![Fraunhofer IPK logo]

Fraunhofer

IPK

AUTOMATION TECHNOLOGY

CONTENTS

pi4_robotics

AUTOMATION TECHNOLOGY

Fraunhofer IPK's Automation Technology division is cooperating with the Industrial Automation Technology department of the Technische Universität Berlin to develop new technologies and systems that combine innovative robotics, control and security concepts with machine vision methods. The aim of this work is to use the integration and combination of these key automation components to allow our customers to benefit from more efficient processes. As an example, new force control procedures have been developed that enable industrial robots to carry out machining processes – a more versatile and cost-effective solution than conventional machine structures. We are also using innovative methods and automation concepts from the world of production engineering to pave the way for new applications and business divisions in the fields of security technology and medicine. Well-known examples include our process for automated virtual document reconstruction and our robot systems for stroke rehabilitation.

» *Our vision is human-centered automation, in which human and machine can work together closely, but also flexibly.* «

Our expertise is embodied by two specialist departments and two work groups. The R&D work performed in our Process Automation and Robotics department is aimed at an efficient use of resources. Flexible cooperation between human and robot increases the resource efficiency of both man and automation system in variable production processes. To increase energy efficiency, we are developing procedures for intelligently acquiring information from energy-related production data (energy mining) as well as data on energy efficiency controlling.

The Security Technology department draws on many years of image processing and pattern recognition expertise to open the door to new applications, in particular for mobile sensor systems and automated reconstruction of objects. Our customers also benefit from our experience in the field of automatic optical quality control, which has been strengthened by the addition of new robot-aided testing procedures for mechanical production properties.

A specialist exploration field has drawn increased attention to optical inspection using networked line scan cameras. Finally, our portfolio is rounded off by a work group that is responsible for the further development of exercise devices for stationary and remote medical rehabilitation (telerehabilitation).

Left: pi4 Workerbot – its control system was developed at Fraunhofer IPK.

