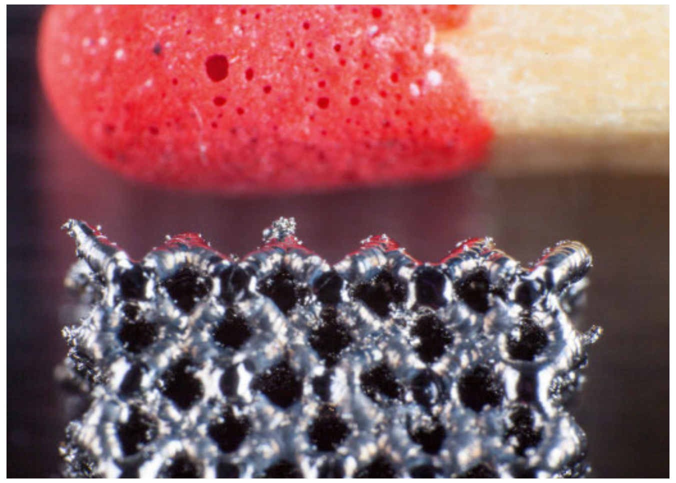

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1
With the aid of high-voltage lightning bolts, concrete can be broken down into its components gravel, sand and cement. The lightning bolts make a noise. AI can be used to assess whether the lightning has hit the target effectively enough.

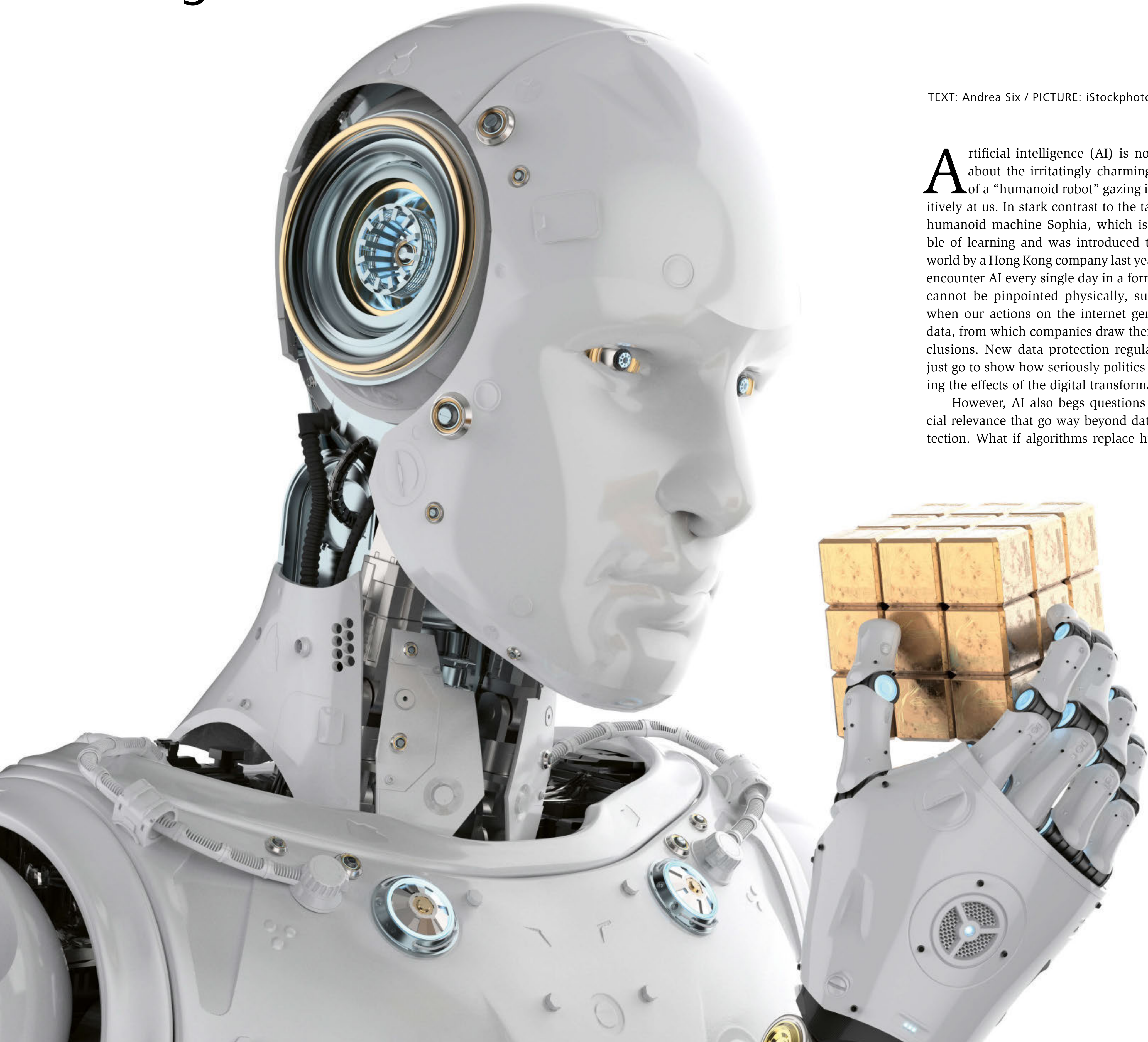
2
A 200-ton offset printing machine makes a considerable amount of noise when running. AI can be used to make out whether the mechanics are still healthy or a revision is required from the complex background noise.

