Fraunhofer IGD

ANNIVERSARY YEAR 2017

ANNUAL REPORT 2017

Dear friends and partners,

Today, virtual monsters are commonplace across towns and villages, in forests and meadows—hunted by smartphone-wielding Pokémon Go players. But while augmented-reality applications are in great demand for consumer entertainment, these technologies have yet to gain traction in industrial environments. A key reason is the lack of enabling technologies, such as highly precise tracking of camera-captured objects. At Fraunhofer IGD, we are closing these gaps: our researchers have developed a number of outstanding solutions, including for tracking—our VisionLib software recognizes objects fully autonomously, laying the foundation for a seamless, stable augmented reality experience.

Turning visions into reality

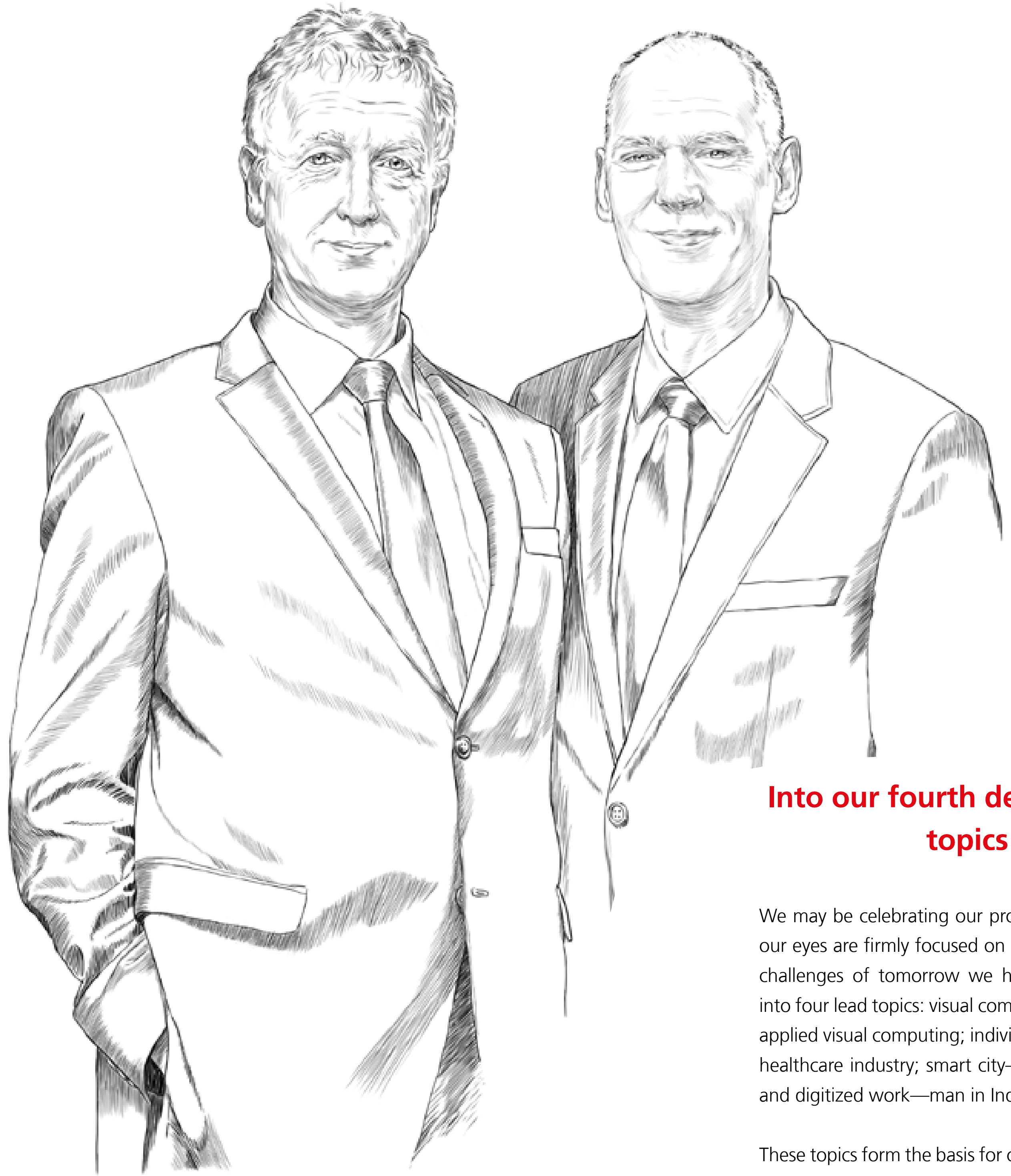
We have also made it our mission to put bold ideas into practice in other areas, and to drive visual computing forward wherever it serves a useful purpose. And we have been doing so for 30 years: Fraunhofer IGD was founded in 1987 as the Working Group for Graphical Data Processing AGD, under the leadership of Professor José Luis Encarnação. In 1992, the working group morphed into Fraunhofer Institute for Computer Graphics Research IGD, and a second site was established in Rostock.

Milestones of achievement followed in quick succession. In 1993, our scientists created the very first dynamic, auto-generated 3D weather map for German public TV broadcasters ARD and Hessischer Rundfunk. In the same year, our employees unveiled a training simulator for arthroscopic surgery on knee joints—the first to leverage virtual environments. This was a boon for surgeons-in-training in particular, allowing them to practice this difficult procedure without undue pressure, and to gain confidence for real-life operations. In 1997, our researchers installed Europe's first five-sided CAVE, capable of immersing viewers in virtual worlds by generating wrap-around images. In 1998, our digital watermark enabled copyright symbols to be attached to electronic documents. And there are many, many more examples we could list, such as the online ticket ordering system launched in 2000. Or CityServer3D, a three-dimensional city model that offers intuitive access to complex information.

Charting a course for continued success

You cannot have a history stretching back 30 years without encountering changes in staff, and Fraunhofer IGD is no exception. In 2006, the baton of leadership was handed from Professor José Luis Encarnação to Professor Dieter W. Fellner. The institute continued to go from strength to strength—setting new standards and delivering further innovations, such as CapFloor, a smart floor covering that recognizes when a room occupant has a fall. Or CultLab3D, a scanning system that creates three-dimensional models of works of art in large quantities and high speed, generating digital replicas for society. Or the Cuttlefish printer driver software that allows animation studio Laika to produce 3D models of unprecedented quality for its stop-motion movies. So we can confidently conclude: Fraunhofer IGD remains an innovative development partner to industry.

Our outlook has always been international. Since 1998, Fraunhofer IGD has been active in Singapore. This led to the establishment of Fraunhofer Singapore in 2017. In 2018, Fraunhofer IGD expanded its network further with a site in Graz, Austria.



Prof. Dr. techn. Dieter W. Fellner
Director of Fraunhofer IGD

Dr.-Ing. Matthias Unbescheiden
Deputy Director of Fraunhofer IGD

Into our fourth decade, with four lead topics to match

We may be celebrating our proud past in our anniversary year, but our eyes are firmly focused on the future. To effectively address the challenges of tomorrow we have grouped our research activities into four lead topics: visual computing as a service—the platform for applied visual computing; individual health—digital solutions for the healthcare industry; smart city—innovative, digital and sustainable; and digitized work—man in Industry 4.0.

These topics form the basis for our work, and transcend the boundaries of individual competence centers. How do we make them come to life? This annual report offers a number of illustrative examples.

We hope you find the updates on our latest research projects inspirational and illuminating.

Prof. Dr. techn. Dieter W. Fellner   Dr.-Ing. Matthias Unbescheiden

_Contents

Fraunhofer IGD
Anniversary year 2017

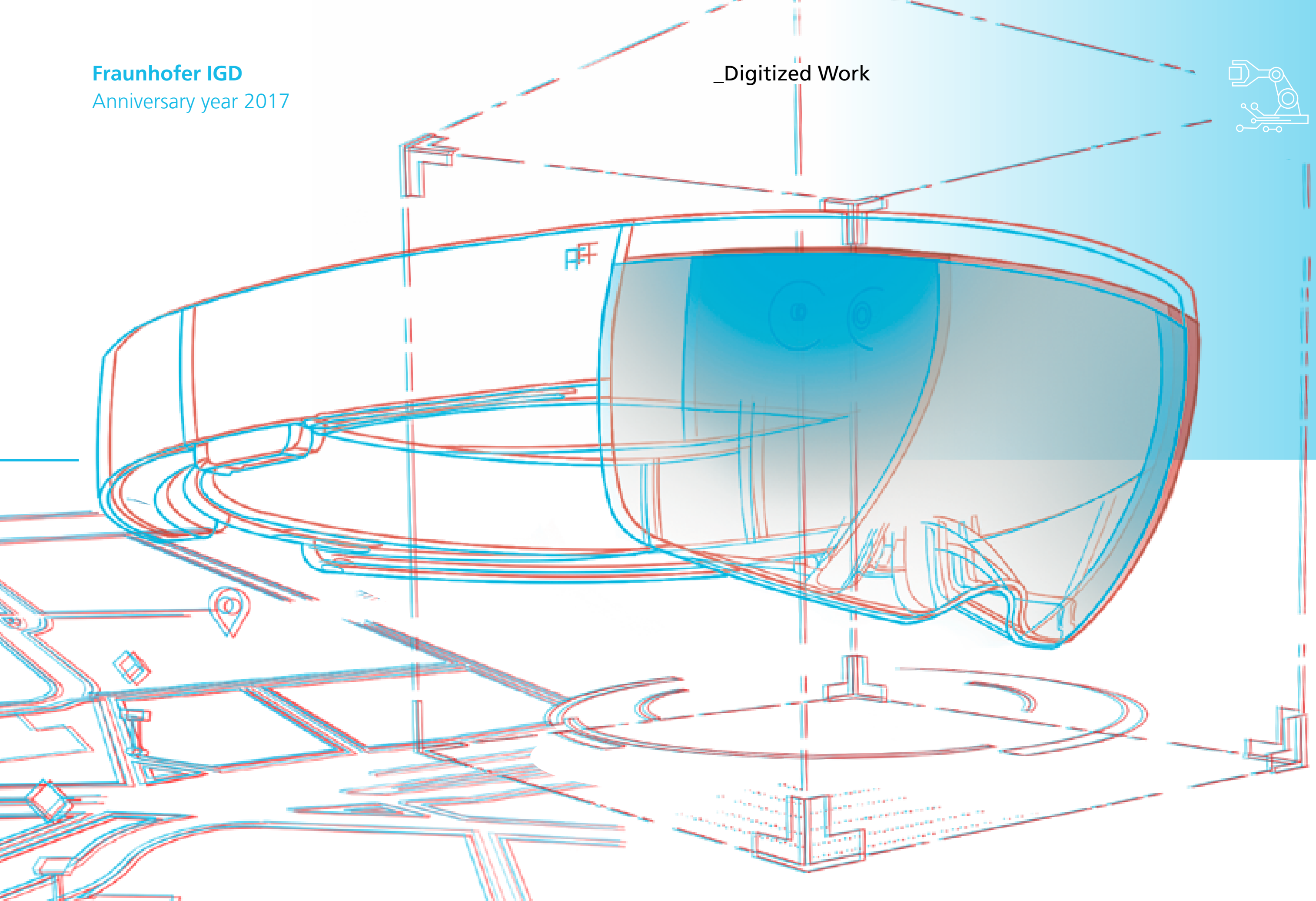
_Contents

8 – 21

_ DIGITIZED WORK

AR FOR INDUSTRY 4.0:
A NEW WAY OF SEEING: BLENDING VIRTUAL AND PHYSICAL WORLDS

Augmented reality has made limited inroads into industrial processes. The latest advances by researchers at Fraunhofer IGD are now making it possible to track objects with greater precision and to scale CAD data in line with the target device to significantly increase productivity in construction, manufacturing, and quality assurance.



Around the globe, millions of Pokémon players have been chasing virtual monsters with their smartphones. When they look at their screens, they see their physical surroundings overlaid with the occasional fictional character. The game is relatively straightforward, as is the underlying technology: sensors track the camera direction and movements and the monsters are superimposed on the actual scenery. However, this entertaining example of augmented reality only hints at its possibilities.

Industrial applications require precise tracking. Highly accurate identification and measurement are the basis for all industrial AR developments. There is a world of difference between knowing that a virtual game character is "sitting somewhere over there under a tree," and being certain of the exact position and orientation of a machine component. Researchers at Fraunhofer IGD have been working successfully on this kind of tracking technology for several years. Industrial tracking offers immense potential in training, manufacturing, quality assurance, and more. As a result, major players such as Daimler, Porsche, BMW, and Airbus have long been employing AR technologies developed by Fraunhofer IGD.

Tracking technology

So how does industrial tracking work? And how can companies make the best use of it? The definition is relatively simple: "Tracking allows us to precisely determine the position of objects captured via a camera," says Dr. Ulrich Bockholt, Head of the Virtual and Augmented Reality Competence Center. Industrial tracking needs to be a reliable and stable process in order to compare an object—depicted on a design drawing and modeled using CAD data—with a physical reality. "This comparison makes it possible to immediately recognize differences between the two worlds," Bockholt explains. Users are able to notice instantly if something is missing or incorrectly assembled. It is also possible to superimpose virtual references to physical objects, such as an engine, as long as they are modeled in the form of CAD data. In this way, tracking can be employed to create a software program that guides a worker through an inspection or maintenance routine. Important information can be inserted into the real-life image: for instance, written descriptions, acoustic warnings, spoken instructions, or illustrations indicating what to do next. There is no need to waste time thumbing through a hard-copy manual.

Industrial use cases

Comparable solutions exist on the market, but Fraunhofer IGD's tracking technology possesses a number of standout strengths, particularly in an industrial context. "We provide the basic technology and a developer kit. That is a major difference. The user can then develop an augmented reality application that is tailored to their specific purpose. They therefore enjoy far greater flexibility," states Bockholt. The system also works by tracking "edges." Since edges are far easier to identify, it is possible to clearly recognize 3D objects and machine components even under varying light conditions and in diverse environments. Consequently, users can employ tracking not just in static settings, but also in dynamic ones—in workshops for example, and outside the confines of a factory building.

VisionLib

VisionLib is a tangible result of Fraunhofer IGD's work in the realm of industrial tracking. This software is able to precisely determine the position and orientation of a camera in relation to a given object, and to use this information to analyze camera images. There is no need for previous knowledge of the tracking environment. The corresponding software development kit (SDK) can be licensed for iOS, Android, and Windows operating systems, and the application deployed on HoloLens. Visometry GmbH (www.visionlib.com), a Fraunhofer IGD spin-off, evolved VisionLib further in line with market needs, and launched it in 2017, subsequently garnering numerous awards.

But the institute is already aspiring to take the VisionLib solution to the next level. "This includes scenarios such as housing or road construction sites. We want to implement precise tracking in these situations, despite the fact they typically feature large expanses of homogenous surfaces and comparatively few edges," says Bockholt. There are also still issues if, for instance, certain small but important details of a vehicle differ from the CAD data: "The tracking system can be confused if the doors are left half open on a physical car whereas they are closed or fully open on the design drawing." For this reason, the researchers are now investigating how best to ensure accurate recognition of objects in a wide variety of states.

instant3Dhub

But tracking is not the only consideration if augmented reality is to increase efficiency in construction, manufacturing, and quality assurance. There is another challenge to be tackled: the huge volume of CAD data that AR software must process. "Digital transformation is generating data of ever greater granularity. The sheer quantity of data overwhelms the graphics cards and CPUs in mobile devices," explains Dr. Johannes Behr, Head of Visual Computing System Technologies at Fraunhofer IGD. But AR needs to be deployed on versatile handhelds such as tablets, smartphones, and head-mounted displays if it is to deliver genuinely practical benefits. Mobile applications are the key to blending the CAD model with physical reality for greater efficiency under real world conditions.

Behr and his team have developed a platform—instant3Dhub—that makes it possible, for the first time, to transfer only the data actually required for an application's calculations. The concept is comparable to a digital map, such as Google Earth. "Google Earth is based on a huge amount of data capable of precisely describing and depicting any location in the world. But if, for example, you enter 'Darmstadt,' the system will only transfer the data to the endpoint necessary to display the tiles in and around that particular German city," states Behr. Fraunhofer IGD's platform instant3Dhub works in a similar way by scaling the data. "As a result, we do not impact the performance of the user device, even if very large data volumes are involved. The system is highly intelligent, allowing us to fully and automatically analyze and split data in terms of its spatial content, and to transmit only those elements necessary to display a particular image," emphasizes Behr. The platform then employs conventional Internet technologies for actual visualization. Even 25-gigabyte 3D models, such as those encountered in aircraft design, can be displayed "jitter free" on simple devices. And although each project is different, making a comparison difficult, the platform has considerable potential for entire departments. In the past, applications had to be launched in the evening in order to load and crunch the data required for work the next morning. This can now be slashed to a fraction of the time.

Plug-and-play simplicity

There is further significant benefit for instant3Dhub users: the platform can be deployed in the cloud in exactly the same way as in a conventional software environment. And it supports diverse CAD formats as well. No matter which (often multiple) data and graphics formats are used in a particular organization, the system understands the information—it no longer has to be laboriously converted (as has generally been the case until now). There is also no need to purchase expensive specialist software.

The system can process data from a wide variety of sources with plug-and-play simplicity, and then scale it for—and provision it to—the target device.

instant3Dhub is already a proven and successful technology. It demonstrates that seamless processing and scaling of CAD data in multiple formats opens up many opportunities for industry. However, there is more to come in terms of a focus on user devices. The scientists at Fraunhofer IGD are currently working on the development of a printing-as-a-service offering. The intention is to provision data to industrial 3D printers—in a similar way as described above for tablets and head-mounted displays—on a lean, "need-to-know" basis.

Like VisionLib, instant3Dhub will be available to users as a licensed bare-bones application. More than a dozen customers are already putting the platform to good use: the automotive industry, aerospace, plant engineering, and construction. instant3Dhub is part of Fraunhofer IGD's visual-computing-as-a-service platform strategy. This will harness existing experience of and continuing research into extremely large systems to create compact platforms that are then provisioned as a service.

