Fraunhofer
IUK-TECHNOLOGIE

FRAUNHOFER GROUP INFORMATION AND COMMUNICATION TECHNOLOGY

PROGRAMMED FOR CHALLENGES

INTRODUCTION

The importance of information and communications technologies in society radically changed in this second decade of the 21st century. Today, these technologies play leading roles as engines of digitalization in all areas of business and society.

With its 20 member Institutes, about 4300 employees, and an annual budget of approx. 275 million EUR – of which three-quarters are sourced from competitively-awarded government projects and contract research from business – the Fraunhofer ICT Group is the largest provider of applied research in the field of information and communications technologies in Europe. It marshals key expertise for business and society to utilize in exploiting opportunities and meeting the challenges that result from the comprehensive digitalization of virtually all aspects of today's new world. The Fraunhofer ICT Group covers a broad spectrum of technological fields through its member institutes, from grass-roots applied research to practical solutions in informatics, mathematics, as well as information and communications technology, and it offers assistance to national and international IT providers and IT users alike, particularly SMEs.

In addition, the Fraunhofer ICT Group defines and works on the predominant topics crucial for the future of business and society through interdisciplinary initiatives at the highest conceptual level. In pursuing its vision, the Fraunhofer ICT Group works closely with trade associations, scientific organizations, and the body politic, as well as engaging the public through its information channels as well as educating the coming generation.

This current brochure is meant to provide an overview of the Group's main fields of services and technology, and serve as an invitation to work with us.

Matthias Jarke

Dieter Fellner

Images:
Prof. Matthias Jarke (left, Chair of the Fraunhofer ICT Group thru 2015) and Prof. Dieter W. Fellner (right, new Chair of the Fraunhofer ICT Group, Jan. 2016)

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Fraunhofer Verlag

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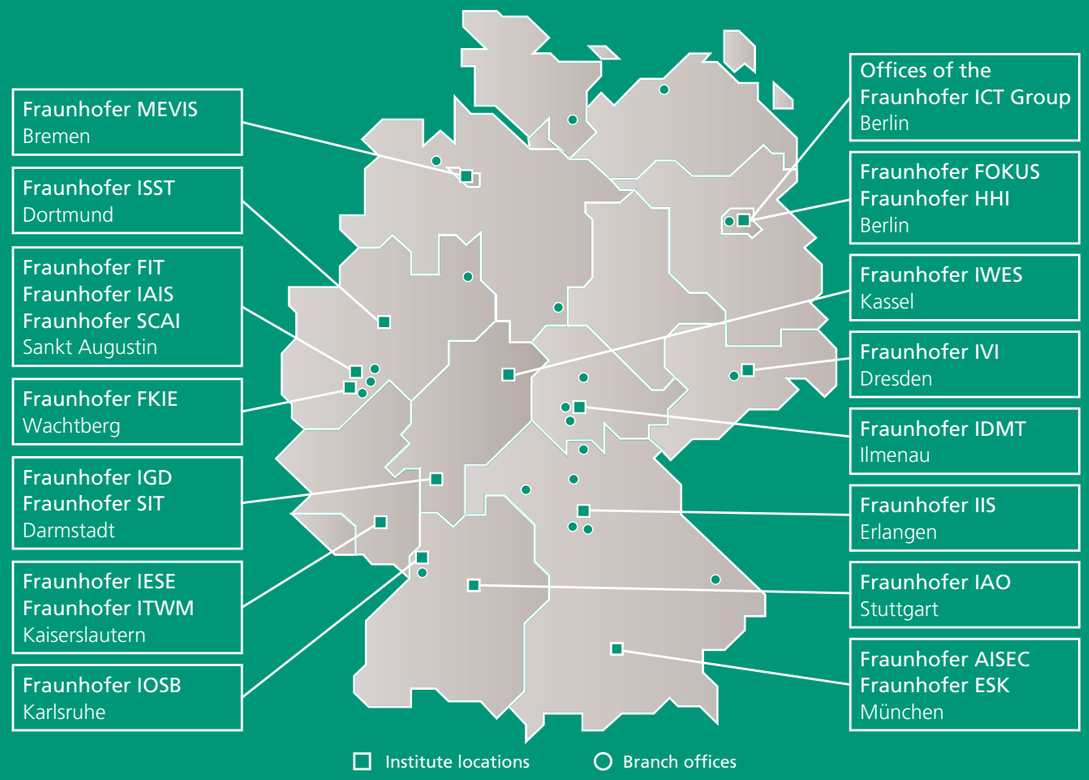

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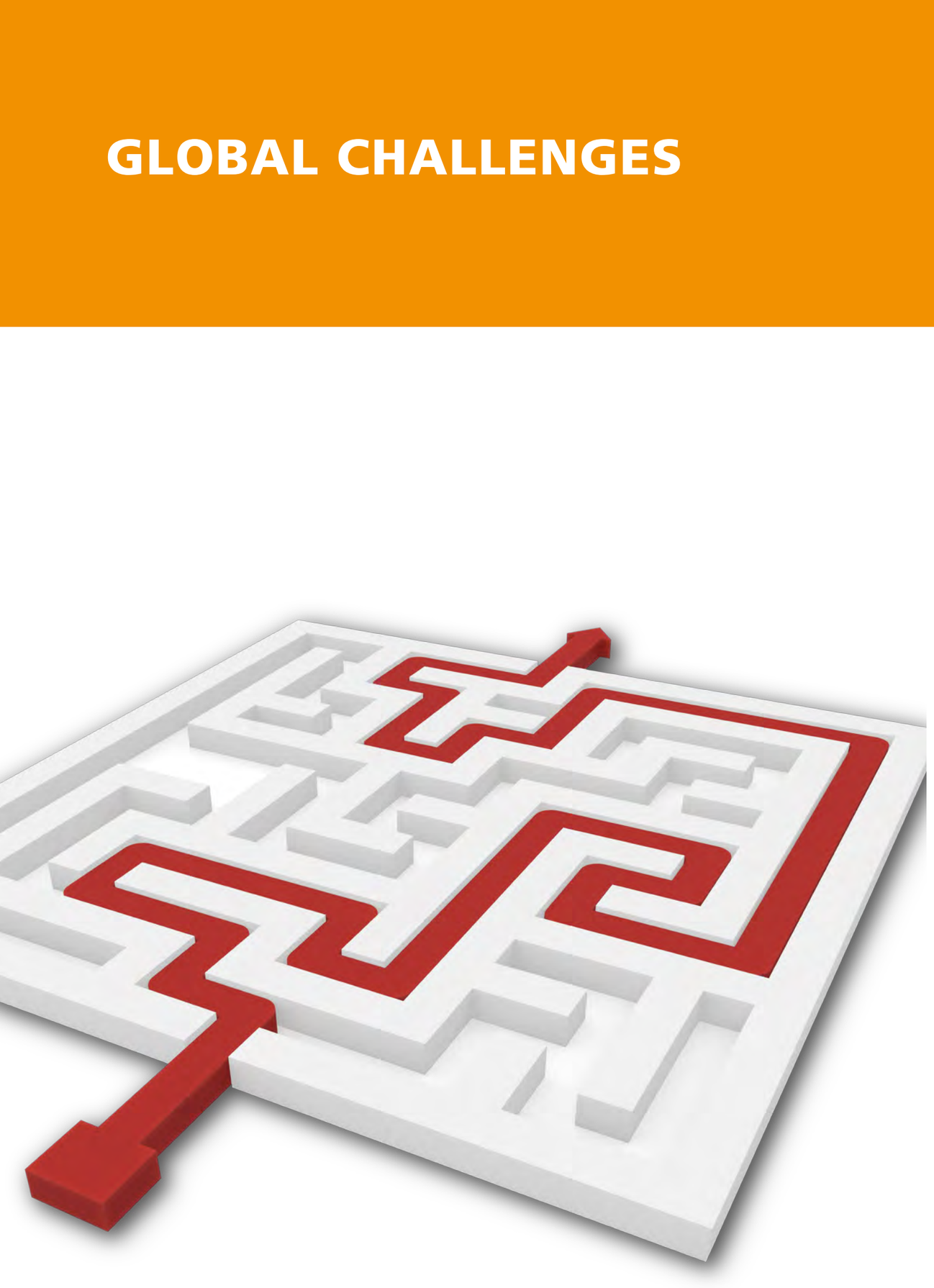
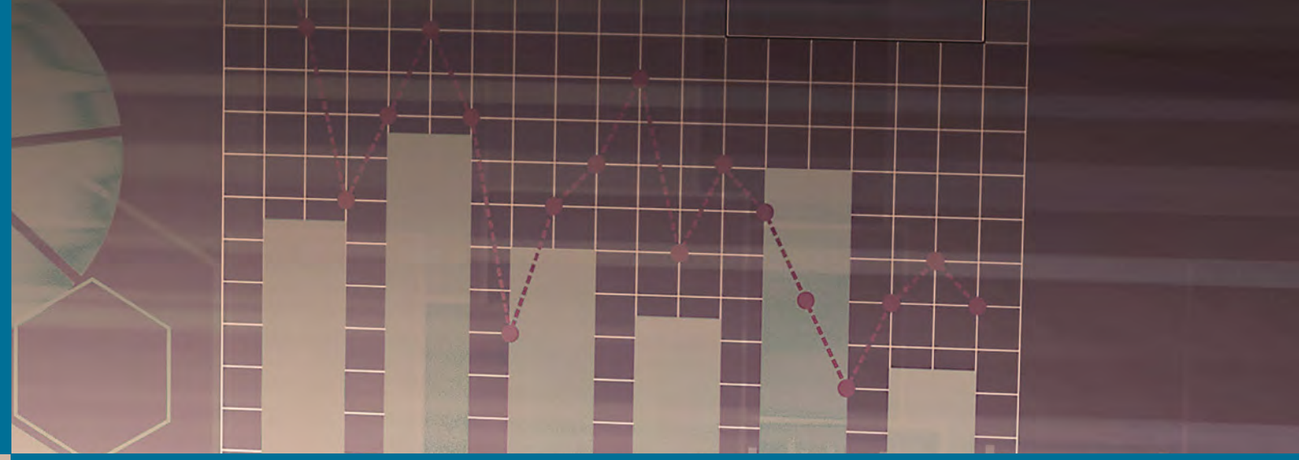
GLOBAL CHALLENGES



