Fraunhofer

RESEARCH NEWS

02 | 2015 ||

1 Mini synthetic organism instead of test animals

In medical research, animal-based experiments have thus far been a necessary evil. Fraunhofer researchers have developed a highly promising alternative, however: They are developing a mini-organism inside a chip. This way, complex metabolic processes within the human body can be analyzed realistically.

2 Interconnected IT for business models in rural areas

More and more people are moving from rural areas to cities, leaving behind crumbling infrastructures that make daily life difficult for those who stay. Some people are bucking this trend. Now they get support from researchers: At CeBIT, they will show how they plan to create new business models in rural areas with the help of interconnected IT.

3 Safe production in Industry 4.0

Production facilities and components of Industry 4.0 are linked to the Internet, networked with each other, and thus open to attack. Using an IT security laboratory, Fraunhofer researchers offer a test environment in order to simulate attacks on this network and to detect any gaps. They will unveil the possibilities at this year's Hannover Messe.

4 Scalable electric drive for buses, trucks etc.

Although electric cars meet current trends, driving axles are still too heavy, too expensive and too large for them. To address this situation, Fraunhofer researchers joined forces with partners to design an optimized axle module for commercial vehicles. It is powerful, lightweight, compact and cost-effective.

5 Fitness game for the physically impaired

Modern IT has the potential to make fitness training more varied for people with physical limitations. But what exactly is required? Fraunhofer put this question to thalidomide victims, and developed new IT-based fitness training technology in close collaboration with them. The method motivates users with elements found in computer games.

6 Finding valuable materials in metallurgical dumps

Since metallic raw materials are scarce in Germany, it is reliant on imports. Yet some of these valuable materials are lying around unnoticed in dumps. Fraunhofer researchers are now compiling a Germany-wide registry of these resources, which reveals where these deposits are located and what metals they contain.

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 67 Fraunhofer Institutes and research units at over 40 different locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of around 23,000, who work with an annual research budget totaling 2 billion euros. About 70 percent of this sum is generated through contract research on behalf of industry and publicly funded research projects. Branches in the Americas and Asia serve to promote international cooperation.

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Mini synthetic organism instead of test animals

No one wishes to dispense with the blessings of modern medicine, which took away the dread of many diseases. The flipside of the coin: To ensure that effective and safe medications are available, experiments on animals in research laboratories are indispensable. Throughout the world, researchers are working on alternatives to animal experiments. Yet it is difficult to find a substitute. Because in order to understand the effect of a substance, it is not enough to test the substance on isolated tissue samples or cells. "Most medications work systemically - that is to say, on the organism as a whole. In doing so, toxic substances frequently emerge through metabolic processes, which in turn damage only certain organs," explains Dr. Frank Sonntag of the Fraunhofer Institute for Material and Beam Technology IWS.

Chip simulates human circulatory system

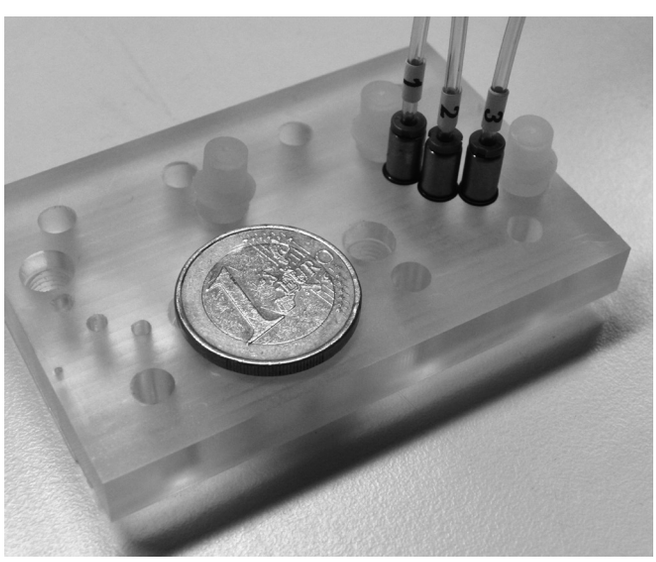
Researchers at the Dresden-based institute, working jointly with the Institute for Biotechnology at the Technical University (TU) of Berlin, engineered a new kind of solution that could render the use of animal-based experiments superfluous in medical research: a multi-organ chip that faithfully replicates complex metabolic processes in the human body with startling accuracy. "Our system is a mini-organism on a 1:100,000 scale to the human being," says Sonntag. Human cells from various organs can be applied to several different positions within the chip. The researchers obtained the cells from blood donations that were made available for research purposes. These "mini-organs" are connected to each other through tiny canals. This way we simulate human blood circulation," Sonntag explains. Working much like the human heart, a micro-pump continuously transports liquid cell culture medium through infinitesimal micro-channels. The IWS researchers can modify the exact configuration of the chip, i.e. the number of mini-organs and the connection to the micro-channels, specifically to different sets of questions and different applications. With the chip, it is possible to test both the active ingredients in new medications, and also study cosmetics for their skin tolerability.

