



HIGHLIGHTS
2019
ANNUAL REPORT

The online version of the Annual Report is available at:



www.iis.fraunhofer.de/annualreport



Link to further information on the topic



Link to multimedia content

FRAUNHOFER IIS

The Fraunhofer Institute for Integrated Circuits IIS in Erlangen is one of the world's leading application-oriented research institutions for microelectronic and IT system solutions and services. Today, it is the largest of all Fraunhofer Institutes.

Research at Fraunhofer IIS revolves around two guiding topics: audio and media technologies and cognitive sensor systems. Applications of our research results are found in connected mobility, in communication and application solutions for the Internet of Things, in the digitalization of human sensing, in product and material monitoring, and in business analytics in supply chains.

Cover image

The ADA Lovelace Center represents a unique research infrastructure in Bavaria created by the Fraunhofer Institute for Integrated Circuits IIS and its Supply Chain Services (SCS) working group in collaboration with Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and Ludwig-Maximilian-Universität München (LMU). The Center also benefits from the involvement of the Fraunhofer Institutes for Cognitive Systems IKS and Integrated Systems and Device Technology IISB.

HIGHLIGHTS
2019
ANNUAL REPORT



Dear reader,

In the future, artificial intelligence (AI) will enable us to address new problems and develop innovative new lines of business. This is part of the reason why, for several years, we have been reinforcing our activities and research in this area.

On November 1, 2019, the Management of the Institute gained a new member: Professor Alexander Martin is a prominent expert in AI – and especially in the area of mathematical optimization – and has previously overseen the establishment of the ADA Lovelace Center for Analytics, Data and Applications, which opened in 2019.

Last year also saw us develop and implement many original ideas, and this Annual Report presents our highlights from the year 2019. We look forward to continuing to provide you with added value through our research.

Kind regards,

Handwritten signature of Professor Albert Heuberger in black ink.

Professor Albert Heuberger

Handwritten signature of Dr. Bernhard Grill in black ink.

Dr. Bernhard Grill

Handwritten signature of Professor Alexander Martin in black ink.

Professor Alexander Martin

Fraunhofer IIS Management of the Institute

6



MAKING VOICE ASSISTANTS BETTER

14



ARTIFICIAL INTELLIGENCE AT THE ADA LOVELACE CENTER

22



POSITIONING IN 5G

- 10 Sennheiser Soundbar with MPEG-H Audio now available | Media workflows via Internet Protocol (IP) networks | Apple, Amazon, and Android products with xHE-AAC | Improved voice and audio quality thanks to LC3plus
- 12 MPEG-H Audio Update
- 18 »Joint Lab Data Analytics« founded | R2D – Road to Digital Production

- 20 Data-based trend and scenario research | Helping the digital transformation take off
- 26 The cognitive Internet for industry | GOOSE technology for autonomous driving
- 28 Shots and dunks – wearables for use in basketball | Energy harvesting and positioning for MIOTY® technology | TRILUM smart warehouse picking system | easyPILOT Follow: efficient order picking

CONTENTS

30



SATELLITE IOT PAVES THE WAY FOR WORLDWIDE NETWORKING

38



PHENOTYPING ROBOT TAKES TO THE FIELD

34	Groundbreaking system architectures for SMEs New packaging for more than Moore
36	Status quo of AI activities in Saxony
42	3D CT scan of a Peruvian mummy Retrofitting outdated X-ray systems XXL CT of the Me 163 rocket-powered interceptor
44	Miniaturized optical spectrometers Medical Valley Center opened in Bamberg

46	Fraunhofer IIS as a partner
47	Training at Fraunhofer IIS
48	Research Fab Microelectronics Germany
50	In brief
56	Figures data facts
68	Publishing notes



MAKING VOICE ASSISTANTS BETTER

Voice assistants are growing in popularity and are even being adopted in industry. To work reliably, they need to »hear« voice commands clearly and must be trained to understand what is being said. A platform »made in Germany« is needed in order to retain ultimate control over these training models and the data the assistant collects. The Fraunhofer SPEAKER project is pursuing precisely that objective.

The use of virtual voice assistants such as Alexa, Siri, and others is becoming increasingly popular, with one in six Germans using »smart speakers« in 2018. The number of users of these speakers equipped with digital voice assistants has therefore tripled compared to the previous year.¹ However, despite the technology's growing popularity, surveys reveal that many consumers have concerns regarding data protection.² In addition, users of the various assistants feel that their virtual helpers often fail to understand them correctly.³ At Fraunhofer IIS, we are addressing both of these problems with our natural language user interface (NLUI) projects. These interfaces allow humans and machines to interact using natural language – and we take two key steps to ensure that the machine understands and processes voice commands correctly.

1 Donath, T. (2019): »Smart Speaker & Voice Control.« In: *Trendmonitor Deutschland*. Available at: <https://trendmonitor-deutschland.de/smart-speaker-voice-control/>.

2 Bodenhöfer, X. (2018): »Digitale Sprachassistenten als intelligente Helfer im Alltag« [Digital voice assistants as smart helpers in everyday life]. In: Research articles by eresult GmbH.

3 Adobe 2019 Voice Report.

AT A GLANCE

- 1 | The Fraunhofer upHear algorithm processes the voice signal for the smart speaker.
- 2 | A German voice assistant solution would allow the implementation of European data protection standards.
- 3 | In the SPEAKER project, the aim is to develop open, transparent, and secure voice assistant applications.

Step one: The voice assistant needs to have good hearing

For voice commands to be processed correctly, they must reach the »artificial ear« loud and clear. This isn't always as trivial as it sounds – indeed, many virtual assistants are housed inside a smart speaker that is also used to listen to music, for example. Likewise, the room in which voice assistants are used may produce echoes, the environment may be too loud or simply too large, or the user may be standing too far away. It was to solve these problems and others that we developed the Fraunhofer upHear Voice Quality Enhancement (VQE) technology, which ensures optimum processing of the voice signal for the smart speaker – for example, by suppressing acoustic echoes in the microphone signal. The device can therefore be voice-operated while simultaneously playing back music or announcements. Background noise is removed to allow operation even while the user is far away. This approach ensures that the »keyword spotter« receives a clear voice signal, significantly improving recognition performance.

Step two: The voice assistant must be »trained«

Voice assistants »exist« on human–machine interaction, allowing people to communicate with devices via voice commands and therefore to access products and services in natural language.

In order for the system to understand human beings, it is first necessary to train reliable models so that the machine can learn what voice commands mean. Until now, these technologies have lacked solutions that meet European data protection standards, because the market in voice assistance solutions has so far been dominated by companies from the USA and Asia. There is, however, huge demand from German business and industry for solutions of this kind. Particularly in relation to data sovereignty, there is a need for improved protection and secure exchange of personal data. This is possible with a voice assistant solution made in Germany, as it will implement European data security standards. At the same time, a new level of quality is emerging in human-machine communication that far exceeds the semantic capabilities of current systems and is therefore much more user-friendly.

Fraunhofer SPEAKER project

In the Fraunhofer SPEAKER project, we have joined forces with the Fraunhofer Institute for Intelligent Analysis and Information Systems (IAIS) to bring together experts in the areas of natural language understanding, artificial intelligence, and software engineering in an interinstitutional collaboration. As part of this major research and development project, which is supported by the Federal Ministry for Economic Affairs and Energy (BMWi), there are plans to develop a voice assistant that is »made in Germany«. The aim of the SPEAKER platform is to provide open, transparent, and secure voice assistant applications. With this in mind, it is important to facilitate the simple and straightforward use of leading technologies in the areas of audio preprocessing, speech recognition, natural language understanding, question answering, dialog management, and speech synthesis with the help of artificial intelligence and machine learning. These key modules are used to develop industrial voice assistance applications that can in turn be made available as finished applications to other market participants via the platform. The SPEAKER project received an award as part of the BMWi »artificial intelligence as a driver for economically relevant ecosystems« innovation competition and was therefore one of 16 outstanding concepts that prevailed in a field of more than 130 submissions.

April 1, 2020, marks the official start of the implementation phase of the SPEAKER project. Once the platform's development is complete, it will be transferred to an operating company and offered at a similar cost to established platforms. ■

 www.speaker.fraunhofer.de/en.html

 www.iis.fraunhofer.de/en/magazin/aufdenpunkt.html



CONTACT

Mandy Garcia

Audio and Media Technologies Division

Phone +49 9131 776-6178

mandy.garcia@iis.fraunhofer.de



SENNHEISER SOUNDBAR WITH MPEG-H AUDIO NOW AVAILABLE

The AMBEO soundbar from Sennheiser has won multiple awards and is now commercially available

With a view to creating an immersive sound experience in the living room, we have worked with Sennheiser to develop virtualization technology based on Sennheiser AMBEO and Fraunhofer upHear technology for use in a soundbar.

The upHear Immersive Audio Virtualizer is a form of post-processing technology from Fraunhofer IIS and provides a convincing, immersive 3D audio experience with soundbars or televisions – regardless of the format and without the need for elaborate loudspeaker installations. Moreover, upHear paves the way for 3D audio soundbars that require neither satellite speakers nor a subwoofer.

Thanks to the combination of AMBEO technology with the upHear algorithm and integrated room calibration, the characteristics of the room can be utilized to allow the Sennheiser AMBEO soundbar to generate immersive 5.1+4 sound. Speaking of immersive sound, the soundbar features MPEG-H Audio compatibility and integrated upmix technology that can transform 5.1 movie surround sound or even stereo music into a highly immersive audio experience.

 youtu.be/JCtvKtB1Bj8

MEDIA WORKFLOWS VIA INTERNET PROTOCOL (IP) NETWORKS

JPEG XS SDK available under license for professional production and studio equipment

Among broadcasting stations and media providers, there is an increasingly clear trend toward the IP-based transmission of high-resolution production and contribution content. This marks the end of an era in which image and video signals are transmitted via SDI using a variety of different networks – even in the studio environment. After all, studios transmit thousands of signals via receivers, video mixers, encoders, decoders, monitors, and numerous other devices. Our developers played a significant role in the development of the new ISO standard known as JPEG XS, which offers a form of compression that is specifically adapted to the transmission of high-resolution image data in the studio context. We now offer the first JPEG XS software development kit (SDK) under license for interested parties. The SDK comes complete

with a CPU-optimized encoder and decoder. Since it utilizes numerous opportunities for parallel processing on CPUs, it is perfectly suited to multicore processors, enabling real-time encoding/decoding of 4k and 8k video streams for high-end applications as well as for integration into cameras and monitors. The software codec is available for licensing to all professional media device manufacturers and for integration into studio equipment from this year onward.

  www.iis.fraunhofer.de/jpegxs



APPLE, AMAZON, AND ANDROID PRODUCTS WITH XHE-AAC

Devices with latest Android and Apple operating systems provide native support for most efficient AAC codec

Interrupted or buffering audio and video streams will soon be a thing of the past, with a rapidly growing number of platforms and playback devices now providing native support for an xHE-AAC decoder. We are working with large content and operating system providers to make xHE-AAC and MPEG-D DRC available to an even wider circle of users.

xHE-AAC was developed for adaptive streaming via DASH or HLS and delivers transparent audio quality in favorable network conditions. If necessary, the technology seamlessly switches over to data rates and quality levels that are appropriate for an overloaded network. MPEG-D DRC metadata are required as standard and ensure an optimum user experience in any listening environment: For example, the volume of hard-to-understand dialog can be dynamically boosted in loud environments without modifying the original audio content.

Native support for xHE-AAC and MPEG-D DRC is provided in Google's Android 9 and 10 as well Android TV 9, in Amazon Fire OS 7 (based on Android 9 Pie), and in Apple's iOS 13, macOS 10.15 Catalina, tvOS 13, iPadOS, and watchOS 6.

With xHE-AAC, users of products with these operating systems can enjoy uninterrupted streaming of all kinds of content – such as movies, music, audiobooks, or podcasts. xHE-AAC offers maximum coding efficiency at effective stereo data rates of 12 kbit/s to 500 kbit/s and higher. This efficiency is particularly important in developing countries where consumers are still reliant on 2G or 3G connections.

 www.xhe-aac.com

IMPROVED VOICE AND AUDIO QUALITY THANKS TO LC3PLUS

New DECT »Evolution« standard incorporates an audio codec developed in collaboration with Ericsson

The Enhanced Voice Services (EVS) voice and audio codec, which we co-developed, allows people to speak to each other on cellphones using the LTE network as if they were in the same room. For landlines, however, the requirements for the codec are slightly different. For a long time, achieving this level of quality on DECT wireless phones was therefore nothing more than wishful thinking. In 2019, the European Telecommunications Standards Institute (ETSI) standardized the new LC3plus audio codec and incorporated it into the DECT »Evolution« standard.

LC3plus is an extension of the new Low Complexity Communication Codec (LC3), which was standardized by the Bluetooth Special Interest Group (SIG). Both versions were developed

jointly with Ericsson in order to improve voice and audio transmission for wireless communication devices and so that, among other things, super-wideband (SWB) quality could also be provided for Bluetooth and DECT – all while ensuring low latency, low complexity, and low storage requirements. In addition, LC3plus exhibits excellent robustness against packet loss and bit errors. Its inherent tools for error concealment have been adapted specifically to DECT phones and deliver a significant improvement in voice quality compared with predecessor codecs. Conversations can therefore be enjoyed without interruption even when the handset is located far away from the base station.

 www.iis.fraunhofer.de/LC3



MPEG-H AUDIO UPDATE

Successful trials, new partnerships and licensees, and new standards with MPEG-H Audio

The year 2019 got off to a sensational start at the Consumer Electronics Show in Las Vegas, where Sony presented »360 Reality Audio«, a new streaming format for an immersive music experience based on the open MPEG-H Audio standard. By fall 2019, around 1,000 songs were available in 360 Reality Audio from labels such as Sony Music, Universal, and Warner, and the format can now be heard on some of the most famous music streaming services, including Amazon Music HD, Tidal, Deezer, and nugs.net.