The role of information and communications technologies (ICT) in business and our society has radically changed in recent years. This is reflected in the theme of the Year of Science sponsored by German Federal Ministry of Education and Research (BMBF). If 2006 was the BMBF "Year of Informatics", and two years later the "Year of Mathematics" co-sponsored by the Fraunhofer ICT Group, the 2014 Year of Science was designated as "The Digital Society". A social field with substantial contribution of ICT was accentuated once again in the 2015 Year of Science with the theme of "City of the Future" (Zukunftsstadt). The main reason for their rapidly growing importance is the increasing confluence of information and communications technologies with one another, as well as with other kinds of devices or entire environments. At the beginning of the century, progress in the confluence of informatics and mechanical engineering was still thought of and described in terms of embedded systems and separately distinguished from progress in the Internet and mobile communications. The triumph of smart phones has largely merged and accelerated these trends. The massive propagation of sensors and actuators will increase the number of networked devices by 2020.

Meanwhile, at the level of business models and processes, these technological trends lead to an inexorable digitalization of the whole society. In the 1990s, areas that could be represented in a purely virtual form, such as administration, the financial business, and trade, were digitalized. Major sectors such as manufacturing and logistics, medicine and health, the energy transition and public service are following via the current generation of cyber physical systems. The tight mesh of all of these sectors with those already digitalized leads to new business models and to a new paradigm of international competition and cooperation. Every individual step of digitalization generates an additional new set of data and contributes to the exponentially growing complexity of Big Data. This leads to new opportunities for analysis and linkages to all of the post-digitalized sectors.

While leading US providers are driving this development forward through digital commerce based on their dominance of generic ICT (Google, Facebook, Cisco, Uber etc.), Germany prefers to pursue a high-tech strategy of digitalizing traditionally successful sectors. The overall European research strategy moves between these two poles. However, the USA (along with China) meanwhile also perceives the importance of IT in an industrial setting (e.g. the Industrial Internet Consortium). Germany and Europe have recognized that they also need to expand their generic ICT core expertise in Europe, at least in the subsectors that are important for us such as industrial microelectronics and IT security and data protection. In the view of the Fraunhofer ICT Group, the same applies especially for the often underestimated sector of software engineering including data management. Fraunhofer ICT calls for recognition of software engineering as an additional key enabling technology at the pan-European level.



SECTORS

MOBILITY AND TRANSPORTATION

The test vehicle that Fraunhofer uses for researching vehicle-environment networking applications, mutual driver-assist systems, and driving environment modeling is named VICTOR. The vehicle has several antennas with which it receives not just GPS and LTE signals, but also ITS-G5 signals (the WLAN standard for vehicles). Laser scanners and two side-looking radar systems provide the mechanism for recognizing obstacles and other drivers.

Nine billion people are carried on average via regular scheduled transport in Germany annually. Roughly six times as many routes are traveled by automobiles in this country. While mobility for people is becoming increasingly important, it consumes enormous resources as well. The main component is the networking of vehicles with other vehicles, traffic management nodes, traffic lights, and local public transit. Information technologies help to deal efficiently with time and energy resources as well to protect the environment and ensuring safety. Traffic scheduling for all transportation modes, which increasingly use cooperative models and mode sharing, creates new latitude. In the near future, even the dream of highly automated driving will become reality. For electric vehicles, it is no longer a question of what new power trains will be used in the future, but also how to intelligently arrange supply and maintenance infrastructure.

The vehicle of tomorrow will deliver its occupants to their destination efficiently, safely, and with low emissions while communicating with other vehicles and the vehicular infrastructure. Thanks to different acoustic zones in the vehicle, passengers will be able to listen to music, call up traffic reports, or watch a video without disturbing one another. Vehicle-to-vehicle communications will immediately warn drivers of accidents, dangerous spots, or traffic holdups, as well as driver fatigue and will recognize if drivers nod off momentarily. Electromobility will replace conventional power trains in several areas and supplement it in many others.

Autonomous driving is familiar to many of us only from science fiction books. However, the last several years have brought enormous leaps in technology. Besides sensor systems that can instantly collect highly accurate data on the vehicle's surroundings, this technology also comprises comprehensive digital map materials, robust and secure software components, as well as dependable communication infrastructure. Comprehensive field tests have already been successfully conducted using vehicles having a high level of autonomy – and the first regularly driverless vehicles will be seen on our streets not too long from now.

Getting from point A to point B is possible in many different ways. IT helps to find the best ones. Passengers in local and long-distance public transit benefit from real-time navigational and information applications that report road construction, traffic congestion, and schedule changes. It is the unforeseen delays that can make traveling to work or to an important appointment a real ordeal for passengers. Multimodal traffic systems, travel time predictions, and dynamic travel scheduling can improve the process for travelers. Electronic ticketing also facilitates secure mobile payment modes.

E-GOVERNMENT

Digital proof of identity with online capability contained in the new personal identity cards – the size of a credit card – offers new reliability for business transactions on the Internet. The chip in the identity card facilitates simple and secure transmittal of the holder's personal data – their electronic identity. The testing and demonstration center operated by Fraunhofer for application-specific advising and support during the introductory phase of the new personal identity card serves as the main contact and information point for the application testing program.

E-government of the future represents a globally important contribution by government for de-bureaucratizing and modernizing administration as well as developing interstate services. Moreover, transparency will be increased for all interest groups and the viability of locales and offices strengthened. The objective is to improve government services and democratic processes, as well as simplifying the form and completion of administrative activity. Online government services are oriented primarily toward citizens and companies, but also toward administrative bodies and will lead to a reduction in the workloads they face. Effective e-government protects against excessive regulation and the accompanying obligatory bureaucratic duties.

Early recognition of technological and social trends is important for government to be able to be successful over the medium and long term. It is only by recognizing trends like autonomous vehicles and smart microgrids early and creating the right conditions for their expansion that international competitiveness can be maintained. E-government research helps government to shape and actively guide these paradigm changes.