MASS PRODUCED. BUT CUSTOMIZED. FROM DESIGN TO 3D PRINTING.

One of the great hopes of the Industry 4.0 age is mass customization: the consumer uses a template to create a personal, made-to-measure product design. The design is then checked for structural integrity and fine-tuned by a software program before being manufactured. Fraunhofer IGD has already taken steps towards making mass customization a reality by means of an interactive simulation solution: CUPstomizer.

Simulation in the age of Industry 4.0

When planning production processes, it is necessary to consider multiple interdependent factors. If any single factor is not fully taken into account, this can have a negative and costly impact on subsequent manufacturing. For mass customization in particular, in which each end product is unique, the timely correction of a design fault is crucial.

Made-to-measure manufacturing on an industrial scale is ultimately only possible in conjunction with interactive simulation. In the past, this took considerable time to complete. Today's software is much more responsive to customer-specific requirements. It verifies that the user's design can be turned into a viable product, suitable for the intended use, and provides recommendations for any necessary modifications. This form of simulation not only considers outer appearance but also the materials themselves, by querying a database of properties. In other words, volumetric information is used to check the proposed components to ensure they will withstand the expected stresses and strains of daily use. This combination of design and simulation saves time and cuts costs by confirming the feasibility of the product prior to manufacture.

CUPstomizer as a prototype

An example of this principle—a holder for a cup originally made without a handle (i.e., a plastic product similar to the sleeves used on coffee-to-go cups to prevent customers from scalding their fingers)—demonstrates the possibilities and constraints of mass customization. Visitors to the Hanover industrial trade fair (Hannover Messe) and formnext in Frankfurt were invited to perform this particular experiment with CUPstomizer for themselves. Utilizing an interactive user interface, they were able to create their very own cup holder. The application provided a template, and visitors could then make the holder thicker or thinner, broader or narrower. At the same time, the software checked whether the geometrical changes to the proposed design would affect its structural integrity. Whenever a problem was detected, the user was provided with guidance via the interactive interface, suggesting which parameters needed adjustment. Once this iterative process resulted in a feasible product, the user simply approved the design and initiated the final step: additive manufacture by a 3D printer.

LAYER-BY-LAYER: 3D PRINTING ENABLES FLEXIBLE MASS CUSTOMIZATION

3D printing is an increasingly popular way to make prototypes, products, and replicas. It cuts feedstock waste, enables on-site production of objects, and reduces the need for shipment. Experts believe 3D printing technology will transform manufacturing and the economy. According to conservative estimates, the value of the global market for machinery, goods, and services relating to additive manufacturing will grow to over nine billion euros by 2018. In other words, 3D printing has rich potential.

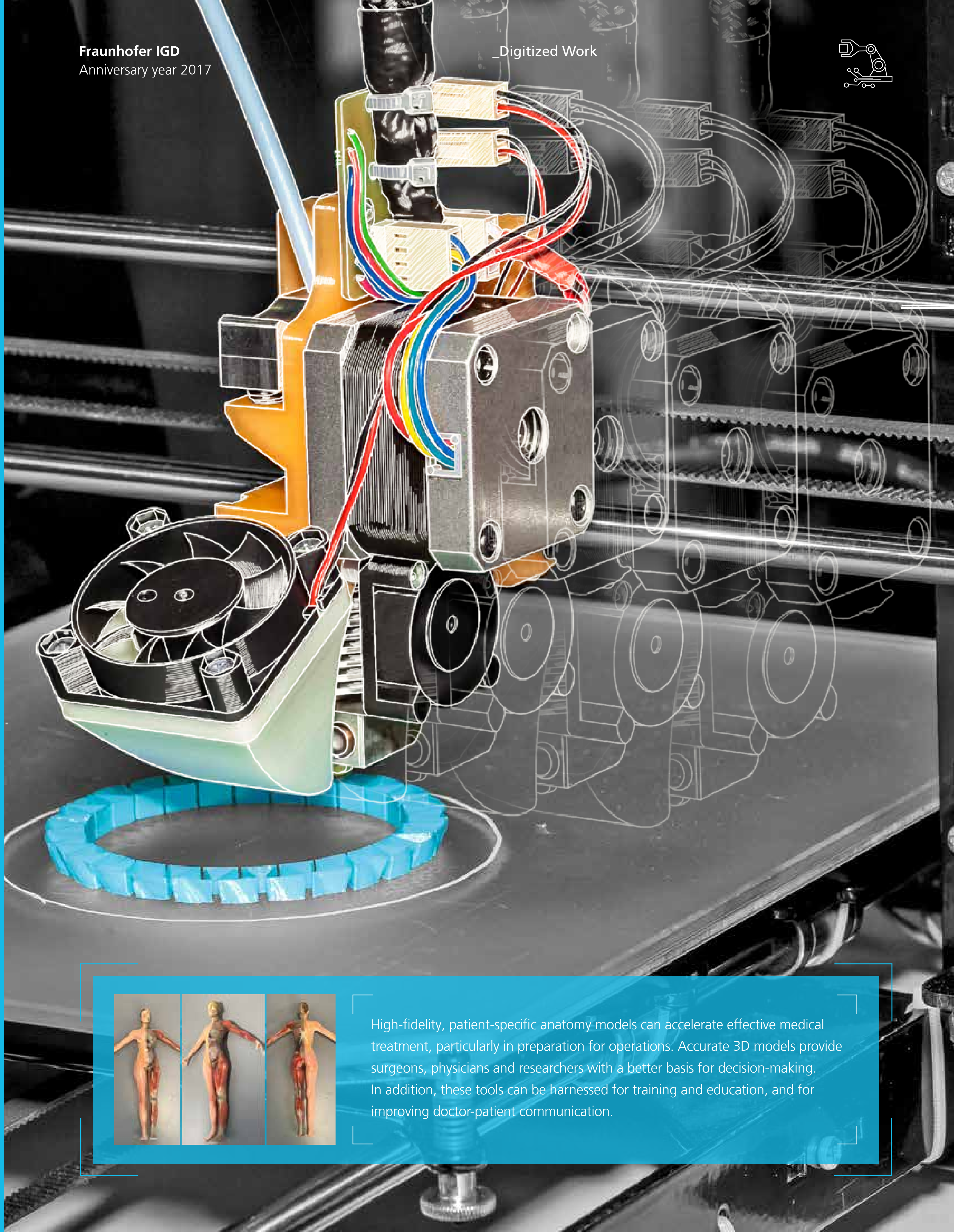
As the capabilities of 3D printers increase—for example, as the range of supported feedstock types broadens—so do the challenges that the software must overcome. Enormous volumes of data are needed to accurately position the input material and achieve the required visual and geometrical properties. Fraunhofer IGD had these requirements in mind when it developed Cuttlefish, a voxel-based printer driver that enables streaming and is designed for multi-material 3D printers. Cuttlefish processes only the data required for the specific print job, minimizing the amount of memory needed. Even complex and large 3D models are ready to start printing in a matter of seconds.

The latest version of Cuttlefish supports RGBA textures that contain information on both color and translucency—varying from entirely opaque to fully transparent. The driver enables multiple overlapping models to be printed, each with one or more RGBA textures. “Thanks to our printer software, we can work with multiple feedstocks simultaneously to reproduce shapes, colors and subtle color transitions with high fidelity,” emphasizes Dr. Philipp Urban, Head of the 3D Printing Technology Competence Center. “In addition, we have successfully printed translucency—including partial translucency and diffusion of light through the object—in combination with accurate coloration for the very first time. As a result, 3D-printed replicas of human skin look very realistic.”

The Cuttlefish printing software’s features are clearly evident in a 3D-printed anatomy model formed from 28 components—each assigned a unique material, and together described by just 425 megapixels of color texture data. The transparent parts are created simply by modifying the RGBA data. This degree of realism for 3D models will change anatomy education across the world. As Urban underscores, “There are many applications for this new combination of color and transparency—ranging from the visualization of prototypes in manufacturing to printing dental implants.”

Fraunhofer IGD
Anniversary year 2017

_Digitized Work



High-fidelity, patient-specific anatomy models can accelerate effective medical treatment, particularly in preparation for operations. Accurate 3D models provide surgeons, physicians and researchers with a better basis for decision-making. In addition, these tools can be harnessed for training and education, and for improving doctor-patient communication.

DATA-DRIVEN DESIGN: THE BIGGER, BETTER PICTURE

Design decision-making is complex—for products, components, processes, infrastructure, environments, entire buildings, or individual rooms. Researchers at Fraunhofer Austria are developing specialized and made-to-measure data-driven visualization systems that allow designs to be examined and tested in advance. This means that data and correlations are immediately apparent.

"A picture is worth a thousand words," is the well-known aphorism. But an image alone is usually not enough. How useful visualization is depends on the way content is presented. This is particularly true when information has to be tailored to the specific needs of development engineers, product designers, process planners, urban planners and architects. Consequently, data-driven design is a key focus at Fraunhofer Austria Research GmbH. The goal is to visualize data and correlations in a way that enables users to rapidly and intuitively recognize the impact of design proposals and changes.

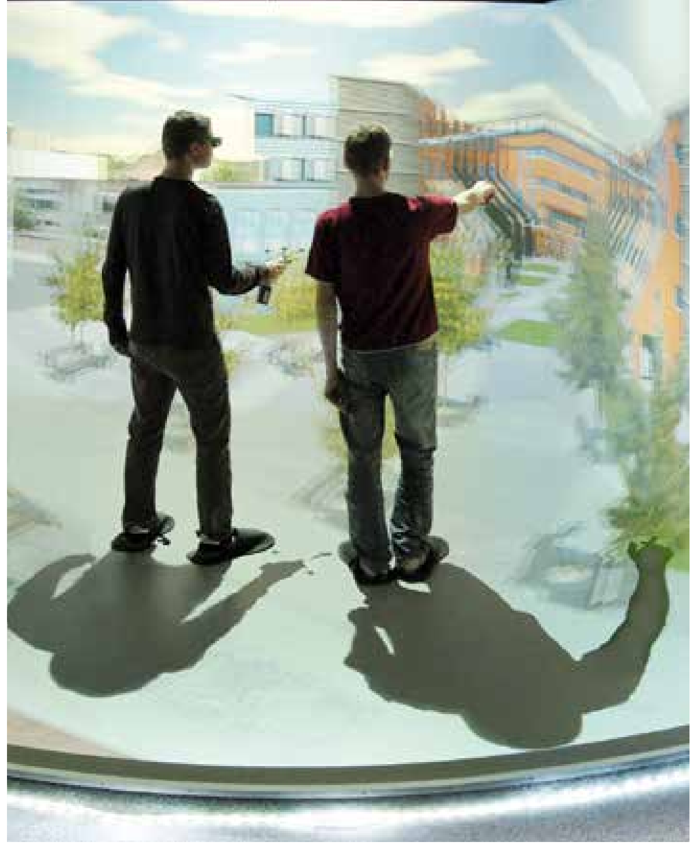
Key project close to market launch

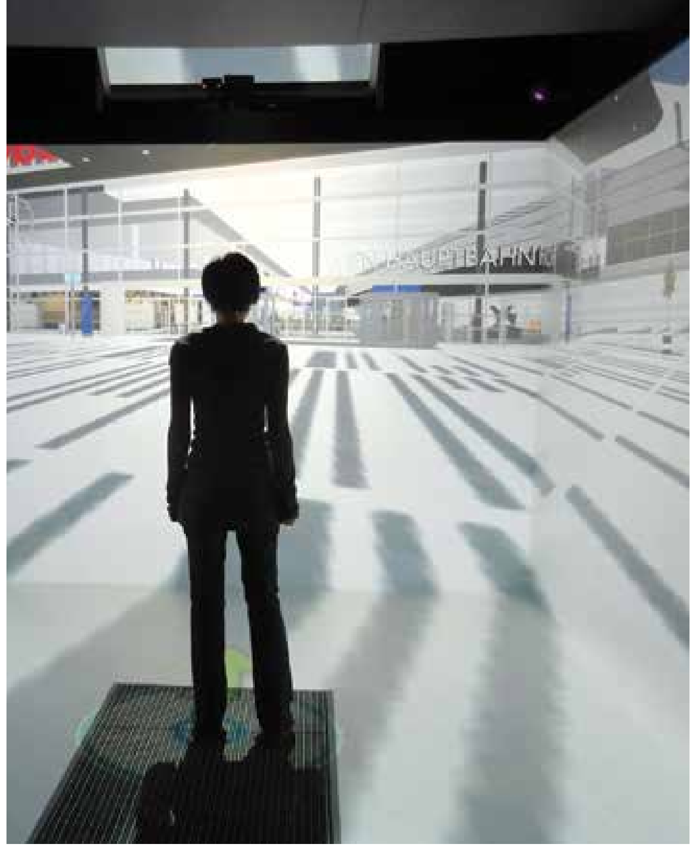
The work of Fraunhofer Austria, a sister institute of Fraunhofer IGD, can be broadly divided into three fields: visualization services, research, and technologies that make visualizations a real-life experience. "We want to turn content into something you can see. This entails capturing and presenting data in a way that ensures it delivers value added to the viewer," says René Berndt, sales manager at Fraunhofer Austria. The research extends far beyond what conventional graphs and charts can achieve. Industrial machines, for example, may be equipped with a wide variety of sensors, generating data of types and quantities that cannot easily be converted into traditional graphics. For multiple but independent processes, visualizing parameters becomes even more challenging.

A number of projects in 2017 underscore the degree of complexity involved. One such project is GrAPPA, a graphical tool that supports the design of manufacturing plant and equipment. This technology is now nearly ready to go to market. GrAPPA enables the design and completion of factories with greater speed and ease, and at lower cost. "For instance, the software allows us to define a new production line within an existing floor layout," says Berndt. It is possible to create a virtual layout of equipment within an existing production building, and to reconfigure it as many times as necessary to determine the optimal outcome. For example, designers can see immediately what impact their ideas have on the flow of components and materials from one process step to the next. Does one proposed path intersect with another? Are there obstacles in the way? And engineers can recognize weaknesses; for example, when production systems are positioned too far away from each other, requiring heavy items to be moved farther and more frequently than necessary.

Value-stream mapping

Vasco, a market-ready project at Fraunhofer Austria, aims to accelerate value-stream mapping, and to make the process more user-friendly. "Imagine you have a customer order for an unusually large quantity of products. Our tool enables manufacturers to identify potential bottlenecks, and to calculate the expense and manpower required to overcome them," explains Berndt, highlighting one example among many. Users can also simulate the effect on their carbon footprint, or discover how to cut waste by reengineering selected production processes.





Researchers are also refining specific aspects of existing visualization solutions. Last year, for example, Fraunhofer added workers' arms to a virtual reality application for a firm of engineering consultants. Berndt explains: "Typically, today's VR headsets only consider the wearer's hands. But for certain activities, the position of the entire arm is important. What's more, we are able to optimize certain actions if we take into account how far the user's body is from the object to be manipulated." Berndt continues, "We can now use VR to guide the worker quickly to components inside a machine or help them to precisely position an item of equipment."

DAVE

The data-driven design activities of Fraunhofer Austria are best illustrated by visualization solutions such as the Definitely Affordable Virtual Environment, known as DAVE for short. Standard virtual reality headsets enable the user to view an imaginary world—DAVE goes a step further. With DAVE, the wearer can experience artificial surroundings without being completely isolated from physical reality. Users can see themselves (and others), while being part of a virtual environment. And they can take real-world objects with them into the virtual sphere, such as a tablet or smartphone to run applications. DAVE operates within a room measuring 2.5 by 2.5 meters, equipped with screens on all sides that are back-projected with the desired environment.

DAVE was trialed in Vienna to help visitors navigate the proposed new central rail station. The test participants performed a variety of tasks, such as attempting to locate a particular store, or find their way to their chosen platform by means of available signage. Movements and line of sight were recorded and analyzed. This form of virtual experimentation allows architects to identify possible weaknesses within expensive building projects, and to correct them quickly and cost-efficiently, in advance of actual construction. DAVE is ideal for innovative engineering, allowing design faults to be recognized at an early stage to save costs. Significant progress has already been made with DAVE, enabling researchers to begin work on a mobile version in 2018.

MARIO AEHNELT

NEW HEAD OF THE VAT COMPETENCE CENTER

A new face, a new name: in July 2017, Dr. Mario Aehnelt was appointed Head of the Visual Assistance Technologies Center (formerly the Interactive Document Engineering Competence Center).

Vincent van Gogh said, "Change is as necessary as the renewal of leaves in spring." After all, life is inherently about change. And there is plenty of life to be found at a research facility such as Fraunhofer IGD—particularly in the Interactive Document Engineering (IDE) Competence Center. In July 2017, IDE was given a brand-new name: Visual Assistance Technologies (VAT), and Dr. Mario Aehnelt was appointed as new Head. Dr. Aehnelt, age 39, succeeds Professor Bodo Urban, who is entering well-earned retirement in 2018. Aehnelt explains, "The transition will be very gentle. Professor Urban will remain an active member of the organization until his retirement, and we will continue to exchange information and insights." Aehnelt has been part of Fraunhofer IGD for many years. His first foray was an internship in 2000, followed by undergraduate and final-degree dissertations. Since 2002, he has been a permanent member of staff. In April 2017, he defended his doctoral thesis on Cognitive In-Process Support for a Mechanic: forging a link between the technical and psychological aspects of cognitive information assistance.

A focus on visual assistance

The reason for the changing of the guard was clear. But why a new name? "Strictly speaking, the term interactive document engineering had not really described what we do for a number of years. Our focus is visual assistance," states the father of two children. The team therefore expressed a wish to move with the times, and to choose a name more reflective of the competence center's actual tasks. A workshop was held in May 2017 to answer the question: what direction does this center want to take in the future? The answer: visual assistance continues to point the way forward. As Aehnelt underscores, "The new name, Visual Assistance Technologies, abbreviated to VAT, mirrors this fact."

