

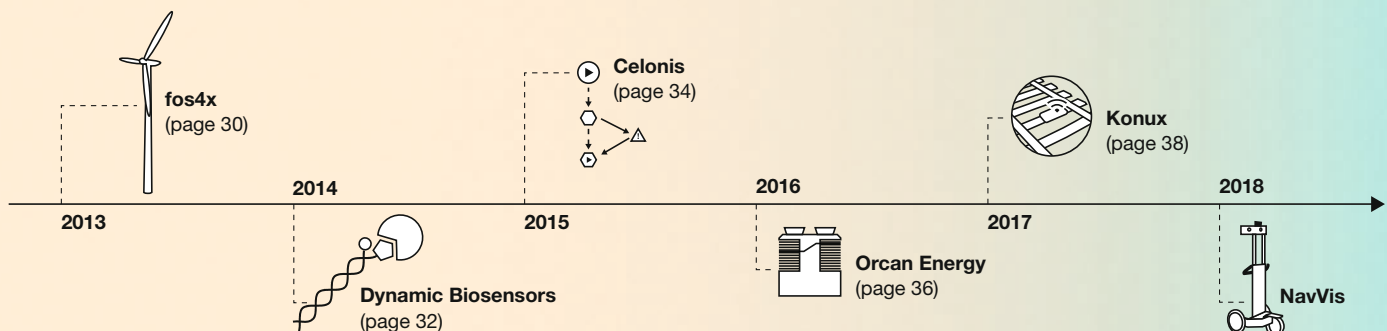
Presidential Entrepreneurship Award Recognition and Inspiration

The annual TUM Entrepreneurship Day invites visitors to experience the entrepreneurial spirit of the Technical University of Munich. This year, they were able to participate in the rapid prototyping workshop, watch TUM startup pitches, get in touch with TUM startups, and get the low-down on startup support.

A highlight of the event is the announcement of the Presidential Entrepreneurship Award. This EUR 10,000 prize is bestowed by the President of TUM to honor an outstanding spin-off with a largely research-based business idea.

“Young people are the ones keen to try new things, taking risks to turn their ideas into useful products, processes and services,” says TUM President Wolfgang A. Herrmann. “We want to encourage their entrepreneurial spirit, in keeping with the philosophy of our entrepreneurial university.”

On the following pages, Faszination Forschung presents the winners of this award since its introduction in 2013. They have all gone on to become success stories. Celonis, for instance, the winner of the 2015 award, has become one of Germany’s most successful startups. A new round of investment this summer means the company is now worth more than one billion dollars. The varied range of products, processes and services showcased here reflects the diversity of TUM.



The winner of the 2018 Presidential Entrepreneurship Award is NavVis, which develops applications for highly accurate mapmaking and navigation in interior spaces. Founded in 2013 with the support of TUM and UnternehmerTUM, the company currently has approximately 140 employees working on its innovative digitalization project in Munich and New York. NavVis helps smartphone users to find their way around complex buildings such as plant halls, convention centers, airports, train stations and shopping malls. It also makes it possible to experience entire exhibitions online. To do this, the company digitalizes indoor spaces using mobile trolleys equipped with a variety of cameras. The footage is used to create photo-realistic 3D maps of buildings. This data is supplemented with a navigation system and interactive, location-specific services.

The technology for a camera-based navigation system was developed by Georg Schroth, later one of the company's founders, during his doctoral studies at the TUM Chair for Media Technology. The first to join the subsequent research project were PhD students Sebastian Hilsenbeck and Robert Huitl, followed by Economics PhD graduate Felix Reinshagen. The four men founded NavVis in 2013 with the support of TUM and UnternehmerTUM – the Center for Innovation and Business Creation – benefiting from services such as the KICKSTART startup program.

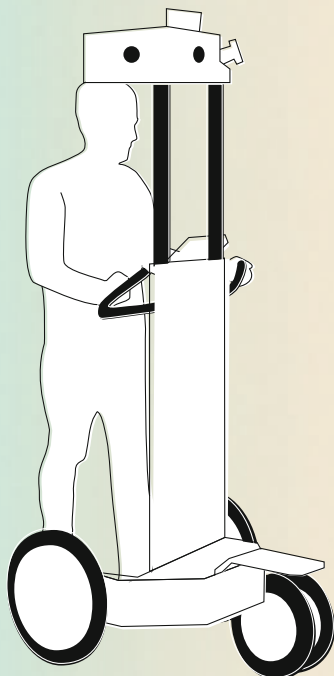
In addition to basic research and startup consulting, TUM also played a major role in many of the technical development steps. Thus, for example, the trolley prototypes and the company's corporate design were created in collaboration with the Chair for Industrial Design (see article on page 84).