Digital administration increasingly means becoming a service provider in the future. Communication with government offices will become less bureaucratic and more streamlined for citizens, and electronic services will make visiting them unnecessary. Employing innovative technical solutions, such as digital identities and electronic signatures for example, contributes to devolution of bureaucracy and faster provision of administrative services. Citizens can access virtual offices in the Internet with greater security by using certified portals through which they can communicate simply and efficiently.

The growth of IT infrastructure in public administration was historic and extremely heterogeneous. The **modernization and consolidation** of this IT infrastructure is essential in order to meet the challenges of tight public budgets, shortages of qualified staff, and rising security requirements. This means that modern information and communications technology is also a driver of reconfigured, lean processes and organizational structures.

Open Government is a step towards greater participation by all groups in society. Administration in the future should be more accountable and comprehensible for citizens. Open Government should soon enable everyone to view electronic files, just as utilization of available raw data for creating useful services and applications should be free of charge. In this way, greater transparency in government and administration will become normal practice. The benefit is enormous: the knowledge already present in datasets like crime statistics, social budgets, data regarding cooperative development projects, and research data can be used by anyone.

PUBLIC SAFETY AND SECURITY

The MobiKat system helps to prevent and to cope with large-scale disasters as well as to assist with prevention of ordinary perils. Senior staff, team leaders, and disaster relief teams on site receive a valuable basis for decisions about effective planning and implementation of protection and rescue measures. Guaranteeing mobility for all participants is a priority. This ensures rapid assistance and facilitates considerable reduction of property damage and personal injury.

Natural catastrophes, industrial accidents, as well as global political threats and their consequences are complex perils that require comprehensive and resilient strategies for catastrophe and crisis management. In crisis situations, the protection of the population as well as the safety of rescue teams, communications systems, and supply infrastructure must all be ensured. Fail-safe information transmission and processing are prerequisites for early warning and coordination of aid teams. Active communications with and via the population must be ensured in crisis situations as well. Making use of increasingly specialized networking offers a big opportunity. It is also necessary to detect perils early in fighting and preventing terrorism and crime. The challenge here consists of developing and implementing secure systems that protect the population from harm on one hand, and on the other preserve individual rights and privacy.

Early detection and warning systems provide protection of the population and critical infrastructure. Camera-based systems, sensor networks, and Big Data analyses can provide the means for timely identification of potential perils posed by natural catastrophes, disruptive technical factors, or the propagation of epidemics. Early warning systems can then inform the population about the peril and the area affected, and instruct them on how they should conduct themselves.

Catastrophe management requires fast and carefully thought-out actions in a crisis situation. The team leaders make difficult decisions in as little time as possible that can have life and death consequences. Interoperable networked assistance systems and computer-aided scenario analysis support the decision-making process. They focus the continuous flow of information, deliver comprehensible presentations of the complex relationships and facilitate rapid overview of the crisis situation and how to cope with it effectively while conserving resources.

Simulation and modeling of complex operational processes in critical infrastructure like electrical and water supplies is indispensable for protecting these. In this way, failures and environment-dependent or political changes can be analyzed and their consequences identified, as well as various safety and security measures evaluated. However, the development of detailed and integrated safety plans with testing and training areas for operational and rescue forces also contributes to protection of public buildings, companies, as well as scientific and cultural institutions.

MANUFACTURING AND LOGISTICS

Guidance systems monitor and control automated facilities, most of them manufacturing plants. The focus of Fraunhofer research is on fabrication engineering – but the systems are also employed in the processing industry, monitoring of computer centers, and other areas of application. ProVis.Agent® is the guidance system for control and monitoring of all production equipment for fabrication of the C-Class series of vehicles at the Mercedes Benz factory in Bremen, Germany, and employed in the plant's manufacturing, paint, and assembly lines.

Knowledge in the form of important data will be linked with products and machines in the future. The availability of all information in real time already represents high value today. Networking all of the entities that participate in adding value opens up additional potential, as does the capability of deriving the optimal flow of value from data. Fabrication processes and transport of the goods are merged through networking in the Internet of Things, while services and data are automatically matched in real time to client preferences or to adaptable production requirements. Refined software solutions, intelligent sensors, as well as measurement and test systems contribute to quality assurance as well as to process and logistics optimization. The fabrication industry is still the backbone of business, particularly in Germany, which is why new paradigms must first be proven – not only regarding their effectiveness, but also their dependability. For this reason, norms and standards are required that assure protection of shared data and a high fail-safe level.

Industry 4.0 brings people and machines closer to one another. The fourth industrial revolution in manufacturing comprises what is known as cyber physical systems, for one. These link real products, tools, and production facilities in the virtual world. The economic networking of intelligent machines facilitates distributed, automated control and increases productivity as well as flexibility. For another, Industry 4.0 also describes new diverse opportunities for integrating human work into the production process as well.

Object identification and positioning recognition are included in the cornerstone technologies of Industry 4.0. With the help of RFID, sensors, and individualized software solutions, products and goods always carry the essential information about their state and their position with them. Loading and unloading, sorting, shipment, and assembly tasks will be automated by software. This increases the speed and also the quality, if correctly implemented. For people, industrial automation importantly means less physical or dangerous work.

Measurement and testing systems facilitate process-integrated quality assurance of manufacturing and logistics. Where previously only spot-sampling types of monitoring were feasible, today all products can be checked for material, manufacturing, or software defects based on standardized rules. With the development of software architectures for logistics and manufacturing facilities, standards for guaranteeing quality and safety are already being integrated. Through the use of virtual models, components and entire products can be made in advance in realistically appearing and sounding fashion and assessed. Automated, networked software systems check products and machinery as well as operational processes and manufacturing control systems.

MEDIA AND CREATIVE SECTOR

High Efficiency Video Coding (HEVC) is the next-generation video compression standard. It was developed by the Joint Collaborative Team on Video Coding (JCT-VC) to which Fraunhofer made important contributions. Compared to its predecessor H.264/AVC, HEVC achieves about a 50 percent reduction in bit rate for the same quality video. Since the standard has been finalized, Fraunhofer also develops software and hardware solutions that benefit from the outstanding characteristics of HEVC.

The digitalization and convergence of different media are driving technological as well as cultural change. The way we utilize media has fundamentally changed: everywhere we go we are constantly accessing the content we are looking for – independent of whether it is text, images, videos, or games. This immeasurable amount of content must be recorded, made accessible, stored, transmitted, and presented. In addition, we interact more than ever with other users and communities by producing our own content, transmitting it, and assessing it. This use of media requires dependable transmission formats and stable network connections, as well as reliable protection mechanisms.

Entertainment and media of tomorrow are characterized by personalized information services, multi-screen applications, interactive television, and high-resolution 3D presentation of sound and image. All sorts of hybrids and hierarchies of devices facilitate simultaneous use and seamless transition between them, so that the borders between screens, set-top boxes, tablet computers, and gadgets increasingly disappear. Every medium benefits from the strength of the others. Intelligent algorithms and intuitive control embedded in a common interface for operating the devices permit the users to concentrate entirely on the content.

Culture and digital learning give rise to new approaches and formats through the use of new media that are interactive and participative. At the same time, there is also the opportunity to make up-to-date knowledge and traditional global cultural heritage accessible to everyone in visual form.

Entertainment, information, and learning are available everywhere through mobile service and devices. Different types of adaptive (educational) computer games become widespread at nearly all levels of society and are part of our day-to-day culture. New types of games that more powerfully involve the player and the environment are able to address continually new target groups.

Film and television use digitalization of production, marketing, and distribution processes, which satisfies a prerequisite for advanced formats. The television allows viewers to be more involved in events through better image and audio quality as well as through opportunities for interaction. Film theaters attract viewers with high-resolution 3D films and superior spatial sound for feature films as well as for transmission and presentation of musical and sporting events. Concerts and live events also acquire a completely new experiential dimension thanks to 3D sound.

DIGITAL SERVICES

Fraunhofer offers a comprehensive solution for visual display tasks with its webVis and instant3Dhub. Web-based display of 3D data will drive the current selection of tools to be supplemented with web-based, cost-effective, and efficient components. The instant3Dhub platform offers a unique infrastructure that implements the visualization-as-service design effectively and efficiently, thereby accommodating the varied requirements of the display environment. Exemplary features include security aspects, available bandwidth, and new technical capabilities of the user's display device.