As well as being a format for music streaming, MPEG-H was also developed specifically for UHDTV content. We were therefore able to achieve its incorporation into other standards during the reporting period: Brazil has now joined, China, Europe, and South Korea in including MPEG-H Audio in their digital TV standard (ISDB-Tb).

We achieved this partly by conducting numerous successful trials over the past year, in which we were able to demonstrate how reliably and straightforwardly MPEG-H can be integrated into existing systems. One particularly noteworthy example was the live transmission of the Rock in Rio concerts in Brazil with MPEG-H audio via ISDB-Tb and 5G.

Reliable tools are needed to ensure that productions run smoothly both live and in post-production. With this in mind, prominent manufacturers such as Blackmagic Design or New Audio Technology have expanded their range to include MPEG-H Audio. With the new MPEG-H Authoring Plug-in, we are also offering users an additional building block in the DAW production chain, which is constantly being improved and expanded.

 youtu.be/oErdKT2o56U

1 MPEG-H Audio has been included as an additional audio system in the ISDB-Tb specifications by the SBTVD (Sistema Brasileiro de Televisão Digital/Brazilian Digital Television System) forum.



ADA
LOVELACE
CENTER

ARTIFICIAL INTELLIGENCE AT THE ADA LOVELACE CENTER

At the ADA Lovelace Center for Analytics, Data and Applications, we deal with issues relating to artificial intelligence (AI): What progress has been made in AI research? What opportunities do specific applications of AI present? How can AI methods be further developed? As a cooperation platform for research and industry, the ADA Lovelace Center offers an innovative combination of AI research and AI applications.

Artificial intelligence is a key factor in the digital transformation of industry and society. Accordingly, it is vital that the latest research findings be translated into applications as quickly as possible. It was with this in mind that we teamed up with Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and Ludwig-Maximilian-Universität München (LMU) to launch the ADA Lovelace Center, which also benefits from the involvement of the Fraunhofer Institutes for Cognitive Systems IKS and Integrated Systems and Device Technology IISB. It offers a unique way of interlinking research into AI with its industrial applications. »The ADA Lovelace Center will play a key role in ensuring that Germany remains ahead of the international competition as a hub for technological innovation,« says Professor Reimund Neugebauer, President of the Fraunhofer-Gesellschaft.

Analytics: focusing on nine AI methods

At the ADA Lovelace Center, we conduct research into nine different areas of expertise in AI, as well as incorporating a wide range of scientific partners at the national and international level. The methods range from semantic data models and learning using small annotated datasets (few labels learning) to techniques such as automatic and explainable learning, machine learning, and mathematical optimization. The latter is particularly useful for finding answers to previously unsolvable problems in industry and leveraging efficiency potentials.

AT A GLANCE

- 1 | AI is a key factor in the digital transformation of industry and society.
- 2 | The ADA Lovelace Center takes an innovative approach to linking up methods and applications of AI.
- 3 | By adopting new formats, we are seeking to reinforce collaboration with partners in science and industry.

1 Fraunhofer IIS and its SCS working group have teamed up with FAU Erlangen-Nürnberg and LMU München to create the ADA Lovelace Center, a unique research infrastructure in Bavaria that also benefits from the involvement of the Fraunhofer Institutes IKS and IISB.

Data: resource-efficient handling of data

At the ADA Lovelace Center, we place particular emphasis on research throughout the data life cycle, which is analogous to the life cycle of products. In the context of AI, the objective is not to collect as much indiscriminate data as possible, but rather to collect the right data and on an appropriate scale. This raises questions such as: How should data be stored, structured, and transmitted? What added value can be derived from data? What happens to data that can't be used to generate insights? Indeed, with the storage of large volumes of data already leading to considerable CO₂ emissions, resource-efficient handling will be essential in the future.

»WE MUST SEE DATA AS A RAW MATERIAL AND HANDLE IT ACCORDINGLY – IN A RESOURCE-SAVING AND SUSTAINABLE MANNER.«

Professor Alexander Martin, head of the ADA Lovelace Center

Applications: a wide range of uses

At the ADA Lovelace Center, we focus on applications in production, mobility, logistics, sports, and healthcare. In the context of logistics, for example, we develop AI methods that use publicly available sources of data (for example, infrastructure, market trends, purchasing power, demographic trends, and weather) to generate added value for logistics network planning and related business decisions. In sports such as soccer or hockey, we aim to automate game analysis with the help of a search engine. This would use positioning data to compare game situations with similar situations in the past with a view to evaluating their execution.



Innovative forms of networking and collaboration

The ADA Lovelace Center is a scientific network that brings together local, regional, and national actors as well as engaging in strategic collaborations with international partners such as the Machine Learning Center at the Georgia Institute of Technology or the RIKEN Center for Advanced Intelligence in Tokyo. In this way, we hope to raise our international visibility and boost interest in the ADA Lovelace Center among researchers and students in Germany and abroad.

With a view to developing profitable and practical applications of AI, we also encourage a process of exchange between industry and research. Scientists and employees from companies work together in Joint Labs on specific problems from research and industry in small, agile, and interdisciplinary development teams outside of their day-to-day business for a fixed period of time. These innovative forms of collaboration benefit from the new CoWiS coworking space at our location in Nuremberg, which offers a creativity-enhancing »Work 4.0« environment. »The ADA Lovelace Center sees itself as a multiplier for building up, reinforcing, or further developing a company's AI expertise,« says Alexander Martin. ■

 www.scs.fraunhofer.de/ada-lovelace-center-en

www.scs.fraunhofer.de/cowis-nuernberg-en

 youtu.be/q95c-nU4P7U



CONTACT

Professor Alexander Martin

Institute Director

Phone +49 911 58061-5000

alexander.martin@iis.fraunhofer.de



»JOINT LAB DATA ANALYTICS« FOUNDED

Collaboration with BHS Corrugated and a hackathon to kick off the Joint Lab

BHS Corrugated Maschinen- und Anlagenbau GmbH and our Center for Applied Research on Supply Chain Services SCS have founded the »Joint Lab Data Analytics«, a pioneering new format for collaboration between research and industry. Scientists and company staff work together in small, agile, interdisciplinary development teams for a fixed period of time in a creativity-enhancing »Work 4.0« environment with a view to solving specific issues facing the company.

BHS Corrugated is a global market leader in the development and production of corrugating rolls, corrugators, and their individual assemblies and has adopted the digital transformation as a key component of its corporate strategy in order to transition toward intelligent products and processes. By doing so, the company hopes to raise its service level, optimize operational processes and related experience-based decision-making, and compensate for the limited supply of qualified data scientists.

This three-year collaboration aims to push forward with the digital transformation of BHS Corrugated and expand the company's data analytics expertise on a lasting basis. We are providing not only data analytics expertise but also skills and consultancy services in the area of business transformation. Compared with classical cooperation formats, this model allows us to acquire more comprehensive insights into the company and therefore to provide more in-depth scientific support.

On July 12, 2019, the »Hack-ADA-thon – Inspired by BHS Corrugated« was held as the kick-off event for the Joint Lab. Five teams were given eight hours to work on a real-world problem derived from one of the Joint Lab's use cases. The participants – developers, students, doctoral students, and graduates in the fields of statistics, data science, computer science, mechanical engineering, and mathematics – developed creative solutions rooted in data analytics and optimization. The results were fed into subsequent work at the Joint Lab. At the same time, the Hack-ADA-thon served as a recruitment event, giving participants a chance to learn about job opportunities in data analytics at BHS Corrugated and Fraunhofer IIS.

2 Participants in the kick-off event for the Joint Lab. At the »Hack-ADA-thon – Inspired by BHS Corrugated«, five teams were given eight hours to work on a real-world problem derived from one of the Joint Lab's use cases. The resulting data analytics and optimization solutions were fed into subsequent work at the Joint Lab.

 www.scs.fraunhofer.de/bhs-jointlab

 youtu.be/ExCoytV8iVw



R2D – ROAD TO DIGITAL PRODUCTION

Beacon of digitization in Nuremberg sends strong signals

Beginning in September 2016, our Center for Applied Research on Supply Chain Services SCS and our Positioning and Networks Division worked with Siemens AG, Simplifier AG, and KINEXON Industries GmbH on the digitization of individualized industrial production processes as part of the R2D – Road to Digital Production project. The aim was to develop a cyber-physical production system (CPPS) for production processes with a lot size of 1, allowing processes to be automated for improved cooperation between humans and technology. This was intended to flexibilize and speed up the centralized planning of production and material supply, which was commonplace until now, while ensuring optimum quality assurance. To this end, a product is accompanied throughout the production process by a Smart Production Tag that features communication and positioning capabilities as well as carrying product data and context information. This allows it to act independently in order to recognize, log, and control process steps on the basis of dynamic decision-making.

To ensure successful implementation, it was necessary not only to define the production process clearly and select suitable technologies, but also to develop software that integrated the recorded data into the existing infrastructure. Decentralized control of the CPPS was also supported by a real-time positioning system – for example, to ensure that driverless transport vehicles can be located and can navigate to the next destination independently. The generated data was used for a range of applications, including elements to support networked operations, such as intelligent apps for tablets, smartwatches, and eye tracking.

In February 2019, the end of the project was marked by a three-day event to present the results, including a live presentation of the 1,500-square-meter proof-of-concept demonstrator at our Test and Application Center L.I.N.K. in Nuremberg. Guests from Germany and abroad were impressed by the practical relevance of the implementation, with many saying they either wanted to apply selected technologies at their company divisions or implement the CPPS technology in its entirety within their organization. With this in mind, we are working with Siemens AG, Simplifier AG, and KINEXON Industries GmbH to explore the possibility of follow-up projects.

 www.scs.fraunhofer.de/r2d

 youtu.be/yOWdIVGbW50

3 Robot ballet at the Test and Application Center L.I.N.K. of Fraunhofer IIS in Nuremberg.



DATA-BASED TREND AND SCENARIO ANALYSIS

Our Future Engineering research group compiles automated market and technology trends

Sustainable and targeted business development relies on valid forecasting, which must be based on specific monitoring of relevant major trends. This is the only way to identify risks and opportunities in good time and to secure strategic decisions in a well-founded manner – but this calls for the right information. In the age of the Internet, this is easier to access than ever before, but the sheer wealth of information also leads to a greater workload for companies, market researchers, or trend spotters seeking to generate comprehensive and detailed information about trends or changes in the market at an early stage. This is where the Future Engineering research group comes in. Founded in 2018, the group is a collaboration between scientists from our Center for Applied Research on Supply Chain Services SCS and the Nuremberg Institute of Technology, whose common goal is to develop highly automated systems for knowledge generation and trend analysis and to make these available to companies and market researchers. To give one example, Professor Ralph Blum, the head of the research group, says that the database on the topic of electromobility grows by up to 10,000 reports a week.

To create this database, researchers searched the Internet for 1,000 subject-specific sources that provide useful information at both the national and international level. All of the reports from the selected websites, such as those of businesses, associations, and media companies, are processed automatically and stored in a graph database. Such huge quantities of data involving different formats and content can no longer be browsed efficiently by humans, so the research group employs innovative methods of natural language processing and semantic web analysis to extract the information that is relevant to them. Different types of data are represented and interlinked in knowledge graphs in order to harness them for the prediction of future trends. The research group then combines this data analysis with traditional methods of future studies such as the Delphi technique or scenario planning. As before, a group of experts ultimately decides whether these future scenarios are realistic or not.

 www.scs.fraunhofer.de/en/research/data-based-trend-scenario-analysis.html

4 *Our Future Engineering research group develops highly automated systems for knowledge generation and trend analysis and makes them available to companies and market researchers. Here, the researchers introduce themselves: Dr. Renato Budinich, Professor Ralph Blum, Andreas Belger, and Alexander Köhler (from left).*

HELPING THE DIGITAL TRANSFORMATION TAKE OFF

Development of holistic IoT solutions at LabCampus in collaboration with Munich Airport

In 2019, Fraunhofer IIS embarked on a five-year cooperation agreement with Flughafen München GmbH, the operator of Munich Airport, in relation to LabCampus. Covering a total area of 500,000 square meters, LabCampus at Munich Airport was conceived as a hub for new, smart forms of collaboration that transcend boundaries between companies and sectors. The project will see the creation of an innovative, urban, and seamlessly interconnected environment where various stakeholders – innovators and knowledge carriers, SMEs and global players, entrepreneurs, start-ups, and investors – can pool and unlock their future potential. In a single location offering state-of-the-art amenities, companies and individuals will collaborate on the development of pioneering and interdisciplinary product and service ideas and test them directly on site.

From the outset, LabCampus has collaborated with leading innovation partners, renowned institutions, and research entities – including Fraunhofer IIS – on the development of this platform for cooperation and innovation. As part of this cross-sectoral collaboration, we are working with Munich Airport under the project management of our Center for Applied Research on Supply Chain Services SCS to implement IoT-based and data-driven innovation projects at every stage of the IoT value chain.

In 2019, projects were developed in relation to four use cases:

- Infrastructure: construction of an IoT network based on MIOTY® technology (Chair of Information Technologies with a Focus on Communication Electronics LIKE, Positioning and Networks division, Communication Systems division)
- Asset management: development of IoT-based services for load carriers (SCS)
- Analytics: establishment of data-driven services – e.g., for the uses cases of building and fleet management (Division Engineering of Adaptive Systems EAS, SCS)
- Training: pooling of insights within application-oriented training opportunities (SCS)

All activities as part of the collaboration are intended to help establish LabCampus and Munich Airport as key locations for digital innovation in Bavaria and to further stimulate the digital transformation in the region. This entails working with our cooperation partner to develop innovative, data-driven services under real-life conditions and to set up and support a complex IoT ecosystem. To this end, we are leveraging our expertise in relation to IoT, cognitive sensor technologies, data analytics, and business model development across multiple divisions in order to provide LabCampus and Munich Airport with holistic, technology-based support.



www.scs.fraunhofer.de/en.html



POSITIONING IN 5G

Precise positioning plays a key role in the Internet of Things and particularly in semi-automated and autonomous systems in industry. The availability of reliable positioning information is therefore an essential factor in the success of Industry 4.0. One solution is to build and operate 5G infrastructures not only for communication but also for positioning applications.

Existing mobile communication standards such as 3G and 4G/LTE were developed primarily for voice and data communication. Indeed, support for positioning applications was only driven forward by statutory requirements – for example, in relation to localizing emergency calls. This is currently achieved using the following methods:

- Enhanced cell ID (E-CID) can locate mobile devices by identifying a cell, providing approximate location information that can be enhanced by analyzing additional delay information.
- UTDOA (uplink time difference of arrival) and OTDOA (observed time difference of arrival) can determine the position of a mobile device by measuring the time delay.

At best, these methods have permitted accuracies of between 20 and 50 meters over existing mobile networks.

Prospective positioning capabilities of 5G NR

The standardization of 5G is an ongoing process that involves agreeing on clearly defined developments, which are then published in releases.

AT A GLANCE

- 1 | 5G offers high network availability, higher bandwidths, and low latencies.
- 2 | With 5G, it is possible to accommodate both communication and precise positioning capabilities within the same standard.
- 3 | 5G allows sensor deployment and communication on a huge scale for IIoT applications.

1 5G is an essential prerequisite to Industry 4.0 and autonomous driving.

In June 2018, the first generation of 5G New Radio (NR) was defined in Release 15 of the standardization process for the 3rd Generation Partnership Project (3GPP), a worldwide collaboration by standardization bodies for mobile communications.

As with LTE, 5G will also undergo several stages of development within the framework of future releases. With the upcoming Release 16, the aim is to achieve a horizontal positioning accuracy of less than 3 meters indoors for the first time, and we expect to see further accuracy improvements in Releases 17 and 18 (see box). The 5G positioning architecture will also be able to incorporate a multitude of sensors, paving the way for hybrid systems that are specially tailored to and optimized for the requirements of a given application.

5G developments in our research areas

Delay-based methods such as OTDOA and UTDOA allow positioning with submeter accuracy over 5G networks thanks to the high 5G bandwidth of up to 100 MHz for frequency band FR1 (< 6 GHz) and the resulting increase in time resolution. With a bandwidth of 400 MHz in frequency band FR2 (> 6 GHz), positioning performance will be able to extend into the decimeter range.

To test these innovations, Fraunhofer IIS in Nuremberg operates a 5G test bed focused on industrial applications. This includes the installation of a UTDOA system for precise positioning. The software-defined radio (SDR) platform allows the performance of 5G positioning to be determined at a very early stage and put through its paces in specific industrial applications. The challenging task of evaluating the actual capabilities of 5G depends on all kinds of implementation details, as well as on hardware and software support in mobile communication devices after 2020. We also provide our customers with advice and expertise to support them during implementation.

3GPP releases: planned or projected horizontal positioning accuracy in buildings

- **Release 16:** < 3 meters, completion of standard in 2019/possible availability of compliant devices from approx. 2021
- **Release 17:** < 1 meter, planned completion of standard in 2021/possible availability of compliant devices from approx. 2023
- **Release 18:** up to a few decimeters, planned completion of standard in 2023

»5G-BASED POSITIONING WILL MAKE IIOT PROCESSES MUCH MORE EFFICIENT.«

Thomas von der Grün, Business Unit Coordinator Positioning

Positioning applications with 5G

Thanks to the ongoing standardization, 5G positioning will help to boost efficiency in industrial and logistical processes over the next few years. One new application to benefit from this significant increase in positioning accuracy is the use of drones to transport production parts in industrial settings – and, many companies are already using driverless transport systems that navigate through the manufacturing process autonomously. However, precise positioning with 5G is also of interest for the many AV/VR applications that are now seeing greater use in manufacturing and remote applications.

Alongside our research activities in the area of 5G, we at Fraunhofer IIS offer not only the expertise but also the premises to test 5G in industrial and logistical processes under real-life conditions at our 5G test bed for Industry 4.0 applications, which receives support from the Free State of Bavaria. As well as these real-life implementations, the accompanying 5G test center can also emulate and simulate 5G use cases, helping to bridge the gap between the completion of a new release and the availability of compliant hardware. ■

 youtu.be/7LOmnxwesgs

Fraunhofer IIS has 20 years of experience with various positioning methods, such as UTDOA, DoA, RSSI, GNSS, and multi-sensor fusion. This experience underpins its expertise in the implementation of positioning over 5G networks in an industrial setting. As well as implementing a wide range of solutions, we have also worked alongside various companies to bring applications to the market.



CONTACT

Karin Loidl

Positioning and Networks Division

Phone +49 911 58061-9413

karin.loidl@iis.fraunhofer.de



THE COGNITIVE INTERNET FOR INDUSTRY

At the IoT-COMMs Research Center, we work on application-oriented technologies


Increasing digitization and networking will present challenges for industry in the long term. In order to rise to these challenges, we are working with various Fraunhofer Institutes to develop technologies for an Internet that benefits from cognitive abilities and secure, networked data spaces.

The IoT-COMMs Research Center is one of three research centers within the Fraunhofer Cluster of Excellence Cognitive Internet Technologies CCIT and spurs on the development of networked, agile, and mobile production systems as well as applications for autonomous driving. We do this by combining and developing the enabling technologies of networking, positioning, and information security.

The research results obtained so far have given rise to the CPS.connect project, which allows constant monitoring of critical parameters in machines and systems within the production process via wirelessly connected sensors that exchange data with the machine in real time. This is particularly important for coordination with the »digital twin«, which allows processes to be optimized during production itself. The integrated measuring technology also reduces the need for time-consuming and cost-intensive processing of the digital model.

In the SmartTool.connect project, a tool holder is equipped with built-in intelligent sensors that use ultrasound technology to ensure improved chip formation and monitor the tool's condition during the ongoing production process. This improves process efficiency in terms of tool life and costs, and both solutions can easily be retrofitted to existing tools and machines.

One major challenge in the Smart Intersection project is to record traffic situations quickly and assess them correctly at the same time. Using a system known as cooperative environment perception, the smart intersection compiles a 360° environment model of an intersection, classifies the objects within it and their patterns of movement, and relays this information to the vehicles.

 www.cit.fraunhofer.de/fiot



GOOSE TECHNOLOGY FOR AUTONOMOUS DRIVING

Autonomous driving relies on extremely precise and reliable positioning – otherwise, it becomes dangerous

Complex traffic situations during merging and overtaking require the driver to pay extremely close attention, as carelessness during these maneuvers can quickly lead to accidents. Autonomous assistance systems can help to counteract this problem. The Precise and Robust Positioning for Automated Road Transports (PRoPART) project uses all the benefits of satellite signals as well as other navigation solutions, such as radar and cameras in the vehicle, to provide the vehicle with the highly accurate positioning in the decimeter range that it needs for these situations.

However, the satellite connection may be interrupted as the vehicle passes through tunnels or under bridges, and satellite signals can also be subject to interference or even spoofing. In these cases, the driver must take the wheel once again – before things become dangerous.

Our GOOSE GNSS receiver is able to bridge short signal interruptions so that the driver does not need to intervene even in situations such as these. GOOSE is already using the Open Service Navigation Message Authentication (OSNMA) service provided by the Galileo satellite navigation system, which is officially available from 2020 onward. This service transmits Galileo satellite signals with a form of encryption that makes it much more difficult to fake a position. With the help of GOOSE technology, we can therefore make complex traffic situations a manageable exercise for autonomous driving systems.

 www.iis.fraunhofer.de/propart-en
www.iis.fraunhofer.de/goose-en

 youtu.be/wzMkVOflxX0



SHOTS AND DUNKS – WEARABLES FOR USE IN BASKETBALL

Validation of sports technologies for the NBA (National Basketball Association)

Following an international selection procedure, the National Basketball Association (NBA) Wearables Committee and the National Basketball Player Association (NBPA) have commissioned us to validate the suitability of various commercially available wearable measuring systems for use in sports. Wearables are already used by numerous NBA teams during games and in training.

As positioning specialists, we collect data relating to movements and test the wearables for measurements such as player speed, distance covered, jump height when receiving the ball and under the basket, and the number of direction changes and steps taken. These data provide players and trainers with key information that allows optimum monitoring of games and training.

Vital parameters such as heart rate, TRIMP (training impulse) training load, and muscle activity (ECG) are validated by our Image Processing and Medical Engineering department, while the University of Michigan carries out the safety tests. The university coordinates all the tasks and provides all of the teams with the results for each tested system on an annual basis. In work involving athletes, it is essential to consider not only human factors but also ethical regulations. Our measurement procedures were considered to ensure fair and consistent assessment from the planning stage through to the analysis of measurement data. The current phase of validation will be completed in 2020.

 www.iis.fraunhofer.de/validation-en


ENERGY HARVESTING AND POSITIONING FOR MIOTY® TECHNOLOGY

Self-sufficient power supply for massive IoT sensor applications and precise sensor positioning

Wireless MIOTY® transmission technology is used for massive IoT applications in the Industrial Internet of things (IIoT) or in smart city applications and transmits data from several hundred thousand sensors reliably and robustly even over large distances. This is made possible by the patented telegram splitting method developed at Fraunhofer IIS. MIOTY® is a hardware-independent software solution used in an ETSI-standardized form – especially for low-power wide-area networks (LPWANs) – and is available under license for integration into a variety of customer solutions. It is also possible to create a self-sufficient power supply for MIOTY® sensors using energy harvesting technologies. Indeed, we have developed solutions that generate power by exploiting minimal vibrations or temperature differences, which is particularly beneficial

when it comes to operating several hundred or thousand sensors self-sufficiently and in an energy-efficient manner over a period of several years.

The field strength-based positioning technology locadis can be incorporated in order to determine the position of sensors in massive IoT networks. This enables indoor and outdoor positioning within a MIOTY® network using only the infrastructure (base stations) and the sensors connected to the MIOTY® technology.

 www.iis.fraunhofer.de/mioty-en
www.iis.fraunhofer.de/energyharvesting-en
www.iis.fraunhofer.de/locadis-en



TRILUM SMART WAREHOUSE PICKING SYSTEM

Mobile pick-by-light systems based on s-net® networking technology are now commercially available

Under the brand name TRILUM, we have developed a wireless pick-by-light system for warehouse picking and assembly processes – and especially for flexible, temporary, and mobile storage structures. The system is easy to adapt and is therefore ideally suited to environments where storage bins, removal compartments, and shelves are redesigned or changed often – for example, in picking, assembly, and distribution processes. TRILUM uses LED light signals to guide staff to the correct storage bin, where they then save time by viewing crucial information such as the removal quantity on a convenient e-paper display. The removal of goods is confirmed quickly and easily at the touch of a button – providing a fully automatic and paperless method of feeding information back to the warehouse management system.

System components are wirelessly connected to our power-saving s-net® networking technology, allowing battery-operated and mobile applications of the TRILUM shelf displays. The system has been commercially available via our partner AST-X since fall 2019.

 www.iis.fraunhofer.de/s-net-en

EASYPILOT FOLLOW: EFFICIENT ORDER PICKING

Wismit technology simplifies processes during loading and unloading

The Wismit technology developed by Fraunhofer IIS allows a picking vehicle to follow the picker automatically, hugely simplifying processes during loading and unloading. You can imagine the connection as being like a virtual leash between the human and the machine: Thanks to Wismit positioning, the vehicle stops when the picker stands still and proceeds once they start walking again. This saves time and only requires the picker to carry a sensor in their pocket – leaving their hands free for loading and unloading. Positioning reliability is also ensured even when the vehicle is heavily loaded.

After undergoing extensive testing in collaboration with Jungheinrich, easyPILOT Follow is now available as a finished product. The Wismit platform is a hardware system used to evaluate positioning, communication, and identification technologies and can be operated concurrently with various positioning technologies.

 www.iis.fraunhofer.de/wismit-en

Wismit technology is based on reliable ultra-wideband (UWB) technology that measures the time for the UWB radio signal to travel between the vehicle and the sensor carried by the operator. As a result, it can always determine the position accurately.



SATELLITE IOT PAVES THE WAY FOR WORLDWIDE CONNECTIVITY

Satellites can be used to transmit data all around the globe. They gather data for the Internet of Things (IoT) and relay them to well-connected ground stations, from where the data ultimately make their way to the user. To make things even easier, we are developing efficient transmission methods for IoT transmitters that send signals directly to the satellite from any location on Earth.

It is clear from the numerous applications that worldwide connectivity via the IoT has been a reality for some time. Many of these applications are tailored to life in the city, where sensors are used to monitor parking spaces or to measure environmental and weather data. At present, IoT networks therefore tend to emerge at well-connected locations, typically in major urban centers. Low-power wide-area networks (LPWANs) feature energy-efficient transmitters and a range of about 15 kilometers and are therefore ideally suited to smart city applications. The networks needed here consist of a large number of objects that transmit their sensor data to a central IoT base station. From there, the data are relayed via mobile communications or DSL so that they can be accessed over the Internet at any time.

Satellites are growth accelerators for the IoT

What is easy to do in a city becomes a genuine challenge in the most remote regions of the planet, given the lack of communication infrastructure. Out on the ocean, deep in the jungle, or in the desert or the Arctic, there is simply no infrastructure for feeding data into the Internet. This can be remedied by using satellites to establish a communication network with global availability and to relay data to distant ground stations that are connected to the Internet. These satellite-based IoT applications, which are currently in operation, use an LPWAN with an

« Terrestrial IoT networks

Ground-based IoT systems in which all radio communications take place on Earth – without support from satellites.

AT A GLANCE

- 1 | Satellites carry IoT data to the user from any location on Earth.
- 2 | With our satellite IoT solution, objects transmit their data directly to the satellite.
- 3 | IoT objects with a direct satellite link are cost-efficient and flexible to use because they send data into space from anywhere in the world.

IoT base station to first receive and bundle data from sensors over a wide area before sending them to a satellite. As a result, collecting IoT data at very remote locations is no longer a problem – albeit only if the network is limited to a specific area. For example, a farm could install a single, central base station with a satellite link in order to monitor a wide range of machinery as well as the animal population and environmental and soil parameters. After all, satellite connectivity allows the IoT to reach even the most remote locations.

IoT transmitters send signals directly to the satellite

Another problem arises, however, as soon as there is movement involved, such as when determining the position of vehicles moving around within a larger radius. Although the range of traditional LPWAN solutions is large, it is not unlimited. To allow uninterrupted monitoring of a vehicle fleet, the vehicles must never lose their connection to an IoT base station, however, it is extremely costly to build a seamless network of this kind – especially in remote regions and when relatively few objects need to be connected.

We have therefore developed a solution in which the IoT objects no longer require a fixed base station, but rather transmit data directly to the satellite. The only requirements for this are an IoT transmitter designed for satellite operation and a suitable transmission method. Theoretically, any device can therefore transmit data directly to the satellite, allowing an unlimited range of movement for IoT devices.

The transmission method for transporting data from the mobile transmitter to the satellite is based on our well-established MIOTY® LPWAN technology, which is in turn based on a standard issued by the European Telecommunications Standards Institute (ETSI). In the method known as telegram splitting, the transmitter divides every message up into smaller packages and sends them at different frequencies in staggered transmissions. As only about 50 percent of the packages need to reach the receiver for the message to be unscrambled, this method is extremely robust against interference factors and allows transmissions by a large number of sensors at the same time. We have tailored the transmission method especially to satellite communications so that signals can cover the distance to the satellite in space.

»THE INTERNET OF THINGS TRAVELS AROUND THE WORLD BY SATELLITE.«

Satellite constellations provide seamless coverage

The special thing about our satellite IoT solution is its easy implementation. It can be incorporated into existing commercially available chipsets, allowing transmitters to be developed and produced cost-efficiently. Moreover, the transmission method is so energy-efficient that even small batteries can supply the IoT transmitters with the necessary power for a prolonged period of time. To increase battery life further, our transmitters can also be extended with solar cells or other energy harvesting techniques.

Once the transmitters are in operation, they are almost maintenance-free and can be used with satellite constellations in low Earth orbit (LEO) over a period of years – for example, to record and relay environmental and positioning data. These LEO satellites travel around Earth at high speed and in large constellations with several satellites per orbit. This guarantees that a satellite is always available to receive the data from the transmitters and to transport them to the nearest base station. For example, forest fires or leaks in oil pipelines can therefore be detected and brought under control at an early stage. ■

« Low Earth orbit (LEO)

Satellites in low Earth orbit are typically only at a height of about 1,000 kilometers.

 www.iis.fraunhofer.de/en/ff/kom/satkom/satellite_iot.html

 www.iis.fraunhofer.de/en/magazin/aufdenpunkt.html



CONTACT

Claudia Wutz

Communication Systems Division

Phone +49 9131 776-4071

claudia.wutz@iis.fraunhofer.de

GROUNDBREAKING SYSTEM ARCHITECTURES FOR SMEs

Globalfoundries, Fraunhofer, and Next Big Thing launch start-up in Dresden

Much of Germany's innovative and economic strength can be attributed to small and medium-sized enterprises (SMEs) that successfully compete on the market with high-performance products and services. To be able to do this, more and more SMEs rely on highly integrated technologies. For many companies, however, developing these technologies in-house is a prohibitively elaborate, time-consuming, and expensive process.

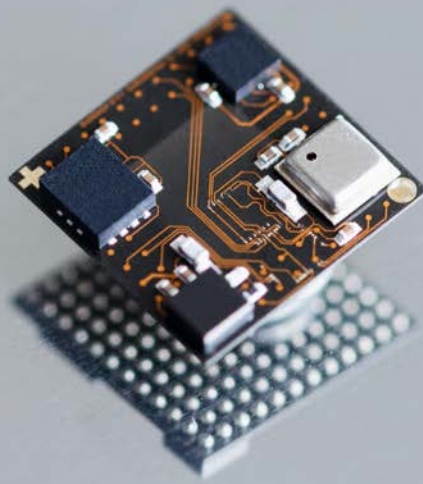
The start-up Sensry gives its customers access to highly integrated, energy-efficient, and cost-effective sensor systems based on Globalfoundries 22FDX® technology. This enables them to easily use groundbreaking system architectures and manufacturing methods even for prototypes and small production runs, in combination with cutting-edge assembly

and packaging technologies. Moreover, Sensry's »building block approach« employs a modular design offering an exceptional degree of flexibility. As a result, customers receive a customized sensor node equipped with a flexible, customer-specific selection of sensors and communication solutions.

Sensry has its roots in the joint project USeP (Universal Sensor Platform), a collaboration between a consortium of Fraunhofer institutes in Saxony and Globalfoundries Dresden, funded by the Free State of Saxony and the European Union. The start-up was founded in conjunction with Next Big Thing to market the results of this project.



www.eas.iis.fraunhofer.de/sensry-en



1

NEW PACKAGING FOR MORE THAN MOORE

Engineering of Adaptive Systems EAS division develops »Assembly Design Kit« for Globalfoundries

Gordon Moore, one of the co-founders of Intel, predicted in the 1960s that the number of circuits on a microchip would double every year. For a long time, Moore's law was regarded as a golden rule in electronics, but more recently the principle has begun to approach its limits. As a result, many manufacturers are looking for new ways to boost the functionality and performance of their chips.

To support the German semiconductor industry in this regard, the Fraunhofer IIS Engineering of Adaptive Systems EAS division is developing »Assembly Design Kits« (ADKs) for the foundry Globalfoundries, with facilities in Dresden and elsewhere. With these ADKs, already tested at the prototype stage, methods from circuit design are applied to problems in package design to enable the creation of suitably complex packages to match the increasing complexity of chip designs, as the high packaging density in modern electronic systems threatens to overthrow the traditional workflow in which chip design occurs separately from package design.

Until now, data such as manufacturing rules, information on materials, conductor widths, or distance rules have not generally been available in electronic form for the package design stage. This is a major drawback in light of the huge amount of extra effort involved in the exchange of information between chip and package manufacturers as a result of the steady increase in performance – but also complexity – of electronic assemblies.

To address this crucial issue, we have adapted a method from IC design, preparing package specifications for groundbreaking semiconductor technologies in such a way that they can be integrated in all major software solutions for chip design. The benefits of this approach include pre-production simulations that take packaging into account in addition to the actual electronics. In this way, electronics designers can design both components of a finished electronic system in parallel – without the distraction of external package design. What is more, thanks to the resulting uniform data structure they can exchange information between different design programs. The first ADK ready for application in Globalfoundries technology will be completed in 2020.



www.eas.iis.fraunhofer.de/system-packaging-en

1 Chip package from the project
»Universal Sensor Platform (USEP)«
in Globalfoundries technology.



STATUS QUO OF AI ACTIVITIES IN SAXONY

Extensive interviews with experts in research and industry reveal need for action

With a view to boosting the competitiveness of industry and research in the field of AI in Saxony, in November 2018 the project »Artificial Intelligence – Expertise and Innovation Potential in Saxony« (KIKiS) was launched. In the following months, the Fraunhofer IIS division Engineering of Adaptive Systems EAS and the Chair of Highly-Parallel VLSI Systems and Neuro-Microelectronics at Dresden University of Technology examined the status quo and future prospects of AI activities in the Free State of Saxony. The focus of the project was on providers' concrete views regarding the challenges faced by the sector, its potential and needs, and the framework conditions required for successful development of AI solutions in the region.

Extensive interviews with experts from research and industry on topics ranging from machine learning to artificial neural networks have now pinpointed the areas in which a need for action is perceived. These areas include knowledge and technology transfer, teaching, availability of analyzable databases, or qualification and further training of employees.

»One of the conclusions we can draw is that the exchange and transfer of knowledge among research, teaching, and industry must become even more efficient – and above all reciprocal – in the future,« says Dr. Peter Schneider, project manager of KIKiS and head of the Fraunhofer EAS division, summarizing one of the key findings from the survey.

»THIS IS THE ONLY WAY FOR SAXONY TO MOVE BEYOND ISOLATED SUCCESSSES AND ACHIEVE SIGNIFICANT COMPETITIVE ADVANTAGES WITH ITS AI ACTIVITIES.«

An overview of the project's main findings was presented by the Fraunhofer EAS division and Dresden University of Technology as part of a roadshow with stops in four of Saxony's regions. The KIKiS project is supported by Saxony's State Ministry of Economic Affairs, Labour and Transport through its technology funding program, and co-financed with tax revenue under the budget approved by the Saxon State Parliament.



www.eas.iis.fraunhofer.de/project-kikis

2 In conversation with Martin Dulig, Saxony's State Minister for Economic Affairs, Labour and Transport, during the roadshow stop at the »Digital Saxony Forum«.



PHENOTYPING ROBOT TAKES TO THE FIELD

Global warming and rising demand for food, coupled with global population growth, are among the key challenges of the 21st century. In this context, the ability to breed new, adapted varieties of food crops is a crucial asset. The budding research field of digital phenotyping is devoted to non-destructive trait detection to enable selective breeding of food crops.

At a leisurely pace, the field robot makes its way back and forth across the densely planted wheat field. To a casual observer, the machine's outlandish appearance might seem more suited to the exploration of distant planets. The contraption, designed to cause as little damage as possible to the delicate crops as it traverses the field, is equipped with a collection of sensors that literally watch the plants in the field grow. With prototypes like this one, researchers at Fraunhofer IIS and industry partners such as the companies PhenoKey, Strube, and Saatzucht Streng & Engelen, have taken an important step forward in the field of phenotyping research: »This approach enables us to closely observe plant growth in its natural environment, providing us with objective and undistorted data,« says Dr. Stefan Gerth, head of the »Innovative System Design« group at the Fraunhofer Development Center X-Ray Technology EZRT.

People are not robots

The foremost criterion by which varieties are selected for crop breeding purposes is the yield of a given species. To date, modern varieties have been selected by breeding experts primarily on the basis of visually detectable above-ground traits. However, this method suffers from limited accuracy and reproducibility due to the subjective nature of the experts' observations and assessment.

AT A GLANCE

- 1 | Concealed areas under a plant's leaf canopy can be revealed using X-ray technology.
- 2 | Non-destructive trait detection allows selective breeding of food crops.
- 3 | Non-destructive measuring technology guarantees objectivity and repeatability of measurements.

In wheat breeding, for instance, breeders typically select for stalk height and number of ears. While these traits do correlate with a variety's yield, they are only used because there is no technological solution so far that allows biomass to be accurately determined using non-destructive methods. Accordingly, biomass is measured only indirectly by measuring the correlated traits.

In sugar beet breeding, meanwhile, the focus of phenotyping research is on entirely different plant traits. Here, breeders aim for uniform crop emergence to ensure a harvest of sugar beets of roughly the same size. Leaf area, shape, and orientation continue to provide an indication of growth patterns and sugar content.

Multimodality improves data

A section of the test field planted with wheat is divided into plots between 1.25 and 1.5 meters wide. Comparability of the individual measurements currently depends mainly on optical volumetric measurements using technologies such as LiDAR and laser line scanning. »However, depending on the density of the section – i.e. the number of stalks and ears in the plot – the relationship between biomass, that is yield, and volume is very imprecise for both optical methods. Optical methods can – in much the same way as a breeding expert – determine stalk height,« explains Gerth. »In conjunction with the distance traveled, this information can be used to calculate the volume of a plot. But as soon as the leaf canopy closes, there is no information on the crop's actual density. The leaf cover also means that the quality of the ears can no longer be visually assessed.«

This is where X-ray technology comes into play: We can use X-rays to uncover areas concealed by the leaf canopy. And that is not all: Using X-ray technology, we can measure the exact biomass of the stalks and ears. Combined with the optical image data, this provides highly relevant data for the selection of varieties.

3D modeling for precise leaf analysis

Digital phenotyping of plants in test fields has become an indispensable tool for breeders in sugar beet breeding, too. As the beet itself is hidden underground, the focus is on the plant leaves. The task of these »solar collectors« is to absorb sunlight as efficiently as possible, harnessing it for sugar production, among other purposes. By contrast, excessive exposure to sunlight is stressful to the plant. Accordingly, leaf shape and orientation are crucial factors when it comes to assessing varieties.

LiDAR »

light detection and ranging

»In order to determine the area and shape of a leaf as precisely as possible, three-dimensional scanning is indispensable,« explains Oliver Scholz, group manager in the Contactless Test and Measuring Systems department at the EZRT. »Depending on the environmental conditions, we use various methods tailored to the situation at hand to provide optimal data for subsequent analysis.«

The resulting three-dimensional data on each individual leaf provide the basis for a digital model of the leaf that captures the characteristics of relevance to breeders. In this process, hundreds of thousands of data points per leaf are compressed into a handful of parameters that nevertheless accurately characterize the leaf. This is comparable to mp3 encoding of audio data, another process in which a very large volume of data is distilled to its essence. The leaf descriptions obtained in this way provide breeders with detailed insights into how their varieties grow, giving them a sound basis for subsequent breeding decisions.

Human-machine collaboration

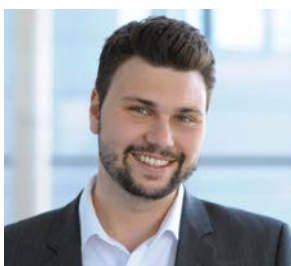
The key benefit of phenotyping based on non-destructive measurements performed by inspection robots is the objectivity of the digital measurements and reproducibility of the results obtained. The robot can be thought of as a tool that supports human decision-making by giving breeders a precise data evidence basis on which to plan the breeding process. We are nevertheless working toward a higher degree of automation: In the next few years, we hope to develop field robots that are able to autonomously navigate crop fields, scan the plants they find there, and evaluate the resulting data. ■



www.iis.fraunhofer.de/phaenotypisierung



www.iis.fraunhofer.de/en/magazin/aufdenpunkt.html



CONTACT

Thomas Kestler

Fraunhofer Development Center X-Ray Technology EZRT

Phone +49 911 58061-7611

thomas.kestler@iis.fraunhofer.de



3D CT SCAN OF A PERUVIAN MUMMY

»Big Picture« research project points the way in handling large volumes of data

In the context of the research project »Big Picture«, we used 3D computed tomography (CT) to examine a mummy dating back to the period between the 11th and 15th century AD. from the collection of the Linden Museum in Stuttgart. The central focus of this project is on high-accuracy digital scanning of three-dimensional objects. The scan was an opportunity to demonstrate the progress of our research efforts since the project began in February 2018.

Before the scan, very little was known about the mummy aside from its geographical origin and approximate age. Thanks to the 3D CT data, numerous burial gifts were identified, including a corncob in the head area. Until recently, high-resolution datasets such as those resulting from the mummy scan could

only be viewed using very expensive and powerful industrial computers. However, thanks to newly developed software, the high-resolution dataset can now be viewed with a standard off-the-shelf notebook.

In the course of earlier research and industry projects, several reference applications offering considerable economic benefits were identified. In terms of content, the Big Picture project was designed with a particular focus on the needs of our industry partners in Bavaria.

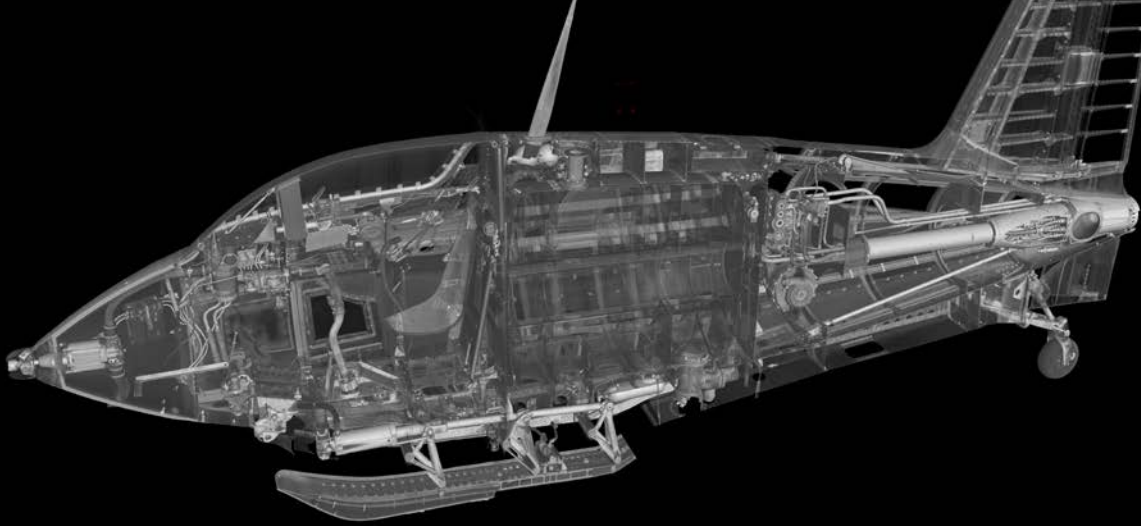
  www.iis.fraunhofer.de/bigpicture-en

RETROFITTING OUTDATED X-RAY SYSTEMS

Retrofit service transforms obsolete X-ray equipment into high-performance CT or DR systems

With our retrofit service for industrial X-ray systems, existing but outdated X-ray equipment is transformed into high-performance computed tomography (CT) or digital radiology (DR) systems for industrial applications. In many companies, research institutions, and museums, existing systems are retired because they are no longer deemed suitable for use, or have faulty components. However, in many cases a few simple steps are all that is needed to give an existing system a new lease of life. The VOLEX retrofit package provides a robust, long-term solution for such cases that is unrivaled on the market.

At the heart of the solution is the VOLEX measurement data collection and reconstruction software, which has been continually refined over a number of years and supports a broad range of hardware components. Most individual components are often still in good working order and fit for use. As well as the frequently expensive radiation protection cabin, the manipulation system can also usually remain in use with only minor adjustments. However, for measurements in line with current state-of-the-art quality levels, it is often advisable to replace the detector, and in some cases the X-ray source.



XXL CT OF THE ME 163 ROCKET-POWERED INTERCEPTOR

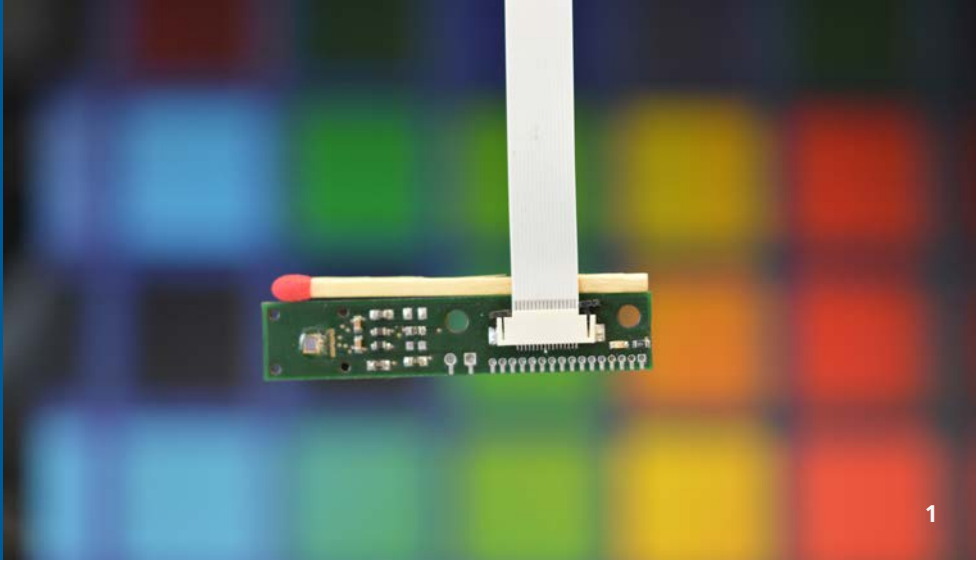
Unlocking history with detailed X-ray images

Last year, we examined the Me 163 Messerschmitt rocket-powered interceptor from the collection of the Deutsches Museum, using XXL computed tomography. This was a special project in many respects: Besides being a highly unusual specimen of incalculable value, the aircraft was much larger than any of the objects previously imaged using this technology. The curatorial team for aviation history at the Deutsches Museum hopes the scan will provide fresh insights into the history of the machine.

The »Kraftei« – as the unusually shaped rocket-powered interceptor plane was often nicknamed in aviation circles – reached our facility in a custom-built steel frame. Before we could perform the scan, the wings had to be removed. Four scan sequences were needed to fully tomograph the interceptor plane and its wings – by far the most demanding project since the system went into operation in 2013.

The detailed X-ray image data has enabled the curatorial team to distinguish original components from replacement parts installed in the aircraft over time, for example. Previously hidden areas, such as those behind welded plates inside the aircraft, can now also be examined in minute detail. However, the curators will not just use the CT data for research purposes – visitors to the Deutsches Museum's new 2020 aeronautics exhibition will be able to explore the interceptor plane using a virtual and augmented reality system.

 youtu.be/jG6fHxHflms



MINIATURIZED OPTICAL SPECTROMETERS

Cost-effective implementation of numerous spectral channels

At present, the high cost of sensors with more than six spectral channels severely restricts their scope of application. They are rarely employed in price-sensitive areas such as mobile consumer products, scanning of field crops or in the cosmetics and food industries. Thanks to the nanoSPECTRAL technology developed by our Optical Sensor Systems group, however, the necessary optical filters can now be produced at very low cost.

With this technology, production costs remain practically constant regardless of the number of spectral channels to be implemented. This is achieved by structuring the metal layers in the CMOS semiconductor process. In contrast to conventional optical filters such as thin-film filters, these optical nanostructures require no additional production steps (e.g. deposition of the filters).

Thanks to CMOS integration of filters and photodiodes, as well as analog and digital signal processing, our nanoSPECTRAL technology enables highly integrated monolithic sensors. As the technology is being established in two commercial CMOS foundries, products based on it will be available in industrial quality.

The chip-scale spectrometer already has over 30 channels, making it suitable for applications including analysis of foodstuffs, environmental analysis, and smart lighting. The number of spectral channels can be increased and their wavelength adjusted according to the use case.

Another use case for cost-effective multispectral sensors is being explored in the INFIMEDAR research project, funded by the German Federal Ministry of Education and Research (BMBF). The goal of this project is to determine the condition of plants in the field and enable targeted application of weed control products such as herbicides with a view to reducing the amounts used. Our involvement in the project consists in the design and simulation of the spectral properties of the filters, and chip design of the sensor IC, as well as optical characterization of the multispectral sensors.

 www.iis.fraunhofer.de/optnanostructures

1 *The nanoSPECTRAL technology enables implementation of several highly integrated spectral channels at very low cost.*



MEDICAL VALLEY CENTER OPENED IN BAMBERG

Institutions devoted to digital solutions for the future of healthcare

On May 31, a formal event was held to mark the opening of the Medical Valley Center in Bamberg. During the ceremony, Bavaria's economics minister Hubert Aiwanger officially announced the approval of funding for four projects, including the Mobile Health Lab, a new working group within Fraunhofer IIS, and the Digital Health Application Center GmbH (dmac), a joint venture between Medical Valley and Fraunhofer IIS. Both institutions are devoted to researching digital solutions for the future of healthcare and contributing to the progress of telemedicine by connecting patients and physicians.

The goal of the Mobile Health Lab in Bamberg is to use telemedicine to bring healthcare into the home. The lab is working on a generic telemedicine IT platform, the »Digital Patient Manager«, which is designed to connect service providers across all sectors and create a decentralized infrastructure for medical communication. Individual patient data can be automatically collected and shared between users and healthcare providers (such as physicians, hospitals, or therapists). Patients control who has access to which data, and can use the platform themselves to obtain all relevant information.

The Digital Health Application Center GmbH (dmac), also headquartered in Bamberg, is a joint venture between Fraunhofer IIS and Medical Valley GmbH. Its purpose is to pave the way for and support new innovations and products in the field of medical technology, as well as helping companies prepare for digital healthcare in tomorrow's world. By integrating ideas into healthcare and research as well as facilitating patient-centered development and validation studies, it aims to make technological solutions available to all in a newly evolving digital health ecosystem.

 www.iis.fraunhofer.de/mobile-health-lab-en
www.mv-dmac.de

2 Christian Weigand (Mobile Health Lab) accepts official notification of funding from Bavaria's economics minister Hubert Aiwanger, alongside Professor Erich R. Reinhardt (executive chairman of Medical Valley EMN e.V.), Melanie Huml (Bavaria's health minister), Professor Jochen Klucken (Medical Valley Digital Health Application Center GmbH) and Professor Albert Heuberger (executive director of Fraunhofer IIS).

FRAUNHOFER IIS AS A PARTNER

Outstanding ideas. Application-oriented research. Reliable cooperation.

Fraunhofer IIS is a partner for clients in industry and the public sector. We develop, implement, and optimize processes, products, and equipment all the way to operational and market readiness. Combining research and development skills and capacities within the Institute, we are able to satisfy even the most elaborate project requirements and deliver complex system solutions.

Market studies – knowledge for innovation

Prior to a research collaboration, we can provide you with tailored studies, market observations, trend analyses, and feasibility studies.

Consulting and project support

You can engage us for consulting on technological issues, to refine individual work processes or to develop a product from square one. We offer guidance for your investment decisions. Furthermore, we support you in the implementation of new technologies and help you to successfully develop your applications.

Research to order

Industrial and service companies of all sizes can benefit from contract research; we are happy to share our know-how. We develop and optimize technologies, processes, and products all the way to the production of prototypes for our industry clients.

Licensing of technologies and systems

The results of our research form the basis for internationally filed patents, which we make available to industry in the form of licenses.



CONTACT

Jan Plogsties

Advisor to the executive director

Phone +49 9131 776-1021

jan.plogsties@iis.fraunhofer.de

TRAINING AT FRAUNHOFER IIS

At Fraunhofer IIS, we work on cutting-edge technologies in various fields of application. We are happy to support you with customized training both for you and your employees. To this end, we offer seminars in a variety of fields.

A networking platform connecting industry and research, the **Machine Learning Forum** helps small and medium enterprises employ machine learning to harness the data resulting from digitalization and simplify decision-making processes.