Evdoxia Tsakiridou



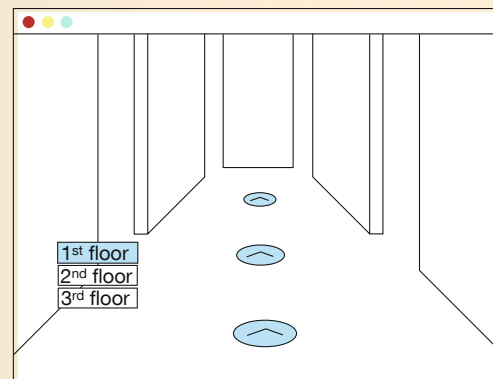
TUM Presidential Entrepreneurship Award 2018 for NavVis. The photo shows the team (from left to right): Dr. Felix Reinshagen, Robert Huitl, Dr. Georg Schroth and Sebastian Hilsenbeck.

All-in-one mobile scanning
captures 360° images



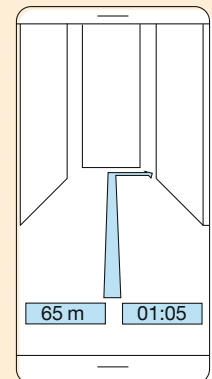
Indoor viewer

Explore the indoors with a fully immersive 3D walkthrough



Mobile app

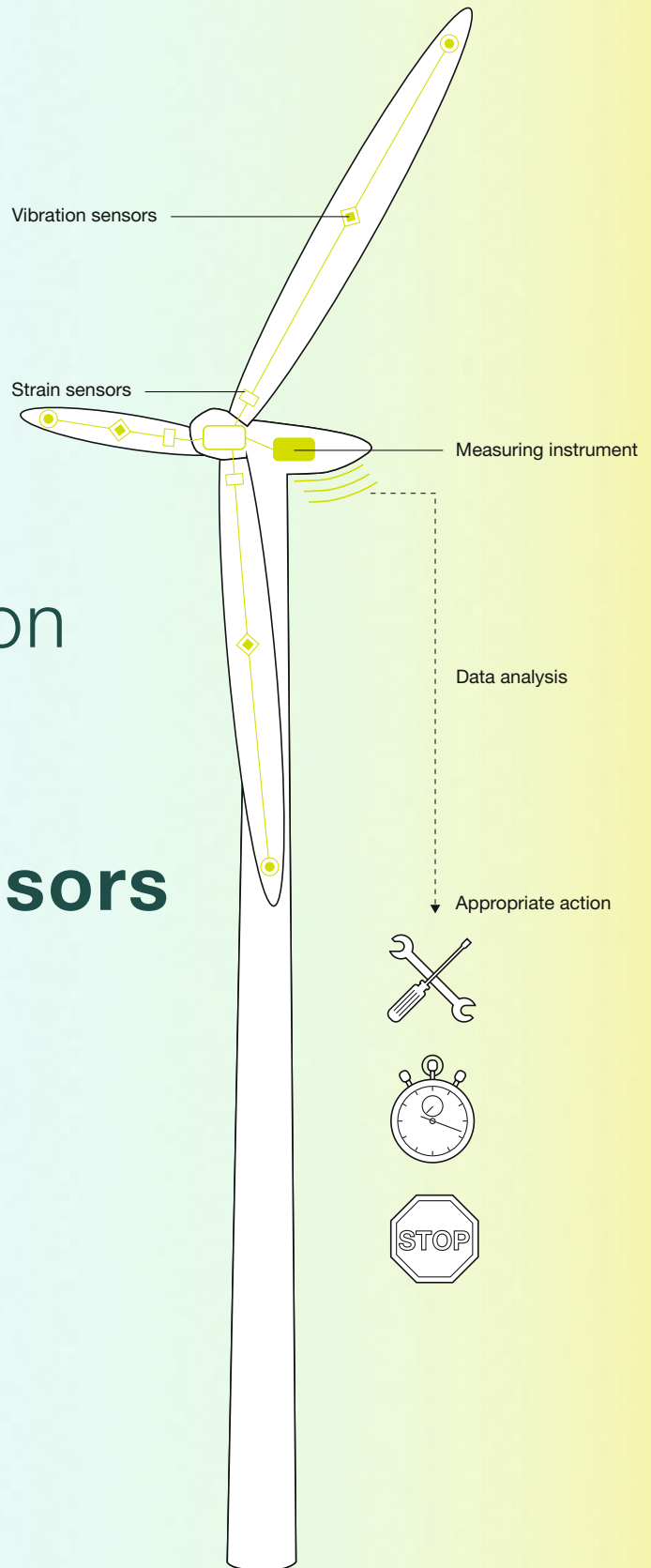
Indoor navigation and routing



Gleaning information from rotor blades

Optimizing wind turbines with sensors and smart apps

Sensors have made their way into just about every conceivable industrial system. Up until a few years ago, however, they were not to be found in wind turbines. That changed in 2010 when TUM startup fos4X developed sensors specifically for turbine rotor blades that are exposed to exceptional levels of stress.



Sensors record physical parameters directly on the rotor blades, with a control unit turning the blade out of the wind or stopping the system in case of overload.

The company's name stands for "fiber-optic sensors for x applications". Although the "x" had admittedly shrunk by the time the four founders left the TUM family in 2012 to move into their new offices and production facilities in Sendling, in the south of Munich.

Alongside the electromobility and rail sectors, wind energy was a promising market. The high-tech firm developed a modular sensor platform to track the physical performance indicators of industrial facilities. Smart apps then use these data to optimize the performance of wind turbines or wind farms.

Fewer failures and increased annual yield

Manufacturers and operators are looking to this technology not just to avoid failures and downtime, but also to increase annual yield and prolong the service life of their equipment. Factors like the bending and vibration stresses that rotor blades are exposed to play a key role here. Load alternations, lightning strikes, ice formation and other stresses can all have the effect of shortening service life.