In the Internet of the future, services will be even simpler to provide and use than today. The big advantage of Internet-based services lies in their enormous efficiency: companies will be placed in the position of outsourcing their expensive IT activity through appropriate offers, enabling costs for backup, system maintenance, and redundancy to be reduced. One immediate sign of the digital transformation is that conventional processes and flows can be digitally emulated. It will be exciting as incremental values and services take shape that did not previously exist. Business models can be tailored to individual requirements on emerging service platforms. These include out-sourced cloud storage and software-as-a-service, as well as online marketplaces, data analysis and evaluation tools, and brokerage platforms. The new digital services can more intuitively and better comprehend user needs, such as through semantic technologies for example. A prerequisite for a functioning network is that all the services use common technical standards for data access in order to link various processes with one another and be able to take into account security as well as data protection aspects.

Automatically recognize instead of searching is the vision for gleaning information from large data inventories. Semantic technologies can be employed here that also acquire information from video, pictures, and audio files through the use of content descriptors. Moreover, software tools can differentiate between important and irrelevant information as well as recognize connections and context. Enormous savings arise from metadata no longer needing to be manually allocated or annotated.

Innovative business models are increasingly the focus of service providers in the Internet because models define the quality and utility of services offered. Offers for services often work differently on the Internet than in off-line business. The detailed description of the customer benefit as well as the information streams and financial inputs for generating this benefit are emphasized particularly by service providers on the web. With flexible and adaptable business models, all client groups can develop their own web services that are best-suited down to the last detail, implement them, and adjust them any time as needed.

Everything-as-a-service means the idea of not only outsourcing data storage and applications as digital services from central platforms, but even outsourcing entire development frameworks and infrastructure. Services can be configured from start to finish down to the smallest detail without the company having to buy in and maintain the whole infrastructure under their own roof.

BUSINESS AND FINANCE INFORMATICS

Under the Pension Product Information Office project (Produktinformationsstelle Altersvorsorge/PIA) funded by the German Federal Ministry of Finance, Fraunhofer is studying the risk-reward classes of pension products with the help of mathematical simulations and based on probability calculations. Various predictions for the legislated product information sheet on funded pension products depend upon this product and tariff-specific classification.

Technological progress and its dominating influence on the economic performance of companies, regions, and countries play a key role in sustainable economic development. In order for companies and policymakers under the new framework to be able to make sustainable decisions (in the sense of value-oriented administration and management) and simultaneously fulfill legislative requirements, dependable baseline data entailing profit and risk information is needed. This will be produced from the development and implementation of new mathematical finance models. Deep Data Analysis and refined knowledge management can help to assess future risks posed by increasingly complex scenarios. Besides technological or IT-aided approaches in financial management, integrated profit and risk management based on empirical economic and financial methods and indicators is advantageous. Standardization and optimization of business and control processes in conjunction with IT infrastructure constitute the basis for integration of internal and external services.

The financial markets only have a few geographical points of reference remaining. They continuously adapt to current requirements and economic developments. Changes are recognized early and strong fluctuations can be avoided through fast reactions. Clear representations make the complex connections and flows comprehensible and manageable. Opportunities for investing in innovative technologies and business ideas are systematically sought and evaluated. Collaborations for most of the players are indispensable in order for them to be able to concentrate on their core businesses and yet flexibly broaden their own portfolios.

Economic models and simulations can answer questions pertaining to distributive and fiscal effects of individual financial policy measures or bundles of services under the German tax revenue transfer system. Increasingly higher accuracy is being attained through the utilization of comprehensive empirical micro-simulation models and statistical parameters. Similarly, predictions about future education and labor market participation by the population can be made based on the expected demographic developments.

Bank IT ensures the smooth running of all processes thanks to the highest levels of security and availability. Flexible outsourcing and simple integration of external services in operations are feasible through standardized interfaces. Adherence to international standards and measures like Basel II, the Sarbanes-Oxley Act, EuroSOX, and IFRS increases transparency and additionally secures operations.

MEDICAL AND HEALTHCARE SYSTEMS

Fraunhofer experts have succeeded in substantially accelerating the capture of images during magnetic resonance tomography examinations and thereby broadened the range of applications for the method. Real-time MRT facilitates the filming of a beating heart at 30 to 50 images per second while the patient breathes normally and without an ECG. This allows the reactions of the heart muscle and blood flow under physical stress to be directly observed.

Fraunhofer research in the field of health has the objectives of improving the quality of patient care, of structuring the health-care system to be as efficient as possible, and of identifying trends in medical engineering. Medical systems of today offer many opportunities to simplify and improve care, diagnoses, treatment scheduling, as well as monitoring of treatment and success rates with the help of IT. Interactive assistance systems in clinical practice facilitate acquiring important diagnostic and treatment information. Software systems aid the work in physicians' offices, in hospitals, and in pharmacies. Digital process chains, for example having an electronic patient record, facilitate individualized forms of treatment. Thanks to healthcare teleinformatics, consultations as well as treatment can be carried out independent of location. However, these require sustainable standards for data protection and information security.

The medical engineering of tomorrow is completely computer controlled. There are new application areas in the healthcare system, from image-based diagnostic processes, to telemedical solutions, to prosthetics and robotics. In addition, software aids the workflow with pre-operative planning and support of therapeutic interventions during operations, for example. These kinds of new applications not only preserve our high quality of life, they also counter the increasing costs in the healthcare system.

Networked databases facilitate reliable, rapid diagnoses and individualized treatment for patients. Information on current and previous medications and allergies as well as past operations and patient X-rays can be merged in a digital patient chart in the future. That enables physicians to select the best treatment for every case. Since all of the important information about the course of an illness is available digitally, whole groups of patients can also compare with one another in detail. Modern encryption technologies and security standards are employed to ensure the security of this highly sensitive data.

Intelligent sensor systems are one of the pioneering technologies augmenting assistance systems to provide independent living for seniors. These adapt to the needs of users and make life easier for the elderly as well as those with restricted mobility in their domestic environment. Sensor systems are also employed in fitness and the health field to improve the personal health of every user. They measure vital signs like heart and respiration rates, and also specific sequences of motion during physical therapy exercises at home, enabling individualized training programs to be developed and implemented to optimize healthcare.

ENERGY AND SUSTAINABILITY

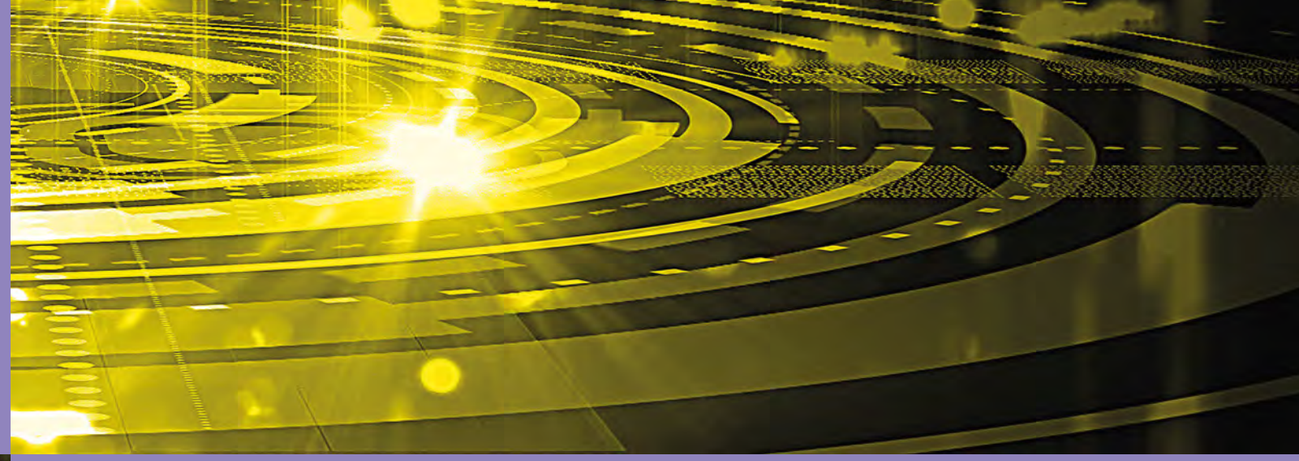
Deregulation of the energy markets requires comprehensive consideration of the processes involved in supplying energy. The EMS-EDM PROPHET® energy and energy data management solution comprises a powerful time series management module, a comprehensive energy data management unit with modules for grid usage and balancing group management, a scheduler for automation of business processes, and an optimization and forecasting module for sustainable energy management.

With the rapid growth of the world population, humanity faces the challenge of ensuring a supply of energy without exhausting natural resources and damaging the environment. Stable, efficient, and intelligent supply and waste disposal systems are part of a sustainable economy. Intelligent networking of power generation, supply, storage, and consumption offer enormous opportunities to utilize energy conservation in parallel to the development of new forms of energy production. Variable electricity pricing – low for oversupply of energy and commensurately high for shortages – provides motivation for private and industrial buyers to adapt their consumption pattern to availability. Intelligent networking and efficient energy distribution can help to avoid system blackouts and minimize costs.

Smart microgrids network energy producers, storage operations, and consumers together at a local level to reduce transmission losses caused by sourcing power at greater distances. Microgrids constitute the main interface for autonomous network branches to the rest of the energy distribution network. With the help of a local energy management system, the integrated energy producers and consumers can be guided by the smart microgrid. Compatible communications standards ensure the security and the interoperability of the systems that are networked with one another.

Sustainable resource utilization comprises the development of recyclable products and processes that conserve resources. Information and communications technologies in the energy sector support feeding renewable energy into the grid and manage its intelligent distribution. Rising rates of water consumption can be controlled with the help of intelligent water supply systems and optimized through gray water purification strategies.

Smart metering has the objective of achieving savings through intelligent meters for electricity, natural gas, and water, and contributing to situational management of consumption. These interactive systems facilitate detailed acquisition of individual device usage as well as their control. Smart meters are connected to control centers that can provide real-time communications to measurement and switching stations in the smart grid. Intelligent energy distribution networks and electrical meters can increase the efficiency of energy usage, as the end customers are provided with detailed information about their consumption as well as the resulting costs and savings potential.



TECHNOLOGY FIELDS

NUMERICAL SOFTWARE AND SIMULATION

Optimization problems in an industrial setting and the attendant need for simulations occur in many forms. Whether coping with conservation of resources, optimizing physical properties in design, maximizing capacity utilization of manufacturing assets, or in planning transportation routes and supplies – methods of mathematical optimization and discrete element simulation can help to make sound business decisions, to improve processes, and to reduce costs. Due to the increasingly stringent requirements for quality in innovative products, computer simulations are becoming increasingly important for industry. They accelerate development of new designs and assist with process optimization. Simulation reduces development cycle times, replaces "real" experiments, and facilitates the construction of better prototypes while at the same time reducing costs.

The core of Fraunhofer's research work is to develop efficient numerical methods for solving high-dimensional problems. The Fraunhofer ICT Group creates processes, for example, that allow advantageous prediction results to be obtained for large data sets in a relatively short time. These are suited to customer applications that depend on rapid analysis and processing of diverse data for which conventional non-linear processing is too slow. Software solutions based on dimensional reduction techniques are developed that allow engineers to simply and interactively explore large quantities of data from either virtual product development or empirical monitoring. These analytical methods enable the engineers to make decisions more quickly based on the dataset. The Fraunhofer ICT Group develops new approaches that help shorten computation time of simulations for the same resolving power of the models and high resolution of the output data.

Core expertise

- Parallelized numerical algorithms
- High-efficiency methods for optimal and scalable solutions to large systems of linear equations
- Performance analysis and optimization
- Software architectures for multi-core processors and various hardware accelerators (incl. GPUs)
- Analysis and reduction of large quantities of numerical simulation data
- Investigation of sensor data from monitoring systems

Application areas

- Material simulations for Virtual Rapid Prototyping (VRP)
- Environmental simulations
- Transportation optimization and route planning in logistics
- Packaging and cutting problems in manufacturing
- Resource optimization based on allocation of machinery, work schedules, and consumption of materials
- Site selection for companies according to various criteria
- Trend forecasting of exchange rates and other financial products
- Recommendation mechanisms for product suggestions in online commerce

USABILITY AND HUMAN-COMPUTER INTERACTION

Engineering and technology should maximally benefit our living situation and working environment without imposing additional limitations. For products or services that have an IT component, the ease of operation, user experience, and design are determinants of success in the marketplace. How does an online shop need to be arranged in order to invite visitors to browse? What is the best way for a supplier relationship management system (SRM) to contribute to internal company acquisition processes? How should the enterprise-wide electronic appointment calendar look for it to fulfill the requirements of both trainees and executive management? How should the workplace of the future be designed for it to fulfill the contrasting demands of productivity and ergonomics?

User experience involves far more than simple operation or the basic application of technology. The Fraunhofer ICT researches and develops contextual and use scenarios in order to define requirements for interactive products on the basis of user characteristics, processes, and operational conditions and limitations. These scenarios can be used to develop new systems, optimize extant systems, or trigger innovation processes. By methodically embedding feedback mechanisms at the user-context analysis level, the validity of requirement specifications from the point of view of the user can be confirmed early in the product development cycle.

Core expertise

- Quantitative assessments of usability and user experience (UX) for interactive products
- Design of usability and UX questionnaires and their evaluation
- Identification of usability and UX optimization potential for interactive products in user research
- Expert-based usability and UX testing for interactive products
- Methods for evaluating designs and product ideas
- Participative design processes and technology mediation
- Advanced training to obtain usability engineer qualification

Application areas

Optimizations of usability and human-computer interaction have an effect on all areas of living and work in which technology is intended to aid humans in carrying out their activities, fulfilling task requirements, and solving problems. This applies to all sectors of the economy – to simple as well as complex processes. Only if tools and working conditions are suited to the tasks will technological support find acceptance with employees and lead to higher productivity.

RELIABLE CYBER PHYSICAL SYSTEMS

Software is the heart of innovative systems and ensures a sustainable future for our society and economy. We are convinced that the networking of systems and sensors into a collaborative, smart ecosystem will also characterize our future. For that reason, the highest demands for quality will be placed on software in critical security systems. The increasing complexity of these systems will become a growing challenge for companies. Complex processes with many different participants underlie the development of software. While software in embedded systems has previously been characterized by longer development and innovation cycles and therefore advanced more slowly, in future the development speeds of IT systems will become increasingly difficult for embedded systems to evade. The flexibility and intelligence in smart phones and cloud applications that customers have become accustomed to will be expected to characterize embedded systems as well.

The Fraunhofer ICT Group develops innovative methods and solutions for creating high-quality, complex information systems and embedded systems. System development is making methodical and technological progress through new approaches such as model-based development, for example. This enables increasingly complex systems to be developed in ever-shorter cycles. Against a backdrop of faster and faster system enhancements and the great diversity of variants, we develop new methods and chains of tools for developing secure and reliable software systems. The goal is not only to be able to "manufacture" more software in less time, but instead to also exclude defects and weak points. Reliability and failure-mode tolerance will become important performance indicators of hardware and software systems. Structured approaches for testing procedures and quality assurance help to take these indicators into account during the software origination process. Besides increasing quality and reducing costs, research in this area increasingly focuses on scaling effects and greater interoperability.

Core expertise

- Requirement analysis
- Software architectures
- Software development processes
- Software development tools
- Systematic and automated software tests

Application areas

Cyber physical systems combine IT with the physical world and play an important role in more and more areas such as automotive manufacturing, aviation, transportation, energy, manufacturing, healthcare, and infrastructure as well as entertainment. If machines, installations, and automation engineering are to continue to be worthy of the "Made in Germany" seal of approval, the traditionally high standards of quality must also be applied to the continually increasing fraction of software in products and services. Software that must meet these high requirements meanwhile is found in products from nearly every area of industry.