3
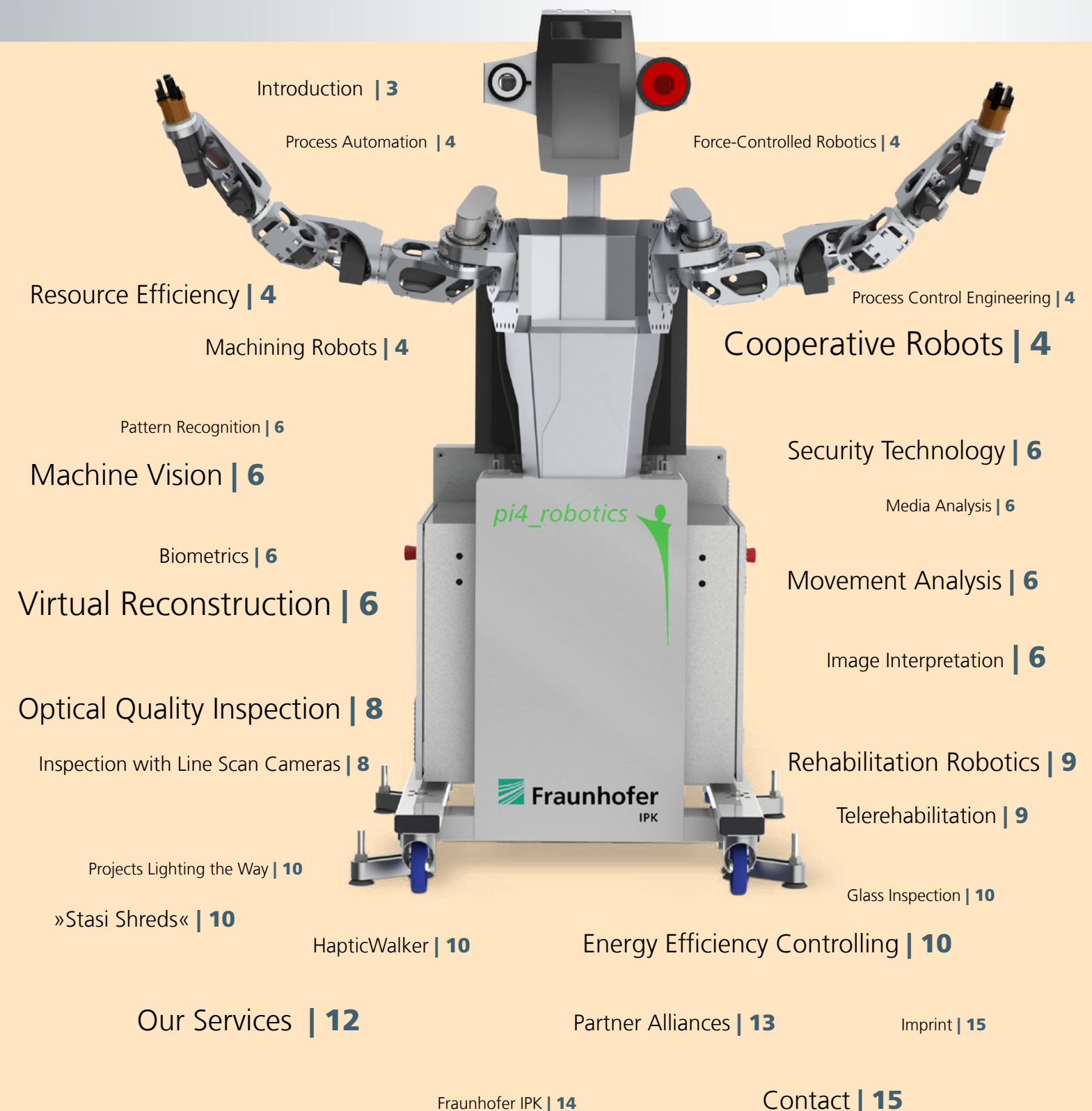
SMART AUTOMATION

Today, production automation is no longer governed solely by economic considerations. Instead, sustainable use of resources and the effects of demographic change are becoming key priorities. The Process Automation and Robotics department is tackling these challenges using intelligent control systems as well as advanced robot technology.

PROCESS AUTOMATION AND ROBOTICS

Automation as we know it is facing great challenges: ecological aspects and the efficient use of resources are playing an increasingly important role in the development of production processes and systems. At the same time, differing customer preferences are leading to a wide range of variants but a low number of pieces per variant – a situation that requires flexible production methods. The complexity of the procedures associated with these changes can be reduced by increasing the involvement of human cognitive and fine motor skills in the production process. The effects of demographic change on the labor market also need to be taken into account.

Solutions to this conundrum can be found in new, IT-based automation technology, such as intelligent control systems, and advanced robotics. We have over 30 years of experience in this field. Our spectrum of expertise ranges from process modeling and simulation tools and innovative kinematics systems with new drive and control solutions, through to superordinate process control systems and technology for supporting operating personnel. Our specialties include force-controlled robot systems and human-robot cooperation. In addition to production applications, our developments are also used in handicrafts, medicine and rehabilitation as well as in the service sector.

❖ | Robots with feeling

Advanced control systems and sensors enable robots to adapt independently to changes in their environmental conditions. We develop force and compliance control systems that allow them to react to deviations from the preset geometry or process – whether these are caused by the robot itself, the work piece or the work environment. Upgrading robots to »feeling« machines opens doors to new areas of application, such as assembly and testing tasks, where direct human contact was previously required to guide the movement of objects.

❖ | Human-centered automation with COBOTs

Where the capabilities of full automation are pushed to the limit, the potential of human-centered automation is just beginning. Instead of imitating human abilities, this approach aims to provide the best possible support for them. This is the objective behind cooperative robots (COBOTs). These machines relieve human operators of physically strenuous tasks, while granting them full control of movement. As a result, we get automation systems of significantly reduced complexity that allow for quick training and cost-effective full system solutions.

❖ | Machining robots

Industrial robots are increasingly taking on tasks that were previously the domain of machine tools or specialized industrial machines. We are carrying out research into robot-based milling, grinding and polishing. In addition to the manufacture of new parts, we are also focusing on repair processes, which are particularly demanding in terms of procedure and process adaptivity. We are also promoting the increased use of robots in natural stone processing applications, both as a means of supporting stone-working machines and as a semi-automated, power-assisted system for direct interaction with the stone sculptor. Analyzing the potential uses and limits of robots in machining tasks is one of our specialities.