3
Additive Manufacturing enables minuscule metal structures with a complex geometry to be produced. Here is a test piece compared with a match head. Using AI to monitor the manufacturing process acoustically guarantees that the workpiece is devoid of any interior defects.

The pros and cons of artificial intelligence

AI is set to trigger a major transformation in society. As soon as algorithms influence our voting habits or design school curricula, it is up to politics to limit the damage. A new study on the opportunities and risks of AI is now being conducted on behalf of TA-Swiss.

TEXT: Andrea Six / PICTURE: iStockphoto



Artificial intelligence (AI) is not just about the irritatingly charming face of a "humanoid robot" gazing inquisitively at us. In stark contrast to the talking, humanoid machine Sophia, which is capable of learning and was introduced to the world by a Hong Kong company last year, we encounter AI every single day in a form that cannot be pinpointed physically, such as when our actions on the internet generate data, from which companies draw their conclusions. New data protection regulations just go to show how seriously politics is taking the effects of the digital transformation.

However, AI also begs questions of social relevance that go way beyond data protection. What if algorithms replace human decisions, trade on the stock exchange or influence voter habits? That's why the Swiss Center for Technological Assessment (TA-Swiss) recently commissioned three research institutes to study the new challenges. Until 2019 a team at Empa is compiling specific action recommendations for Swiss politics and industry in this extremely dynamic field. The Digital Society Initiative at the University of Zurich (UZH) and the Institute of Technology Assessment of the Austrian Academy of Sciences (ÖAW) are also on board as project partners.

"We are currently examining the opportunities and risks for innovations, research and education that are associated with AI," says Clemens Mader from Empa's Technology and Society lab in St. Gallen, who is involved in the project along with Claudia Som and Lorenz Hilty. Scientists from UZH and ÖAW are also working on the areas of consumption, media, work and administration. Moreover, every sub-section will also be scrutinized in terms of ethical and legal aspects.

As soon as initial results are available, the researchers will study the fields of application in more depth and across disciplines in a dialog with national and international stakeholders. "This will enable us to piece together a picture of socially relevant topics from all necessary angles as opposed to assessing them inside a bubble of individual researchers and disciplines," explains Mader.

One of the tasks facing the scientists is now to study possible applications of AI in scientific research and as a driver for innovation. "The use of learning algorithms should be discussed where large data quantities accumulate and the analysis of complex correlations is promising, for instance," says the researcher. This is obviously the case when analyzing weather or traffic data. However, the use of AI-based processes could also be beneficial for industrial applications.