Meanwhile, our Development Center X-Ray Technology (EZRT) in Fürth offers training courses on non-destructive testing using X-ray technology, including courses in **Digital Radioscopy** and seminars in the field of **Industrial Computed Tomography**.

The seminar **Predictive Maintenance & Data-Driven Quality Assurance**, offered by the Engineering of Adaptive Systems EAS division in Dresden in collaboration with the VDI, covers maintenance strategies and illustrates the competitive advantages of intelligent condition monitoring to participants. Attendees receive a concrete checklist for the implementation of predictive maintenance practices in their company.

The AI Services training program consists of modular workshops that can be tailored to match the participants' knowledge level and field of work. Our two-day hands-on workshop **Deep Learning and Computer Vision** combines theory and practice. In closely supervised exercises, participants acquire practical experience of deep learning workflows by working through concrete examples. Those merely seeking a brief foray into the world of AI are well served by the introductory seminar **AI Essentials**. Besides an introduction to AI, the seminar provides a condensed overview of machine learning and deep learning methods.

The Fraunhofer Center for Applied Research on Supply Chain Services SCS has launched a dedicated training program devoted to the challenges of the digital transformation. Since 2018, the Center has held training events such as

the three-week management program **Leading Digital Transformation** in collaboration with Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and the Indian Institute of Management Bangalore.

The program comprises three phases attended in person in Bangalore and Nuremberg over a six-month period. The training is tailored to the needs of managerial staff and decision-makers, employing a methodologically grounded approach complemented by case studies, industry visits, and interviews with successful innovators to equip them with the strategic and organizational tools they need to promote digital transformation at their companies.

A training concept with a more regional, albeit no less digital focus, has been developed by the Mittelstand 4.0 Competence Center in Augsburg, where Fraunhofer SCS offers training for business model development to medium-sized companies in and around Bavaria.

The Cybersecurity Training Lab, coordinated by the Fraunhofer Academy, offers courses on topics in the field of IT security. At present, in-person training on the topics **IT Security in Wireless Communication Systems** and **5G, a safe bet?** is available for participants with no special prior knowledge. The courses can also be adapted for in-house training tailored to the needs of individual companies. Further courses are currently being developed.



www.iis.fraunhofer.de/education

www.cybersicherheit.fraunhofer.de/drahtlose-kommunikationssysteme

www.cybersicherheit.fraunhofer.de/5g

RESEARCH FAB MICROELECTRONICS GERMANY

One-Stop-Shop: Microelectronics innovation from fundamental research to pilot products

Since April 2017, Institute XY is part of the Germany-wide Research Fab Microelectronics Germany (FMD). With 13 member institutes and over 2000 active researchers, this research network represents Europe's largest R&D collaboration for micro- and nanoelectronics.

The investments in FMD are paying off

Within the last two and a half years, successful project ventures have been established and numerous contracts completed in cooperation with the FMD. In 2019, projects with a combined volume of €66.8 million were made possible as a result of investments into the FMD. Pure industry projects accounted for more than €17 million in 2019, underlining the importance of this unique cooperation in German microelectronics research.

FMD – a promising model for major project initiatives

In 2020, the final set-up phase for the Research Fab Microelectronics Germany is being initiated. The innovative concept's great potential for cross-site cooperation has already been proven e.g. in the »miniLiDAR« project, a major initiative (with a volume of €5.65 million) supported by the FMD's business office since its launch in late 2019. The project will design miniaturized LiDAR components for robotic applications with the aid of an industry partner actively scouted for and won over by the FMD business office. Four FMD institutes – the Ferdinand Braun Institute FBH in Berlin, the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg, the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden, and the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin – are involved in the project.

Founders' dreams come real in the FMD-Space

The start-up support concept FMD-Space – first proposed at the very start of the FMD's set-up – has continued to make headway in 2019 in several successful pilot projects. Technology-driven start-ups are thus provided efficient and ready access to the technologies and facilities of the member institutes. The enterprising minds behind the start-ups team up with the institutes' research staff to produce working demonstrators of their product concepts. The services of the FMD-Space are, for instance, being used by the founders of »Ghost - feel it«, the »OQmented GmbH«, and »nxtbase technologies GmbH«. Two further project ideas won their places in the FMD-Space in late 2019: »Quantune Technologies« and »Twenty-One Semiconductors«.

Modernizing the FMD's facilities at full speed

The FMD vision of successful research and development work happening collaboratively at locations across Germany is supported by Germany's Federal Ministry of Education and Research, with approx. €350 million in funding set aside until late 2020. This investment into the FMD fuels the future viability of applied microelectronics research in Germany. Practically, this primarily takes the form of updated and modernized research facilities at the 13 participating institutes from the Fraunhofer-Gesellschaft and Leibniz Association. By the end of 2019, 157 new pieces of equipment have already been delivered and are, in the main, already up and running – a great step forward in substantially expanding the institutes' technological capabilities.

IN BRIEF

A selection of news topics:

- AI expert Professor Alexander Martin
- Special honor for Professor Albert Heuberger
- Digital Media Alliance celebrates 15th anniversary
- »Long Night« at Fraunhofer IIS
- ICL-GNSS conference comes to town
- Study and research in the summer holidays
- Machine Learning Forum 2019
- Swiss team victorious at NXP Cup



AI EXPERT PROFESSOR ALEXANDER MARTIN

Mathematics professor appointed third director of Fraunhofer IIS

On November 1, 2019, the Institute's management team was joined by a renowned expert in the field of artificial intelligence (AI), with a particular interest in mathematical optimization. As the largest institute of the Fraunhofer-Gesellschaft, we have been scaling up our activities in this area for several years. At Fraunhofer IIS, Martin established the ADA Lovelace Center. »ADA« stands for »Analytics, Data, Applications«, reflecting the Center's mission of collecting and analyzing large volumes of data with a view to improving existing processes and business models or developing new ones. In pursuit of these goals, the Center employs methods from the fields of artificial intelligence, machine learning, and mathematical optimization.

Born in Memmingen in 1965, Martin studied at the University of Augsburg before completing a doctorate and then his habilitation thesis at the Technical University of Berlin. After a stint as a deputy head of department at the Zuse Institute, he accepted a post at the Technical University of Darmstadt in 2000, where he later served as vice president from 2008 to 2010. In 2010, he was appointed to the Chair of Economics, Discrete Optimization, and Mathematics at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU). In 2015, he also took the helm of our Analytics department in the Center for Applied Research on Supply Chain Services (SCS).

Alongside the technical management of the ADA Lovelace Center, the new Institute director's responsibilities will lie largely with the Nuremberg location, which is home to the Positioning and Networks division and the SCS.

Martin's research areas include studying and solving general mixed-integer linear and nonlinear optimization problems, including development and mathematical analysis of suitable models, and design and implementation of efficient algorithms to solve them. Key areas of application include problems posed by transport, traffic and energy optimization. He is especially motivated to see his findings implemented in industrial applications.



SPECIAL HONOR FOR PROFESSOR ALBERT HEUBERGER

Institute director awarded Fraunhofer Medal in recognition of achievements

To mark the occasion of the 60th birthday of the Institute's executive director Professor Albert Heuberger, we hosted a symposium featuring high-profile guests and specialist lectures. In recognition of his services to the Fraunhofer-Gesellschaft, Heuberger was presented with the Fraunhofer Medal by Fraunhofer-Gesellschaft president Professor Reimund Neugebauer. The distinction is awarded to individuals who have made an especially valuable contribution to the Fraunhofer-Gesellschaft.

In his laudatory speech, the President highlighted Heuberger's outstanding connections both within the Fraunhofer-Gesellschaft and at the regional, national, and international levels.

Heuberger, who joined Fraunhofer IIS in 1987, was promoted to deputy director in 1999 and director of the Institute in 2011. In this time, the Institute has enjoyed dynamic growth, with employee numbers rising from around 700 to more than 1,100 today, and a budget that has grown from less than 100 million euros to its current level in excess of 160 million euros. Under Heuberger's stewardship, the Institute underwent a restructuring process in which seven thematic divisions were established, new strategic topics were identified, and clear priorities were set with the two guiding topics »Audio and Media Technologies« and »Cognitive Sensor Technologies«.

DIGITAL MEDIA ALLIANCE CELEBRATES 15TH ANNIVERSARY

Members of the alliance are trendsetters and innovators in the field of new media technologies

This year, the Fraunhofer Digital Media Alliance, comprising Fraunhofer IIS, Fraunhofer HHI, Fraunhofer IDMT, and Fraunhofer FOKUS, celebrates 15 years of pooled expertise and countless innovations and disruptive technologies that have helped shape the media landscape. With codecs including mp3, AAC, and HEV, projects such as specifications for digital cinema commissioned by Hollywood studios, and numerous

current research topics ranging from IP-based workflows to MPEG-H audio and volumetric video, the members of the Digital Media Alliance have distinguished themselves as trendsetters and innovators in the field of new media technologies.



www.digitalmedia.fraunhofer.de/en.html



»LONG NIGHT« AT FRAUNHOFER IIS

Events at several locations give visitors a glimpse into our research activities

At the 9th iteration of the »Long Night of the Sciences« on October 19, inquisitive visitors and young researchers were invited to discover the academic and research institutions of northern Bavaria. Throughout the day, hundreds of higher education institutions, municipal bodies, and private associations opened their doors to give people a glimpse into their day-to-day research and other activities normally hidden from view.

We participated in the event at our Erlangen-Tennenlohe, Fürth-Atzenhof, and Nürnberg-Nordostpark sites. At our main headquarters, a variety of exhibits showcased the theme of artificial intelligence (AI). In short presentations, researchers discussed the current state of research and demonstrated applications exploiting the capabilities of AI. Meanwhile, guests could enjoy hands-on activities like adjusting the audio mix on a television, hearing what a phone call in HiFi sounds like, or experiencing in-car 3D sound. At the Campus of the Senses, visitors had the opportunity to try out a next-generation driving simulator or test their sense of smell and taste. A treasure hunt was held with 27 stops throughout the Institute, and the HR team was on hand with information on jobs and career opportunities at Fraunhofer IIS.

In Fürth, the major attraction was the XXL computed tomography scanner, which occupies an area of around 400 square meters and is the only one of its kind in the world. The scanner allows X-ray examinations of entire cars, revealing even the tiniest details. Other exhibits demonstrated how plant growth can be observed non-destructively, or how robots can monitor quality in the production process.

At our location in Nuremberg, employees of the ADA Lovelace Center answered questions on the benefits of AI to the industrial and service sectors, and demonstrated how positioning technologies can be used to create order and efficiency in logistics. In an activity exploring machine learning, guests had fun observing how a machine reacted to them.


 youtu.be/VeueTDkERZI

ICL-GNSS CONFERENCE COMES TO TOWN

Nuremberg hosts leading research institutions and companies

The International Conference on Localization and GNSS (ICL-GNSS) is devoted to topics involving positioning and the use of wireless technologies for 5G, IoT, and networked mobility. In 2019, the leading research institutions and companies in the sector convened at Fraunhofer IIS in Nuremberg for their annual exchange of scientific know-how.

Nuremberg is home to the pooled positioning expertise of Fraunhofer IIS, one of Europe's foremost development hubs for Galileo receiver technologies.

 www.icl-gnss.org
www.iis.fraunhofer.de/positioning



STUDY AND RESEARCH IN THE SUMMER BREAK

30 youngsters attend the 2019 edition of Junior Academy Bavaria

In the middle of the summer vacation, from late August to early September, our research campus in Waischenfeld in Franconian Switzerland hosted the Junior Academy Bavaria, a ten-day event in which exceptionally talented and inquisitive pupils with wide-ranging interests in the 8th or 9th grade at high schools in Bavaria attended courses on a range of topics. Besides these courses, the 30 youngsters could also choose from interdisciplinary activities including sports, creative workshops, and excursions.

The research campus in Waischenfeld, a creative work environment that encourages straightforward and unconventional project-based scientific work, research, testing, cooperation, and exchange, provides ideal conditions for the Junior Academy Bavaria. Set in the heart of Franconian Switzerland, the venue combines all the benefits of a facility equipped to the standards of our Institute with seclusion from the hustle and bustle of everyday life.

MACHINE LEARNING FORUM 2019

Connecting industry and research for AI

We have collaborations in place with several chairs at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) to promote research activities for Machine Learning and Artificial Intelligence (AI) beyond the Nuremberg metropolitan region. Our annual Machine Learning Forum, held in September, provides a networking platform for research and industry

devoted to the current state of research, but also and above all to the challenges and potential of AI in industry, and possibilities for its implementation in applications.



www.iis.fraunhofer.de/machinelearning-en



youtu.be/DrZ3YdkqvBo



SWISS TEAM VICTORIOUS AT NXP CUP

Self-driving vehicles turn the Institute into a competitive racing venue

In 2019, the EMEA finals of the NXP Cup were once again hosted by Fraunhofer IIS. The Cup is an international competition staged by semiconductor manufacturer NXP in which students receive cutting-edge technology for self-driving vehicles and then spend four months assembling, programming and testing their cars before pitting them against each other on an undisclosed race track at Fraunhofer IIS. A total of 19 teams from eleven different countries made it into the final round, turning the Institute into a competitive racing venue for two days.

For most of the students, participating in the event was a leisure activity pursued alongside their studies. »The great thing about the NXP Cup is connecting and competing with other people in Europe – it's fantastic that so many people are here. That's very important to us, as we've been working on this project all year,« said the winning team ARCAR1 from the Haute Ecole ARC Ingénierie in Le Locle, Switzerland.

Second and third places in the race for self-driving intelligent cars went to the teams ARCAR2 (also from Switzerland) and KAW4Wheels, from Cracow, Poland. The two Czech teams, VAXNA from Rožnov pod Radhoštěm and SlowFox MUNI Corp from Brno received awards for the »most innovative« vehicles.