❖ | Process optimization in complex systems

Recognizing interdependencies is an essential part of a holistic optimization process. However, in networked installations with a variety of heterogeneous individual systems – from the machines to the IT infrastructure – it also represents a huge challenge. We provide several different types of support for this process, including tools that use data mining methods in production. Among other things, they can analyze the energy efficiency of production systems (energy data mining).

The aim of process automation and robotics is to make production processes energy- and resource-efficient.

MACHINES LEARN TO SEE

The ability to process visual information is a basic requirement for many automated processes. Since the early 1980s, the Security Technology department has been using innovative digital image processing and pattern recognition methods to teach machines how to »see«. The department has become internationally renowned, mainly due to a software that virtually reconstructs torn up documents.

SECURITY TECHNOLOGY

The automation of industrial processes brought with it the need to equip technical systems with visual capabilities. A machine can only work autonomously if it can »recognize« a component, as well as its position and condition. Furthermore, machine vision opens the door to applications that would otherwise be inconceivable, such as optical inspection systems that assess structures the human eye can detect only barely or not at all. In addition to this, they operate in environments where the safety conditions mean it would be irresponsible to use human workers. Similar circumstances apply to measuring and process control systems.

Our Security Technology department is a driving force behind the development of image analysis systems. It was here where we first developed learning methods for inspecting material surfaces for quality assurance purposes, for controlling handling and assembly processes and monitoring systems that ensure the safety of workers in hazardous areas. Since the 1990s, we have opened up new fields by transferring production engineering solutions to non-industrial applications. Since then, the department has become an internationally recognized player in the fields of image segmentation, character and document interpretation, movement analysis, object classification, and biometric recognition systems. For example, they have developed systems for vehicle recognition and personal identification using biometric features.

❖ | Automated virtual reconstruction

Fraunhofer IPK's most prominent application in the field of image processing is a technology that virtually reconstructs documents that have been torn up or shredded. This allows the analysis of damaged archive material and pieces of evidence. This system has been developed to allow us to read back over files shredded by East Germany's State Security Service (Stasi). However, the procedure could also be useful for a variety of other applications. The heart of the virtual reconstruction

system is the ePuzzler, a software developed at IPK that uses new image processing and pattern recognition algorithms to piece together scanned in fragments of paper to form complete pages. The system uses an adaptive, non-deterministic workflow to process a wide range of characteristics, such as the contour, color, writing and lines of the fragments.

❖ | From reconstruction to »repair«

As we continue to expand on the idea of virtual reconstruction, the next logical step would be to use it on three-dimensional objects. The aim of this – especially in archeological applications – is not simply to virtually reconstruct objects, but rather to use the result of a virtual 3D reconstruction as a template for an actual reconstruction. In future, we also plan to develop tools that will help archeologists with physical reconstruction. These include a »reconstruction robot«, which could be used to help reconstruct damaged facades or wall mosaics. This will combine the expertise of both departments of the Automation Technology division.