The sensor platform from fos4X consists of fiber-optic strain and vibration sensors along with a measuring instrument to read out the recorded data. The sensors are integrated in the rotor blades and connected to corresponding measuring instruments. The latter convert optical input signals into electrical output values. Strain sensors record information like material changes. In the event of an overload, a control unit steers the blade away from the wind. The system is not only able to detect structural damage to the blades, it also works out a precise preventive maintenance schedule to avoid damage.

The vibration sensors, on the other hand, measure the natural frequency of the material. The formation of ice causes this value to change. A specially developed software solution is able to determine the weight of the layer of ice. If the load is too high, the control unit stops the turbine for the time it takes the rotor blade heating system to melt the ice. The sensor system detects the change and automatically restarts the wind turbine.

Freedom to develop ideas

Lars Hoffmann is one of the co-founders of the company. Along with his peers, he was already zoning in on sensors at TUM's Institute for Measurement Systems and Sensor Technology. After obtaining his doctorate, the metrology specialist spent some time working for a consultancy firm before reuniting with his team to create the startup. The EXIST funding program also provided support for fos4X. Hoffmann is still full of gratitude to TUM for "giving us rooms, exclusive rights of use for patents and above all plenty of freedom to develop our ideas". Being singled out for the Presidential Entrepreneurship Award means a lot to him: "All five of the previous winners are successful young enterprises, so the selection process is a reliable indicator of things to come."

The other three founders have left fos4X in the meantime to pursue different projects. Since their departure, the company's workforce has grown to 70 employees and it is cooperating with nine of the top ten manufacturers of wind turbines. From its base in Munich, the company supports customers in Europe, North America and China. *Evdoxia Tsakiridou*



Lars Hoffmann is a co-founder of fos4X. After completing his doctorate, the metrology specialist worked as a consultant prior to starting his own venture.

Swaying to and fro on a biochip **Optical sensor technology measures the dynamics of proteins**



Dr. Ulrich Rant examines a biochip in a Petri dish. His company develops measuring instruments that use these chips to analyze biomolecules.