Enhancing proven technologies

The nature of the center's research will not change significantly. But against the backdrop of ever greater digital transformation, Aehnelt intends to shift the emphasis more towards predictive analytics: "We do not want to just analyze the past and the present, we also want to open up a window on the future, and make forecasts—for instance with Health@Hand, Plant@Hand3D, and Machine@Hand." The new VAT Head will continue to leverage proven technologies, but intends to add new capabilities. In other words, users in manufacturing, medicine, and other fields will be able to harness Fraunhofer platforms and methodologies to visualize future states. This will allow them to assess, for example, how modifying a specific parameter will impact production.

VISIBILITY INTO THE DEEP

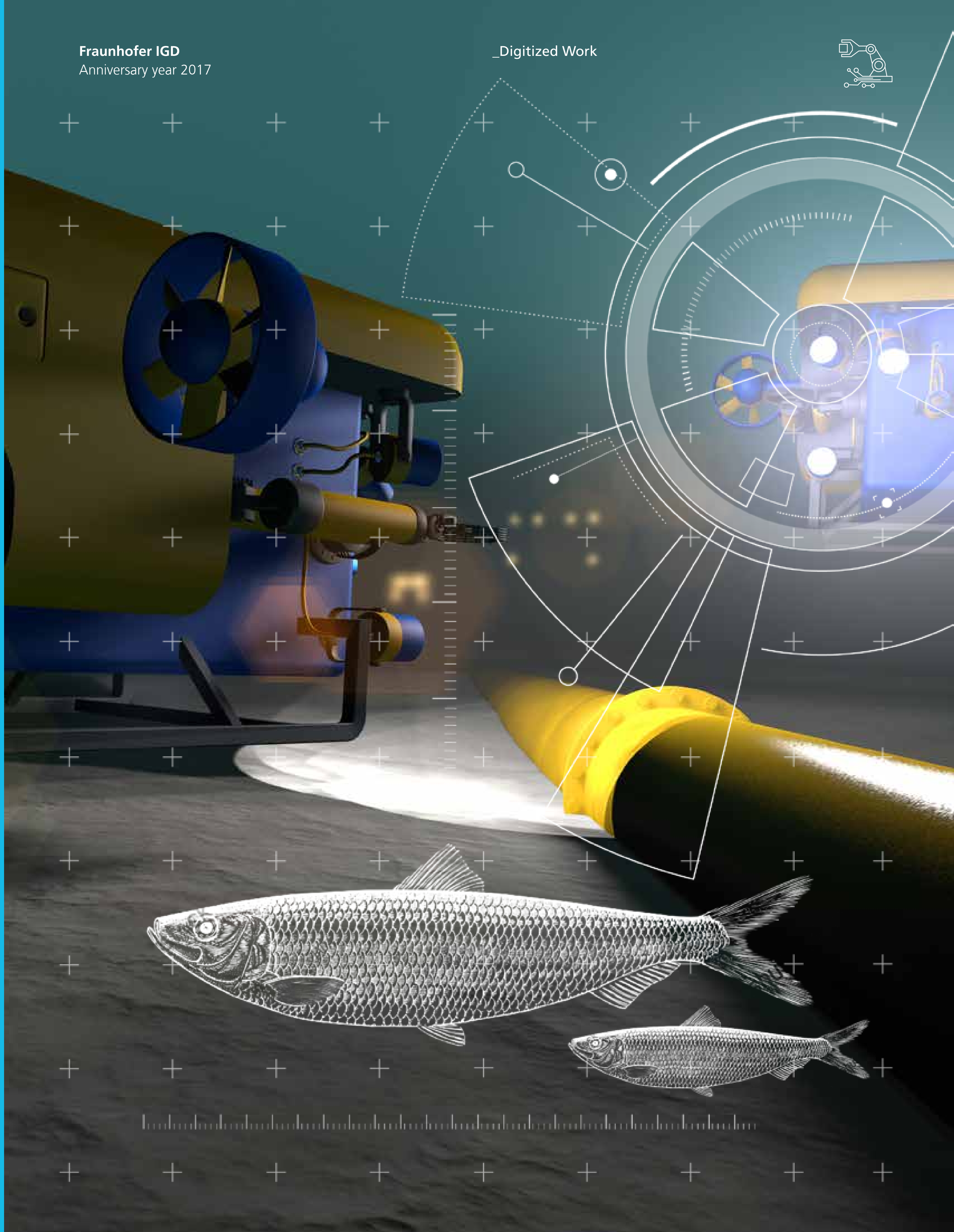
To round out Germany's Science Year 2016/2017 (Seas and Oceans) Fraunhofer IGD is presenting advanced solutions that provide greater visibility into this economically important and ecologically rich environment. One example is underwater image processing.

"Washed out" is not exactly a scientific term. But it aptly describes the problem underwater photographers face. The images captured often appear faded or foggy, in part because water has a different refraction index than air. Additionally, water attenuates light quickly, preferentially absorbing specific wavelengths (red first, at shallower depths, and blue last, at greater depths). Furthermore, scattering, backscattering, and light reflected from suspended particles—i.e., marine snow—all impact image quality. Despite the challenges, underwater photography is invaluable, not only for science and research but also in terms of economic activity and infrastructure management. These images are important for resource extraction, for example, and for the construction of structural foundations on the seafloor, maintenance operations, fish stock management, and environmental protection. Clear, informative pictures are also critical in pinpointing and salvaging wrecks and recovering hazardous goods.

Multiple research teams at Fraunhofer IGD are working on methods to significantly improve the quality of underwater images and make them easier to analyze. The underlying goal is to "remove the water." As Matthias Vahl, Deputy Head of the Maritime Graphics Competence Center, explains, "Our eyes are designed to see through air. So we are attempting to make corrections for the distortions caused by water." But even in the best of scenarios that is only a first step. The researchers not only adjust the image in line with human vision—and automatically improve the quality—they also employ new, automated methods to identify objects, and are developing ways to scan and survey.

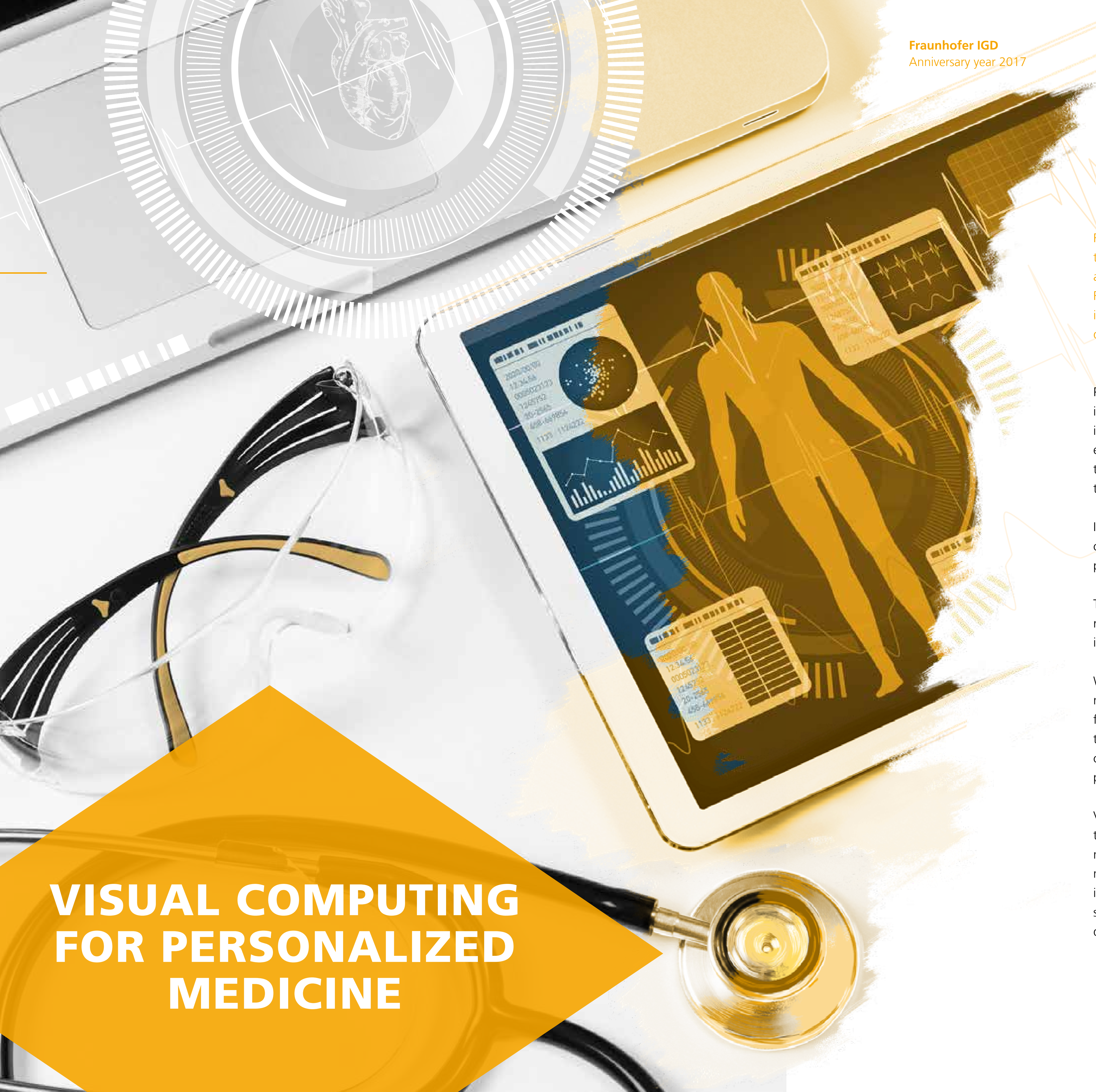
"In our case, enhancing an image is not simply a matter of sharpening edges and accentuating details. We want to add information that was previously not visible, but highly likely to be present," states Vahl. This could significantly improve visibility into the secrets of the deep.

In particular, Fraunhofer researchers are focusing their efforts on 3D reconstruction and object recognition. These capabilities play a key role in semi-automated searches for shipwrecks that, increasingly, deploy special lasers. The findings will also contribute to monitoring fish populations, tracking their movements and migration in near real time. In the past, photographed fish were merely counted manually; now it is also possible to automatically categorize individual species, and to scan fish dimensions to estimate their weights. To this end, researchers are harnessing neural networks to optimize and restore images; pre-trained models also help to differentiate between types of fish, and to correctly interpret what the scientists are seeing.



24 – 31

_INDIVIDUAL HEALTH



VISUAL COMPUTING FOR PERSONALIZED MEDICINE

Fraunhofer IGD is leveraging its expertise in visual computing to drive digital transformation in healthcare. Its solutions include a visual control center that autonomously captures, analyzes and visualizes all available data. In addition, Fraunhofer IGD has developed a method that harnesses the experience of medical staff and information extracted from images and patient data to simplify decision-making.

Patients want their doctors to provide advice and treatment tailored to their unique situation. However, in today's healthcare industry there is often simply not enough time to do so, particularly as each patient is associated with immense amounts of data. Medical professionals must also contend with fluctuating, erratic workloads—after all, emergencies and hospital stays are unpredictable in nature. At the same time, implementing truly personalized healthcare means providing patients with made-to-measure, end-to-end support—from preventive measures, to diagnosis and therapy, to follow-up care.

In this context, Fraunhofer IGD is focusing on its core competency: visual computing. Big data—a phrase on everyone's lips—has the potential to open up entirely new opportunities in healthcare, and enable personalized medicine. And that means capturing, processing, analyzing and visualizing data.

The goal is to make personalized medical care in Germany a reality in the near future. But what will that require? A key element will be identifying the treatment with the greatest chance of success for each individual patient. And medical imaging will have a pivotal part to play.

Within the scope of their VA4Radiomics project, researchers at Fraunhofer IGD are working on a diagnostic imaging method that can be deployed, for example, in oncology, i.e., cancer treatment. In the future, in place of surgery to remove samples from a tumor, it will be possible to draw conclusions on tissue attributes using radiomics. This will enable a virtual biopsy based on quantitative analysis of images obtained via radiological examinations. As a result, the patient will no longer need to undergo an invasive procedure, as CT or MRI scans can provide the information needed for a diagnosis.

Visual computing has benefits for doctors and patients beyond conventional medical treatment. These technologies can be harnessed to better organize care facilities—enhancing efficiency and delivering a more personalized service. Currently, many systems within hospital infrastructures are completely siloed, meaning they cannot communicate with each other. Consequently, patient data must be recorded manually in each room. In the future, this laborious process may no longer be necessary. Physicians, nurses and care staff would simply require a single endpoint, such as a multi-touch table or a tablet, to view all patient data at a glance. The key to this approach is the visual control center Health@Hand.

VA4RADIOMICS

If doctors can compare multiple similar medical cases, they are better placed to decide on the most suitable treatment for each patient. However, studying patient cohorts to identify significant similarities and differences is extremely time-consuming and not feasible in practice.

The Fraunhofer VA4Radiomics project addresses this issue. The name stands for visual analytics for radiomics—and refers to a method that combines the experience of medical staff with information extracted from images and patient data, with the aim of gaining actionable insights.

But how exactly does VA4Radiomics accomplish that? Let us consider the various components of the project's name. Visual analytics makes complex data easily accessible and understandable: data is automatically processed and visualized in a user-friendly way. There are many applications for visual analytics, including (as described in this article) medical data analysis.

The second part of the project's name—radiomics—is a portmanteau word that blends radiology and genomics, and refers to the analysis of quantitative image attributes in large medical databases. Radiomics takes radiological image data, for instance, an MRI or CT scan, and extracts quantifiable parameters, such as the diameter of a tumor. This information is subsequently analyzed and visualized. This enables virtual biopsies, and incorporates data from large groups of patients to draw statistics-based conclusions on tissue characteristics, disease progression and diagnoses—solely based on radiological images.

In other words, the VA4Radiomics project derives information from radiological image data and then correlates this with the corresponding patient data. This allows the visualization of individual patient attributes, plus the definition of patient cohorts, i.e., groups of patients with similar disease patterns and progression. These cohorts, in turn, serve medical professionals as a basis for comparison for better diagnoses, treatments and outcomes. A further advantage of VA4Radiomics is that doctors can include patients they have never seen in person—for example, where the condition in question is extremely rare. Patients can be selected not just by age or gender, but by any attribute extracted from the image data.

The researchers aim to empower medical professionals to present clinical, radiological and pathological data in a meaningful, effective way—and to help determine the best treatment for each individual patient.

HEALTH@HAND

Healthcare workers are under immense pressure. While the patient's well-being and recovery are of the utmost importance to doctors and nurses, bureaucratic red tape in hospitals and care homes is often perplexing—and time-consuming. This burden comes at the expense of tailored advice and assistance for each patient. With this in mind, researchers at Fraunhofer IGD in Rostock have recognized that personalized medicine can and should not only benefit patients but also ease the workload on medical professionals.

Each person is unique, and each hospital stay varies from patient to patient. Many are only short in duration while others may extend for a longer, uncertain amount of time. In each and every case, staff must have access to the latest information on the patient's precise condition in order to do their work. Was it Ms. Miller or Ms. Freeman who is allergic to that pain killer? To proceed with certainty, the doctor or nurse must study the patient's records. A process that repeats itself—for each bed, in each department.

What about a solution that captures all patient data and makes it available at a glance? Dr. Mario Aehnelt, Head of the Visual Assistance Technologies Competence Center, and his team in Rostock are working to make this a reality. Fraunhofer's Health@Hand visual control center can be accessed not only via the hospital's conventional desktop IT environment but via mobile devices such as tablets. Health@Hand presents the hospital department in the form of a real-time 3D model. This gives users insight into all medically relevant developments. The patient's vital signs and other data are visualized, providing doctors with all the actionable information they need. Health@Hand also aids in disease prevention, not just cure. "While the previous system was primarily designed to provide documentation, and avoided interpretation, Health@Hand has a greater focus on analysis," explains Aehnelt.

To this end, Health@Hand consolidates data relevant to decision-making from diverse hospital data solutions. This enables entirely new insights: patterns in patient health can be identified sooner and a prognosis made earlier. It is also possible to integrate vital signs and activity data transmitted from wearables, e.g., fitness trackers or smartwatches, into Health@Hand. Moreover, information on ambient conditions—room temperature, noise levels, humidity—can be fed into the software to ensure the best possible patient experience. In addition, the visual control center helps medical staff to avoid wasting time tracking down colleagues by providing their precise location and availability.

"The system is designed for personalized medicine, where an individual's data play a central role," Aehnelt concludes. If medical professionals have less administrative overhead, and spend less of their working day walking from A to B and back again, then there is more time for them to perform their core tasks. After all, personalized medicine is no replacement for the most important aspect of healthcare: direct, face-to-face interaction between patients and their care providers.

AR NAVIGATION FOR LYMPH NODE BIOPSIES

Malignant tumors often metastasize via the lymphatic system, spreading from the primary tumor to distant sites throughout the body. Determining the exact location of relevant lymph nodes and fully excising them requires considerable skill. Against this background, Fraunhofer researchers have developed a navigation tool to assist surgeons and simplify these operations: 3D-ARILE is an augmented reality (AR) system that pinpoints the precise position of the targeted lymph node via a head-mounted display (HMD).

According to the German Federal Statistical Office, the number of hospital-treated skin cancer cases has soared in recent years. One variety, malignant melanoma, is particularly dangerous. Lymph fluid can transport cancer cells from the primary tumor to nearby lymph nodes—where secondary growths, or metastases, can develop.

The first nodes likely to be affected are the sentinel lymph nodes, i.e., the first nodes the tumor would drain into. If cancer cells are already present in these nodes, it is highly probable that the disease has spread further. Sentinel lymph nodes therefore play a crucial role in diagnosing, staging, and treating various types of cancer, including of the skin, breast, and prostate. Once a tumor has been removed, doctors perform a biopsy of the sentinel lymph nodes to determine whether the cancer has metastasized.