❖ | Pattern recognition in digital worlds

Activities related to pattern recognition in digital media are currently taking us back to our safety and security engineering roots. Tools for analyzing the content of photos and films are designed to help investigators find illegal content on data carriers and the Internet. By analyzing images from security cameras and looking for patterns of movement that suggest aggression or fear, we can help to ensure safety in public spaces. The algorithms developed for this purpose are also of great interest in the media industry, for applications such as the automation of time-consuming media analyses and detecting plagiarism.
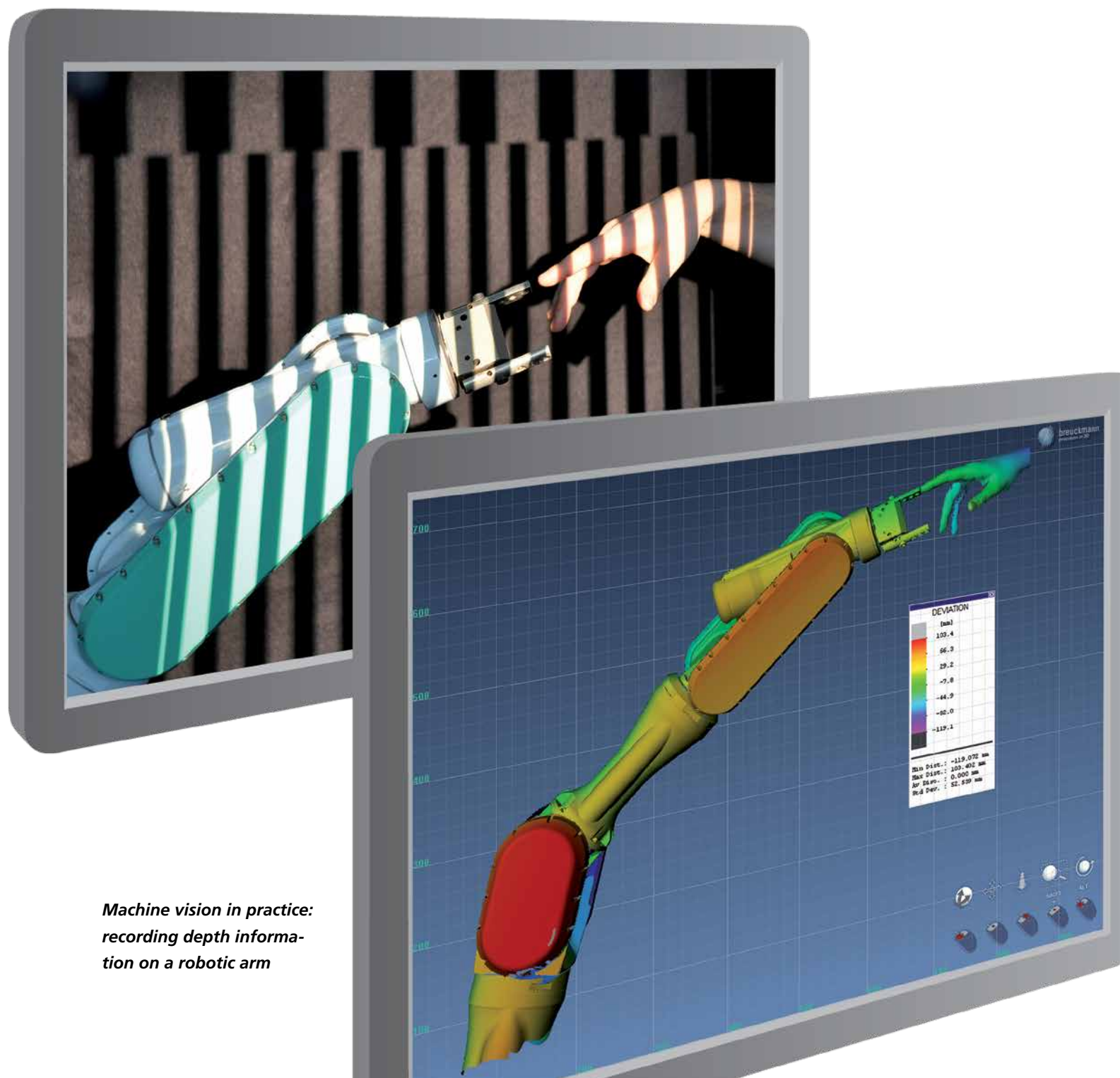
Machine vision in practice: recording depth information on a robotic arm