The concept of combining various cell samples with fluid channels has been around for a long while. This new system, however, has two distinct advantages over previous approaches: Thanks to the expertise of the engineers at IWS, the microfluidic system is extremely miniaturized. The pump is capable of channeling the tiniest flow rates of less than 0.5 microliters (µl/s) per second through the channels. This means the relationship between cell sample and liquid media is authentic," Sonntag explains. If this ratio is incorrect, then that will lead to imprecise results. Secondly, the microfluidic system ensures there is a constant flow of liquid cell culture medium; like human blood, the medium flows continuously through the entire circuit on the chip. That is important, since some types of calls can only present euthentic "body-like" morphology if they are stimulated by a current or flow.

In order to test the effect of a substance, the scientists initially load various cell samples onto the chip. Then the active ingredient to be tested is added via the medium for the cell sample of that organ at which the substance would be introduced into the blood stream in the real human body. They include the cells of the intestinal lining, for instance. The same metabolic responses are then processed on the chip just like in the human organism. "We use cell samples from various sexes and ethnicities. We can set variations in body size and weight as desired on a scale of 1:100,000," Sonntag says. The scientists can see exactly which metabolic products form within specific cell samples, and whether and which effects they have on other cells. The results are ultimately even more predictive than those of animal-based experiments. Because the effects on the body of a mouse or a rat cannot be applied to human beings at a 1:1 ratio.

For some companies, such as those in the cosmetics industry, the artificial organism is already in use. In addition to research on active ingredients, there is also another potential application. "We know today that certain kidney cells, the endothelial cells, play a key role in almost every kidney disease. With the in vitro tests to date, there was always the problem that the endothelial cells worked only under current. Here, our multi-organ chip could offer a test environment that would allow you to observe how cells regenerate following an injury," says Sonntag.

As alternatives to animal testing, the artificial mini-organism was recently awarded the animal safety research prize in 2014.



Using the compact multi-organ chip (comparable in size to a one-euro piece), and those of three separate microcircuits, researchers can study the regeneration of certain kidney cells (© Fraunhofer IWS) | Picture in color and printing quality: www.fraunhofer.de/press

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Interconnected IT for business models in rural areas

A lone bale of hay tumbles across a dry and dusty road. Somewhere a wooden door creaks in its rusty hinges. Not a soul in sight as far as the eye can see. A familiar scenario from old Western movies. But today, many German towns and villages also appear to be almost abandoned. Just this summer, the headline of a major German daily newspaper read: "Young people heading for big cities in droves." And with the people goes the infrastructure. No baker to bake fresh bread, no bus waiting at the bus stop, no doctor to take care of you when you are sick. At the same time, people living in cities, in particular, dream of living in the countryside: they long for nature, animals, wide open spaces, fresh air. And to be far away from the stress, noise, and hectic of the big city. But, unfortunately, this also means being far away from everything else.

People living in rural areas are developing concepts to counteract the crumbling infrastructure: There are public transport busses that also deliver packages, school busses that do not drop the school children off at a bus stop, but rather right in front of their homes, etc. etc. In less densely populated areas, necessity is the mother of invention. "The potential is still far from exhausted though. We can use the existing initiatives that are aimed at preserving rural infrastructures in even smarter ways: by interconnecting them via modern communication technologies," says Dr. Mario Trapp from the Fraunhofer Institute for Experimental Software Engineering IESE in Kaiserslautern, citing an example: "Were it not for the school children, public bus services would have disappeared in some regions. In other areas, car sharing is offered. If all stakeholders knew about each other, modern IT could help to optimize the transportation system of an entire region."

New platform "Smart Rural Areas" to be presented at CeBIT

In order to make this vision a reality, IESE is developing a platform that interconnects various IT systems – such as the bus system with the package delivery logistics. The system provides the interfaces needed by the different insular solutions to communicate with each other securely and in real time. This technology is the basis of the Living Lab "Smart Rural Areas", which the researchers will present at CeBIT in Hanover from 16 to 20 March (Hall 9, Booth E40). Here people can test their business models for rural areas with the help of a real-life simulation – without having to repeatedly reprogram the application for their particular purposes. To date, this is being done with previously elicited data. Starting from next year, information collected in pilot projects in the region will also be used.

"It is not a trivial endeavor to make individual IT systems work together. In addition, there are special challenges regarding IT networks in rural areas," says Trapp. In contrast to cities, data cannot flow without interruption from sensors to the Cloud. The problem is that the different worlds of IT systems are based on different software proto-

cols, IT infrastructures, computer languages, development phases, simulators, etc. The various components of rural networks are widely distributed and must also function when they are cut off from the network – for example, if there are problems with the wireless network or with the broadband.

Initially, simulations for model regions in the state of Rhineland-Palatinate will be developed in the Living Lab. The state government provides support for the project. In the spring, a new research lab will take up work on these issues at IESE in Kaiserslautern. "Many companies recognize the potential of the new IT world in rural areas, but are afraid of the high investments involved. In the Living Lab they can test their ideas first. This is also interesting for small and medium-sized enterprises or start-ups. The focus of our research is always on the people. At the same time, however, we must realize that technology is the crucial factor for giving rural areas a perspective for the future. Our goal is to bring together those people who are working on making rural life in the future a viable reality and to offer them a development and testing platform for innovative ideas," states Trapp.

"With the Living Lab, we have taken a first step towards smart life in the country. Of course, this is just the beginning. But we are already trying now to implement whatever is possible," says Trapp. For example with the help of smartphones, which are virtually ubiquitous today. The scientists want to use them to organize a package service at gas stations. "Most of them are located along the main traffic routes taken by commuters and are thus also easy to reach for people living in more remote areas," adds Trapp. This approach is a win-win situation for everyone involved: for the recipients, who can conveniently pick up their packages on their way home from work – the information is sent to their smartphones; for the package delivery industry, which saves costs for the expensive last mile to the recipient; and for the gas station, which earns money from the additional service it offers.

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Safe production in Industry 4.0

Beautiful new production world: For value-creation chains that span multiple locations, equipment, robotics, systems components, minicomputers in components and sensors are all networked with each other in Industry 4.0. They exchange data, retrieve the status of equipment and components, calculate the optimal sequence of work processes, schedule equipment usage and much more. Yet with the entry of communications into factories via Internet technologies, the safety risk also increases. Beside the known viruses, there are new, custom-tailored malware programs threatening the networked production plants. They can spy out system parameters, remotely control machinery, manipulate controls or paralyze processes. Industry 4.0 networks therefore require particular protective measures, sophisticated network technology and effective test methods that detect security gaps and close them reliably. With an IT security laboratory specially equipped for production and automation technology, the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB in Karlsruhe provides a secured test environment in order to readjust potential attacks on production networks, to study the effects and thus, to deduce new strategies and suitable defense measures. It also enables researchers to assess the security functions of conventional communications standards and protocols for industrial automation systems. These regulate, among other things, the data encryption to counter product piracy, espionage and sabotage.

Different framework conditions than in office IT

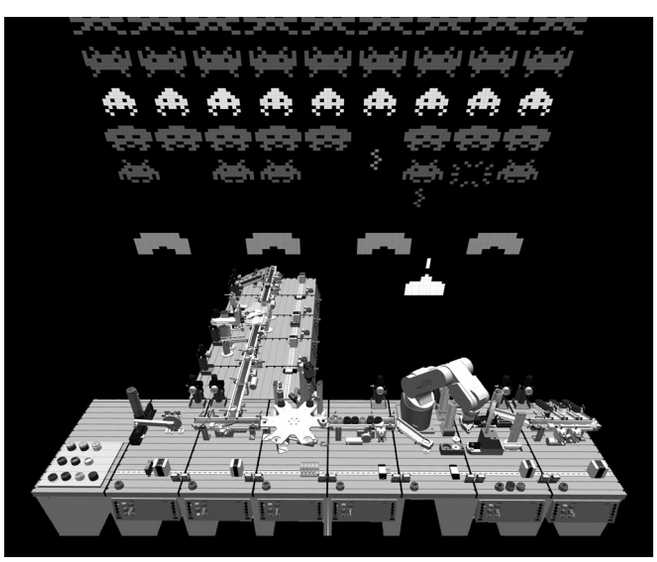
"IT security in industrial production must take into account entirely different framework conditions that do not exist accordingly in Office IT," says Birger Krägelin, project manager at IOSB's IT Security Laboratory. The control of production facilities entails real time requirements that make changes to the systems difficult. Downloading available software patches onto the systems and installing surveillance software, malware scanners, and antivirus programs influence the stability of meticulously coordinated processes. By the same token, production processes affect conditions when updates can be realized. Firewalls within the network and encrypted connection between systems can diminish real-time conditions. "For example, it is possible that the built-in of known security measures from the office environment can delay the dispatch of messages between computers. That can lead to conveyor belts running slower, valves or outlets closing with a delay, light barriers are triggered incorrectly, the rotational speed of motors increases, or control components break down," Krägelin explains. Even the relatively long usage period of hardware and software in production is markedly different from other areas where IT is deployed.

In order to find and establish appropriate IT security mechanisms for the production environment, the research team of specialists in automation technology and IT security equipped the laboratory accordingly. It features its own model factory with real auto-

mation components that control a simulated production facility, complete with conveyor belts, electric motors, robots, and lifting equipment. All network levels of a factory are equipped with typical components, including firewalls, circuits, and components for wireless parts. Having its own private cloud means it is possible for the IOSB experts to flexibly arrange various configurations and set up the model factory for a variety of scenarios.

"In the cloud, we can patch in virtual firewalls, PCs, add additional client computers and modify entire network structures with just one mouse-click. This makes it possible for us to install a virtual firewall or even analytical systems between two components, such as a machine and an overarching MES system (Manufacturing Execution System). From the cloud, we can start malware detection and for example text controls and systems visualizations for infections," the master of information science (MIS) explains. "We are capable of building other factory situations and simulate cyber attacks – without having to buy components and configure circuitry."

The researchers from IOSB will be demonstrating which attack scenarios could happen to networked production facilities at the Fraunhofer joint exhibition booth at this year's Hannover Messe, in Hall 2, Booth C16 from April 13 to 17. Companies can use the laboratory so they can consult on the planning and operational launch of secure industrial network structures. In addition, they benefit from the know-how of the IOSB experts when it comes to the analysis of their already existing network and components. Furthermore, the researchers want to offer the laboratory in the future as an education and learning platform for training measures. "The one thing that engineers often don't have is the knowledge of how to deal with cyber threats," Krägelin points out.



Space invaders haven't got a chance: Production networks of the future will be attack-proof – with the aid of the IT security laboratory found at Fraunhofer IOSB. (© Fraunhofer IOSB) | Picture in color and printing quality: www.fraunhofer.de/press

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Scalable electric drive for buses, trucks etc.

The future belongs to electric motors, and commercial vehicles are no exception. To date, however, many attempts to develop electric motors for commercial vehicles have stalled at the prototype stage or are extremely expensive: Usually electric models cost between two and three times as much as their conventional equivalents. The reason for this is the lack of suitable technologies for series production. This is where ESKAM comes in. Short for Electric, Scalable Axle Module, the project is sponsored by the German Federal Ministry of Education and Research (BMBF). A total of eleven partners, including the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz, are developing an axle module for commercial vehicles, consisting of a motor, gearbox and power electronics. Everything fits neatly and compactly into a shared housing, which is fitted in the respective vehicle using a special frame construction also developed by the project scientists.

The axle module presents numerous advantages. For example, it has a high power density and a very high torque. For drivers, this means very fast acceleration. While the speed of most electric motors is approximately 10,000 to 15,000 rpm, the ESKAM motor achieves speeds of 20,000 rpm. "When we started on the project three years ago, we were the only ones who could obtain such high speeds," recalls Dr. Hans Bräunlich, project manager at IWU. "In the meantime, others have been attempting similarly high speeds. But our head-start in accumulating development experience has given us a technological edge, which we intend to further extend."

Cost-effective manufacturing through series production technologies

However, the chief advantage concerns another aspect entirely: As well as designing the axle module, the project researchers and developers simultaneously developed the required series production technologies. IWU had the lead role in this work as well as being the technological lead for the overall project. "Thanks to the innovative concept, there is great flexibility when manufacturing the modules – for small quantities and large batches alike," says Bräunlich. Series production brings economic advantages, with reductions in production costs of up to 20 percent, according to Bräunlich.

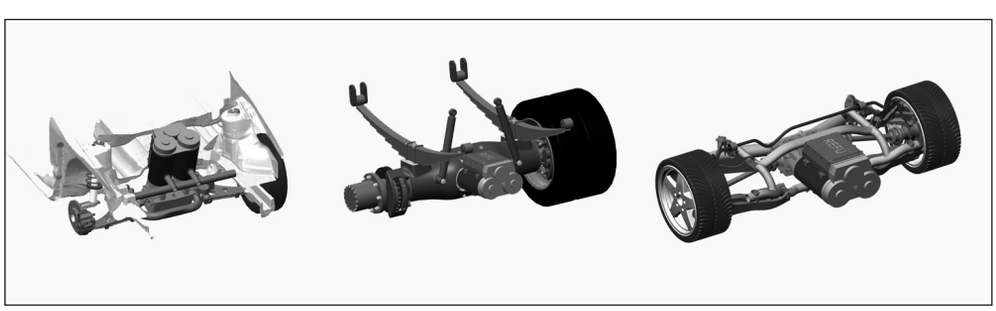
Let's take the gearbox that forms part of the axle module as an example. It consists of shafts and toothed wheels. Usually, shafts like these are manufactured from expensive cylinders or by means of deep-hole drilling. In both cases, the excess material is unused. By contrast, researchers at IWU have chosen new, short process chains together with methods that allow greater material efficiency. One such method is spin extrusion, which was developed by IWU. Although it also uses a block of material, here the blank is shorter than the finished shaft. "To help visualize the process, think of pottery," explains Bräunlich. "The material is extruded during the shaping process – and pressed outward in a longitudinal direction. This allows us to use virtually all the material,

cutting material costs by approximately 30 percent and reducing the overall weight of components." Until now, there have been only initial ad-hoc approaches for this method. Now the scientists have made the technology fit for series production. The toothed wheels are also made using a different process. Instead of milling them from the material, they are now manufactured using a special forming process called gear-rolling, which was also developed at IWU. This method does not produce any metal chips, and effectively no material is lost.

All-purpose module, from small cars to buses

The flexibility of the axle module is not limited to batch sizes either, but also extends to geometry. "Because the module is scalable, we can use it in everything from small vans and municipal vehicles to buses and trucks," says Bräunlich. With a wheel hub motor, that would not be possible. While wheel hub motors have definite advantages – such as a wider steering angle and greater responsiveness – they are not suitable for commercial vehicles, as they scarcely deliver more than 2,000 rpm. Since each wheel also requires its own power electronics, costs are higher. "Both developed versions have their own clear raison d'être and should be chosen specifically for a planned vehicle type," says Bräunlich.

The individual modules developed by the various partners are finished and ready to go, as are the manufacturing techniques. In the next stage, the consortium is now putting the individual parts together to make a demonstrator. After that, they want to fit the axle module into a real car for testing by the end of 2015.



In electric commercial vehicles of the future, the drive will be integrated into the axle. Modules consisting of a drive and axle are scalable for various vehicle types. (© Fraunhofer IWU) | Picture in color and printing quality: www.fraunhofer.de/press

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Fitness game for the physically impaired

A test subject rocks her upper body from left to right. She rotates her shoulders in little circles. Suddenly she cries out: "Did it! New record!" She has just beaten her personal best in a computer adventure. But this is no ordinary video game flickering on the tablet computer's screen in front of her: Behind all the excitement is a new kind of fitness tool for the physically impaired. The game's required movements help the woman exercise motor functions, train concentration and coordination, and improve fitness and stamina. "She controlled her on-screen avatar with the movements of her upper body and the aid of our smart shoulder pad," says Andreas Huber, scientist at the Fraunhofer Institute for Integrated Circuits IIS in Erlangen. Fitted inside the pad are small sensors that record each movement of the test subject and wirelessly transmit them via Bluetooth to the tablet on the table in front of her, where software processes all the data and relays it to her avatar.

Huber's shoulder pad is part of the akrobatik@home project. Other elements of the IT-based fitness game, which was created by the firm Exozet Berlin, include a special seat cushion developed by project partner GeBioM for controlling the game by means of weight shifts, voice controls from the Fraunhofer Institute for Open Communication Systems FOKUS that enable users to navigate through the game's menu, and a video communication system from the company Bravis that allows users to interact via webcams. "Nearly fifty percent of adults in Germany suffer from physical impairments of a temporary or permanent nature, whether as result of accidents, injuries or illnesses," observes Huber. Under the motto "The New Future of Old Age", the German Federal Ministry of Education and Research (BMBF) is sponsoring research projects for technical solutions – such as akrobatik@home – that help and enable people to be physically active.

Research in collaboration with users

"Our project is not just about developing innovative technology, but about starting with concrete needs," says Karolina Mizera, who coordinates the project centrally from the Center for Responsible Research and Innovation in Berlin, which belongs to the Stuttgart-based Fraunhofer Institute for Industrial Engineering IAO. "The prototypes were created in conjunction with people who know very well what it means to live with physical limitations: thalidomide victims." These volunteers were willing to share their personal strategies for coping with the challenges of everyday life and to develop ideas for technical assistance systems together with Fraunhofer researchers on that basis. Some of them are missing limbs as a result of damage caused by the drug thalidomide, while others suffer from hearing impairments. "These specific disabilities led to concrete ideas," explains Mizera. Three ideas were implemented by the researchers together with the thalidomide victims, Heidelberg University, and physiotherapists from Reha-Zentrum Lübben rehab center: The "e-bag", an application for tablet computers

that makes it easy for users to show their tickets on buses and trains, a mobile signaler that enables communication with hearing-impaired people even when they are out of sight, and finally akrobatik@home, the largest of the three projects.

The pad adapts to every shoulder size and shape and contains some very clever electronics. Researchers have fitted sensors for every conceivable movement, whether rotational, vertical or horizontal. "While users play, they unconsciously do the exercises recommended by therapists. The playful approach is designed to motivate people to keep repeating the movements on their own initiative. After all, they'll be looking to improve their scores," says Huber, while the volunteer beside him rotates her torso as she makes her way through a warren of caves.

The research project comes to an end this spring. So what's the next step? "What was unusual in this case was that there was no clearly defined technical goal at the outset," says Mizera. "Our focus was on closely integrating end users into the process and thereby developing technical solutions that are genuinely helpful and above all gain acceptance among them. The project has shown how important participation is in terms of involving users and stakeholders before starting the technical development stage. Recent research agendas have been emphasizing the very same thing, including the EU's major Horizon 2020 framework program for research and innovation." Now the researchers want to explore other applications for their technical findings. This includes developing advanced control technology for commercial video games and testing how the sensor technology could be integrated directly into clothing.

Fraunhofer has developed new IT-based fitness training technology in collaboration with thalidomide victims and research partners. (© Fraunhofer IIS/Sandra Riedel) | Picture in color and printing quality: www.fraunhofer.de/press

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Finding valuable materials in metallurgical dumps

When it comes to important raw materials, Germany is dependent on imports – a situation that government and industry would love to change. Could we possibly have buried things in dumps that we could still use? Might the blast-furnace slag, converter dust, or blast-furnace gas sludge deposited in metallurgical dumps still contain some usable metal here and there? To this day, we simply do not have enough information.

Now the collaborative "REStrateGIS" project is shining a light into the gloom of German metallurgical dumps in the form of a nationwide resource registry. Coordinated by the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT in Oberhausen, the registry reveals where metallurgical dumps, landfills and other disposal sites in Germany are located and ideally also what is deposited there. If you want to take a closer look at a site in the future, one mouse-click is all you will need to get a detailed view. Technically, nothing prevents the incorporation of additional information such as historical and current aerial photos, other photos of the site, and information about the main body of the dump and its contents. A total of four partners are involved in REStrateGIS, while the German Federal Ministry of Education and Research (BMBF) is funding the project.

The visual display is based on a geographic information system, into which the researchers have entered the relevant data. "Procuring the data is real detective work," says Jochen Nühlen, scientist at UMSICHT. "We trawled through reams of documentation and slowly put together the pieces of the jigsaw." The researchers scoured state archives and contaminated land registries, and pored over the archives of mining authorities and companies. And they were successful: Now the task of locating the sites has been completed and the foundation laid for the resource registry. In the process, the researchers developed a method that details the most efficient way of characterizing and describing dumps. "Our handbook contains useful information such as where to find the right data and who the relevant contact persons are," says Nühlen.

While the UMSICHT researchers wade through the archives, their colleagues at EFTAS Fernerkundung Technologietransfer GmbH analyze satellite data for specific test regions, which include the Saarland, the western Ruhr area, and the Mansfeld Land region in Saxony-Anhalt. Using automated processes, they identify possible dump sites from the images. The UMSICHT scientists then compare this data against their own findings and send their conclusions back to EFTAS. "In this way, we are helping to optimize remote satellite identification for this task," says Dr. Asja Mrotzek, group manager at UMSICHT. "In future, the method might conceivably be used for the detection of deposit sites worldwide – even in regions whose archives hold less data."

The UMSICHT researchers have examined one such dump more closely together with colleagues from Martin Luther University Halle-Wittenberg, the Duisburg-based "Insti-

tut für Baustoffforschung FEhS" building materials research institute, and Stahlwerk Thüringen steelworks. After the researchers had interviewed experts, examined historical documentation, and inspected the grounds, they took samples, on which the personnel at FEhS carried out chemical analyses. This yielded a precise itemization of the materials the samples contained. The partners at Martin Luther University investigated the samples using reflection spectrometry measurements to discover the materials' spectral fingerprint. By comparing the results with the chemical analyses, they create a database. "This allows people to do targeted searches: You could use the measurement technology on unknown dumps to get initial rough data about which materials the site contains," explains Nühlen. "Then you could carry out further analyses on potentially interesting locations."

So what do the dumps actually contain? "Mostly iron, depending on the process," says Mrotzek. "Phosphate-rich slag was also buried there, which can be used directly as fertilizer for instance. Under certain conditions, waste material with high iron content can be reused in the iron and steel industry." In a further stage, UMSICHT researchers will now carry out a cost-effectiveness analysis. Is it profitable to extract these materials from the dumps now or – depending on how the price for the raw material develops – only in five or ten years' time? After all, it is not just a matter of extracting the raw materials for the sake of it – it also has to be profitable.

Processed material recovered from slag. (© Fraunhofer UMSICHT) | Picture in color and printing quality: www.fraunhofer.de/press

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