Despite advancements in medicine, it remains difficult to precisely locate these nodes, and to ensure they have been completely excised. Fraunhofer Institute for Computer Graphics Research IGD's 3D-ARILE helps surgeons to navigate accurately during lymph node biopsies. Within the scope of the project, the Darmstadt-based researchers collaborated with the Clinic of Dermatology at Essen University Hospital, and with Trivisio Prototyping in Trier.

The new AR system is a head-mounted display (HMD) that assists doctors by indicating the position of the targeted lymph nodes. In combination with powerful surgery navigation software, 3D-ARILE leverages stereo near-infrared (NIR) cameras and the fluorescent dye indocyanine green (ICG). Dr. Stefan Wesarg, Head of the Visual Healthcare Technologies Competence Center at Fraunhofer IGD, explains: "To make the targeted lymph nodes visible, the fluorescent dye is injected near the tumor. The dye spreads through lymphatic vessels, draining into the sentinel lymph nodes." Infrared light excites the tracer dye, causing it to fluoresce—and that is where the infrared LEDs come into play. The NIR cameras capture the resulting fluorescence and reconstruct a 3D image of the lymph node. The node's precise location is depicted in real time on the surgeon's AR head-mounted display. The corresponding software was developed by researchers in Darmstadt. "In our case, the diseased tissue appears green," states Wesarg. "The surgeon sees this coloration, and can determine whether all of the targeted tissue has been excised."

Fluorescent dye as an alternative to radioactive nanocolloid

To date, surgeons have employed the radioactive nanocolloid technetium-99m as a tracer. The hope is that ICG will eliminate the need for this hazardous substance, enabling a treatment method that is significantly more patient-friendly. Furthermore, ICG saves time. Lymph nodes injected with technetium-99m emit low levels of gamma rays; consequently, a scintillation (or gamma) camera requires approximately 30 minutes to capture the node's precise position. The head-mounted display, by contrast, indicates the targeted lymph nodes instantaneously. As a result, the surgeon no longer has to glance back at an additional screen and compare images—making the operation simpler to perform. As Wesarg underscores: "The doctor is free to focus entirely on the patient, and operates with less stress."

A comfortable AR head-mounted display

A further advantage of the AR head-mounted display is that it is lightweight and comfortable to wear—something doctors from the Clinic of Dermatology at Essen University can confirm after many tests. All project stakeholders worked hand in hand, exchanging ideas and insights throughout development to ensure the tool would best meet surgeons' needs.

The AR solution comprises hardware and software. Specifically, Trivisio Prototyping provided the hardware, which includes the headset with an integrated camera and two displays—specially designed for medical use—plus two infrared cameras and two standard-spectrum cameras. During the operation, the cameras are mounted in a cube-shaped enclosure above the patient. Fraunhofer IGD researchers developed the corresponding software, including image processing functionality. This detects the fluorescing lymph nodes, calculates their position in 3D, and superimposes this information on the head-mounted display. Software is also used to calibrate the hardware, and sophisticated algorithms crunch the data extracted from images. 3D-ARILE manages all hardware devices. In addition, the system includes a user interface for the surgeon.

The researchers presented a prototype of 3D-ARILE from November 13 to 16, 2017, at the Medica trade show in Düsseldorf, Germany. A patent application has been filed, and enterprise Arvyss will take the system to market. ◆

https://www.youtube.com/watch?v=Y_Kv5j07wBE

In our video podcast, a surgeon shares his OR experiences using the AR headset.

MOBILE DEVICES CONTROLLED BY FACIAL EXPRESSIONS

Mobile devices play an ever greater role in our lives—however, in some situations they can be difficult to use, and even accepting a call can be a challenge. Researchers at Fraunhofer Institute for Computer Graphics Research IGD in Rostock have conducted a study into alternative methods of operating handhelds. Ear field sensing (EarFS), a technology that originated at Fraunhofer IGD, offers substantial potential. It uses a special earplug to recognize facial expressions, and could potentially be deployed not just for controlling mobile devices but also in other fields.

Today's mobile devices are generally operated via a touch screen. But there are many situations where this form of control is simply not feasible. For instance, if you are wearing gloves or carrying shopping bags, it is almost impossible to use a smartphone or similar device in the conventional way. Researchers at Fraunhofer IGD have therefore been exploring alternative methods. Voice control would seem a logical choice, but this faces challenges such as ambient noise and social acceptance. Fraunhofer's answer is control via head gestures and facial expressions, such as winking, smiling, and nodding.

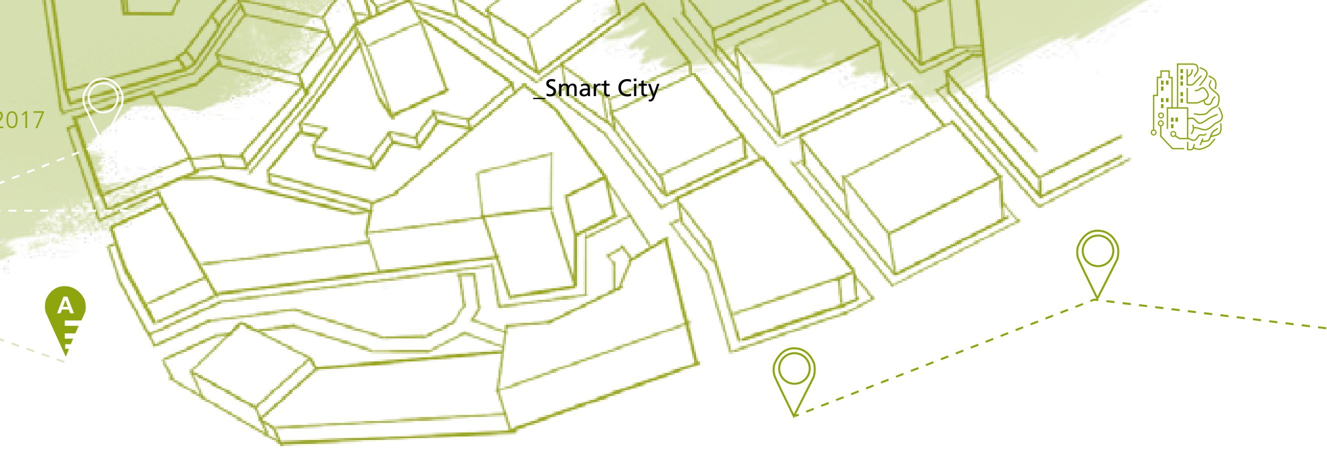
EarFS detects your smile via your ear

The researchers in Rostock have been looking into non-contact operating methods and evaluating a variety of technologies that could enable mobile devices to understand head and facial movements. Practicality in day-to-day situations is an essential consideration. Systems that employ sensors attached to a person's face, for example, are extremely accurate, and can interpret a wide variety of movements. But the sensors are uncomfortable to wear and visually very obtrusive, rendering them unsuitable for everyday use in public spaces. What is needed are discrete systems such as EarFS, a solution developed by Fraunhofer IGD. EarFS consists of a special earplug that measures changes to the shape of the auditory canal, and electrical activity in muscles, when the wearer makes facial expressions. The built-in sensor is able to detect even the tiniest facial movements via alterations to the auditory canal, and measures electrical impulses generated by moving the head or face. "These signals and movements are often extremely small, and have to be amplified; this is quite a challenge," explains Denys J. C. Matthies, a researcher at Fraunhofer IGD. "Plus, the sensors must not be distracted by other body movements, such as vibrations caused by walking, or external interference. To eliminate this issue, we have an additional reference electrode attached to the ear lobe to record external signals." The signals captured inside the ear are compared with external signals—and the differential can be used to accurately identify facial expressions, even if the EarFS wearer is moving.

Vast potential across diverse scenarios

EarFS can be employed to accept or decline calls, control music players, and much more. It can detect fatigue and strain, and also gauge the user's mood. This could allow smartphones to provide an early warning to drivers who are growing dangerously tired, or to switch to silent mode when the owner is concentrating on an important work task. The technology could be deployed in healthcare, for example, to allow sufferers of locked-in syndrome to communicate by controlling a computer via facial movements. It could also be harnessed to control equipment within the context of Industry 4.0. In all, EarFS has significant potential in a variety of industries and scenarios.

_SMART CITY



PUBLIC PARTICIPATION 4.0

CITIZEN EMPOWERMENT

Many grassroots initiatives and ideas flounder under the weight of the effort involved or when they encounter government bureaucracy. Fraunhofer IGD's smarticipate project aims to develop a platform that simplifies public participation in urban planning.

Have you come up with a way of combating noise? Want to drum up support for a local childcare center? Know where some trees would make your residential area more attractive, and enhance the microclimate? Or you know how a nearby vacant building could be put to good use? If you want to improve an aspect of your local neighborhood, district, or street, you had better hop on a bus, a train, or rev up your car—because you will have to seek out one or more government agencies, gain an official seal of approval, and hold a public meeting. Improving your local neighborhood typically means leaving it… to deal with red tape. And that can take time. For many people, too much time.

Ideas aplenty

Almost half of all German residents work as volunteers for sports clubs, the Red Cross, and similar organizations. At the same time, efforts to improve the urban landscape, to add plants to the roadside, to find a practical use for an empty store, or to improve road safety seem to get caught up in bureaucracy, with negative results—ideation and implementation are largely left to the local authorities. This is not only regrettable; it is also illogical. More civic engagement would be welcome. After all, residents have a natural interest in the positive development of their immediate environment.

Generally, it is not an issue of citizens lacking the get-up-and-go or imagination. Quite the opposite. Almost every chat includes comments such as: "This place could do with a …" or "Wouldn't it be great if they would…" As Veneta Ivanova at Fraunhofer IGD emphasizes: "There is no lack of ideas. Grassroots initiatives generally fail because of the complicated and laborious procedures involved." What is more, the researcher explains, if citizens do actively participate they are often disappointed to discover that they are not subsequently involved in the approval and decision-making process that they themselves initiated. Many town halls are also reluctant to seek the active participation of the general public. Local authorities can be snowed under by the sheer number of proposals, overwhelmed by the effort of sifting through the ideas, and explaining their decisions.

Facilitating civic engagement

smarticipate—smart open data services and impact assessment for open governance—is a project launched by Fraunhofer IGD in association with nine European partners from five countries, and coordinated from Darmstadt. The hope is that it will greatly reduce the barriers to civic participation. smarticipate is part of the EU's H2020 program, and has a clearly defined goal: "We intend to give ordinary citizens a set of tools that allows them to easily submit proposals for their neighborhood, and to quickly receive clearly explained decisions regarding the feasibility of their suggestions," explains Ivanova. "We are creating a platform that enables a direct connection to be forged between people with ideas on the one hand, and the experts, or urban planning officials, on the other. Here at Fraunhofer IGD we are therefore developing, for example, a front end with user-friendly interaction mechanisms for 3D visualization."

The basic principle is simple

The basic principle can be easily explained. Using a high degree of automation, data from local urban planning agencies—which are generally freely available under open data initiatives in Germany—and data from other local stakeholders are combined to describe the local situation and determine the impact of ideas. Initiators can submit their design proposals via a web portal that is accessible by desktop PC, tablet, or smartphone, and "insert" it directly into the urban plan. The app allows the citizen designer to immediately view a 3D model that indicates what effect an additional floor on a block of apartments, a new park, or an individual tree would have on the look and feel of the immediate environment.

Moreover, "Once the system has been put in place, you usually get immediate feedback," states Joachim Rix, Project Head at Fraunhofer IGD. An increase in building height may block the light enjoyed by surrounding residents, it may simply be an architectural impossibility, or not be permissible under local bylaws. Perhaps certain types of trees would not thrive under prevailing soil conditions, or they would impair road visibility for drivers. But there is a building in the vicinity that could be put to good use. And bushes and shrubs could be planted. Rix highlights the importance of explanations and alternative suggestions. They not only motivate greater civic participation, they also reduce the workload on local government agencies—as authorities only have to process the inquiries that cannot be decided immediately and automatically by the platform.

https://www.youtube.com/watch?v=n8P7JUoet3c

Three cities, three diverse scenarios: view our video podcast to discover how London, Rome and Hamburg are piloting smarticipate.

A platform for greater public participation

To make this vision a reality, smarticipate needs to process data on the urban infrastructure, and more. It needs to "understand" and interpret what exactly is being proposed. "The inclusion of a semantics function is critical for acceptance and workability of our system," underlines Rix. For instance, a request to plant a tree two meters' distance from a stoplight would have to be turned down immediately because it contravenes road traffic regulations. But what if a citizen suggests a tree in five meters' distance (the minimum required by law)? "It still depends on exactly where it is to be planted, and what kind of tree it is," comments Rix. There is, he explains, a huge difference between a tree behind a stoplight (in the middle of an intersection) or to the right of a stoplight. Fraunhofer IGD is defining a set of rules that determine which proposals are permissible and technically feasible. The researchers must design a system that understands the subtle details of an idea. Otherwise, proposals might be rejected because the rules are interpreted too strictly and inflexibly. The system also needs to know what it cannot decide for itself, and must then forward the suggestion to the right contact in local government. However, Rix points out that there is considerable research and testing required before that is possible.

Three pilot projects

The team of researchers led by Veneta Ivanova and Joachim Rix is currently preparing to launch pilots in three cities with the aim of test driving the system in selected areas. In Hamburg, it will attempt to locate suitable locations for trees. In Rome, it will be deployed to develop ideas for the use of a disused army barrack. And in London, it will be employed to critically assess the already completed planning process for the construction of a new museum.

THREE QUESTIONS FOR...: WIEBKE MILDES

Remote sensing has been Wiebke Mildes's constant companion. It was the topic of her master's thesis at Jade University of Applied Sciences in Oldenburg, and for a remote sensing scenario presented at an event organized by the European Startup Awards (CESA), she won a trip to Silicon Valley. We asked the young scientist, who now works as a researcher in the Spatial Information Management Competence Center at Fraunhofer IGD, three questions.

Ms. Mildes, your master's thesis won a prize from Germany's leading association for geodetics and geospatial information, VDV. What subject does your thesis address?

I looked at the Vehnemoor nature reserve in northwestern Lower Saxony. This raised bog is a highly endangered habitat in urgent need of protection. I wanted to know: how has this wetland changed over the last 20 years? And how can advances in remote sensing methods and technology be used to improve our analysis work?

Remote sensing played a key role at Startup Week, an event organized by CESA. In what way?

The theme of Startup Week was how best to use the freely available satellite images from the Copernicus Mission to build a new business model. My suggestion was to employ the images to monitor rail tracks. For instance, it would be possible to detect the presence of tree branches on overhead power lines, rail deformations, landslides, ballast loss through water erosion, and similar hazards at an early stage and to take action. We came up with the idea within the scope of the Transforming Transport project, funded by the EU, which I supervise here at IGD.

As the award winner, you spent a week in Silicon Valley. What was the most interesting aspect of your trip? And what were your impressions with regard to the Smart City vision?

Our visit to Co-Working Spaces 500 was very impressive. It has something of the atmosphere of a huge, open-plan laboratory, with the flair of a university library. Particularly interesting was our trip to the world's largest accelerator: the Plug and Play Tech Center. I was also struck by the large number of electric cars; you also see quite a few self-driving vehicles.

CREATING A SMART NATION WITH THE HELP OF FRAUNHOFER SINGAPORE

Fraunhofer is looking to make its mark in Asia—with Fraunhofer Singapore, established in 2017 as a successor to the Fraunhofer IDM@NTU Project Center. Singapore aims to become a "Smart Nation" and Fraunhofer can contribute in a number of ways—with pioneering technologies in manufacturing, urban development, transportation and workplace design.

Eight is considered a lucky number in Asia. So it is perhaps a positive omen that Fraunhofer Singapore—established in 2017 as a successor to the IDM@NTU Project Center—is the eighth Fraunhofer subsidiary outside Germany. Fraunhofer Singapore's research activities are an excellent fit with the city-state's vision of becoming a Smart Nation. With the digital transformation of life, work, entertainment, and communication, Fraunhofer Singapore will be able to contribute with a number of groundbreaking technologies.

Industry 4.0 is much in demand

Take manufacturing: Germany's Industry 4.0 initiative has created a brand that puts Fraunhofer Singapore in a prime position, not least as the Lion City is still negotiating the early stages of this development. One example is intelligent support for the maintenance and repair of complex plant and equipment. A tablet-based augmented reality application provides the worker with instructions that are superimposed on the physical machinery, guiding them through their task step-by-step. This software can also be leveraged to effectively train new employees. Moreover, the system allows Singapore-based companies to offer customers enhanced service packages, generating competitive advantage.