7
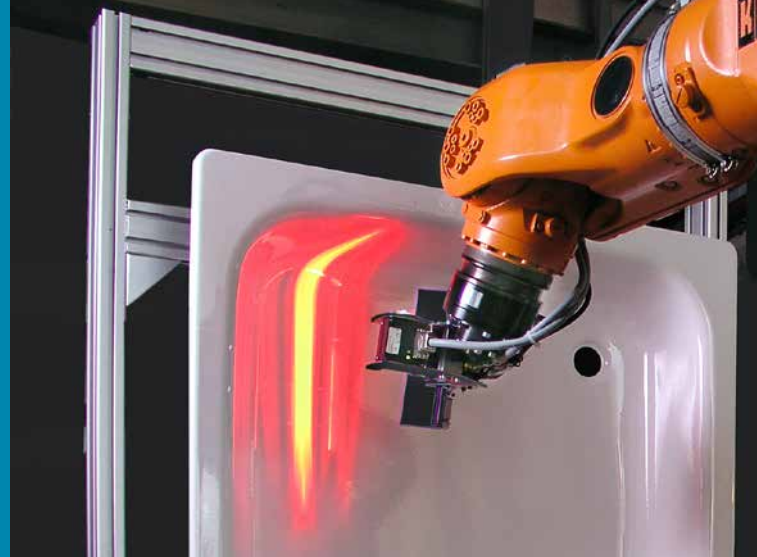
AUTOMATED QUALITY CONTROL

In the context of manufacturing, »quality is the condition of a unit in terms of its suitability to fulfill set and predefined specifications«. In the exploratory field Optical Inspection, methods and procedures are being developed for sensor-based testing of products. These methods are designed to test continuously whether products meet the predefined specifications during production.

In modern manufacturing systems, it is often impossible to separate production and quality assurance. To ensure that complex product requirements are met and defective parts are detected as early as possible, we need to see quality control as an integral part of the production process; one that is seamlessly integrated into production lines. In most cases, this is only possible if individual manual product checks are replaced by a sensor-based automatic inspection system. Such a system also offers the advantage of allowing better documentation of the inspection process than a manual inspection.

Optical procedures play an important role in sensor-based quality control, as they are non-contact and offer the level of sensitivity required for many applications. Modern LED light sources provide an impressive level of adaptation for specific inspection tasks – for example, the available wavelengths allow us to adapt the quality control process to suit the specific materials inspected. If this is combined with the use of standardized software and hardware interfaces, the recording systems can be integrated into the production automation system environment with a minimum of effort.

❖ | **Inspection of surfaces using line scan cameras**

The exploratory field Optical Inspection specializes in the inspection of surfaces using line scan cameras. In many cases, line scan cameras enable simple and efficient integration of

quality inspection into the ongoing manufacturing process, with a high spatial resolution in the direction of movement. We are reknowned for our expertise in the development of customized LED lighting with low total reflection and a long product life. Specially developed algorithms help us to inspect even the smallest of defects on large surfaces with minimum hardware expenses. This process can reach inspection speeds of up to five meters per second, making it possible to carry out quality control even on fast flow processes. The results are continuously documented and archived.

❖ | **Ethernet-based multi-camera systems**

Fraunhofer IPK was one of the first institutions in Germany to use Ethernet-based multi-camera systems. The first available GigE line scan cameras can already be found in inspection systems that our industrial partners have been using with great success since 2005. In recent years, we have not only worked closely with our suppliers to improve the reliability of multi-camera systems; we have also tailored our multi-camera systems for use in extreme conditions – e.g. using water-cooled camera housings for inspecting red-hot components.

RELEARNING MOVEMENT

In Germany alone, over 200,000 people a year suffer a stroke. The majority of them experience partial paralysis or even a complete loss of voluntary motor function. The rehabilitation robotics work group is developing robot-assisted exercise devices that significantly improve the rate of success in neurological rehabilitation therapy for relearning movement abilities.

Neurological rehabilitation treatment for relearning movement abilities after a stroke, paraplegia or traumatic brain injury is based on intensive movement therapy over a period of several weeks and months, sometimes even years. This therapy helps patients relearn everyday arm, hand and leg movements such as walking and climbing stairs, gripping, eating, drinking, and writing. The arms and legs of the patient are repeatedly guided in natural motions so that the healthy areas of the brain can successively learn how to control the paralyzed extremities. Robot-assisted therapy exercise devices can relieve therapists of heavy, monotonous physical work, while at the same time increasing the intensity of the patients' therapy. Clinical studies on patients treated using robot-assisted therapy exercise devices show a greatly improved rate of success compared to patients treated using conventional therapy.

❖ | **Learning to walk again**

The robot-assisted walking simulator HapticWalker was developed at Fraunhofer IPK to aid people in learning to walk again. It is the first device in the world to allow patients to practice any conceivable walking movement, such as walking on a flat surface or climbing stairs, by providing full guidance for the foot. The high dynamic response of the drives in the machine also means that, for the first time, disturbances in walking, such as uneven ground, stumbling and slipping, can be simulated as well. This is very important in ensuring

good results from the therapy. The device also has a built-in man-machine interaction system, which uses force-moment sensors integrated into the foot plates and intelligent control algorithms to reduce the degree of support provided to match the patient's learning progress. An intelligent sensor data processing system provides new opportunities for online walking analysis, biofeedback and quality assurance during rehabilitation.

❖ | **Remote therapy support at home**

To ensure that patients at home continue to receive a similar level of therapy to the one they receive at a hospital, we have developed solutions for remote-controlled movement therapy based on intelligent, robot-assisted therapy exercise devices. These telerehabilitation systems offer patients the opportunity to receive remote support from a therapist in a rehab center or local branch for the exercises they carry out at home. This is made possible via an extended telemedical connection between the patient and their doctor or therapist. Both parties can communicate with each other via the telerehabilitation system using video, audio and, for the first time, haptic communication (force feedback). The system thus transfers the personal presence, aid and motivational support of the therapist into the patient's home.

PROJECTS LIGHTING THE WAY

Project work in the Automation Technology business division is extremely varied. It covers traditional tasks in the fields of process organization, handling and testing, and also pioneers the transfer of automation solutions to a wide range of non-industrial areas. The business division has received international recognition for various projects, which include:
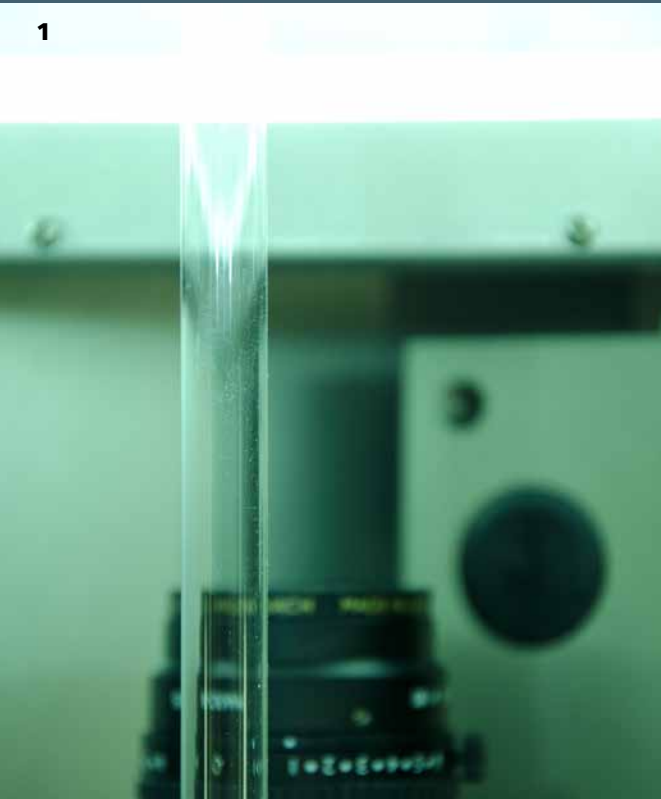
1 | Optical glass quality assurance

Compliance with a level of product quality agreed with the customer is an important requirement for production processes. However, since it is impossible to completely rule out typical glass defects (bubbles etc.) when manufacturing technical glass, a high-sensitivity, reliable full inspection is required for quality assurance purposes. Fraunhofer IPK is working with Schott AG to develop equipment that will perform an automatic optical inspection of glass and can be integrated into the production process. In a transmitted light procedure, multiple cameras inspect the product from different angles before the material is divided into packing quantities. This process reliably detects even the smallest error and determines the size and position of it to allow for safe assessments and discharge in accordance with predefined quality criteria.

2 | EnEffCo – Energy efficiency controlling in automotive production

Using existing production plants and supply systems in an energy-oriented way and reducing overall energy consumption and costs – that is the aim of the joint project »Energy Efficiency Controlling using the example of the Automotive Industry (EnEffCo)«. Fraunhofer IPK contributes to the project by developing analysis and modeling techniques for energy-efficient process management. This includes methods and tools for modeling production processes, machines and systems in terms of the aspects relevant to energy efficiency controlling (energy-oriented process models), using data mining processes for the analysis of energy consumption profiles (energy mining), and calculating and evaluating alternative control and process management strategies that are optimized for energy efficiency controlling of machines and plants.