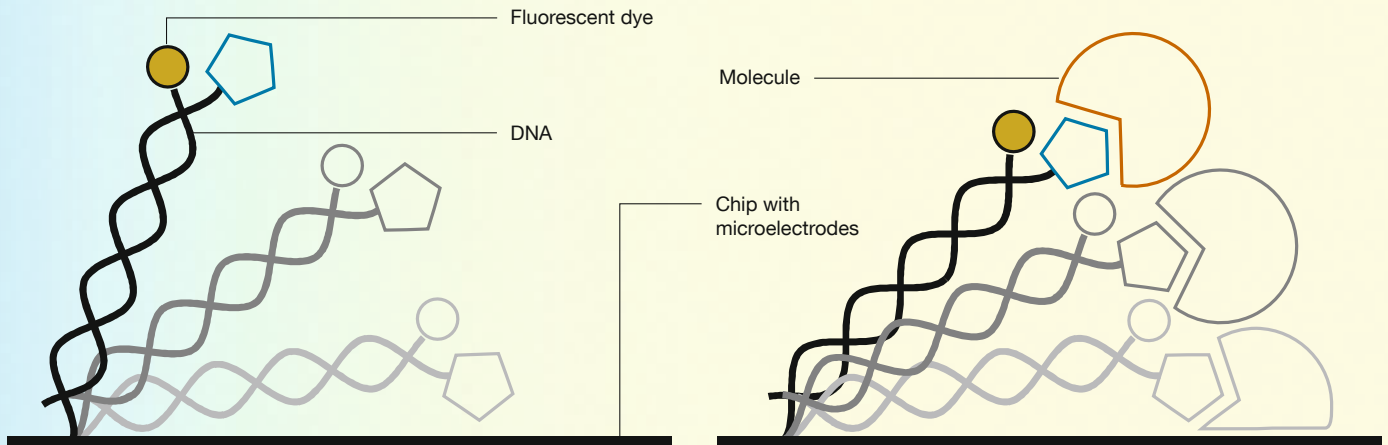
“Our measuring instruments fulfill two functions at the same time: They are able to analyze the bonding behavior of molecules, while also detecting conformational changes. The conformation of proteins is important for their function,” explains Ulrich Rant, CEO of tech firm Dynamic Biosensors (DBS).

Some of his customers are from the pharmaceuticals sector and they use DBS measuring instruments to develop new drugs. Then there are the universities and research institutes who are interested, for example, in determining the size of proteins, measuring the strength of bonds or studying conformational changes.

DNA acting as sensor

An important role is played here by genetic material, or more precisely nanometer-long bits of DNA acting as sensors. These sensors lie on a chip with microelectrodes and they sway from side to side when AC voltage is applied. If proteins are located on the sensors, the vibrations change. Similar to elastic rods, lightweight specimens oscillate at a faster rate than heavy ones.

The optical method used to visualize the molecular movements is based on fluorescent dyes. The luminous intensity of the light molecules varies depending on the movements of the DNA segments. This effect, which is visible under a micro-



Optical sensor technology is used to measure the dynamics of molecules, with nanometer-long DNA fragments acting as sensors. Placed on a chip with microelectrodes, these sway from side to side when AC voltage is applied.

If molecules are located on the sensors, the vibrations change, with light-weight specimens oscillating faster. Fluorescent dye renders these movements visible.

scope, can be amplified and analyzed. The patented process from DBS not only allows the molecular properties of proteins, receptors, antibodies or drugs to be measured, it also lets researchers study the interactions between proteins, nucleic acids or other molecular compounds and determine their chemical and thermal stability.

Ample research freedom

The origins of Dynamic Biosensors date back to 2013 when it was spun off from the Walter Schottky Institute, TUM's central institute for semiconductor electronics. "We felt a bit like outsiders there because of our focus on biotechnology. All the same, we received amazing support from Prof. Gerhard Abstreiter's Chair and from TUM," recalls Ulrich Rant, who holds a PhD in physics. The provision of rooms and laboratory facilities, help in preparing research proposals, seamless cooperation between departments and ample research freedom gave the young company the best possible start on the road to success.

The TUM startup received financial support from the EXIST funding program of Germany's Federal Economics Ministry and the GO-Bio initiative of the Federal Ministry of Education and Research. It has also been singled out for a couple of awards, including the TUM Presidential Entrepreneurship Award (2014). The company invested its prize money directly into laboratory equipment. A further distinction followed in 2015 with the German Innovation Award.

Dynamic Biosensors GmbH has been based in Martinsried near Munich since 2013, the year when a 10-strong core team brought the first measurement system to the market. The second version followed three years later. Today, the company has 50 employees based at several locations across Europe and, since 2017, also in the USA (San Diego, California). Four of the company's five founders are still on board and they now have their sights set on the Asian market. *Evdoxia Tsakiridou*



Martin Klenk, Bastian Nominacher and Alexander Rinke (from left to right) want their startup Celonis to become a global software company.