Moreover, socially relevant issues are also to be addressed. How can a society be prepared to refine the field of AI critically and use it confidently? "This is where the education sector comes in," says Mader. "It creates the researchers of the future – all the way from kindergarten to university."

With this in mind, pilot projects for the school sector that already use AI applications, e.g. at a school in Silicon Valley, are being examined. Here, students learn with tablets and their learning behavior is observed by AI software. The programs offer suggestions as to how the children ought to be supported individually. "If the computer decides on the curriculum for school children, we must bear in mind that personal rights, data protection and even societal developments are also affected here," says the researcher.

The worry that computers might not only be useful but also pose a risk for a society – all the way to a transformation in our understanding of democracy – is nothing new. The current study, however, seizes upon the topic precisely now as today's devices have become incomparably powerful and thus the possibilities of machine analyses and learning progress are increasing. "If AI applications collect and evaluate enormous amounts of data, this will change many areas of our everyday lives, way beyond sectors like online shopping," says Mader. This needs to be set in a political framework to handle risks, but also be in a position to exploit the innovative potential of AI.//

“move” through to the next round

Around two years ago, Empa opened “move”, the future mobility demonstrator. Initially, the research focused on the efficient production of hydrogen and refueling the test vehicles. The next phase will be centered around converting hydrogen and CO_2 into synthetic methane.

TEXT: Stephan Kälin / PICTURES: Empa

The demonstration platform “move” enables Empa researchers to develop automotive powertrains with lower CO_2 emissions. Surplus electricity serves as the energy source.

Fossil energy has expedited the economic and social development of the western world in the last 50 years, from which Switzerland has also greatly benefited. But it has also led us to energy dependencies, polluted the air and accentuated climate change. The mobility demonstrator “move” on Empa’s campus in Dübendorf should now reveal how these dark sides of mobility can be turned into opportunities by processing unusable renewable electricity on the power market into local, clean energy and making it usable for the mobility sector.

One of the “customers” at the hydrogen refueling station is the fuel cell street sweeper “hy.muve II”. It was developed at Empa and is currently being used by the City of Dübendorf.

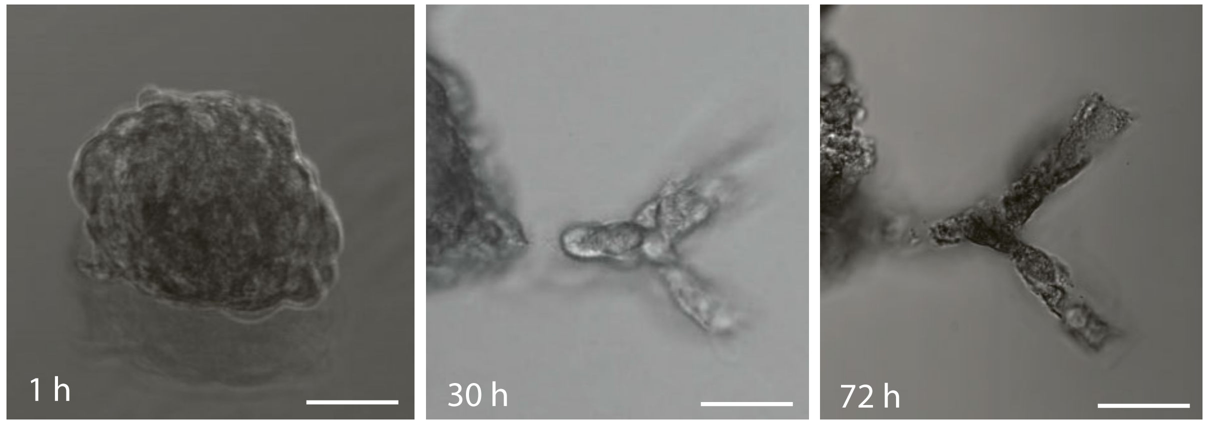
A lot of excess solar power

For Switzerland, the conversion to renewable energy primarily means the expansion of photo-voltaic plants. However, these mainly produce electricity in the summertime, when the majority of the country’s electricity demand can already be covered with hydro-power. As our neighboring countries are investing in the same technology, it may therefore become increasingly difficult to break even on the European market with electricity from photovoltaic and hydroelectric power stations – which may in turn have a negative economic impact on the expansion of photovoltaics.