3 | Automated virtual reconstruction of Stasi files

In fall 1989, staff at the East Germany's State Security Service (Stasi) began to destroy documents and surveillance dossiers. However, some determined citizens were able to get hold of the partially torn up, partially shredded documents before they were completely destroyed. Since then, around 15,000 bags of shredded and torn up files, the contents of which are thought to be controversial, have been awaiting reconstruction and analysis. Fraunhofer IPK is drawing a great deal of attention by developing a pilot system that will initially be used to virtually reconstruct the contents of 400 bags. Experts from a wide range of cultural and forensic fields are following the project with great interest. Until now, if paper, papyrus or parchment were damaged, the information stored on it often had to be dismissed as lost. The work being carried out at Fraunhofer IPK will fundamentally change this situation.

4 | HapticWalker

Problems with motor functions following a stroke, paraplegia or traumatic brain injury do not have to mean spending the rest of your life in a wheelchair. Patients can learn to walk again if healthy areas of their brain and spinal cord can take over the functions that have been lost. However, the patient must undergo months of exercise therapy under the manual guidance of therapists to relearn all their movements. To lighten the load on physiotherapy experts, Fraunhofer IPK has worked closely with the Charité – Universitätsmedizin Berlin to develop the HapticWalker. The world's first robot-assisted walking rehabilitation simulator allows patients to train any everyday motion, from walking on a flat surface to climbing stairs, stumbling, or slipping. The multi-award winning device is currently being evaluated in a range of clinical studies.

CONSULTING – RESEARCH – DEVELOPMENT

We offer a wide range of tailor-made services for process automation and optimization, from the development and investigation of new technologies to their implementation and system integration for specific applications. We have many years of experience, especially in the automotive industry, machinery and plant engineering, and security technology.

OUR SERVICES

OUR CUSTOMERS BENEFIT FROM THE FOLLOWING SERVICE PORTFOLIO

❖ | **Technology and methods consulting**

Our focused technology consulting services help you identify and make the right choice of future technologies.

❖ | **Potential analyses and surveys**

We use product and technology-oriented feasibility studies, market monitoring, and trend analyses to investigate and evaluate the inherent potential of technologies and products.

❖ | **Implementing new technologies**

Our on-going, forward looking research and further development of our methods puts us in an excellent position to offer you fully comprehensive technological expertise and support you in the realization and roll-out of novel technologies in your own automated production.

❖ | **Optimizing automated processes**

On behalf of our clients, we implement on-track process and technology optimization that make your own automated processes more efficient and flexible.

❖ | **Developing prototypes**

We develop new systems on behalf of our customers and help them with process integration. You can also benefit from our experience in turning prototype systems into marketable products.

❖ | **Networking**

We have an extensive network of partners in science, economy, government authorities and politics. These contacts promote the constitution of strategic research and development collaborations for our customers.

❖ | **Support with national and international research and development projects**

We provide advance consultation for clients before entering into collaborative research and help them to identify suitable support programs and acquire the means needed to carry out the project.

WORKING TOGETHER ON YOUR SUCCESS

Innovation is vital for a company's success. Only innovative companies can succeed in engaging as technology leaders on the global market. With our distinguished track record of proven expertise we develop innovative products, technologies and methods and support you in mastering the challenges of tomorrow's world.

PARTNER ALLIANCES

WE OFFER A BROAD SPECTRUM OF TYPES OF PARTNERSHIPS AND ALLIANCES

❖ | **Industry projects**

Research and development projects are an effective means of driving forward innovation in a company. We develop economically viable solutions on your behalf.

❖ | **Competence networks**

To ensure that our customers really do have fully comprehensive expertise brought to bear on finding solutions to their specific application-related problems, we cooperate with a variety of other institutes and associations. We are affiliated to:
- Fraunhofer Group for Production
- Fraunhofer AutoMOBILE Production Alliance
- Fraunhofer Alliance Water Systems (SysWasser)
- German Academic Society for Production Engineering WGP
- International Academy for Production Engineering CIRP
- Scientific Society for Assembly, Handling and Industrial Robotics – MHI e.V.