This year's event included three short race tracks posing new challenges to the teams: obstacle avoidance (steering round a cube in the middle of the track), speed limit (slowing down at certain points), and figure of 8 (completing as many laps of a track in the shape of an 8 as possible in 90 seconds). »This year was not just about speed, but also about precise driving performance,« said Flavio Stiffan of Stiffan Consulting, part of the project management team that helped semiconductor manufacturer NXP organize the EMEA competition. »The greatest challenge was the lighting conditions. The students had to work very hard to calibrate their camera systems.«

 youtu.be/RCXCy0vvfAs

FRAUNHOFER-GESELLSCHAFT IN GERMANY

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector, and public administration.

At present, the Fraunhofer-Gesellschaft maintains 74 institutes and research units. The majority of the roughly 28,000 staff are qualified scientists and engineers, who work with an annual research budget in excess of 2.8 billion euros. Of this sum, over 2.3 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

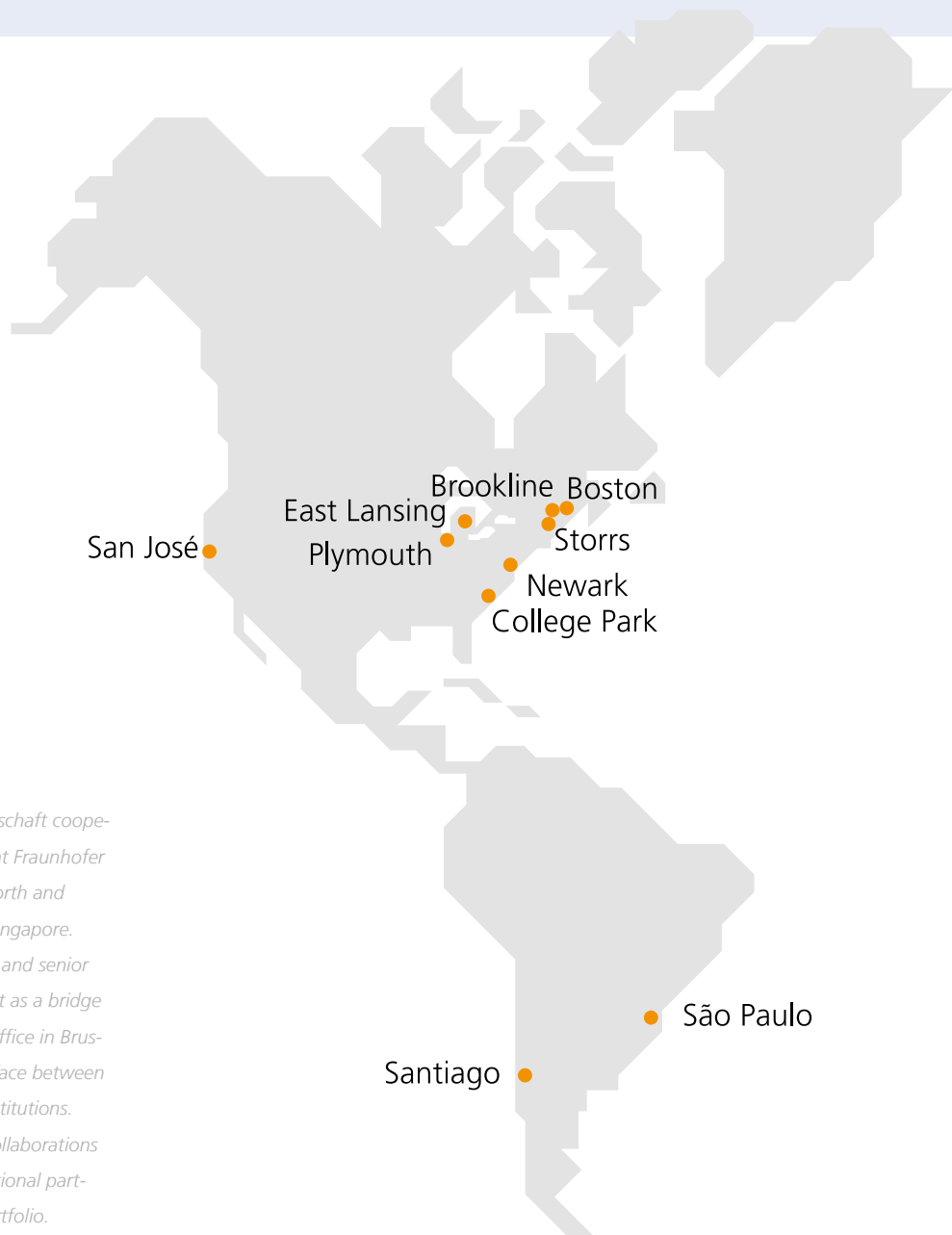
International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry, and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired. The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor, and entrepreneur.

Last amended: January 2020

FRAUNHOFER-GESELLSCHAFT WORLDWIDE



The Fraunhofer-Gesellschaft cooperates with independent Fraunhofer affiliates in Europe, North and South America, and Singapore. Representative offices and senior advisors worldwide act as a bridge to local markets. An office in Brussels works as an interface between Fraunhofer and EU institutions. Numerous strategic collaborations with excellent international partners round off the portfolio.

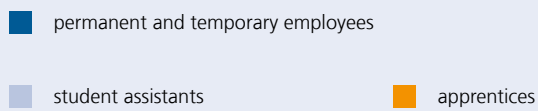


Data from 2019

FRAUNHOFER IIS IN NUMBERS

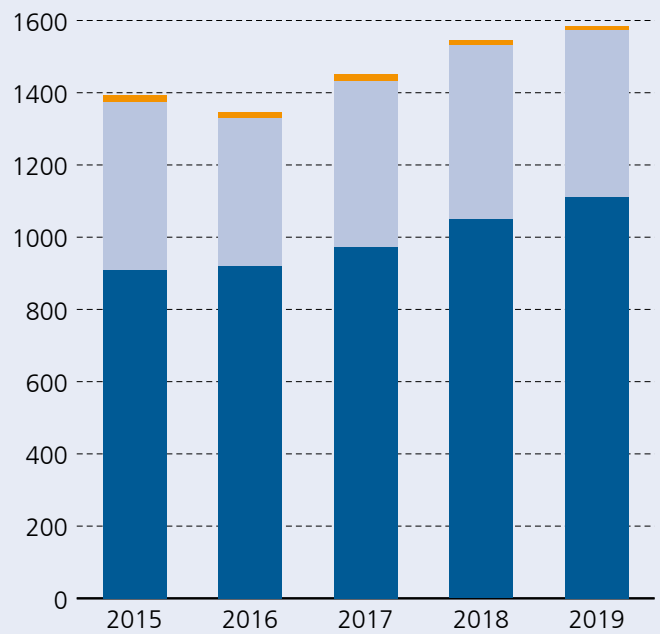
Employee numbers on the rise

Our employees are the key to the Institute's success. In line with previous years, 2019 brought an increase in staff numbers, from 1,048 in 2018 to 1,112 in 2019. These figures refer to employees listed in the staffing plan.



1,112

permanent and temporary employees



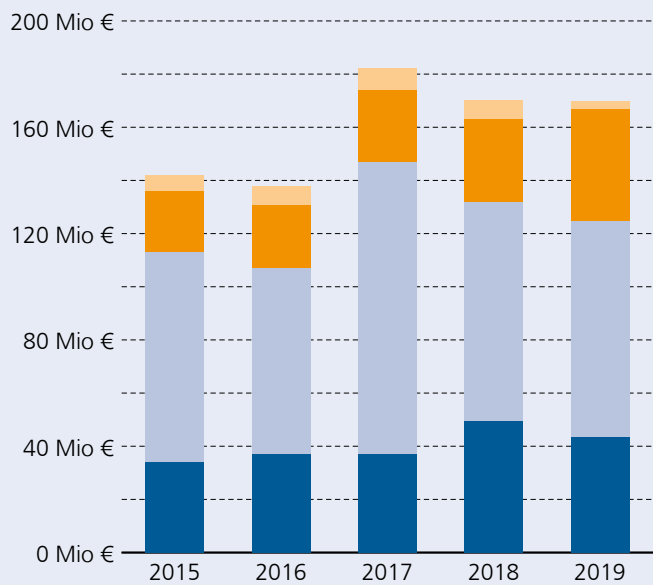
48 percent of income from industry

As in previous years, Fraunhofer IIS maintained a balanced budget and a positive carry-over in 2019. Of the institute's total income, 48 percent came from industry and business. Base funding at federal and state level accounted for 26 percent. 25 percent of the budget came from public-sector revenue.



169.9 MIO €

million euros in funding



Numerous invention disclosures once again in 2019

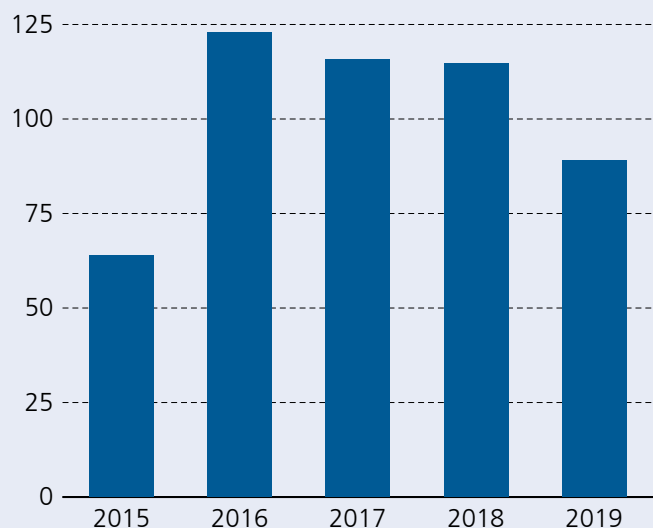
The number of invention disclosures remains at a very high level, with 89 inventions disclosed by Fraunhofer IIS employees in 2019.

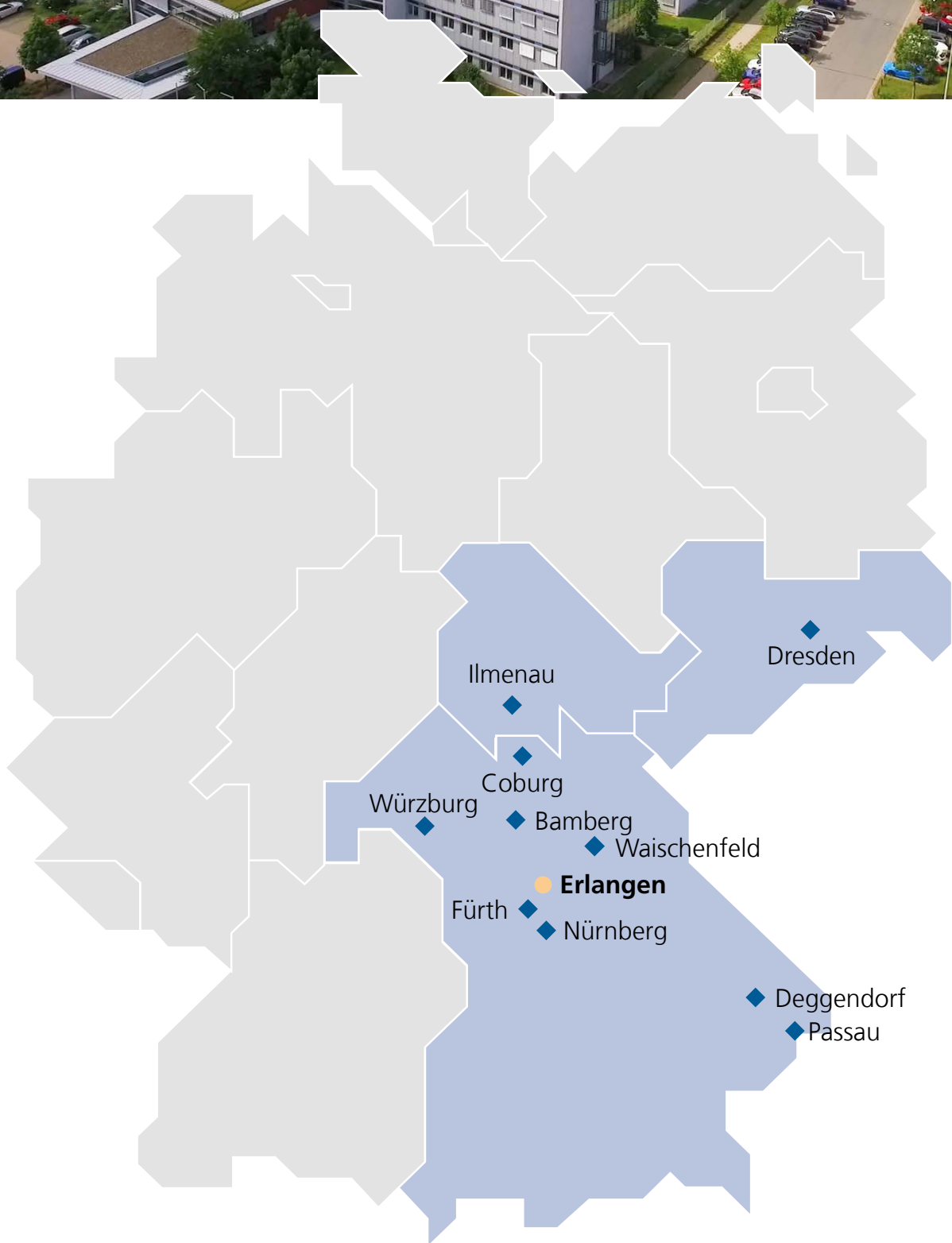
As in previous years, the research areas Communication Systems and Audio and Media Technologies accounted for the largest share of inventions, with topics such as 5G and wireless communication, or speech and audio encoding.