X-ray view of process data Software to analyze process bottlenecks and highlight savings potential

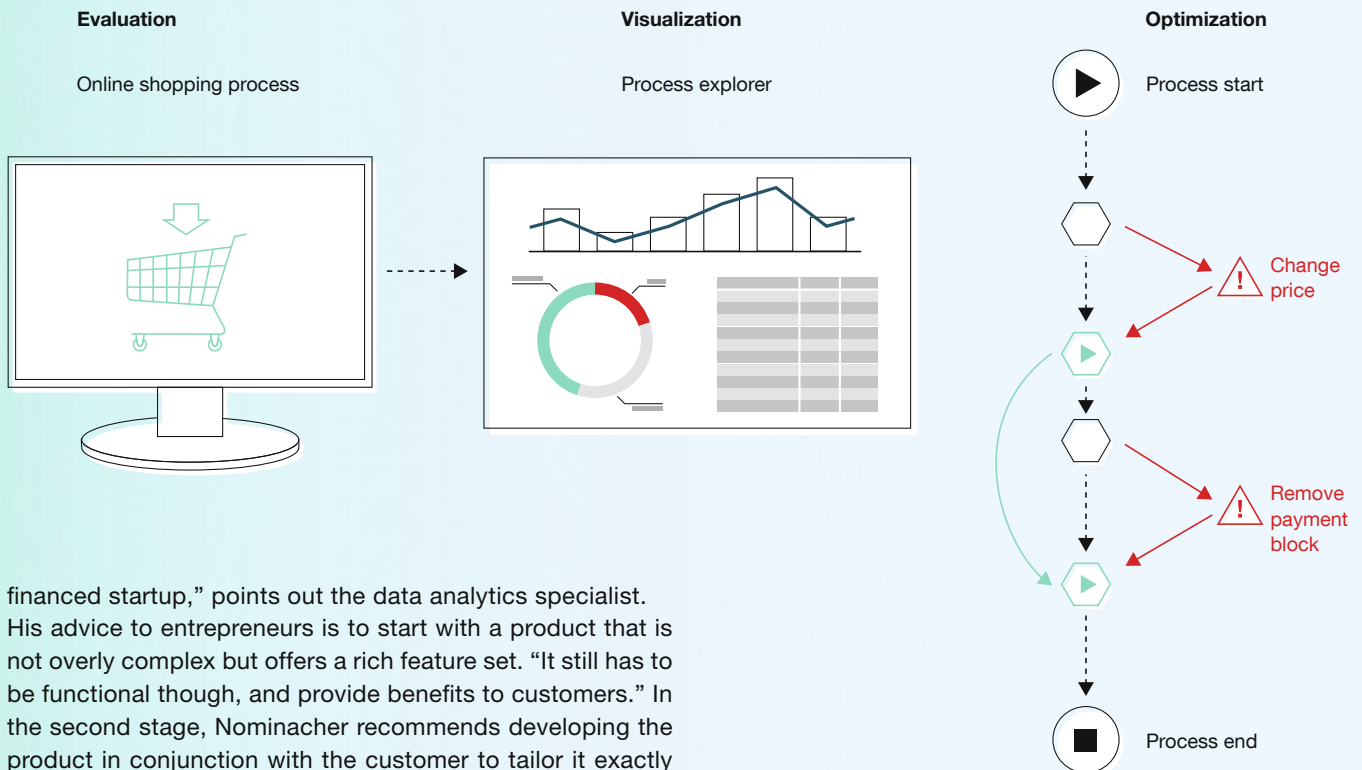
How can processes that are supported by IT systems become more transparent and efficient? What optimization measures have the potential to cut costs? Celonis developed its process mining technology to answer these questions. The company's software analyzes and visualizes process data in real time.

The analogy of mining – extracting valuable coal from underground – is highly apt. What Celonis does is help companies extract an equally valuable resource: data. A business process – such as purchasing – is analyzed from start to finish, extending from the prep stage through ordering to actual payment. The output visualizes where bottlenecks occur and where workarounds or redundancies can be eliminated.

Gain insights

“Machines have become completely autonomous in many sectors. This fact alone creates a stream of extremely valuable data which businesses can use to gain insights and develop innovative way of conducting their business. The underlying potential is huge: Processes can be accelerated and associated manual effort avoided. The scope for savings can be identified at first glance,” maintains founder Bastian Nominacher, who got to know his two co-founders Martin Klenk and Alexander Rinke at the Academy Consult München e.V. student consulting service.

The trio, who were TUM students at the time, developed the data analytics technology on the basis of their research findings. The foundation of Celonis in 2011 was supported by TUM with workstations and a dedicated mentor. Further support was provided by TUM's startup consultation service. “This interaction was very valuable for us – there is no doubt that it put us on the fast track. We were also very grateful for the financial assistance we received from the EXIST startup grant. We are nevertheless proud to be a completely self-



financed startup,” points out the data analytics specialist. His advice to entrepreneurs is to start with a product that is not overly complex but offers a rich feature set. “It still has to be functional though, and provide benefits to customers.” In the second stage, Nominacher recommends developing the product in conjunction with the customer to tailor it exactly to their needs and wishes. This is a time- and cost-saving exercise for entrepreneurs, and it minimizes the risk of off-track development.

From an entrepreneur to a manager

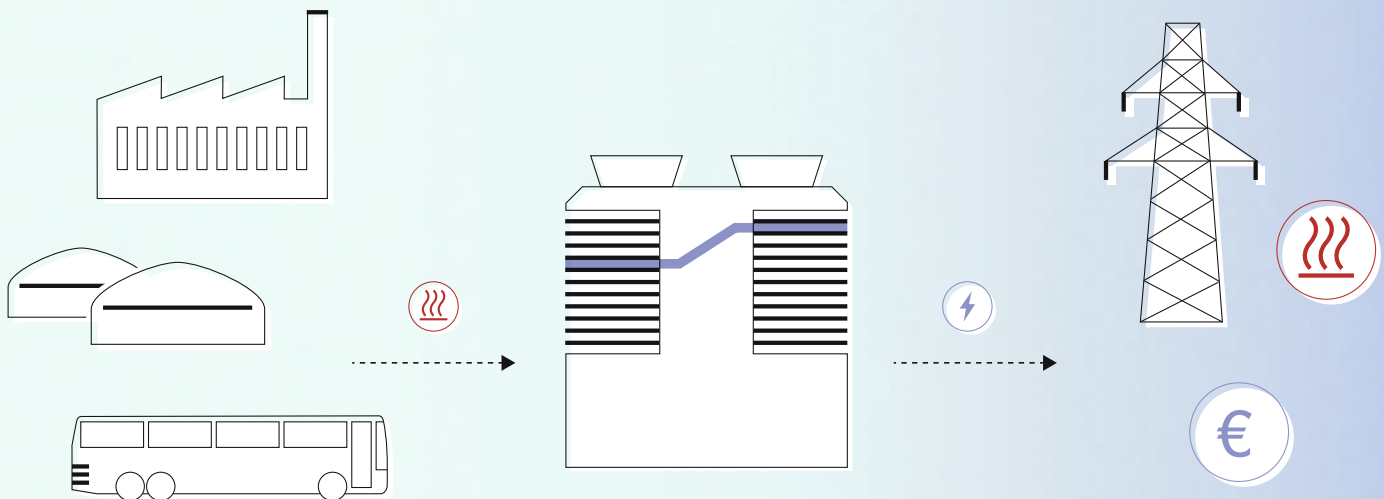
The 33-year-old has another recommendation to share: “As an entrepreneur, you have to learn to loosen the reins and to delegate. Make yourself less of a focal point or you will end up in a bottleneck and throttle your own success. The more the company grows, the harder it becomes to maintain an overview of all processes. That is not scalable in the long run. Your role has to evolve from an entrepreneur to a manager.” Today, the startup ranks as one of Germany’s fastest growing companies (Deloitte Fast 50), and a market leader in process mining, as recently recognized by a Gartner Market Study. In June 2018 Celonis raised \$50 million in Series B funding, which values the company at \$1 billion. “We intend to build on this position and also enlarge the market we are operating in. Our goal is not just to become a global software company, but also to reach the 1,000-employee milestone by 2020,” say the Celonis founders.

Evdoxía Tsakiridou

Process mining is about understanding and optimizing business processes and can easily visualize a broad variety of different processes. One example is Purchase-to-Pay: This process involves a high number of transactions; at the same time, approvals, timelines and many different procedures, requests, suppliers and their conditions drive complexity. Process mining helps procurement organizations to bring full transparency and more efficiency to their processes: It is possible to find and eliminate inefficiencies and faults in the transactional process and check for compliance and supplier performance in real time. Flexible insights allow users to increase and monitor automation rates and minimize interruptions caused by manual changes and rework activities. Dealing with purchasing processes, it is particularly interesting to compare throughput times of different parts of the process. The process explorer allows throughput times to be displayed directly in the process graph. This way, bottlenecks are easily spotted and eliminated.

Recovering energy from waste heat

Mini power plant converts waste heat to electricity



Orcan Energy's mini power plant uses waste heat from industrial plants, biogas facilities and engines to generate CO₂-free power. Thanks to innovative control and regulation technology, waste heat sources with rapidly fluctuating temperatures can be harnessed efficiently even at frequent partial-load operation.



Orcan Energy aims to establish its second-generation ORC technology as a global standard. Dr. Andreas Sichert, one of the company's founders, feels they are on the right track.

“We have developed the second generation of ORC technology,” declares Andreas Sichert, one of the three founders of Orcan Energy AG. The abbreviation ORC, which is also part of the company’s name, stands for Organic Rankine Cycle. The innovation lies in shrinking the steam turbine technology by up to three orders of magnitude and delivering a standard plug-and-play product.

Instead of steam, the miniature power plant is driven by an organic fluid. It is designed for low-temperature operation from 60 °C and can generate up to 100 kilowatts of electricity. This means it can harness waste heat from industrial plants, power generation (biogas plants) or transport (ship engines) to generate not only greener but also more efficient electricity.

The cost squeeze

The miniaturized design was inspired by cost pressures. Steam power plant components are expensive. So when the three founders, Sichert and his colleagues Dr. Andreas Schuster and Richard Aumann, set out on their development journey in 2004, they quickly discovered that necessity is the mother of invention. The technology developed at TUM's Institute for Energy Systems reduces the head height of pumps from several meters to a few centimeters. “Every mistake we made during the development process helped us improve the product,” points out the 36-year-old.

The company was spun off in 2008. “It took us three years to raise the investment capital for our startup. We were lucky enough to receive support along the way, however, including from the EXIST Transfer of Research program and from UnternehmerTUM. Top executives from major companies and successful entrepreneurs also provided us with advice and helped us find an investor. We learned that asking for help really pays off,” stresses the doctor of physics.