❖ | **Cluster initiatives**

The Fraunhofer Innovation Cluster »Secure Identity«, which was founded in 2008, offers our partners new collaboration opportunities in pioneering areas of security technology. The Fraunhofer Innovation Cluster »Maintenance, Repair and Overhaul in Energy and Traffic« (MRO) is another collaboration between scientific, economic and state institutions, which aims to build the foundation for a long-term cooperation and exchange of knowledge in the German capital region Berlin/Brandenburg.

❖ | **Strategic preliminary research**

New and further development of technologies and markets for the future is what independent, publicly financed preliminary research is all about. Our business partners benefit from the insights gained in such preliminary research.

VISIT OUR ESTABLISHED INDUSTRY WORKSHOPS AND CONFERENCES

Our industry workshops and conferences are a forum for the exchange of views and experience between scientists, engineers, and product users. They offer a place where you can talk directly about matters of theory and practice to our own experts and the representatives of major companies and small and medium sized enterprises. The set of objectives such gatherings subscribe to ranges from honing expertise and building cooperation networks to the initiation of joint application-oriented research projects and transfer of research results to the enterprise sector.

The key themes and issues addressed in the Industry Workshops are:
- Virtual reconstruction technology and applications
- Flexible automation with innovative robotic systems

Our conferences will give you an insight into:
- Processes and systems for ensuring the identity of persons, products and intellectual property
- Innovative technology for medical rehabilitation

FRAUNHOFER IPK – YOUR PARTNER

The Fraunhofer Institute for Production Systems and Design Technology IPK and its business divisions – Corporate Management, Virtual Product Creation, Production Systems, Joining and Coating Technology and Automation Technology as well as the exploration area Traffic Engineering – are dedicated to applied research and development for industrial production. We develop methods and technologies for corporate management, product development, production processes and the design of industrial plants and facilities. Our research centers on processes that enhance productivity in terms of the development and realization of products and their integration in systems solutions. This includes such challenges as the design and realization of intelligent production equipment, its integration in complex manufacturing environments, and its operational optimization. On top of this, we also develop novel applications in cutting-edge fields such as security and mobility.

For 40 years now our international, interdisciplinary team of scientists, engineers and student assistants has driven application-oriented research and development for the benefit of our partners and customers. Along with our own in-house applied research, we also develop new solutions in close collaboration with national and international companies. We work together with our industry partners in turning our basic innovations into fully fledged functional applications. Our approach covers the entire product lifecycle – from the initial product idea and its development, layout and manufacturing through to product recycling and disposal. The processes and methods we develop are the hallmark of an all-embracing holistic approach. Our work combines sound economic principles and sophisticated technology with ecological benchmarks such as sustainability and environmental friendliness. We are aware that our achievements rest in large part on the innovativeness and dedication of our team players. This is why we attach great importance to the coming generation of creative scientists by promoting long-term training for specific know-how for our core competencies in management, product creation, production processes, and the design of industrial plants.

Interdisciplinary cooperation of the business divisions:

- *Corporate Management*
- *Virtual Product Creation*
- *Production Systems*
- *Joining and Coating Technology*
- *Automation Technology*
- *Traffic Engineering*

CONTACT

You have questions regarding research and development in the Automation Technology division or require further information on selected research areas? In this case please address our contact persons. They are looking forward to your call!

❖ | HEAD OF BUSINESS DIVISION

Prof. Dr.-Ing. Jörg Krüger
Phone: +49 30 39006-184
Fax: +49 30 391-7517
joerg.krueger@ipk.fraunhofer.de

❖ | PROCESS AUTOMATION AND ROBOTICS

Gerhard Schreck
Phone: +49 30 39006-152
Fax: +49 30 391-7517
gerhard.schreck@ipk.fraunhofer.de

❖ | SECURITY TECHNOLOGY

Dr.-Ing. Bertram Nickolay
Phone: +49 30 39006-201
Fax: +49 30 391-7517
bertram.nickolay@ipk.fraunhofer.de