IT SECURITY AND SAFETY

Information technology offers organizations numerous opportunities to develop new products, offer innovative services, and improve value-added chains. At the same time, our daily lives are filled with IT devices and services that interact in complex ways and are increasingly threatened by attacks and outages. Security and safety of IT systems therefore form the foundation for successful modernization in business and industry as well as for the smooth functioning of government and society.

IT security and safety technologies enable companies and government to improve the reliability, trustworthiness, and immunity to manipulation of IT-based systems, and also to ensure the dependable functioning of critical systems. As one example, the Fraunhofer ICT Group develops tools with which programmers can test the security properties of software beginning already in the development phase. This enables defects and weak points to be identified early on and cost-effectively removed. Moreover, modular safety analyses that are integrated into the development methodology permit efficient certification of systems. The Fraunhofer ICT Group works on safeguarding industrial installations and processes, among other things under the Industry 4.0 program. Because IT security and safety are especially closely meshed here, the Group develops integrated solutions for safeguarding manufacturing processes and data. Fraunhofer develops designs and solutions to make security and safety mechanisms in hardware and software more intelligent and more flexible in order that they are also easy to use. Models focused on IT security and safety relieve the user of having to react to new situations because systems based on these kinds of models are also able to react safely and automatically.

The Fraunhofer ICT Group has a complete command of techniques, methods, and tools with which the security and safety properties of systems can be efficiently specified, analyzed, and validated. Fraunhofer researchers are able to test the immunity to attack and failure tolerance of systems both theoretically and empirically. Together with our partners, we improve the security and safety properties of devices, services, networks, and processes. In addition, the Group members develop innovative software and hardware solutions, make these available for licensing, and support companies in implementing new advances.

Core expertise

- Usability, security, and safety
- Biometrics
- Cyber security
- Information security
- IT forensics
- Modeling and evaluation of security and safety
- Security and safety engineering
- Security for cloud computing
- Comprehensive security and safety for cyber physical systems
- Security for software
- Security for and through Big Data

Application areas

Security and safety technologies and models constitute the foundation for new developments and successful innovations in many sectors and fields, including examples such as

- Corporate software
- Manufacturing systems
- E-government
- E-health
- Big Data
- Software-defined products
- The Internet of Things
- Industry 4.0
- Automotive sector
- Medical engineering
- Electromobility and energy management

DIGITAL NETWORKS AND THE INTERNET

Access to communications networks and services together with the supply of sufficient bandwidth is critically important today for people, companies, and regions. Whether at work or at play, people depend more and more on the Internet. However, telecommunications is about more than just telephones today. It is long since not just a matter of connecting people with one another. Today it involves communications between machines to organize and prepare data for different devices and services. This created the foundation for the Internet of Things and the Internet of Services. The Fraunhofer ICT Group develops access, components, and tools for Next-Generation Networks so that technologies and applications can be interoperable and efficiently implemented. Moreover, the researchers ensure these are device-independent and personalized communications that meet the demands of users for availability, quality, convergence, and interactivity.

The Fraunhofer ICT Group is a pioneer in research and development of the Future Internet, in particular in the areas of Network of the Future, the Internet of Services, and the Internet of Things. The researchers facilitate efficient prototyping of innovative 5G infrastructure and applications, particularly in the areas of professional and industrial communications for international network operators, manufacturers, and users through its newest advances in the areas of Software-defined Networking and Network Functions Virtualization.

Core expertise

- Test environments and toolkits
- Secure and robust communications protocols
- Software-defined networks
- Internet of Things/M2M
- Car-2-X communications
- 5G transmission standards

Application areas

The communication networks for people and machines are the foundation for complex applications in areas including traffic management and transportation systems, healthcare, and administration. The requirements are correspondingly stringent. Countless applications benefit from digital communications. The prerequisite is reliable and secure communications networks that can be standalone or connected via wireless or hard-wired links to the Internet.

GRAPHICS AND MEDIA TECHNOLOGY

Digital media are important components of our culture. Numerous basic technologies are necessary to bring images, audio, video, and interactive 3D worlds to the viewer in high visual and audio quality. Visual displays create the opportunity of presenting complex and interdependent content through sensor data and simulations. Data and experience can be analyzed with the help of visual displays. The objective is to present knowledge comprehensibly and make decision making easier.

The research priorities of the Fraunhofer ICT Group lie in the areas of 3D visual display and audio presentation as well as audio and video coding and transmission. The Fraunhofer ICT makes important contributions to advances in the areas of real-time visual display, aural presentation, efficient compression methods, auto-stereoscopic 3D displays as well as to the integration of real and virtual worlds for immersive multimedia applications.

Core expertise

- Virtual reality
- Mobile augmented reality
- Multimodal interaction and installations
- Visual display software for large data sets
- Graphical presentation of information and data
- Audio and video codecs
- 3D displays
- 3D audio reproduction
- 3D data capture and modeling
- 3D printing

Application areas

The presentation of complex 3D models in real time with photorealistic image quality is an important medium of communication in technical fields such as the automotive sector, mechanical and civil engineering, as well as in medicine and urban planning. In the cultural domain as well, we rely increasingly on the technologies of virtual reality in order to represent and present artistic treasures in their original form and to make them digitally accessible. 3D sound is being incorporated everywhere that improved spatial reinforcement and reproduction matters – in concert halls, at live events, in planetariums and show rooms, as well as in vehicles and for the field of virtual product development.

IMAGE ACQUISITION AND EVALUATION

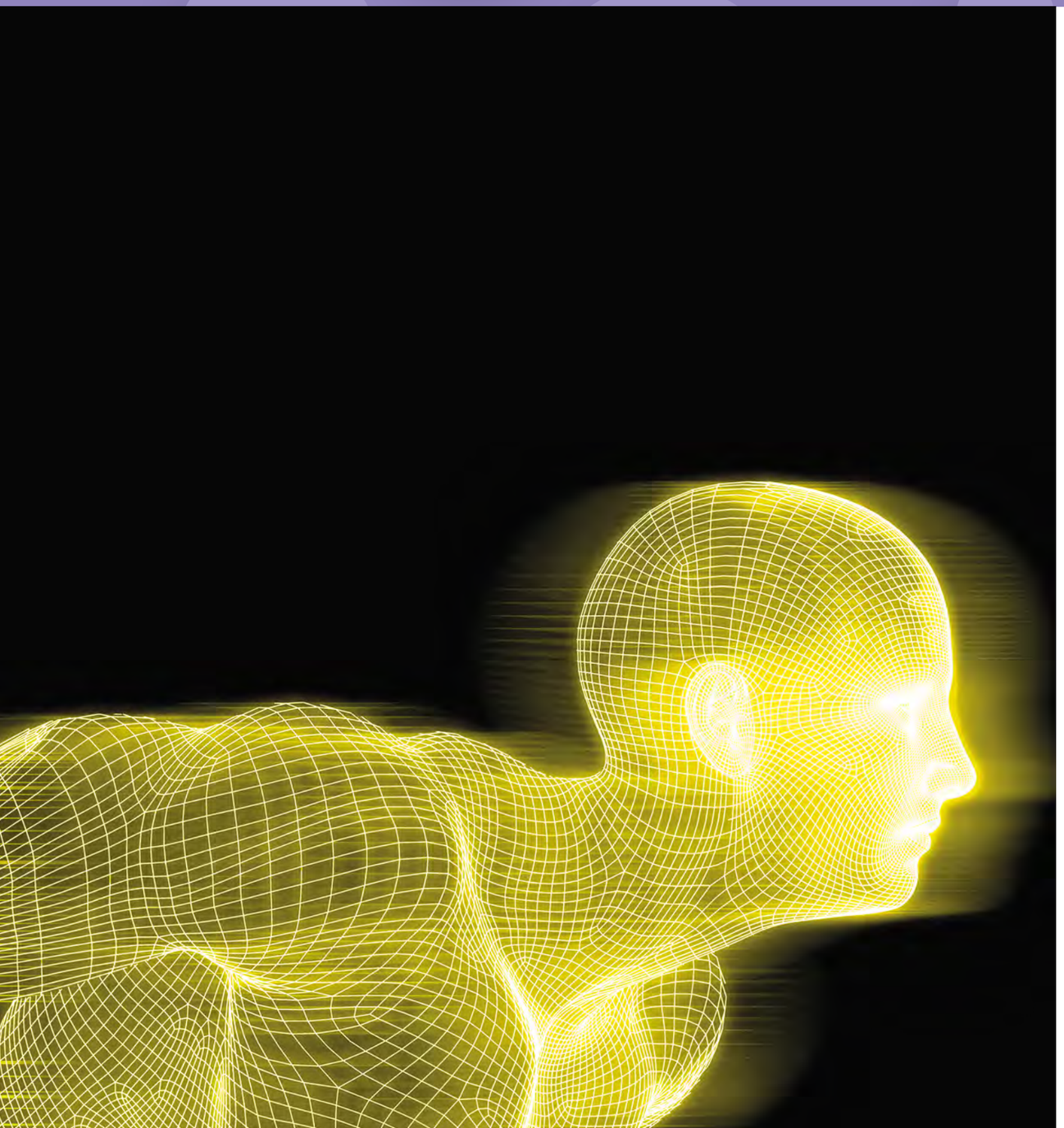


Image evaluation comprises preparation and real-time editing as well as automated and interactive acquisition of information from images and video. In order to be able to represent real objects in virtual form as well, our researchers analyze and interpret real images and transform them into information. Specialized digitalization and analysis processes are needed for this, which are worked out by them.

As a result, machine vision is not just emulating what the human eye can do, it means capturing the entire reflected spectrum as it occurs in nature and technology, from ultraviolet to infrared.

Core expertise

- Analysis, classification, and pattern recognition in images, image sequences, and videos
- Object recognition and tracking
- 3D reconstruction
- Movement analysis and tracking processes
- Machine vision in robotics and vehicles
- Technology-assisted image evaluation systems
- 3D analysis
- Multisensory technologies, system architectures and methods

Application areas

- Medical diagnostics
- Material testing
- Security surveillance
- Digitalization of world heritage
- Evaluation of aerial, satellite, and synthetic aperture radar (SAR) images as well as image sequences
- Visual inspection systems and surface inspections
- Automated quality control and duplicate searches in image and video databases

BIG DATA MANAGEMENT AND ANALYTICS

The digitalization of business and society represents a fundamental change that not only comprises IT sectors, but increasingly leads to disruptive change in other conventional branches as well. We have more and more data at our fingertips – not only about our customers and business processes, but also about machines, devices, and infrastructure (the Internet of Things) through the increasing spread of intelligent sensors. The enormity and diversity of these datasets ("Big Data") enable not only doing what has been done before better and more efficiently, but also permits completely new digital business models in companies or enterprises to be considered. This leads to opportunities for capturing or avoiding loss of market share in certain sectors faster than ever before.

It is therefore crucially important for companies to confront digitalization and the importance of data promptly and profoundly. It means Big Data is not just a technical matter of selecting the correct architecture for computing centers and storage systems, but first and foremost a strategic imperative about the utilization of data for creating new value ("data-driven companies").

As a result, the Fraunhofer ICT Group supports companies at the strategic level in identifying data containing unrealized potential, whether for new business models or for efficiency wins. If they choose, the ICT Group also support companies in realizing concrete projects that result from this process, be it analysis of data, selection of analysis systems and algorithms, or configuring suitable high-performance and scalable infrastructure.

The interdisciplinary expertise of 26 Fraunhofer institutes is linked for this purpose in the Fraunhofer Big Data Alliance. This enables us to assemble teams in which Big Data experts work jointly with sector experts for companies on adaptable solutions. In addition, the Big Data Alliance provides a comprehensive range of training, from small intensive seminars for management, to in-house training, to complete data science education available through the Fraunhofer Academy.

Core expertise

- Technical design of Big Data architectures
- Big Data analytics
- Visual analytics
- Systems and algorithms for data analysis
- Analysis of unrealized potential
- Education in the field of data science

Application areas

- Manufacturing and Industry 4.0
- Logistics and mobility
- Life sciences and healthcare
- Energy and the environment
- Security and safety
- Business and finance
- Business and Finance

AUTOMATION TECHNOLOGY AND ENGINEERING

Guidance and automation engineering are key technologies for the future competitiveness of German manufacturing. However, the problem seen with these technologies is precisely that they are unseen – they are hidden technologies. Overall, studies of automation engineering forecast strong growth in the coming years. Automation here means functional system solutions at all levels of industrial fabrication, all controlled by awareness and continual management of data and information. The priority for the work of this division is real-time IT for complex manufacturing processes.

With its spectrum of capabilities focused over the whole of the automation pyramid, the Fraunhofer ICT Group offers pioneering solutions for manufacturing companies in the fabrication and processing industries, for system integrators, and for automation suppliers.

Core expertise

- Guidance engineering and Manufacturing Execution Systems
- Industry standards for interoperable products and IT systems
- Condition Monitoring and Diagnosis (CMD)
- Industrial communications
- Human-machine interaction in industry
- Robotic systems: mobile platforms and manipulators
- IT security and safety in industry

Application areas

- Industrial fabrication
- Automotive construction
- Agriculture

FORMS OF COOPERATION

WAYS OF WORKING WITH THE FRAUNHOFER ICT GROUP

A company sees a need for research or development under a conventional research project contract. It wants to bring a product innovation to market, improve a process, solve a logistical problem, or have a process examined and certified, for example. A discussion with Fraunhofer points up what solutions there are, what kind of collaboration is most suitable, and what sort of expenditure might be expected. The goal of the collaboration is to solve the problem and introduce the innovation into the company's operations or to the market. In cases of complex problems, several partners develop the solution. In these cases, the expertise from all of the institutes of the Fraunhofer ICT Group is available to the client. External partners and additional companies can also be brought in. Fraunhofer researchers have experience running large projects efficiently and fairly, and also know about suitable public funding programs.

Fraunhofer itself wants to push ahead with promising technologies. Long lasting strategic partnerships with companies often result from this initial research that proceeds independent of contracts at first. The long-term cooperation of several research institutions and companies can be advantageous in running complex projects. This is the reason Fraunhofer originated the Innovation Cluster with support of the German federal government. The purpose of a cluster like this is to bring together expert regional partners for solutions to demanding problems. Networks of research institutions, investors, and companies that develop in geographic proximity can lead to new business ideas and companies. Regional innovation clusters close the gap between business and science. Successful clusters stimulate competition and create fruitful collaboration at the same time, ultimately benefiting everyone. When Fraunhofer researchers develop a new product or process, they found independent spin-offs. Fraunhofer itself only participates to a certain extent in a new undertaking like this. Sometimes the clients involved in a new advance are themselves interested in being part-owner of the spun-off company. This enables them to participate long term in the future development and further success of a technology. The new companies know the advantages of collaborative research from their own experience, use their contacts, and are pleased to work together further with Fraunhofer.

HOW THE FRAUNHOFER ICT GROUP HELPS ITS CUSTOMERS

Companies can never be satisfied with successful products – they need to continually search for improvements and new products they can market. This is where Fraunhofer comes in: we **improve products**, enhance their performance, develop wholly new ones, and make sure, for example, that they can be manufactured at lower cost and are marketable. Sometimes a job is not finished with one detailed solution. Creating an innovative prototype is important, but the manufacturing process is often similarly complex and must be concomitantly **developed with the product**. Fraunhofer researchers in cooperation with the client are able to drive processes and products forward up to and including **short runs**. In this way, Fraunhofer contributes to their clients' achieving success in the marketplace quickly.

Technological trends and developments in the market are carefully monitored at Fraunhofer institutes in order to be able to keep clients apprised. **Feasibility studies, profitability calculations**, and information about support programs augment the services for clients. Fraunhofer moves in the most advanced technological circles. For example, the researchers participated in important ways in the development of light-emitting diodes, audio and video coding, and laser technology. If these kinds of **new technologies** need to become products, you too can turn to Fraunhofer institutes. The right ideas start here, and the researchers also know how to transform them into products and processes.

Fraunhofer not only conducts contract research for companies – its in-house research promises interesting results in selected fields. Inventions maturing from this initial research can be profitably commercialized by companies under **license**. The mp3 format and H.264 video coding scheme are examples of this.