Transportation

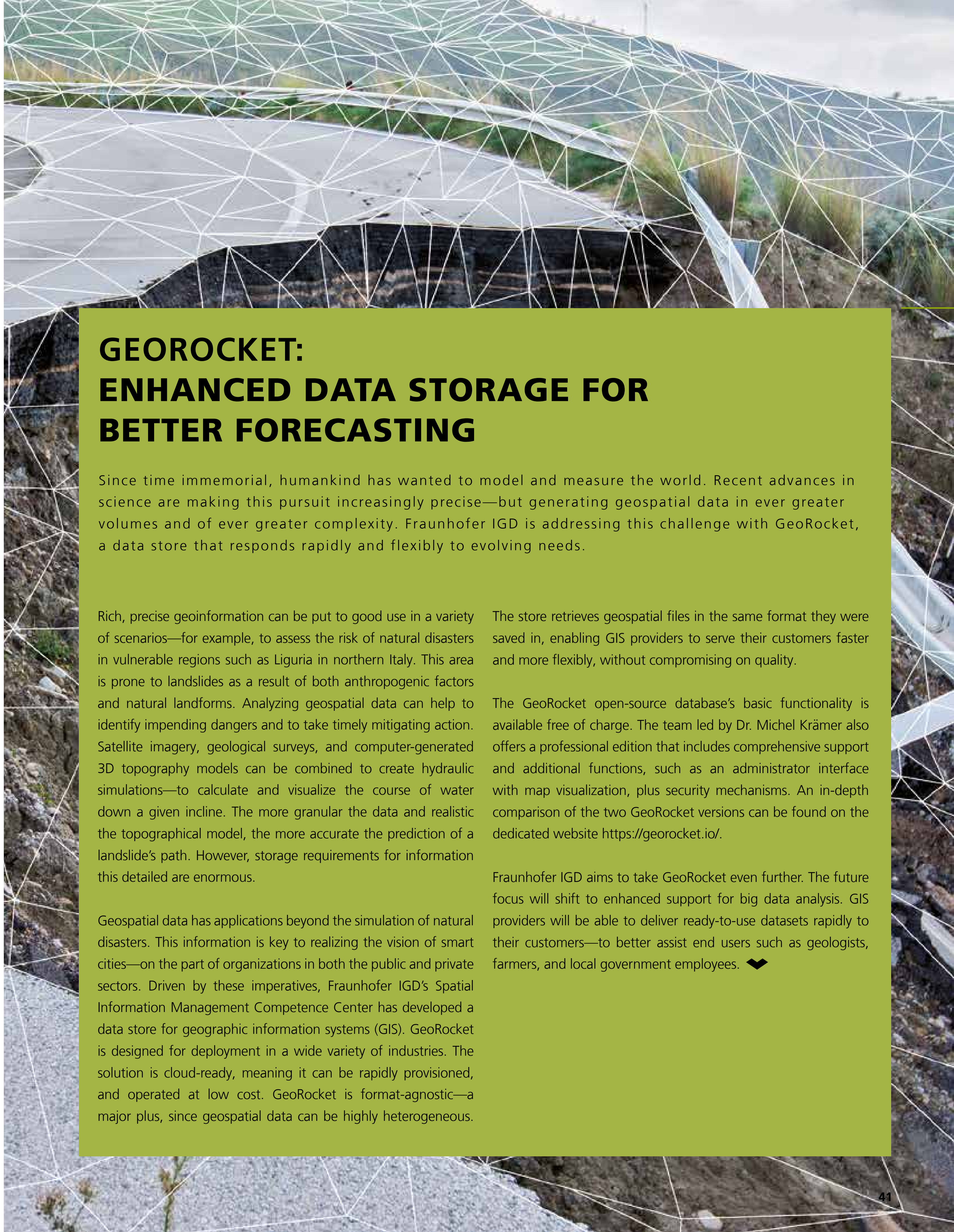
A Smart Nation cannot limit its vision to factories and workshops. It must consider other vital areas of modern society, such as smart personal mobility. Fraunhofer Singapore, for instance, intends to design and plan the bus stops of the future with the help of virtual reality (VR), based on actual transportation data provided by the local authorities. How do people behave and move? Are passengers able to board and alight with ease and speed? These and similar questions can be addressed and answered in advance with VR. Visual computing also offers great potential in another area: the goal of a Smart Port.

A three-dimensional model of the city

Plans are in place to create a digital model of the entire city-state as the basis for improved services. Similar to recent developments in manufacturing, digital and physical objects will "talk to each other" and coordinate their actions—creating what is dubbed a cyber-physical system. Fraunhofer Singapore plays a key role in this project, developing algorithms that enable the rapid and automated three-dimensional depiction of buildings and other structures.

Better working environments with brain-computer interfaces

A further key focus is workplace performance and well-being. Is the environment well designed? The brain-computer interface from Fraunhofer Singapore offers actionable insights. This "skull cap" measures and interprets human brain impulses—offering adaptive assistance comparable to ABS or parking assistants for cars.



GEOROCKET: ENHANCED DATA STORAGE FOR BETTER FORECASTING

Since time immemorial, humankind has wanted to model and measure the world. Recent advances in science are making this pursuit increasingly precise—but generating geospatial data in ever greater volumes and of ever greater complexity. Fraunhofer IGD is addressing this challenge with GeoRocket, a data store that responds rapidly and flexibly to evolving needs.

Rich, precise geoinformation can be put to good use in a variety of scenarios—for example, to assess the risk of natural disasters in vulnerable regions such as Liguria in northern Italy. This area is prone to landslides as a result of both anthropogenic factors and natural landforms. Analyzing geospatial data can help to identify impending dangers and to take timely mitigating action. Satellite imagery, geological surveys, and computer-generated 3D topography models can be combined to create hydraulic simulations—to calculate and visualize the course of water down a given incline. The more granular the data and realistic the topographical model, the more accurate the prediction of a landslide's path. However, storage requirements for information this detailed are enormous.

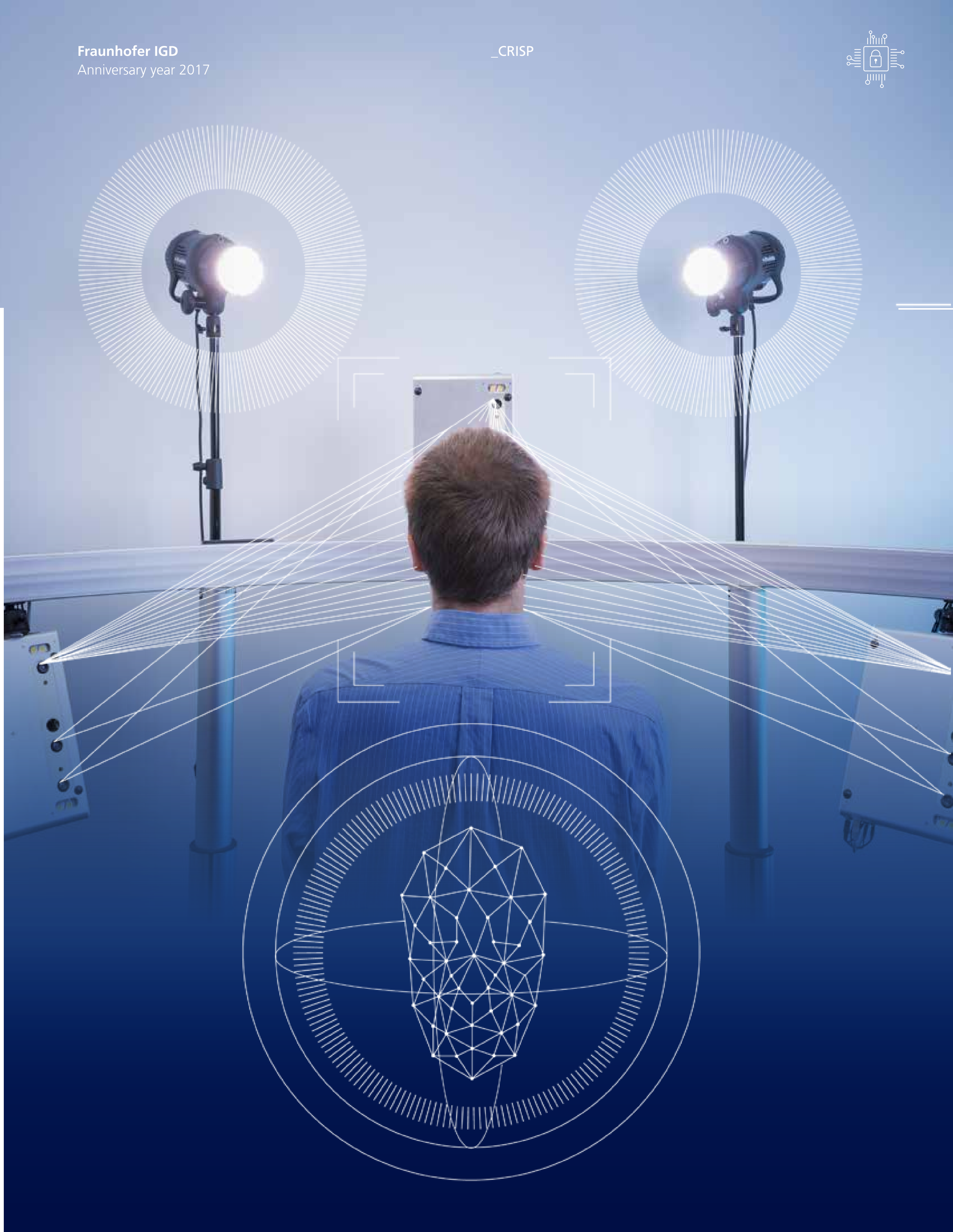
Geospatial data has applications beyond the simulation of natural disasters. This information is key to realizing the vision of smart cities—on the part of organizations in both the public and private sectors. Driven by these imperatives, Fraunhofer IGD's Spatial Information Management Competence Center has developed a data store for geographic information systems (GIS). GeoRocket is designed for deployment in a wide variety of industries. The solution is cloud-ready, meaning it can be rapidly provisioned, and operated at low cost. GeoRocket is format-agnostic—a major plus, since geospatial data can be highly heterogeneous. The store retrieves geospatial files in the same format they were saved in, enabling GIS providers to serve their customers faster and more flexibly, without compromising on quality.

The GeoRocket open-source database's basic functionality is available free of charge. The team led by Dr. Michel Krämer also offers a professional edition that includes comprehensive support and additional functions, such as an administrator interface with map visualization, plus security mechanisms. An in-depth comparison of the two GeoRocket versions can be found on the dedicated website https://georocket.io/.

Fraunhofer IGD aims to take GeoRocket even further. The future focus will shift to enhanced support for big data analysis. GIS providers will be able to deliver ready-to-use datasets rapidly to their customers—to better assist end users such as geologists, farmers, and local government employees.

_CENTER FOR RESEARCH IN SECURITY AND PRIVACY

FRAUNHOFER IGD IS A MEMBER OF EUROPE'S LARGEST ALLIANCE OF INSTITUTES FOR CYBER SECURITY RESEARCH



FACIAL RECOGNITION: THE NEW HYPE?!

We recognize people primarily by their faces. It therefore makes sense that this particular biometric marker is being increasingly adopted in the world of electronics—to unlock smartphones, to identify criminals, and more. However, security mechanisms based on facial recognition are fallible. Researchers at Fraunhofer IGD are seeking to eliminate vulnerabilities.

Rapid access to the Internet now lies in the palm of your hand. On older models all you need to do is enter your smartphone PIN. These four-number codes are designed to keep personal data safe from the prying, unauthorized eyes of others. More recent devices also feature authentication via biometric cues, such as fingerprints and iris scans. The iPhone X, launched in November 2017, goes even further: it identifies users via a 3D facial scan.

Plastic fingers and fake faces

Facial recognition has generated plenty of buzz recently, elevating the technology to hype status. At the same time, this technology is giving security experts considerable cause for concern. Current biometric systems, based on fingerprints, irises, and faces, can be fooled. In the case of fingerprints, for example, a smartphone can be hacked by using an object touched by the authorized user. Exploiting a trick often portrayed in TV crime series, a piece of adhesive tape can be used to capture the print and then transfer it to a plastic finger to gain access.

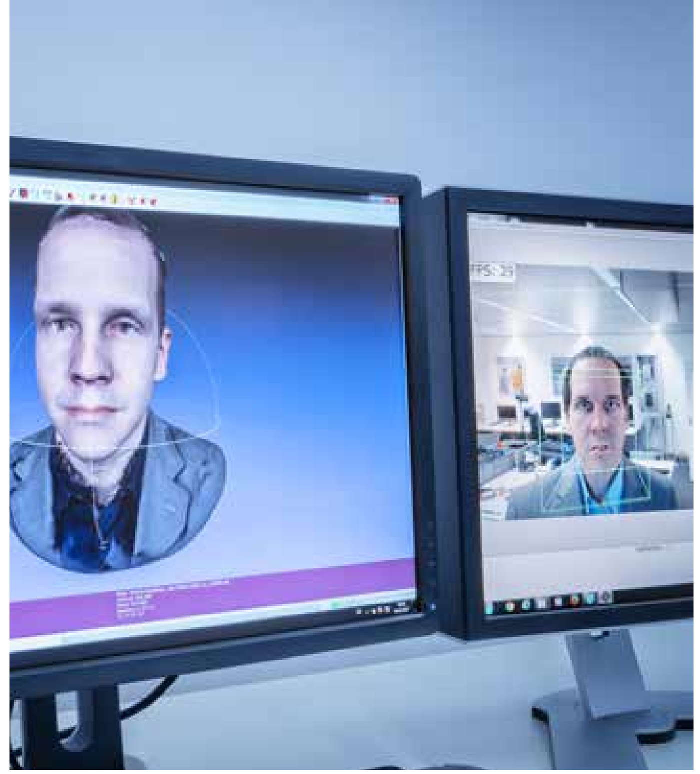
The 3D facial scan on the iPhone X was cracked in a matter of days. Although the scan is three dimensional—simply holding a photograph of the smartphone owner in front of the lens is not enough—it is still less than perfect. As Dr. Andreas Braun, Head of the Smart Living & Biometric Technologies Competence Center at Fraunhofer IGD, explains, "The system was often unable to differentiate between identical twins. And there have been cases where the facial scan could not tell family members apart because of their close resemblance. That's because the markers for 3D facial recognition are not as distinct as irises or fingerprints. Identical twins have very similar faces, but their irises and fingerprints are generally dissimilar." Hackers in Vietnam have outwitted the 3D facial scan using a somewhat different approach, albeit one that requires a great deal of time and effort. They took a 3D scan of the person's face, and created a mask that duped the facial recognition technology. In short, a game of cat-and-mouse has ensued between manufacturers and would-be hackers. And Dr. Braun is sure: "I think we can assume that, in the future, manufacturers will concentrate on detecting attempts to sidestep security mechanisms."

But evasion tactics are not the only issues keeping security experts awake at night. Dr. Braun observes: "It is entirely feasible that someone could simply snatch a smartphone from the owner's hands, or steal it in some other way, briefly pointing the device in the direction of the owner's face to unlock it before making their escape. Fingerprints make life for criminals much more difficult. Particularly when it comes to highly sensitive data, it's advisable to have another layer of protection, e.g., via an additional password."

Greater security for biometric systems

Braun and his team are working on ways to make biometric systems —whether 3D facial scans or iris and fingerprint analysis—more secure. "We want to make these systems more difficult to bypass," says Braun. But how exactly do the researchers aim to achieve their goal? For fingerprint recognition, they want the technology to not only check the individual's unique pattern but also measure their heart rate. "You can also analyze and verify that real skin is pressing the home button, and not silicone or another material—for example, through weak electric fields, or infrared illumination, or even the heat radiated by a human finger," explains Braun.

For facial recognition, Fraunhofer scientists prefer short videos to photos. These clips can be rapidly analyzed by machine learning technologies, or more specifically via deep learning, a new category of artificial neural networks. Modern-day computing power supports neural networks of ever greater complexity. Previously, neural networks operated with two to three layers; now they leverage hundreds. As a result, they are extraordinarily accurate at describing a face by means of a unique code ranging in length from one hundred to five hundred characters. A scan of that person's face then generates a code very similar to the existing database entry, enabling a match to be confirmed and the person's identity verified. The main difference between this approach and earlier biometric methods is that instead of searching for fixed points of the face and measuring the distance between them—between the eyes, for instance, or from the eyes to the nose—deep learning examines the entire face as a whole, looking for the features that best distinguish that particular person. These features usually include the area around the eyes. "We can't say with complete certainty what markers the technology will choose. It's basically a black box: we do not know exactly how the system arrives at the result, but we can prove that it is very effective," reports Braun. Very, very effective. Deep learning recognizes faces with over 99 percent accuracy under laboratory conditions.

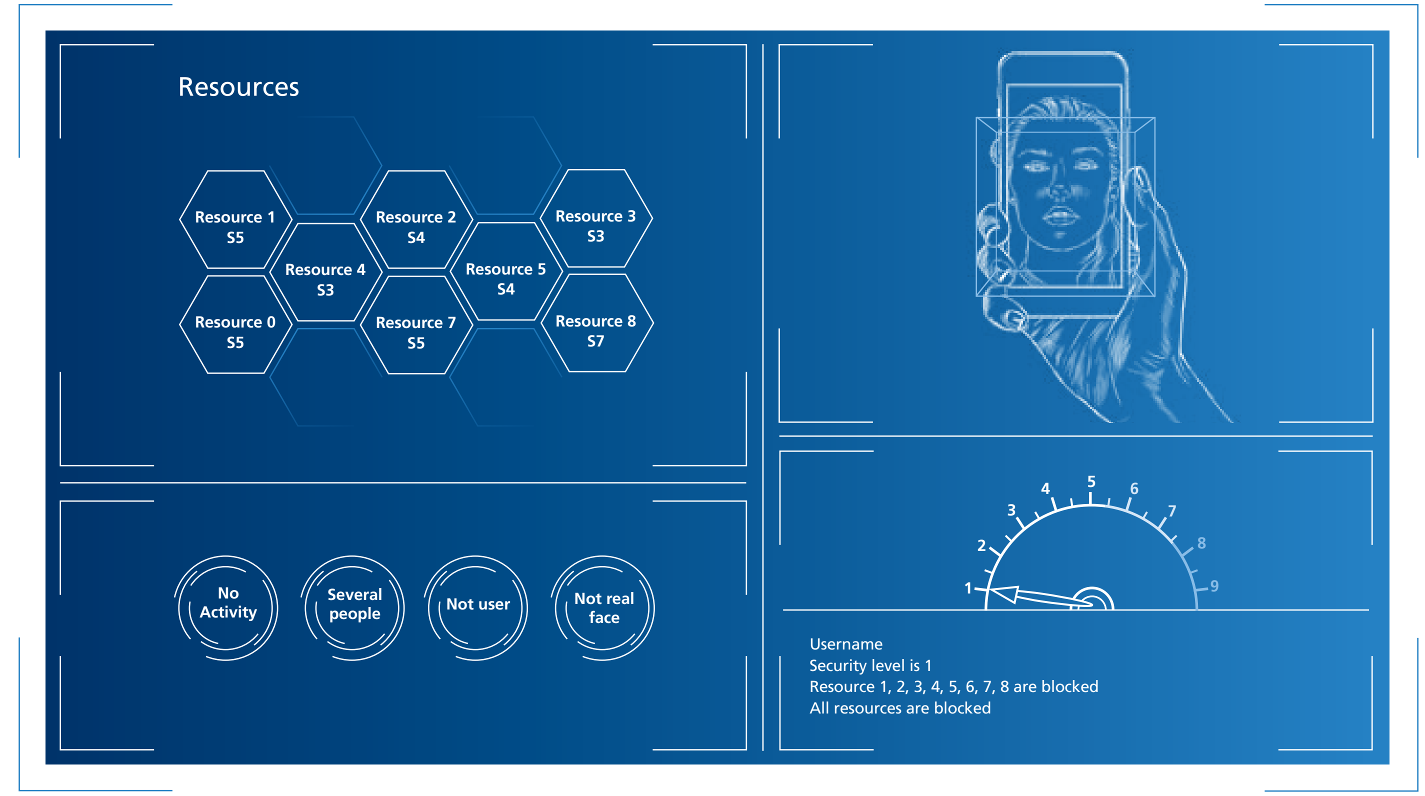


Collaboration with CRISP

For most issues relating to cyber security, Fraunhofer IGD researchers work closely with the Center for Research in Security and Privacy (CRISP), a European alliance of corresponding institutions. In addition to Fraunhofer IGD, members include Fraunhofer SIT, TU Darmstadt, and Darmstadt University of Applied Sciences. CRISP's researchers are dedicated to basic research, while Fraunhofer's focus is on applied research. However, there is plenty of overlap. Ultimately, the collaborative process is all about conducting basic research and applying it. CRISP and its partners explore questions such as: how can multi-biometrics (i.e., authentication technology that examines more than one biometric identifier) be improved? How can recognition via videos be combined with fingerprint scans? And how can systems be made more robust and resilient to attacks?