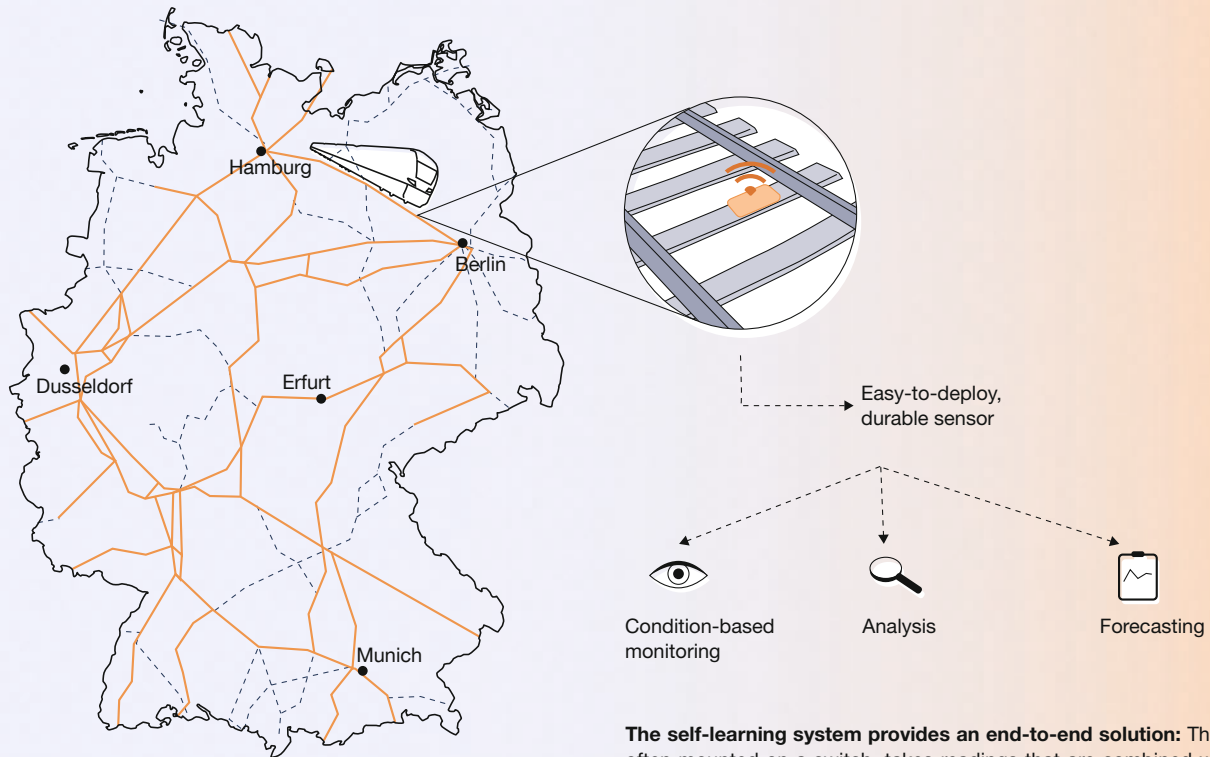
140 patents filed

With support from TUM's patent and licensing office and Bayerische Patentallianz, Orcan's founders were able to file a patent for their first invention in 2009. The number of patents they hold has since risen to 140. At the outset, however, some of the patents originally belonged to TUM. The founders used their investment capital to buy the patents back from their alma mater and get their company ready to enter the market.

Orcan Energy's portfolio includes a series-ready solution whereby the ORC modules can be directly integrated into the waste heat source, as well as electricity generation modules that can be deployed and commissioned straight away. In 2016, the trio received the TUM Presidential Entrepreneurship Award and were ranked among the top 100 innovators in Germany.

“With a current headcount of 60 employees, we are scaling up to become an innovative mid-sized enterprise,” enthuses Andreas Sichert. His company wants to establish its ORC technology as the global standard in low-temperature power generation from waste heat. There are plans to install several thousand plants in the coming five years. There is even a possibility that one day private households will be able to harness the ORC innovation with their own heating systems.

Evdoxia Tsakiridou



The self-learning system provides an end-to-end solution: The sensor, often mounted on a switch, takes readings that are combined with other data and analyzed by intelligent algorithms. These then supply information about the condition, maintenance and repair requirements.

Switch technology goes digital

Intelligent sensor systems increase the capacity of rail networks

“We were very technology-focused at the beginning with notions of becoming the best sensor technology company in the world. But we quickly realized that solving customers’ problems should be our first priority,” recalls Konux co-founder Andreas Kunze.

We” includes his co-founders Dennis Humhal and Vlad Lata. As young students of electrical engineering, computer science and mechanical engineering, they met at a TUM business plan seminar and quickly hit on the idea of developing smart sensors for industrial equipment.

Large network of industry contacts

The trio abandoned their plans to do a Master’s degree, opting instead to focus 100% on their startup with the support of TUM. “With MakerSpace, TUM not only offers great infrastructure for building prototypes, but also a large network of industry contacts. That is how we as founders were able to engage with potential customers,” explains Andreas Kunze. The early days of the company, which was founded in 2014, were a learning experience for the founders, after which they went on to fine-tune their business idea. They decided to offer an end-to-end solution encompassing sensor, data analytics and data management, adding value through the ability to combine sensor readings with other data sources and then analyze the resulting stream of information. The system thus includes an analytics program based on AI technologies such as neural networks, which can be “trained” to detect irregularities or potential failures on the basis of countless past examples. Complementing continuous condition-based monitoring, lifecycle forecasts and predictive maintenance round out the business portfolio.

Enormous savings potential

Deutsche Bahn was one of the first customers that Konux won. The German railway company oversees just under 66,500 switches. Given the number of years racked up by the rail infrastructure and its exposure to high loads, maintenance requirements are rising. If a switch fails, this can severely impact the punctuality of trains and the capacity of the rail network. In the past, DB regularly monitored the condition of its switches with manual inspections, a procedure that has become anachronistic in the digital age. “We can now record over 9,000 times more condition-based data per switch every year, and given the large number of switches involved, this translates into an enormous savings potential,” notes 27-year-old Kunze.

Konux currently has 38 employees, the oldest of whom is 62. “Age doesn’t matter to us. We simply want to hire the best people to advance our company,” underlines Kunze. And when he says “our” company, he doesn’t just mean himself and his two colleagues. Every employee is in charge to an extent, because they are all shareholders of Konux.

The company has by now completed its third round of funding, with the amount received from investors increasing each time. Initially, the founders were highly in awe of the million-euro tags, but these have become quite normal by now: “We have a plan, and the money is being channeled into realizing our goals.” Specifically, this means establishing a footprint in seven countries by the end of the year. They are already halfway toward realizing this aim and are looking to their medium-term goal of becoming “the number one data player in the railway sector”.

Evdoxia Tsakiridou



The Konux founders: (from left) mechanical engineer Dennis Humhal, computer scientist Andreas Kunze and electrical engineer Vlad Lata.