Markets change, just as technologies, legislation, and economic conditions do. A company can expand, enter into new partnerships, or adjust its palette of products. There are many reasons why existing manufacturing facilities or internal organization might no longer suit current requirements. Fraunhofer experts have extensive experience with how to determine **optimization potential** in technical and organizational flows, encourage people about innovative ideas, as well as demonstrate and realize the corresponding potential. Analysis and testing are also part of development. Fraunhofer institutes have a wide range of high-quality equipment for reproducibly testing the functionality, security, and safety of components, materials, coatings, and processes. They also conduct testing under contract for clients and issue test reports and **certificates** (from accredited Fraunhofer testing labs).

Fraunhofer has an outstanding name in business, in the working world, and also among purchasers of finished products. Many companies are therefore pleased to highlight the fact that their developments arose through cooperation with a Fraunhofer institute. Publication of research requires consent. We only disclose the name of the client if we have their express permission.

STRATEGIC MEASURES

IMPROVING ADVANCED TRAINING AND THE QUALITY OF SCIENTIFIC OUTPUT

Scientific output and advanced qualification of employees are one of the central responsibilities of the individual Fraunhofer institutes. Moreover, Fraunhofer-wide statistics are maintained and interdisciplinary advanced training is made available especially in the area of soft skills. The Fraunhofer ICT Group supports these objectives with activities that include:

- Internal Fraunhofer Institute awards for outstanding publications and academic work
- Offer of a dissertation prize at the Fraunhofer ICT Group level, first awarded in 2014
- National and international technical associations were identified as important scientific partners. The Fraunhofer ICT Group has provided three of the four previous presidents of the German Informatics Society ("Gesellschaft für Informatik", GI) and ten out of twelve since 2004. Moreover, the office of the GI in the capital is lodged in the Fraunhofer ICT Group offices in Berlin. Numerous joint initiatives have resulted from co-sponsorship of "Bundeswettbewerb Informatik", the national informatics competition. These include the "Informatics Beavers" for grade school students with currently over 200,000 participants annually, the co-organization of four "Science Years" so far (Informatics 2006, Mathematics 2008, the Digital Society 2014, and City of the Future 2015), as well as jointly addressing policy matters. In addition, several Fraunhofer institute directors have been elected Fellows of the German Informatics Society (Prof. Jarke/Fraunhofer FIT) and its international sister societies ACM (Prof. Encarnação/Fraunhofer IGD, Prof. Rombach/Fraunhofer IESE, Prof. Jarke/Fraunhofer FIT), and the IEEE (Prof. Brandenburg/Fraunhofer IDMT, Prof. Rombach/Fraunhofer IESE).
- At KIC Digital (formerly ICT Labs) of the European Institute of Innovation and Technology, the Fraunhofer ICT Group is involved in the BMBF-sponsored management development program "Software Campus". Thus far, sixteen young high-potential doctoral students from Fraunhofer ICT Group member institutes were able to realize their own small projects in cooperation with industry.

During recent years, the presence of the Fraunhofer ICT Group in the scientific academies, especially in acatech, the German National Academy of Science and Engineering has improved. While only two institute directors (Prof. Encarnação/Fraunhofer IGD, Prof. Spath/Fraunhofer IAO) were members there in the beginning, the number was able to be increased to six institute directors by the end of 2014 (Prof. Beyerer/Fraunhofer IOSB, Prof. Brandenburg/Fraunhofer IDMT, Prof. Eckert/Fraunhofer AISEC, Prof. Encarnação/Fraunhofer IGD, Prof. Jarke/Fraunhofer FIT, Prof. Schieferdecker/Fraunhofer FOKUS). Prof. Claudia Eckert was elected as the first director of a Fraunhofer ICT Group member institute to the acatech Presidential Council in 2015, while the former Fraunhofer ICT Group chairman, Prof. Encarnação, has been head of the acatech Information and Communications Technology Network (IKT) for many years. Institute directors of the Fraunhofer ICT Group are similarly represented in the European academy Europeana (Prof. Fellner/Fraunhofer IGD) as well as in German academies (incl. Prof. Brandenburg/Fraunhofer IDMT and Prof. Encarnação/Fraunhofer IGD).

NETWORKING

The Fraunhofer ICT Group actively augments the networking its institutes carry on with business, the body politic, and the greater society. Over the last three years, the Group has provided more than 300 concrete technology and consulting inquiries to the Fraunhofer institutes. With its own technical seminars and conferences like eCommerce Day, Usability Day, the Vehicle Interaction Summit, IT Security Day, and Big Data Days, the Fraunhofer ICT Group has found a means of presenting a broad spectrum of technical expertise and experience to business from a single source by involving several Fraunhofer institutes at a time.

The individual Fraunhofer institutes' activities in different **commercial and policy networks at the national and international levels** are augmented by those of the Fraunhofer ICT Group, and partly coordinated by it. An example of this is the bundling of numerous individual memberships and over 100 individual activities in the IT industry's association Bitkom into one joint Fraunhofer ICT Group membership that enables all the institutes to participate. The Fraunhofer ICT Group was able to utilize its new weight to claim a seat on the governing board of Bitkom. As a consequence, the Fraunhofer ICT Group chairman was elected to the Bitkom governing board in 2014 after he had already succeeded Prof. Wahlster as the scientific representative on the CeBIT Trade Show commission, the representation of the large exhibitors. At the EU level, the Fraunhofer ICT Group is represented by its chairman as one of two German scientific representatives in the CONNECT Advisory Forum for ICT Research and Innovation, the successor to the Information and Communication Technologies Advisory Group ISTAG, that advises the EU Commission in the formulation of the IT portion of the Horizon 2020 Programme. Additional Fraunhofer Institute directors represent the Fraunhofer ICT Group in the important strategic initiatives ECSEL (successor to Artemis and Nessi) and Big Data Value. Initiatives in the areas of Cross Energy Management and Cloud Computing are being discussed with Günther Oettinger, European Commissioner for Digital Economy and Society.

On the **national policy scene**, the Fraunhofer ICT Group has considerably strengthened its activities and visibility level in Berlin. The following initiatives are especially noteworthy:

- The Fraunhofer ICT Group has been actively accompanying the IT contingent of the German federal government in various working groups for several years.
- Members of the German parliament and their staff are informed objectively and factually about various current IT and Internet topics in the Fraunhofer ICT Group Roundtables that take place seven to eight times per year.
- The Fraunhofer ICT Group has been participating continually in the inaugural event for Girls' Day in the Chancellery attended by German Chancellor Angela Merkel.
- Intense exchanges with the German parliament's Digital Agenda panel and its members (club discussions, participation in private meetings, etc.).
- Political evening and midday events on various current topics.

TRADE SHOWS AND EVENTS

The Fraunhofer ICT Group is increasing its activities at trade shows and large events pertinent to its international profile. These include arranging and coordinating opportunities for presentations by ICT Group institutes at economically and politically important events and trade shows such as the Bitkom hub conference (formerly "Bitkom Trendkongress") and the Science Years conducted by the BMBF, for example, the German Federal Ministry of Education and Research.

Similarly, the Fraunhofer ICT Group is becoming increasingly involved in the planning of themes and content for strategic trade show appearances that are conducted and co-financed by Fraunhofer Headquarters. Under the new trade show strategy of the Fraunhofer-Gesellschaft, nine new strategically important trade shows were identified including CeBIT as the leading show in the field of information and communications technologies. The Fraunhofer ICT Group sends a representative to the team responsible for **CeBIT** themes (formerly called "technical coordinators") in order to give support to the project director from headquarters on matters of technical content. This includes consulting on themes and the design of booths as well as helping prepare the supporting communications. The Fraunhofer ICT Group is working hard to present the expertise of the member institutes in a sharply focused form at **technical trade shows**. An initial measure for this has been to organize joint booths for these trade shows at which several Fraunhofer ICT Group institutes have independently exhibited. Their presence at a joint booth creates synergistic effects for the participating Fraunhofer institutes in the form of greater visibility and additionally ensures that Headquarters shares in the costs. The coordination of these joint booths is carried out by staff members of the Fraunhofer ICT Group.