Fraunhofer IGD and CRISP also collaborate in another area: the security of smart home systems. Braun explains, "For an intelligent living housing project in the city of Weiterstadt, we are capturing data from thousands of sensors. To avoid misuse of data, we need to deploy effective—and above all—secure methods. For a CRISP project, we and our partners are developing, among other things, a secure big-data platform. This conducts the necessary analyses without the data ever leaving the confines of the user's home."

Within the scope of a further project, Braun and his team are working on methods for soft biometrics with relevance for a number of applications. Soft biometrics traits include physical attributes, e.g., eye color and body size, as well as behavioral characteristics, such as gait.



Facial recognition at Südkreuz station in Berlin

But back to facial recognition: the new iPhone unlock function based on this technology has caused quite a stir. And the same is true of a pilot project at Südkreuz commuter train station in Berlin. There is now a blue entrance next to the familiar white one. Whoever passes through the new entrance is automatically subjected to facial analysis. Will this make it possible to recognize and catch fugitives? At the moment, the system does not compare images with a database of criminals. Instead, it seeks matches with photos of 200 trial volunteers. To gauge the accuracy of the system, each participant carries a transponder indicating whether they are in fact physically present at Südkreuz station. In compliance with German privacy legislation, images of all other people must be immediately deleted.

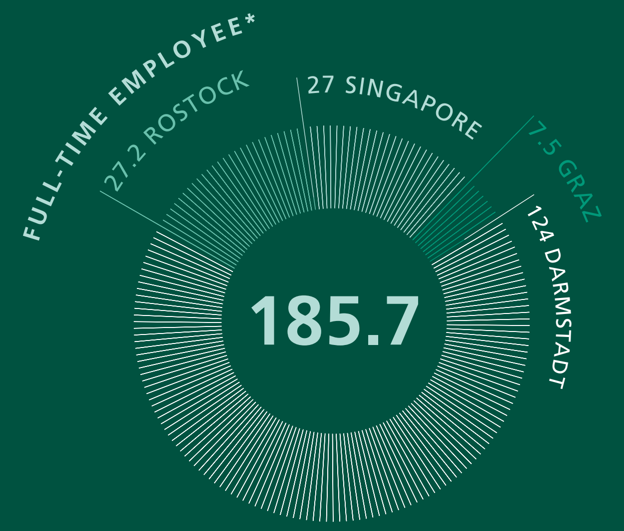
The German chancellor would like to see facial recognition adopted far more widely. After all, these systems open up new possibilities —such as enhanced security. But there are also certain hazards. Braun gives an example: "Imagine an employee at a central government agency tasked with managing all facial recognition data who then gives information on someone's movements to a third party. This is a sensitive issue. Burglars could exploit a time when the tracked person is not at home to empty their house of their valuables without fear of being disturbed." He therefore recommends that the German government take steps to prevent this from happening. However, Braun emphasizes, security violations are a peril not restricted to facial recognition. For example, an activated smartphone can be used by the network carrier to determine the user's position at any given time.

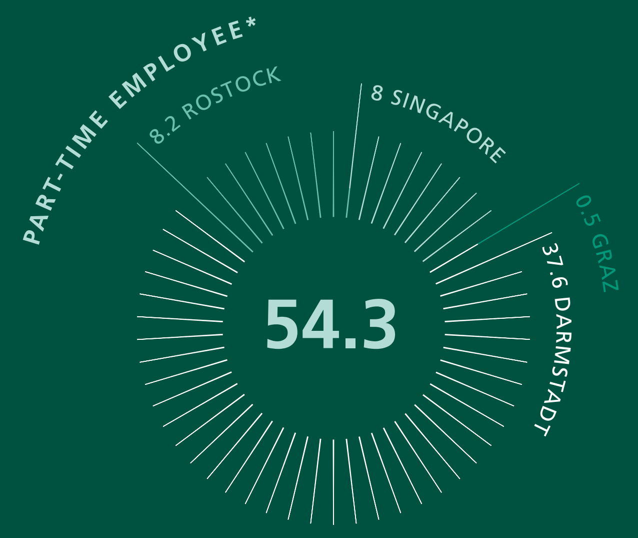
Applying facial recognition principles to manufacturing

The facial recognition methods developed by Fraunhofer IGD are not limited to accessing smartphones or ensuring public safety. They can also be put to good use in manufacturing: to verify reproducibility, a key parameter of production processes, for example. MEWA, for instance, employs biometric techniques to check the colors and reflective properties of its high-visibility clothing. Are the items sufficiently reflective? Are the colors still good enough? The methods and algorithms deployed are similar to those found in facial recognition. However, the researchers must naturally use data of a different kind to train the system for this particular task. MEWA has been recognized for its innovative use of technology from Fraunhofer IGD as the recipient of the German Industrial Prize. The company was named one of the top ten in the optical technology category. In other words, "facial recognition" is not just in demand for smartphone and public safety—but also in manufacturing.

48 – 53

_THE INSTITUTE IN NUMBERS





*FULL-TIME EQUIVALENTS

FRAUNHOFER IGD

Fraunhofer IGD is the leading international institute for applied research in visual computing. This scientific discipline combines computer graphics and image processing. It involves both the extraction of information from images and videos, and the creation of images from computer-generated models.

In 1987, Fraunhofer IGD was formed from a working group originally created by Fraunhofer-Gesellschaft. In 1992, a second site was established in Rostock—one of the first Fraunhofer locations in the former East Germany. Affiliated organizations followed in 2008, when Fraunhofer Austria set up its visual computing division, and in 2017 with the founding of Fraunhofer Singapore.

It is our mission to empower people in the digital age—to enable them to leverage increasingly complex computer systems and rising volumes of data.

To this end, we are continuously evolving and advancing our visual computing technologies, for the benefit of people, society and the economy. Visual computing has a wide range of potential uses, including for the digitized world of work, personalized medicine and smart cities—Fraunhofer IGD's three lead topics that focus on practical application.

In the future, we will make our basic technologies available to customers via our cloud-based visual computing as a service (VcaaS) platform.

TECHNOLOGY LABS

Fraunhofer IGD's dedicated labs demonstrate, test and evolve the technologies developed by the various competence centers. Additionally, the labs conduct experiments and studies within the scope of customer projects. Fraunhofer IGD has the following technology labs and demonstration centers:

- Acti Lab
- Ambient Assisted Living Labor
- CultLab3D
- DAVE
- Spatial Information Management Demonstration Center
- Biometric Systems Evaluation Lab
- Interactive Engineering Lab
- Interactive Showroom & Innovation Lounge
- High-Quality Image Acquisition and Output Lab
- Industry 4.0 Lab
- Maritime Graphics Lab
- Visual Analytics Lab
- Visual Computing for Industry 4.0 Lab
- VR/AR Lab

ADVISORY BOARD

The board not only provides expert advice to the corresponding Fraunhofer institute; it also has a supervisory role. Its members are renowned representatives of both the science and business worlds.

Chairman		
Dr. Kai Beckmann	Merck KGaA	Darmstadt
Deputy Chairman		
Professor Dr. Reiner Anderl	TU Darmstadt	Darmstadt
Members		
Professor Dr. techn. Horst Bischof	TU Graz	Graz
Professor Dr.-Ing. Edgar Dörsam	TU Darmstadt	Darmstadt
Ekkehart Gerlach	Deutsche Medienakademie GmbH	Cologne
Professor Dr. rer. nat. Reinhard Klein	University of Bonn	Bonn
Professor Dr. Stefanie Lindstaedt	Know-Center GmbH	Graz
MinR'in Dr. Ulrike Mattig	Hessen State Ministry for Higher Education, Research and the Arts	Wiesbaden
Dr. Torsten Niederdränk	Siemens AG	Erlangen
Dr. Albert Remke	52° North GmbH	Münster
Professor Dr. Bernt Schiele	Max Planck Institute for Informatics	Saarbrücken
Professor Dr. Heidrun Schumann	University of Rostock	Rostock

RESEARCH LINES

RESEARCH AT FRAUNHOFER IGD IS DIVIDED INTO FIVE STRATEGIC LINES:

COMPUTER GRAPHICS

1 Computer graphics—i.e., image synthesis—is a core discipline within visual computing, and involves the development of technologies and methods to generate images using information. Highly standardized data models are employed for diverse applications. In particular, Fraunhofer IGD researches efficient, flexible methods to keep pace with the latest developments; for example, for shared usage of resources, real-time capabilities and the latest trends in personal transportation.

COMPUTER VISION

2 Computer vision—understanding and interpreting digital images and videos—is gaining importance in automation and engineering. Deploying computer vision technologies in conjunction with sensors helps ensure high process reliability. In this context, Fraunhofer IGD is developing new and enhanced technologies for augmented reality, material acquisition and 3D reconstruction—to capture, track and reproduce objects, their position and their texture at high speed and with high fidelity.

HUMAN-COMPUTER INTERACTION

3 Interactions between man and machine are beginning to resemble natural human behavior. At the same time, ever-growing volumes of data are creating challenges for both visualization and interaction. Researchers at Fraunhofer IGD are developing technologies that enable humans and computers to work together more effectively. In this context, IGD researchers are exploring new interaction modalities, intelligent environments and visualization methods. Moreover, they are improving human-computer interaction in complex, data-intensive applications where robust security is critical.

(INTERACTIVE) SIMULATION

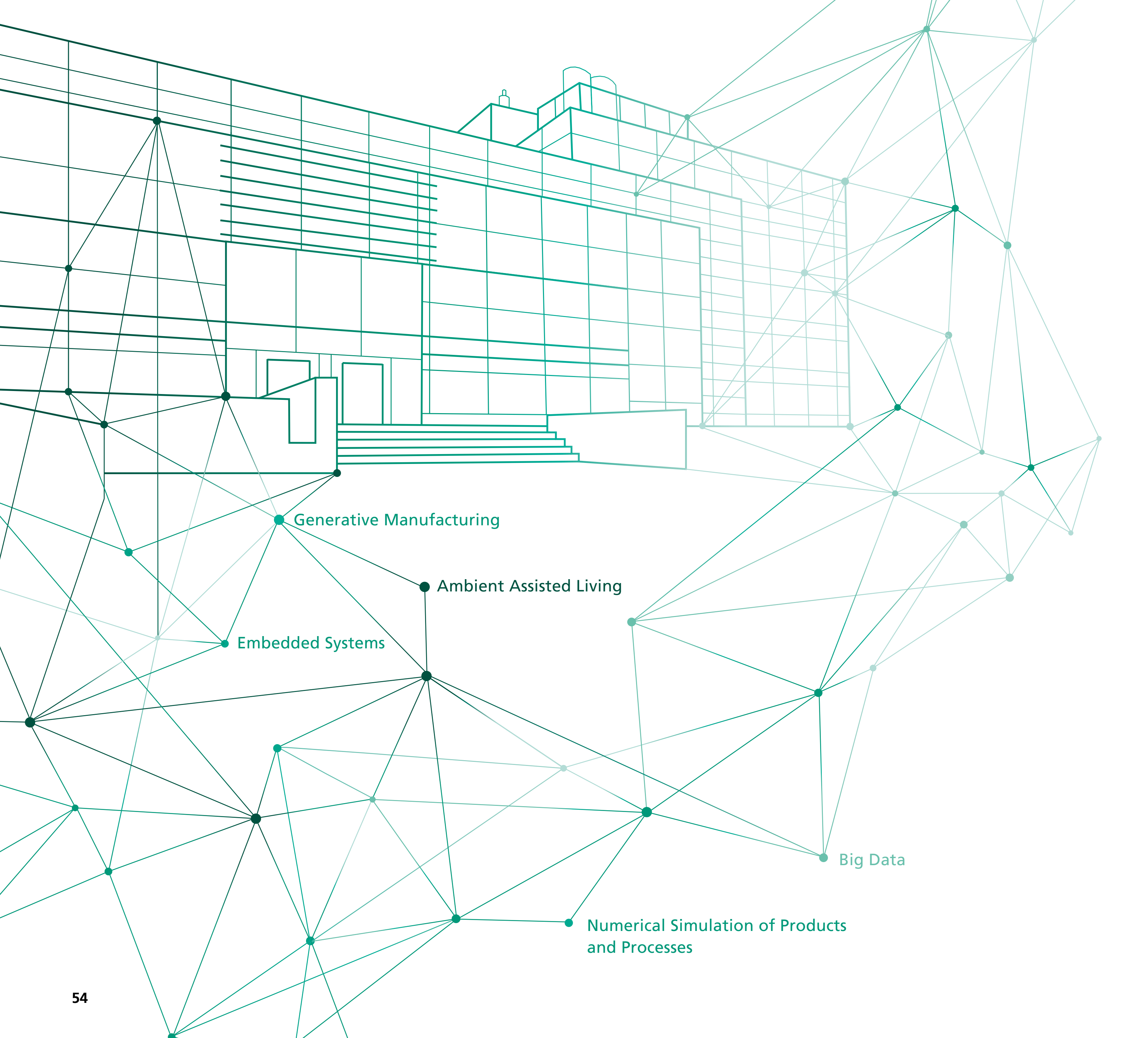
4 One of the main challenges of computer graphics is the support and acceleration of simulation. A simulation is the virtual replication of the behavior of physical objects and phenomena, such as passenger behavior during the evacuation of a ship. Fraunhofer IGD uses the latest methods, including integrated modeling, simulation and visualization, to accelerate the design process, and enable users to directly interact with and modify the simulation.

MODELING

5 Models are a key component of visual computing. They comprise an abstract view of selected aspects of reality within an information processing system. Fraunhofer IGD researches both traditional 2D/3D and more complex, higher-dimension models for use in real-world scenarios. In many cases, supplementary information is added to make models suitable for new applications and connected solutions.

Fraunhofer IGD
Anniversary year 2017
_Fraunhofer IGD in Numbers

NETWORKS



Fraunhofer Alliances

Institutes or individual departments with diverse skills collaborate within Fraunhofer Alliances, working together to develop target business areas and to market their services. Fraunhofer IGD's competence centers cooperate with departments at other Fraunhofer institutes within the scope of the following Fraunhofer Alliances: Ambient Assisted Living, Big Data, Embedded Systems, Generative Manufacturing, and Numerical Simulation of Products and Processes.

www.fraunhofer.de/de/institute/institute-einrichtungen-deutschland/fraunhofer-allianzen.html

Fraunhofer ICT Group

Institutes that work in related areas are organized into Fraunhofer Groups, and cooperate and jointly market their services in research and development (R&D). Fraunhofer IGD is a member of the ICT Group, i.e., information and communications technologies. The Group consolidates the skills of the Fraunhofer-Gesellschaft institutes that develop and implement IT solutions for diverse industries and applications. Moreover, the Group allows the institutes to adopt a holistic and made-to-measure approach to specific business areas—and to offer a single source of expert advice on technology to industry, government agencies, and the media. The Group supports companies and users with its market knowledge, skills, experts and cutting-edge technologies, and is system- and vendor-agnostic.

The Fraunhofer ICT Group represents 20 institutes with a total of approximately 4600 employees. Its central office in Berlin (Mitte) provides services and is a central point of contact for enterprises, political decision-makers, the media, and users with questions on IT innovation. The focus areas of the various institutes are comprehensive and complementary, encompassing the entire ICT value chain. In combination, the member institutes are able to drive innovation.