“move” provides a prime example of how excess electricity can be transferred in the summer-time and used as a replacement for fossil fuels. For instance, the temporary excess electricity can be stored in a battery during the daytime to charge electric vehicles at night. Or it might be used in an electrolysis plant to produce hydrogen. The gaseous hydrogen is then condensed to 440 bar and can either be used directly in fuel cell vehicles or as an admixture for biogas in gas vehicles that have been technically optimized.

Meanwhile, the second phase has been launched, which enables the compression of the locally generated hydrogen to 900 bar and the refueling of fuel cell cars in a matter of minutes. The third expansion phase is currently in the pipeline. Together with CO_2 from the atmosphere, hydrogen is to be converted into synthetic methane (CH_4), which can be stored in the gas network and used to power gas vehicles. In order to increase the efficiency, a novel waste heat usage concept is being developed and realized. //

Signposts for cells



Using the principle of lithography, an infrared laser writes precise structures into the matrix. The cells grow according to the specified plan. This opens new possibilities for the generation of three-dimensional microtissues.

For the replacement of animal testing with alternatives in medical research, complex microtissues need to be cultivated. Researchers from Empa have developed a special polymer scaffold for three-dimensional cell cultures. Light beams act as signposts for the cells.

TEXT: Andrea Six / PICTURE: Empa

In pharmaceutical research, scientists try to do without animal testing wherever possible or replace it with experiments on cell or tissue cultures. Growing highly complex three-dimensional structures made of cells, however, still poses problems for researchers. A team at Empa has now developed a kind of scaffold, in which cells can spread, multiply and interconnect. The innovative aspect about the new matrix: The precision of the desired form and function is controlled by light.

The new material consists of a gel, for which a light-sensitive mechanism can be used to incorporate a large number of functional groups into its polymer structure. "This means that signals can be attached to the polymer backbone, which enable ingrowing cells to 'anchor' themselves within the scaffold," explains Empa researcher Markus Rottmar from the Laboratory for Biointerfaces in St. Gallen. Other groups in this "hydrogel" carry docking points for enzymes, which the cells can use to tailor the synthetic scaffold to their needs. Another advantage: The hydrogel is extremely well tolerable from a biological point of view and offers the cells a specific environment to grow into a three-dimensional structure.

The form of the scaffold needs to be controllable right down to the very last detail if it is to produce a functional tissue. Irradiating it briefly with UV light initially causes the polymer hydrogel to polymerize before a laser puts on the finishing touches: Based on the principle of lithography, the infrared laser writes a precise structural design in the matrix and incorporates components with different functions in the scaffold. "The cells grow based on the prescribed plan and form an initial network," says project leader Katharina Maniura. In a matter of hours, the cells begin to dissolve and reshape the scaffold in these specific positions. According to Maniura, this makes it considerably easier to cultivate complex, three-dimensional microtissues.

Alternative to animal testing

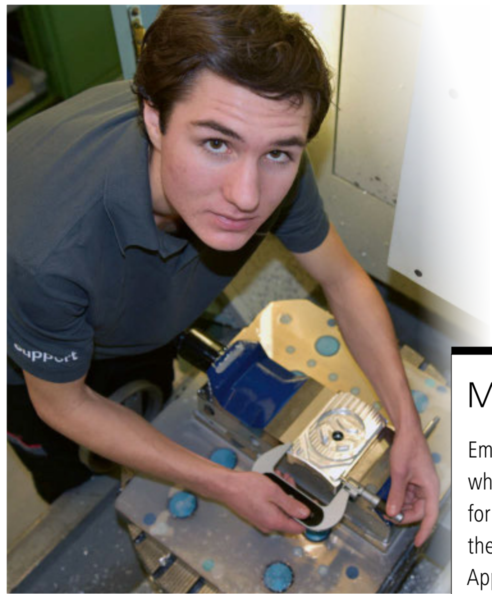
Not only is the hydrogel ideal as a facilitator to develop alternatives to animal testing; investigating diseases and improving our understanding of cell growth are also among the fields of application for the novel material. //

World's largest electric truck

The eDumper dump truck is the largest electric vehicle in the world and is in operation in a quarry in Péry in the Bernese Jura since April. Together with industry partners, the Bern University of Applied Sciences BFH, the NTB Interstaatliche Hochschule für Technik Buchs and Empa have developed this eco-friendly truck.

The electric dump truck designed over the past 18 months is an example of successful applied research in Switzerland. This interdisciplinary cooperation has set three world records. The eDumper is the largest and most powerful battery-powered electric wheeled vehicle in the world. For this purpose, the largest battery ever produced for an electric vehicle was installed, which weighs 4.5 tons and is as heavy as two complete passenger cars. Never before has a comparable vehicle been able to save such a large amount of CO_2. The eDumper will transport more than 300,000 tons of rock per year over the next 10 years amd will save up to 1,300 tons of CO_2 and 500,000 litres of diesel during its lifetime.

During the fully loaded descent, the batteries are charged by recuperation of braking energy. According to preliminary calculations, the electricity generated in this way is largely sufficient for the empty return journey uphill to the mining area. Thus, the vehicle would be a zero-energy vehicle.



Moritz is milling for the title

Empa polymechanic apprentice Moritz Koster has qualified for the SwissSkills championship, which takes place in Bern from 12 to 15 September. Empa is keeping its fingers tightly crossed for Moritz who is working at the Empa site in St. Gallen. You can find out what happened in the competition on the website www.swiss-skills.ch from 15 September.

Apprenticeship championships, both national and international, are yardsticks for the high standard of vocational training in Switzerland. The SwissSkills Foundation is funded by the Swiss government, the cantons, schools and organizations from the world of work. It coordinates the national championships in over 70 professions and has been enabling budding professionals to enter international apprenticeship championships since 1953.

Tage der Technik

Smart Future – wie Digitalisierung unser Leben verändert

Hauptveranstaltung am Donnerstag, 4. Oktober 2018
Empa-Akademie, Dübendorf

Die digitale Transformation verändert unser Leben und unsere Umwelt in rasantem Tempo. Dank ihr bieten sich uns bis vor kurzem undenkbare neue Möglichkeiten, sie fordert aber auch alle Unternehmungen und jeden Menschen heraus. Anpassungsfähigkeit und Innovationskraft sind gefragt, um die sich bietenden Chancen zu nutzen und auf die Veränderungen angemessen zu reagieren. Wer diesen Wandel aktiv mitgeht, kann von der Digitalisierung profitieren – die anderen werden ins Hintertreffen geraten.

Die Hauptveranstaltung der Tage der Technik 2018 greift die vielschichtige Thematik der Digitalisierung auf und beleuchtet sie aus den verschiedenen Blickwinkeln von Wissenschaft, Technik und Gesellschaft. 5 Themen werden speziell hervorgehoben: Smart Living, Smart Security, Smart Mobility, Smart Working und Smart Society.

Die Veranstaltung ist öffentlich und kostenlos. Anmeldung bis spätestens Freitag, 28. September 2018 unter **www.tage-der-technik.ch.**

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24. August 2018

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Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/rfabauen
Empa, Dübendorf

05. September 2018

Kurs: Hightech-Keramiken
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/ht-keramik
Empa, Dübendorf

04. Oktober 2018

Tage der Technik
Smart Future – wie Digitalisierung unser Leben verändert
Zielpublikum: Öffentlichkeit
www.tage-der-technik.ch
Empa, Dübendorf

10. Oktober 2018

Kurs: Klebetechnik für Praktiker
Zielpublikum: Industrie und Wirtschaft
www.empa-akademie.ch/klebetechnik
Empa, Dübendorf

17. Oktober 2018

Kurs: Materialbearbeitung mit Laser
Zielpublikum: Industrie und Wirtschaft
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