89

invention disclosures





headquarters 
sites 

FRAUNHOFER IIS IN PROFILE

The Fraunhofer Institute for Integrated Circuits IIS is one of the world's leading application-oriented research institutions for microelectronic and IT system solutions and services. Today, it is the largest of all Fraunhofer Institutes.

Research at Fraunhofer IIS revolves around two guiding topics:

In the area of **»Audio and Media Technologies«**, the institute has been shaping the digitalization of media for more than 30 years now. Fraunhofer IIS was instrumental in the development of mp3 and AAC and played a significant role in the digitalization of the cinema. Current developments are opening up whole new sound worlds and are being used in virtual reality, automotive sound systems, mobile telephony, streaming, and broadcasting. Any mobile phone you buy today, for instance, uses audio technology developed by the institute, while Fraunhofer codecs provide the basis for sound of more than half of all TV broadcasts worldwide and almost all radio and streaming services. The institute's professional tools for digital film and media production are also being used globally.

In the context of **»Cognitive Sensor Technologies«**, the institute researches technologies for sensor technology, data transmission technology, data analysis methods, and the exploitation of data as part of data-driven services and their accompanying business models. This adds a cognitive component to the function of the conventional »smart« sensor. The results of this research have been applied in the areas of connected mobility, communication and application solutions for the Internet of Things, digitalization of human sensing, product and material monitoring, and business analytics in supply chains.

Over 1,100 employees conduct contract research for industry, the service sector, and public authorities. Founded in 1985 in Erlangen, Fraunhofer IIS now has 14 locations in 11 cities: Erlangen (headquarters), Nuremberg, Fürth, and Dresden, as well as Bamberg, Waischenfeld, Coburg, Würzburg, Ilmenau, Deggendorf, and Passau. The budget of 169.9 million euros a year is mainly financed by contract research projects with 26 percent of the budget subsidized by federal and state funds.

Data from January 2020

 www.iis.fraunhofer.de/en.html

The organizational units for the individual locations are shown in the organizational chart on the following pages.

ORGANIZATIONAL CHART

Management of the Institute Prof. Dr. Albert Heuberger (executive) Dr. Bernhard Grill Prof. Dr. Alexander Martin		Deputy Directors Prof. Dr. Randolph Hanke Dr. Peter Dittrich	
Audio and Media Technologies Dr. Bernhard Grill ER		Development Center X-ray Technology EZRT Prof. Dr. Randolph Hanke FÜ	Smart Sensing and Electronics Josef Sauerer ER
Audio Johannes Hilpert	Media Systems and Applications Harald Fuchs	Application-specific Methods and Systems Dr. Norman Uhlmann	Electronic Imaging Stephan Gick
Audio for Communications Manfred Lutzky	Moving Picture Technologies Dr. Siegfried Föbel	Contactless Test and Measuring Systems Dr. Peter Schmitt	Image Processing and Medical Engineering Dr. Christian Münzenmayer
Audio for Embedded Systems Dr. Nikolaus Färber	Patents and Licensing Stefan Geyersberger	Production Monitoring Dr. Steven Oeckl	Integrated Circuits and Systems Dr. Norbert Weber
AudioLabs-IIS Dr. Frederik Nagel	Semantic Audio Processing Oliver Hellmuth	Magnetic Resonance and X-ray Imaging Dr. Karl-Heinz Hiller WÜ	Integrated Sensor Systems Harald Neubauer
Business Marc Gayer	Staff Audio and Media Technologies Matthias Rose	CT in Metrology Prof. Dr. Jochen Hiller DEG	
humAIIn-IIS Dr. Frederik Nagel			

Last amended: June 2020

Research Management

Dr. Peter Dittrich

IT-Services | Florian Freund**Staff** | Matthias Rose**Senior Director****Administration, Finance
and Human Resources**

Dr. Peter Dittrich

Communication Systems

Michael Schlicht

ER

Positioning and Networks

Dr. Günter Rohmer

N

**Fraunhofer Center for
Applied Research on Supply
Chain Services SCS**

Prof. Dr. Alexander Pflaum

Dr. Roland Fischer

N

**Engineering of Adaptive
Systems EAS**

Dr. Peter Schneider

DD

Broadband and Broadcast

Bernhard Niemann

**Self-Powered Radio
Systems**

Josef Bernhard

**Data Spaces and
IoT Solutions**

Prof. Dr. Andreas Harth

Design Methodology

Dr. Roland Jancke

**Radio Communication
Systems**

Dr. Gerd Kilian

Communication Networks

Jürgen Hupp

Analytics

Christian Menden

Efficient Electronics

Andy Heinig

RF and SatCom Systems

Rainer Wansch

**Precise Positioning and
Analytics** | Thomas von der
Grün, Dr. Christopher Mutschler**Innovation and
Transformation**

Dr. Frank Danzinger

**Intelligent Sensors
and Actuators**

Dr. André Nauen

**Electronic Measurements
and Signal Processing**Prof. Dr. Giovanni Del Galdo **IL****Satellite Based Positioning
Systems**

Dr. Wolfgang Felber

**Distributed Data
Processing & Control**

Dr. Dirk Mayer

ER | Headquarters Erlangen

Am Wolfsmantel 33

91058 Erlangen

Phone +49 9131 776-0

**Distributed Systems and
Security**

Karlheinz Ronge

**DEG | Application Center
for CT in Metrology**

Dieter-Görlitz-Platz 2

94469 Deggendorf

Phone +49 991 3615678

**WÜ | Magnetic Resonance and
X-ray Imaging Department**

Am Hubland

97074 Würzburg

Phone +49 931 31830-60

N | Location Nürnberg

Nordostpark 84 (SCS: 93)

90411 Nürnberg

Phone +49 911 58061-7500

FÜ | Location Fürth

Flugplatzstraße 75

90768 Fürth

Phone +49 911 58061-7500

**DD | Engineering of Adaptive
Systems EAS Devision**

Zeunerstraße 38

01069 Dresden

Phone +49 351 4640-701

**IL | Electronic Measurements
and Signal Processing**

Helmholtzplatz 2

98693 Ilmenau

Phone +49 3677 69-4280

MEMBERS OF THE ADVISORY BOARD

The Advisory Board advises the Institute's directors and helps to forge contacts with industry and other organizations.

Dr. Annerose Beck, Saxon State Ministry for Science and the Arts, Head of National-Regional Research Centers Administration

Dr. Heike Prasse, Federal Ministry of Education and Research (BMBF)

Dr. Bernd Ebersold, Thuringian Ministry for Economic Affairs, Science and Digital Society, Head of Research, Technology and Innovation Department

Professor Godehard Ruppert, Otto-Friedrich-Universität Bamberg

Dr. Astrid Elbe, Managing Director, Intel Labs Europe

Dr. Dietmar Schill, Divisional Director, Sony Deutschland GmbH

Jörg Fürbacher, EUROLOG AG

Dr. Alexander Tettenborn, Federal Ministry for Economic Affairs and Energy (BMWi)

Klaus Helmrich, Siemens AG

Dr. Isabel Thielen, THIELEN Business Coaching GmbH

Professor Joachim Hornegger, Friedrich-Alexander-Universität Erlangen-Nürnberg

Norbert Michael Weber, Federal Ministry of Defense (BMVg)

Anton Kathrein, Kathrein-Werke KG

Jürgen Weyer, NXP Semiconductors

Professor Franz Kraus, ARRI AG

Dr. Manfred Wolter, Bavarian Ministry of Economic Affairs, Regional Development and Energy

Dr. Walther Pelzer, German Aerospace Center (DLR)

Data from January 2020

AWARDS AND PRIZES

Fraunhofer Medal

Awarded on the occasion of Professor Albert Heuberger's 60th birthday in recognition of his achievements in promoting the development of our Institute.

Joseph von Fraunhofer Prize 2019

The 2019 Joseph von Fraunhofer Prize went to the team led by Thomas von der Grün, Norbert Franke, and Thomas Pellkofer in Nuremberg. A jury consisting of representatives from industry and academia were convinced by the team's technology for »Sports tracking – the digital revolution in team sports« of the added value that precise and robust tracking technologies applied in sports such as hockey, football, and many more could offer to viewers, players, and fans.

Fraunhofer SPEAKER project: AI innovation competition award from Federal Ministry

Collaboration project with Fraunhofer IAIS to develop a leading voice assistant platform that is »made in Germany«. Award from the Federal Ministry for Economic Affairs and Energy (BMWi) in the »artificial intelligence as a driver for economically relevant ecosystems« innovation competition.

ISMIR president nomination

Professor Meinard Müller has been nominated as president of the International Society of Music Information Retrieval (ISMIR) for a period of 2 years.

IEEE Fellow

Professor Meinard Müller becomes IEEE Fellow from 2020.

2019 teaching prize at Ilmenau University of Technology

Professor Giovanni Del Galdo has been awarded TU Ilmenau's 2019 teaching prize.

STAEDTLER Foundation doctoral thesis award

Dr. Christian Dittmar, group leader at Fraunhofer IIS, has been recognized by the STAEDTLER Foundation for his outstanding doctoral thesis.

Best doctoral thesis in the field of digital signal processing

Dr. Oliver Thiergart, senior scientist at Fraunhofer IIS, received the prize for the best doctoral thesis in the field of digital signal processing from the European Association for Signal Processing (EURASIP).

AES Board of Governors Award

Dr. Christian Uhle, chief scientist at Fraunhofer IIS, received the AES Board of Governors Award in recognition of his achievements as co-chair of the International AES Conference on Semantic Audio 2017.

Best Paper Award

Matteo Torcoli, Dr. Jouni Paulus, and Christian Simon, together with Alex Freke-Morin and Professor Ben Shirley from the University of Salford, received the award for best paper at the AES Conference in Dublin.

Universitätsgesellschaft Ilmenau e.V. 2019 doctoral thesis award

Dr. Anastasia Lavrenko received the Universitätsgesellschaft Ilmenau e.V. 2019 doctoral thesis award.

2019 Fraunhofer IIS Prize for research with an outstanding practical application

Wolfgang Holub was awarded the 2019 Fraunhofer IIS Prize for robot-assisted X-ray computed tomography.

2019 Fraunhofer IIS Prize for an outstanding academic achievement

Dr. Christian Dittmar was awarded the 2019 Fraunhofer IIS Prize for source separation and the restoration of drum sounds in music recordings.

PUBLISHING NOTES

Published by

Fraunhofer Institute for Integrated Circuits IIS
Professor Albert Heuberger
Dr. Bernhard Grill
Professor Alexander Martin

Am Wolfsmantel 33
91058 Erlangen, Germany
Phone + 49 9131 776-0
Fax +49 9131 7762099
info@iis.fraunhofer.de
www.iis.fraunhofer.de

Editorial team

Thoralf Dietz, Simon Hagen (head), Andrea Auner, Dr. Birgit Brüggemeier, Dr. Christian Dittmar, Mandy Garcia, Hanna Herger, Dr. Nadja Hoßbach, Syndia Ioannidou, Thomas Kestler, Sandra Kundel, Bernd Linz, Karin Loidl, Manfred Lutzky, Stefan Meltzer, Sebastian Meyer, Max Neuendorf, Moritz Protzner, Angela Raguse-Föbel, Romana Redtenbacher, Daniela Rembor, Diana Staack, Dr. Bettina Williger, Claudia Wutz

Layout and production

Claudia Matthias

Proofreading

Eva Bachmann/Redaktionsbüro Bachmann, Thoralf Dietz

Translation and proofreading (English)

Sheila Regan and team/ UNIWORKS, www.uni-works.org

Printed by

Gutenberg Druck & Medien GmbH

Contact

Fraunhofer Institute for Integrated Circuits IIS
Corporate Communication
Am Wolfsmantel 33
91058 Erlangen, Germany
Phone + 49 9131 776-1631
presse@iis.fraunhofer.de

Photo acknowledgements

Cover image, pages 14/20/53: Fraunhofer IIS, Paul Pulkert
Foreword, Pages 45/52/55: Fraunhofer IIS, Peter Roggenthin
Page 6: Fraunhofer IIS, Manuela Wamser
Page 10: Max Threlfall
Page 11: Adobe Stock, VAKSMANV (left) and (right) Fraunhofer IIS, Kurt Fuchs
Page 12: Adobe Stock, Val Thoermer
Page 17: Fotolia.com, dragonstock
Page 18: Fraunhofer IIS, Christina Müller
Page 19: Kinexon GmbH, Julian Graf
Page 22: Fraunhofer IIS, Angela Raguse-Föbel
Page 26: Fraunhofer Institute for Machine Tools and Forming Technology IWU
Page 27: Adobe Stock, assetseller
Page 29: Fraunhofer IIS, Hanna Herger
Page 30: Adobe Stock, Delphotostock
Page 36: SMWA, Kirsten Johannes Lassig
Page 42: Fraunhofer IIS, Visualization by Fraunhofer MEVIS, Bremen, applying physically based volume rendering to high-resolution CT-scans
Page 43: Fraunhofer IIS, Deutsches Museum
Page 44: Fraunhofer IIS, Wladimir Tschekalinskij
All other images: © Fraunhofer IIS

All rights reserved.

Reproduction of any material requires the editors' consent.

Report period


January 1, 2019 to December 31, 2019
© Fraunhofer IIS
Erlangen, February 2020

 facebook.com/FraunhoferIIS

 @FraunhoferIIS

 linkedin.com/company/fraunhofer-iis

 xing.com/companies/fraunhoferiis

 youtube.com/user/FraunhoferIIS