Since January 1, 2016, Professor Dieter W. Fellner (Director of Fraunhofer IGD) has served as the chairman of the Fraunhofer ICT Group. Alexander Nouak, biometrics expert and former competence center head at Fraunhofer IGD, is the managing director of the central office.

www.iuk.fraunhofer.de

Fraunhofer ICT Group industries:

- Mobility and transportation
- E-government
- Public safety and security
- Manufacturing and logistics
- Media and creative industries
- Digital services
- Business and finance informatics
- Medical and healthcare systems
- Energy and sustainability

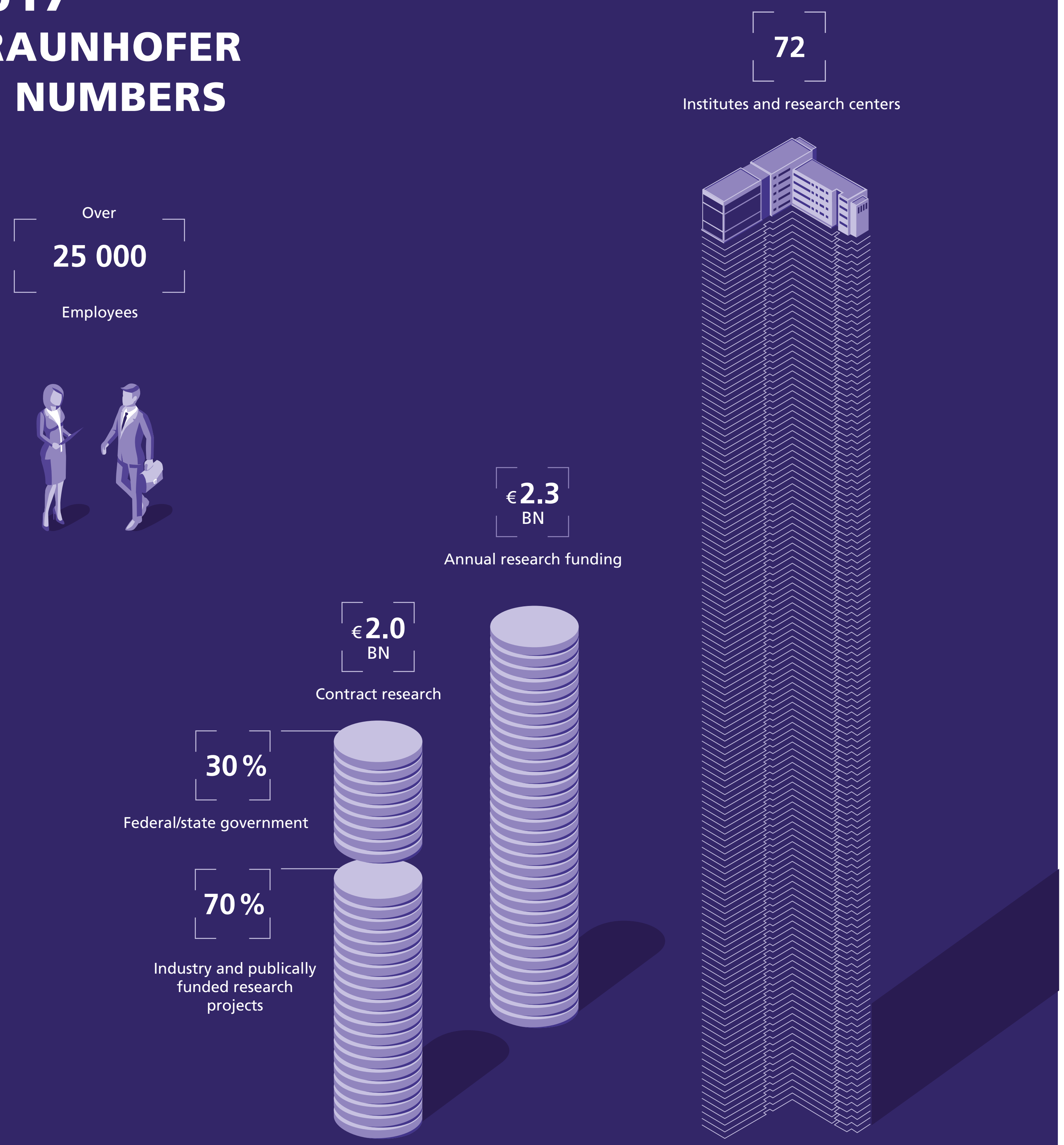
Fraunhofer ICT Group technologies:

- Numerical software and simulation
- Usability and human-computer interaction
- Reliable cyber-physical systems
- IT security and safety
- Digital networks and Internet
- Graphics and media technology
- Image acquisition and evaluation
- Big data management and analytics
- Automation technology and engineering

56 – 69

_ADDITIONAL INFORMATION

2017 FRAUNHOFER IN NUMBERS



FRAUNHOFER-GESELLSCHAFT

Fraunhofer-Gesellschaft's mission is research with a practical application. The organization was founded in 1949, and seeks to achieve outcomes that benefit the economy and society as a whole. Its contractual partners and customers comprise manufacturers, service providers and the public sector.

In Germany, Fraunhofer-Gesellschaft currently operates 72 institutes and research centers. More than 25,000 employees, most with a background in the sciences or engineering, conduct research projects with total annual funding of 2.3 billion euros. Of this amount, just under 2 billion euros is from contract research. Some 70 percent of this sub-total is attributable to contracts from industry and to publically funded research projects. Approximately 30 percent is provided in the form of basic funding from federal and state government, and is designed to support long-term work aimed at developing technologies that will be of relevance to the economy and society within five to ten years' time.

Collaborative relationships with excellent research partners and innovative enterprises around the world ensure direct access to today's and tomorrow's leading economic and research hubs.

The clearly defined focus on applied research and key future technologies ensures that Fraunhofer-Gesellschaft plays a pivotal role in innovation in Germany, and in Europe as a whole. The impact of applied research goes beyond the direct benefit to customers: the research and development activities of the Fraunhofer institutes contribute to the competitiveness of their regions, of Germany, and of Europe. They drive innovation, strengthen technological capabilities, promote acceptance of new technologies, and provide vital training and skills development opportunities for the next generation of scientists and engineers.

FRAUNHOFER EXECUTIVE BOARD

Prof. Dr.-Ing. Reimund Neugebauer
Prof. Dr. Georg Rosenfeld
Prof. Dr. Alexander Kurz
Dipl.-Kfm. Andreas Meuer

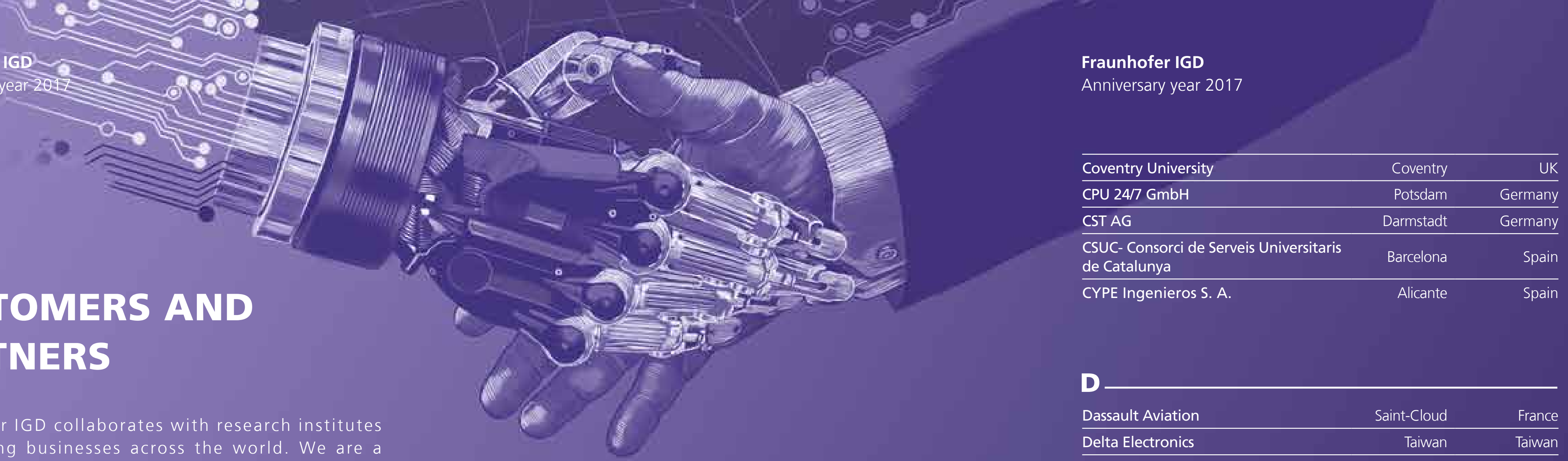
FRAUNHOFER IGD

Institute Advisor Dr. Birgit Geier

Fraunhofer-Gesellschaft offers its employees possibilities for personal and professional development, equipping them for challenging roles within their institutes, at universities, in the business world and in society. By gaining practical training and experience at Fraunhofer institutes, students gain skills that open up excellent entry-level and development opportunities at enterprises.

Fraunhofer-Gesellschaft is a recognized non-profit organization, named for physicist Joseph von Fraunhofer (1787–1826), born in Munich. He was a successful scientific researcher, inventor and entrepreneur.

www.fraunhofer.de



CUSTOMERS AND PARTNERS

Fraunhofer IGD collaborates with research institutes and leading businesses across the world. We are a valued partner to our customers—the following list is a selection of organizations and enterprises that deploy our visual computing technologies.

A

2b AHEAD ThinkTank GmbH	Leipzig	Germany
Airbus	Toulouse	France
Airbus Operations GmbH	Hamburg	Germany
Align Technology B. V.	Amsterdam	Netherlands
All-in-Image Ltd.	Herzliya	Israel
ARCTUR d. o. o.	Nova Gorica	Slovenia
ATHENA Research & Innovation Center	Athens	Greece
Athens Technology Center S. A.	Athens	Greece
ATOS	Madrid	Spain
Audi AG	Ingolstadt	Germany
AVL List GmbH	Graz	Austria

B

Baltic Metalltechnik GmbH	Greves-mühlen	Germany
BASIS Computer- & Systemintegration GmbH	Wismar	Germany
Bergische Universität	Wuppertal	Germany
BioArtProduct GmbH	Rostock	Germany
BioCurve S. L.	Zaragoza	Spain
German Federal Ministry for Education and Research	Berlin	Germany
BOC Asset Management GmbH	Vienna	Austria
BOGE KOMPRESSOREN Otto Boge GmbH & Co. KG	Bielefeld	Germany
Borit NV	Geel	Belgium
British Telecom	London	UK
BTechC	Martorell	Spain
Building Construction Authority	Singapore	Singapore

C

Capvidia GmbH	Neuss	Germany
CARSA	Getxo	Spain
Certis Cisco	Singapore	Singapore
cirp GmbH	Heimsheim	Germany
Clausohm Software GmbH	Neverin	Germany
clesgo UG	Stuttgart	Germany
Cottés Group	Barcelona	Spain

Coventry University	Coventry	UK
CPU 24/7 GmbH	Potsdam	Germany
CST AG	Darmstadt	Germany
CSUC- Consorci de Serveis Universitaris de Catalunya	Barcelona	Spain
CYPE Ingenieros S. A.	Alicante	Spain

D

Dassault Aviation	Saint-Cloud	France
Delta Electronics	Taiwan	Taiwan
Deutsches Herzzentrum	Berlin	Germany
DFKI GmbH	Kaiserslautern	Germany
DHCAE Tools GmbH	Krefeld	Germany
Die Johanniter	Berlin	Germany
DITG GmbH	Düsseldorf	Germany
DocMorris N. V.	Heerlen	Netherlands
Donerre Amortisseur	Montech	France

E

EMO Extrusion Molding GmbH	Micheldorf	Austria
E-PATROL north GmbH	Rostock	Germany
European Union	Brussels	Belgium
EurActiv.com PLC	Brussels	Belgium
European Commission	Brussels	Belgium
European Sensor Systems S. A.	Athens	Greece

F

FCC, Fraunhofer-Chalmers Center for Industrial Mathematics	Göteborg	Sweden
FICEP S. p. A.	Gazzada Schianno	Italy
Fondazione IRCCS – Istituto Nazionale dei tumori	Milan	Italy
FORCAM GmbH	Ravensburg	Germany
FORTecH GmbH	Rostock	Germany
Fotofinder GmbH	Passau	Germany
FutureTV GmbH & Co. KG	Rostock	Germany

G

German Computer Company GmbH	Hamelin	Germany
Gnúbila France	Argonay	France
GPB Arke Ing.-Büro für Umwelttechnik	Hemeringen	Germany

H

Hahn-Schickard-Gesellschaft	Villingen-Schwenningen	Germany
Hamburg Applications MES UG	Hamburg	Germany
Heidelberger Druckmaschinen AG	Heidelberg	Germany
Heinrich-Heine-Universität Düssel-dorf – ENT hospital	Düsseldorf	Germany
Helic S. A.	Marousi	Greece
Darmstadt University of Applied Sciences	Darmstadt	Germany

I

IFQ GmbH	Wismar	Germany
IGN Institut National de l'Information Géographique et Forestière	Saint-Mandé	France
IMATI CNR	Pavia, Genoa	Italy
Infokom GmbH	Neubranden-burg	Germany
Innovagency – Consultoria, Tecnologia e Comunicação S. A.	Lisbon	Portugal
Innovalia Assocation	Bilbao	Spain
INO-Ingenieurbüro für Numerische Optimierungsmethoden	Aachen	Germany
INRIA – Institut National de Recherche en Informatique et en Automatique	Rocquencourt	France
Institut für Prävention und betriebliche Gesundheitsförderung	Rostock	Germany
Institute of Adult Learning	Singapore	Singapore
Institute of Geodesy, Cartography and Remote Sensing, Hungary (FOMI)	Budapest	Hungary
Introsys, S A	Quinta do Anjo	Portugal
IQGen	Cologne	Germany
Istituto Giannina Gaslini	Genoa	Italy
ITAINNOVA Instituto Tecnológico de Aragón	Zaragoza	Spain
ITECAM – Centro Tecnológico del Metal de Castilla-La Mancha	Tomelloso	Spain
iuem – Institut Universitaire Européen de la Mer	Plouzane	France

J

John Deere GmbH & Co. KG	Mannheim	Germany
Jotne EPM Technology AS	Oslo	Norway

K

KIT	Karlsruhe	Germany
Klinikum Karlsburg	Karlsburg	Germany
KOMSA Business Process Services Europe GmbH	Hartmanns-dorf	Germany

L

LDR Pte Ltd	Singapore	Singapore
Leada AG	Filderstadt	Germany
Leonardo Aircraft	Pomigliano	Italy
Liebau Orthopädietechnik	Rostock	Germany
Liebherr-MCCtec Rostock GmbH	Rostock	Germany
Lloyd's Register Marine & Offshore EMEA	Hamburg	Germany
Lufthansa Systems	Raunheim	Germany
Lynkeus Srl	Rome	Italy

M

M.O.S.S. Computer Systeme GmbH	Taufkirchen	Germany
Mankiewicz Gebr. & Co.	Hamburg	Germany
Martini-Klinik am UKE GmbH	Hamburg	Germany
MEYER WERFT GmbH & Co. KG	Papenburg	Germany
MIJU S. A.	Zaragoza	Spain
Ministry of Defense Singapore	Singapore	Singapore
Missler Software	Ramonville	France
Mondon Design	Berlin	Germany
Multimed Engineers SRL	Parma	Italy

N

nablaDot	Zaragoza	Spain
Nanyang Technological University	Singapore	Singapore
National Institute of Education	Singapore	Singapore
Next Step Dynamics	Malmö	Sweden
NOESIS Solutions N. V.	Leuven	Belgium
NOVATRA SAS	Varennes-Saint-Sauveur	France
NUMECA Ingenieurbüro	Altdorf (Nuremberg)	Germany
NUMECA International	Brussels	Belgium

O

OneToNet Srl	Milan	Italy
Ospedale Pediatrico Bambino Gesù	Rome	Italy

P

Phacon GmbH	Leipzig	Germany
Pironex GmbH	Rostock	Germany
Politecnico di Milano	Milan	Italy
PowerKut Ltd.	Coventry	UK
Progether S. A.	Oslo	Norway
ProSeS BDE GmbH	Pforzheim	Germany
PSIPENTA Automotive & Industry GmbH	Berlin	Germany

R

Robert Bosch GmbH	Blaichach	Germany

S

S. K. M. Informatik GmbH	Schwerin	Germany
Sanalytica AG	Zürich	Switzerland
scapos AG	Sankt Augustin	Germany
SEAR GmbH	Rostock/ Weissenfels	Germany
Seazone Solutions Limited	Wallingford Oxfordshire	UK
SenSpec GmbH	Rostock	Germany
SES-Tec OG	Graz	Austria
SGM Solutions Global Media GmbH	Berlin	Germany
ShareDat	Rostock	Germany
Sharedat Deutschland	Rostock	Germany
Siemens AG	Munich	Germany
SimPlan AG	Hanau	Germany
Singapore Maritime Institute	Singapore	Singapore
Singapore Sports Institute	Singapore	Singapore
SINTEF ICT	Oslo	Norway
SIV Software-Architektur und Techno-logie GmbH	Rostock	Germany
SMC Pneumatik GmbH	Egelsbach	Germany
Sonormed GmbH	Hamburg	Germany
STAM S. r. l.	Genoa	Italy
Standard Profil	Logroño	Spain
Stellba Hydro GmbH & Co KG	Herbrechtingen	Germany
Stichting Maastricht Radiation Oncology MAASTRO Clinic	Maastricht	Netherlands
Stichting VU-VUmc	Amsterdam	Netherlands
Stieblich Hallenbau GmbH	Güstrow	Germany
STMicroelectronics Srl	Milan	Italy
STOLLE Sanitätshaus	Schwerin	Germany
STT Systems	San Sebastian	Spain
SUPSI – Scuola Universitaria Professiona-le della Svizzera Italiana	Manno	Switzerland
symmedia GmbH	Bielefeld	Germany

T

Technologie- und Anwendungszent-rum Vorpommern mbH	Greifswald	Germany
Thünen-Institut	Rostock	Germany

Trebing & Himstedt Prozeßautomation GmbH & Co. KG	Schwerin	Germany
TRIMEK	Altube-Zuia	Spain
TRIVISIO Prototyping GmbH	Trier	Germany
Tronrud Engineering AS	Honefoss	Norway
TRW Airbag Systems GmbH	Laage	Netherlands
TTS – Technology Transfer System S. r. l.	Milan	Italy
TU Wien	Vienna	Austria

U

UCL – University College London	London	UK
Universidad de Zaragoza	Zaragoza	Spain
Universidad Politecnica de Madrid	Madrid	Spain
Università degli Studi di Parma	Parma	Italy
Universität Kassel	Kassel	Germany
Universität Konstanz	Konstanz	Germany
Universität Rostock	Rostock	Germany
Universität Stuttgart	Stuttgart	Germany
Universitätsklinikum Essen	Essen	Germany
Universitätsmedizin Rostock	Rostock	Germany
University of Edinburgh	Edinburgh	UK
University of Nottingham	Nottingham	UK
University of Patras	Patras	Greece
University of Sheffield	Sheffield	UK
Universiteit Utrecht	Utrecht	Netherlands

V

VCI	Athens	Greece
Verband Druck und Medien NordOst e. V.	Hanover	Germany
vital & physio GmbH	Rostock	Germany
VIWIS GmbH	Hamburg	Germany
VTT	Tampere	Finland
VU University Medical Center	Amsterdam	Netherlands

W

Werner Otto GmbH	Hamelin	Germany
Worldbank Energy & Extractives	Washington DC	USA
Wulf Gaertner Autoparts AG	Hamburg	Germany

Z

Zentral-Fachausschuss Berufsbildung Druck und Medien (ZFA)	Hanover	Germany

PUBLICATIONS

Scientific publications are a key part of research and are vital to increasing awareness. Fraunhofer IGD's many publications underscore our scientific excellence. Furthermore, we exchange information and insights with visual computing professionals. The following is a selection of our 2017 publications:

Damer, Naser; Terhörst, Philipp; Braun, Andreas; Kuijper, Arjan
Efficient, Accurate, and Rotation-Invariant Iris Code. IEEE Signal Processing Letters 24 (2017), 8, pp. 1233-1237

Siegmund, Dirk; Samartzidis, Timotheos; Fu, Biying; Braun, Andreas; Kuijper, Arjan
Fiber Defect Detection of Inhomogeneous Voluminous Textiles. MCPR 2017, pp. 278-287

Fu, Biying; Gangatharan, Dinesh Vaithyalingam; Kuijper, Arjan; Kirchbuchner, Florian; Braun, Andreas
Exercise Monitoring On Consumer Smart Phones Using Ultrasonic Sensing. iWOAR 2017, 6 p.

Wilmsdorff, Julian von; Kirchbuchner, Florian; Fu, Biying; Braun, Andreas; Kuijper, Arjan
An Exploratory Study on Electric Field Sensing. Ambient Intelligence 2017, pp. 247-262

Altenhofen, Christian; Schuwirth, Felix; Stork, André; Fellner, Dieter W.
Volumetric Subdivision for Consistent Implicit Mesh Generation. Computers & Graphics (2017), 69, pp. 68 - 79

Graf, Holger; Stork, André
CAE/VR Integration - A Path to Follow? A Validation Based on Industrial Use. ECMS, pp. 436-445

Mueller-Roemer, Johannes; Altenhofen, Christian; Stork, André
Ternary Sparse Matrix Representation for Volumetric Mesh Subdivision and Processing on GPUs. Computer Graphics Forum 36 (2017), 5, pp. 59-69

Ruppert, Tobias; Staab, Michael; Bannach, Andreas; Lücke-Tieke, Hendrik; Bernard, Jürgen; Kuijper, Arjan; Kohlhammer, Jörn
Visual Interactive Creation and Validation of Text Clustering Workflows to Explore Document Collections. Visualization and Data Analysis 2017, pp. 46-57

Ulmer, Alex; Kohlhammer, Jörn; Shulman, Haya
Towards Enhancing the Visual Analysis of Interdomain Routing. IVAPP 2017, pp. 209-216

Wientapper, Folker; Kuijper, Arjan
Unifying Algebraic Solvers for Scaled Euclidean Registration from Point, Line and Plane Constraints. ACCV16 , 2017, pp. 52-66

Gutbell, Ralf; Kühnel, Hannes; Kuijper, Arjan
Texturizing and Refinement of 3D City Models with Mobile Devices. ACIVS 2017, pp. 313-324

Khan, Zaheer; Dambruch, Jens; Peters-Anders, Jan; Sackl, Andreas; Strasser, Anton; Fröhlich, Peter; Templer, Simon; Soomro, Kamran
Developing Knowledge-Based Citizen Participation Platform to Support Smart City Decision Making: The Smarticipate Case Study. Information 8 (2017), 2, 24 p.

Oyarzun Laura, Cristina; Drechsler, Klaus; Wesarg, Stefan; Bale, Reto
Accurate Physics-Based Registration for the Outcome Validation of Minimal Invasive Interventions and Open Liver Surgeries. IEEE Transactions on Biomedical Engineering 64 (2017), 2, pp. 362-371

Ma, Jingting; Wang, Anqi; Lin, Feng; Wesarg, Stefan; Erdt, Marius
Nonlinear Statistical Shape Modeling for Ankle Bone Segmentation Using a Novel Kernelized Robust PCA. MICCAI 2017, pp.136-143

Räsch, Sascha; Herz, Maximilian; Behr, Johannes; Kuijper, Arjan
Efficient Compression for Server-Side G-Buffer Streaming in Web Applications. Web3D 2017, 7 p.

Le Moan, Steven; Tanksale, Tejas Madan; Byshko, Roman; Urban, Philipp
An Observer-Metamerism Sensitivity Index for Electronic Displays. Journal of the Society for Information Display 25 (2017), 9, pp. 554-560

Santos, Pedro; Ritz, Martin; Fuhrmann, Constanze; Monroy Rodriguez, Rafael; Schmedt, Hendrik; Tausch, Reimar; Domajnko, Matevz; Knuth, Martin; Fellner, Dieter W.
Acceleration of 3D Mass Digitization Processes: Recent Advances and Challenges. Mixed Reality and Gamification for Cultural Heritage, 2017, pp. 99-128

Farhadifard, Fahimeh; Radolko, Martin; Lukas, Uwe von
Single Image Marine Snow Removal based on a Supervised Median Filtering Scheme. VISAPP 2017, pp. 280-287

Radolko, Martin; Farhadifard, Fahimeh; Lukas, Uwe von
Change Detection in Crowded Underwater Scenes Via an Extended Gaussian Switch Model Combined with a Flux Tensor Pre-segmentation. VISAPP 2017, pp. 405-415

Sadik, Ahmed R.; Taramov, Andrei; Urban, Bodo
Optimization of Tasks Scheduling in Cooperative Robotics Manufacturing via Johnson's Algorithm: Case-Study: One Collaborative Robot in Cooperation with Two Workers. ICSPC 2017, pp. 36-41

Matthies, Denys J.C.; Roumen, Thijs; Kuijper, Arjan; Urban, Bodo
CapSoles: Who Is Walking on What Kind of Floor? MobileHCI 2017, 14 p.

Matthies, Denys J.C.; Strecker, Bernhard Arthur; Urban, Bodo
EarFieldSensing: A Novel In-Ear Electric Field Sensing to Enrich Wearable Gesture Input through Facial Expressions. CHI ,17, pp. 1911-1922

Schinko, Christoph; Vosgien, Thomas; Prante, Thorsten; Schreck, Tobias; Ullrich, Torsten:
Search & Retrieval in CAD Databases : A User-centric State-of-the-Art Overview. GRAPP 2017, 306-313

Zhang, Xingzi; Goesele, Michael; Sourin, Alexei
Tangible Images of Real Life Scenes. Computers & Graphics 64 (2017), pp. 62-73

Edelsbrunner, Johannes; Havemann, Sven; Sourin, Alexei; Fellner, Dieter W.
Procedural Modeling of Architecture with Round Geometry. Computers & Graphics 64 (2017), pp. 14-25

Koa, Ming Di; Johan, Henry; Sourin, Alexei
Interactive Screenspace Fragment Rendering for Direct Illumination from Area Lights Using Gradient Aware Subdivision and Radial Basis Function Interpolation. Computers & Graphics 64 (2017), pp. 37-50

OUR SERVICES – WHAT WE OFFER

We leverage our expertise in applied visual computing to support our customers in industry, business and the public sector—through visualization and simulation technologies for diverse applications.

Visual computing can be implemented wherever cutting-edge computer systems are deployed. Humans are visual beings, and these technologies have the potential to simplify and improve work processes. Particularly when it comes to engineering tasks or decision-making on aesthetics, customized visual computing solutions can improve quality and quantity. Fraunhofer IGD and its partners offer a variety of high-quality contract research and related services, and work hand-in-hand with customers to put them into practice.

Our offering and services at a glance

- Contract research for industry, business, and government agencies
- Development of concepts, models and practical solutions
- Evaluation of software and hardware
- On-site support services for customers
- Information visualization
- 2D and 3D modeling
- Development of new technologies, prototypes and complete systems
- Model simulation
- Licensing
- Training
- Studies and consulting

CONTACTS

01


02


03


04


Technologies and practical applications drive our core competencies. In our research, we employ a broad spectrum of methods that we continuously improve and evolve. Our comprehensive and interdisciplinary approach allows us to offer many diverse services, divided into our 13 competence centers and one service center.

01 **Dr. Johannes Behr**
Darmstadt | +49 6151 155-510 | johannes.behr@igd.fraunhofer.de

VISUAL COMPUTING SYSTEM TECHNOLOGIES

Visual computing encompasses image- and model-based informatics, including virtual and augmented reality, data processing and computer vision. The Visual Computing System Technologies Competence Center led by Dr. Johannes Behr is dedicated to making Fraunhofer IGD's basic technologies available to other research groups and to German industry.

02 **Dr. Ulrich Bockholt**
Darmstadt | +49 6151 155-277 | ulrich.bockholt@igd.fraunhofer.de

VIRTUAL AND AUGMENTED REALITY

Virtual and Augmented Reality is the name and focus of the competence center led by Ulrich Bockholt. The center researches technologies for object recognition and tracking using video camera images. The corresponding solutions are deployed on smartphones and tablets in scenarios that include industrial maintenance, 3D interaction and assisted driving.

03 **Dr. Andreas Braun**
Darmstadt | +49 6151 155-208 | andreas.braun@igd.fraunhofer.de

SMART LIVING & BIOMETRIC TECHNOLOGIES

The Smart Living & Biometric Technologies Competence Center led by Andreas Braun develops pioneering solutions for smart environments. The aim is to seamlessly integrate dynamic sensor systems, intelligent platforms, innovative interaction and biometric systems in workplaces and homes, to assist people in day-to-day life.

04 **Dr. Eva Eggeling**
Graz | +43 316 873-5410 | eva.eggeling@fraunhofer.at

VISUAL COMPUTING

High-quality visualization requires both modeling and simulation. Eva Eggeling's team merges these two challenging disciplines to create immersive environments. Fraunhofer Austria in Graz enables visualization to be deployed in diverse real-world scenarios, with the aim of continuously improving human-computer interaction.

05 **Dr. Eva Klien**

Darmstadt | +49 6151 155-412 | eva.klien@igd.fraunhofer.de

SPATIAL INFORMATION MANAGEMENT

Eva Klien heads the Spatial Information Management Competence Center. Its researchers use new, digital geographic information technologies to enable effective communication and collaboration. Furthermore, the center is breaking new ground in 3D geographic information systems in terms of comprehensive integration, management and visualization.

06 **Prof. Jörn Kohlhammer**

Darmstadt | +49 6151 155-646 | joern.kohlhammer@igd.fraunhofer.de

INFORMATION VISUALIZATION AND VISUAL ANALYTICS

The Information Visualization and Visual Analytics Competence Center not only focuses on visual analytics, but also on semantics visualization and real-time capabilities. Jörn Kohlhammer's team develops solutions for interactive visualization involving large volumes of data, i.e., visual analytics technologies.

07 **Prof. Wolfgang Müller-Wittig**

Singapore | +65 6790 6988 | wolfgang.mueller-wittig@fraunhofer.sg

INTERACTIVE DIGITAL MEDIA

Under the guidance of Wolfgang Müller-Wittig, Fraunhofer Singapore leverages its expertise in real-time rendering, virtual and augmented reality, and human-computer interaction to strengthen the interactive digital media market— and to develop solutions for other sectors, such as transportation, marketing and education. The Singapore site provides valuable insights into the regional characteristics of the Asian market.

08 **Prof. André Stork**

Darmstadt | +49 6151 155-469 | andre.stork@igd.fraunhofer.de

INTERACTIVE ENGINEERING TECHNOLOGIES

The Interactive Engineering Technologies Competence Center led by André Stork creates solutions that streamline decision-making for engineers. To this end, the researchers harness computer graphics technologies, including interactive graphics and simulations, and modeling. Sophisticated simulation methods and interactive visualization provide assistance and deliver visibility into complex issues.

09 **Prof. Uwe Freiherr von Lukas**

Rostock | +49 381 4024-100 | uwe.von.lukas@igd-r.fraunhofer.de

MARITIME GRAPHICS

The Maritime Graphics Competence Center develops solutions for maritime applications. Its pioneering work benefits shipbuilding and ship operation, and marine technology/research. Under the direction of Uwe Freiherr von Lukas, Fraunhofer IGD researchers unite technical expertise in (underwater) image processing and visualization with specialist knowledge of the needs and challenges of the maritime industry.

Fraunhofer IGD
Anniversary year 2017
_Contacts

10 **Dr. Mario Aehnelt**

Rostock | +49 381 4024-100 | mario.aehnelt@igd-r.fraunhofer.de

VISUAL ASSISTANCE TECHNOLOGIES

The competence center develops solutions for the visualization of critical data, particularly in the mechanical and plant engineering and health care industries. Under Dr. Mario Aehnelt's leadership, the center's researchers work on technologies to support people in various aspects of their work, education and personal lives. They also create solutions that provide information and documents in line with needs and contexts, and that enable intuitive human-computer interaction.

11 **Prof. Philipp Urban**

Darmstadt | +49 6151 155-250 | philipp.urban@igd.fraunhofer.de 3D

PRINTING TECHNOLOGY

Philipp Urban leads the 3D Printing Technology Competence Center, which develops models, algorithms and software to create printed 3D copies of objects with high fidelity. The goal is a 3D copier with which the original and reproduction are virtually indistinguishable. The latest developments explore 3D printing with multiple materials.

12 **M. Sc. Pedro Santos**

Darmstadt | +49 6151 155-472 | pedro.santos@igd.fraunhofer.de

CULTURAL HERITAGE DIGITIZATION

The Cultural Heritage Digitization Competence Center led by Pedro Santos develops fast, cost-effective digitization methods to virtually reproduce physical objects with high fidelity. This involves the automatic scanning and capture of an item's geometry and texture, plus physical and visual attributes of the material. The objects are scanned using a variety of optical sensors and light sources; consistent ambient conditions are maintained to ensure high-quality results.

13 **Dr. Stefan Wesarg**

Darmstadt | +49 6151 155-511 | stefan.wesarg@igd.fraunhofer.de

VISUAL HEALTHCARE TECHNOLOGIES

New software is changing medicine and medical technologies. Imaging supports doctors in their day-to-day work, and plays an essential role in hospitals. These technologies help staff with planning, simulating and navigating surgeries. The Visual Healthcare Technologies Competence Center led by Stefan Wesarg develops solutions that enable doctors to use image data to improve diagnoses, treatment plans, and operations.

Do you have any questions, or are considering collaborating with us?
Our contacts in Germany, Austria and Singapore would be glad to help.

HOW TO FIND US

FRAUNHOFER INSTITUTE FOR COMPUTER GRAPHICS RESEARCH IGD

DARMSTADT
Fraunhoferstrasse 5
64283 Darmstadt, Germany

Phone +49 6151 155-0
Fax +49 6151 155-199
info@igd.fraunhofer.de
www.igd.fraunhofer.de

Director
Dieter W. Fellner, Professor
Phone +49 6151 155-100
institutsleitung@igd.fraunhofer.de

Deputy Director
Dr. Matthias Unbescheiden
Phone +49 6151 155-155
matthias.unbescheiden@igd.fraunhofer.de

Director's Office
Elke Emich
Phone +49 6151 155-101
Fax +49 6151 155-105
elke.emich@igd.fraunhofer.de

ROSTOCK
Joachim-Jungius-Strasse 11
18059 Rostock, Germany

Phone +49 381 4024-110
Fax +49 381 4024-199
info@igd-r.fraunhofer.de
www.igd.fraunhofer.de/rostock

GRAZ
Fraunhofer Austria Research GmbH
Visual Computing Business Unit
Inffeldgasse 16c/II
8010 Graz, Austria

Phone +43 316 873-5410
Fax +43 316 873-105410
office.graz@fraunhofer.at
www.vc.fraunhofer.at

SINGAPORE
Fraunhofer Project Center IDM@NTU
50 Nanyang Avenue
Singapore 639798, Singapore

Phone +65 6790 6989
Fax +65 6792 8123
info@fraunhofer.sg
www.fraunhofer.sg

Fraunhofer IGD
Anniversary year 2017

LEGAL NOTICE

Editor
Fraunhofer Institute for Computer Graphics Research IGD
Prof. Dr. techn. Dieter W. Fellner

Editorial Team
Daniela Welling (Team Leader), Janine van Ackeren,
Charlott Kröchert, Andreas Kunkel, Svenja Prasche, Anahit Roth

Design
Julian Egner, Anja Gollnast, Anne Jahnke

Address
Fraunhofer Institute for Computer Graphics Research IGD
Corporate Communications
Fraunhoferstrasse 5
64283 Darmstadt
Phone +49 6151 155-146 | E-mail: uk@igd.fraunhofer.de

For further information on projects, technologies and areas of expertise, plus contact addresses of our institute in German and English, please visit our website at: www.igd.fraunhofer.de

For general inquiries, please e-mail: info@igd.fraunhofer.de

Image sources:
Fotolia: resscott09 p.16, pixone3d p. 21, chombosan p. 24, Kwangmoo p. 26, Sergey Nivens p.30, violetkaipa p. 36, boule1301 p.38 | Trivisio p.29
All other images and graphics: © Fraunhofer IGD

Follow us: