



Fraunhofer
IVI

Institute Report 2021



Research in Times of Unrest



**Fraunhofer Institute for Transportation
and Infrastructure Systems IVI**

Research in Times of Unrest

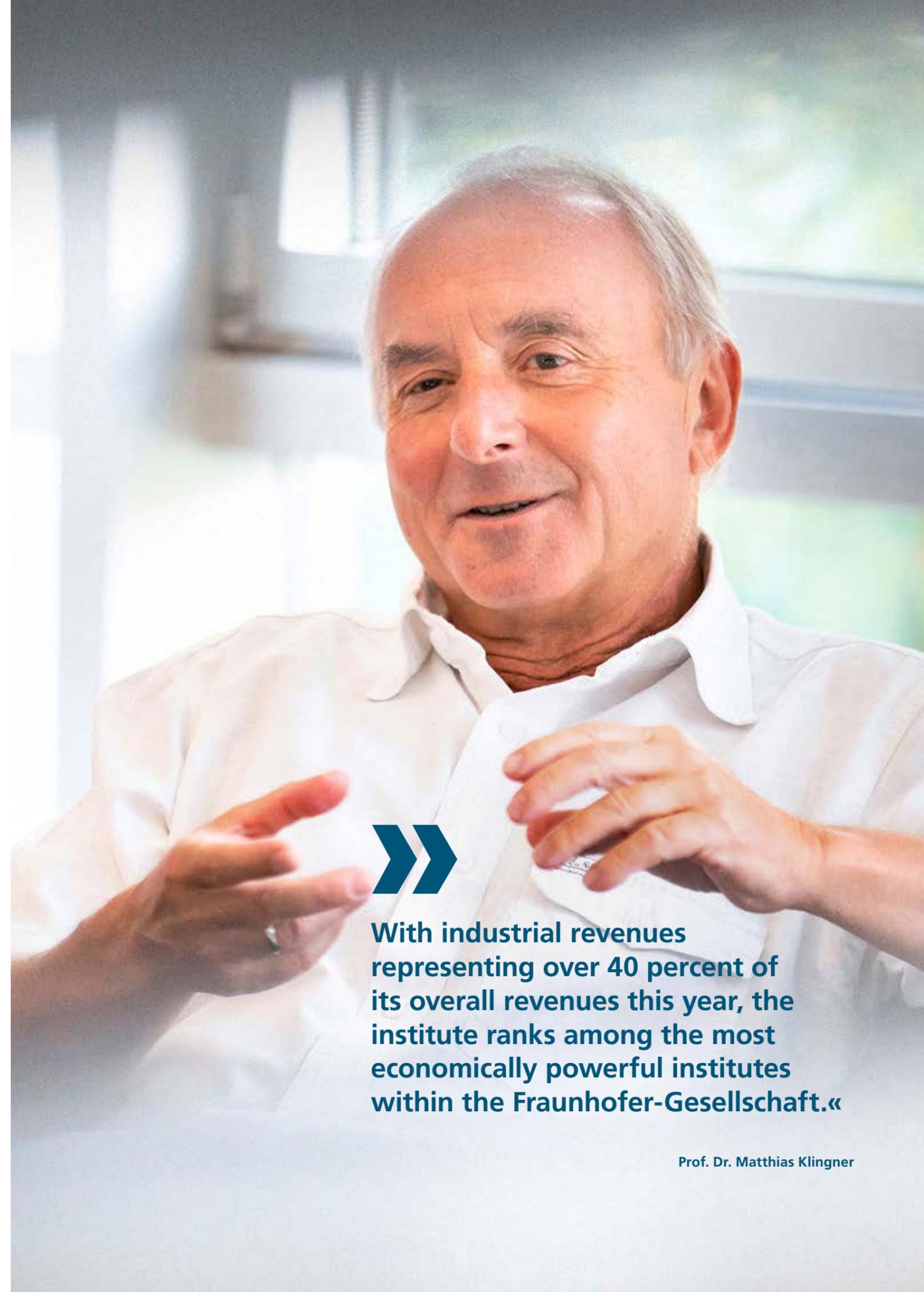
In the Renaissance, restlessness, as an elementary feeling of being driven, was deemed essential for gaining knowledge and practicing science. Faust, the striving scholar from Goethe's famous play, failing to answer the question »... whatever binds the world's innermost core together«, devotes himself to the devil in order to free himself from restlessness. In today's restless time with its many unanswered questions, it should be easy for Mephistopheles to trap the curious, because not every »... good man, in his darkest yearning, is still aware of virtue's ways.« And in times that are increasingly characterized by the phrase »... as always it's us who must obey, and pay more money down«, the result is confusion as to whether »... love, is it, then? Or hate? This fierce embrace« – an emotion that, unfortunately, can be perceived more and more strongly throughout Germany.

I am all the more grateful for the fact that the day-to-day research activities at both our branches in Dresden and Ingolstadt have remained largely unaffected by these tensions despite the massive constraints set by another year dominated by the coronavirus. We can once more present an excellent balance for the 2021 end of year report. By continuing with the quote from Faust, »... who brings a lot, brings something that will pass«, I want to shine a special light on Fraunhofer IVI's great industrial revenues that represent over 40 percent of the overall revenues this year. This means that the institute has claimed a spot among the top ten most economically powerful institutes within the Fraunhofer-Gesellschaft. This past year, we suffered almost no revenue losses due to the pandemic. For this, we owe special thanks to our industry partners and the public funding bodies of the German Federation as well as the States of Saxony and Bavaria. The commission books for 2022 are already well-filled, long-term research contracts give us security, and my colleagues' motivation for facing the challenges of these restless times with great commitment and constructive creativity is still unbroken.

An ambivalently comforting restlessness is currently spread by the ongoing renovation of the institute building's west wing. The 75 new desk spaces, new laboratories and conference rooms that are being created will significantly improve the future working conditions at the institute. Additional considerable investment funds are available for expanding the research infrastructure. All of this brings additional stress for the institute's administration, facility management and construction management teams, to whom I would like to express heartfelt thanks at this point – especially in light of the fact that the entire Fraunhofer-Gesellschaft's transfer to a new business software at the beginning of 2022 has proven to be another strenuous challenge. Knowing that »... what dazzles is a momentary act, what's true is left for posterity, intact«, I would now like to invite you to read our annual report that does not only contain special events and research results, but also summarizes in a pleasant layout our work and life together during trying times. The hope remains that soon there will be a time where you can gain your own impression of the »authenticity« of all this at our institute.

Director

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With industrial revenues representing over 40 percent of its overall revenues this year, the institute ranks among the most economically powerful institutes within the Fraunhofer-Gesellschaft.«

Prof. Dr. Matthias Klingner

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Fraunhofer-Gesellschaft



The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. It is a trailblazer and trendsetter in innovative developments and research excellence. The Fraunhofer-Gesellschaft supports research and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

The Fraunhofer-Gesellschaft's interdisciplinary research teams turn original ideas into innovations together with contracting industry and public sector partners, coordinate and complete essential key research policy projects and strengthen the German and European economy with ethical value creation. International collaborative partnerships with outstanding research partners and businesses all over the world provide for direct dialogue with the most prominent scientific communities and most dominant economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, pre-dominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from contract research. Industry contracts and publicly funded research projects account for around two thirds of that. The federal and state governments contribute around another third as base funding, enabling institutes to develop solutions now to problems that will become crucial to industry and society in the near future.

The impact of applied research goes far beyond its direct benefits to clients: Fraunhofer institutes enhance businesses' performance, improve social acceptance of advanced technology and educate and train the urgently needed next generation of research scientists and engineers.

Highly motivated employees up on cutting-edge research constitute the most important success factor for us as a research organization. Fraunhofer consequently provides opportunities for independent, creative and goal-driven work and thus for professional and personal development, qualifying individuals for challenging positions at our institutes, at higher education institutions, in industry and in society. Practical training and early contacts with clients open outstanding opportunities for students to find jobs and experience growth in business and industry.

The prestigious nonprofit Fraunhofer-Gesellschaft's namesake is Munich scholar Joseph von Fraunhofer (1787–1826). He enjoyed equal success as a researcher, inventor and entrepreneur.



Fraunhofer in Dresden

Institutes, Branches and Research Institutions

- Fraunhofer Institute for Ceramic Technologies and Systems IKTS
- Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP
- Fraunhofer Institute for Photonic Microsystems IPMS
- Fraunhofer Institute for Transportation and Infrastructure Systems IVI
- Fraunhofer Institute for Material and Beam Technology IWS
- Dresden branch of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Bremen
- Dresden branch of the Fraunhofer Institute for Machine Tools and Forming Technology IWU, Chemnitz
- Division Processing Technology of the Fraunhofer Institute for Process Engineering and Packaging IVV, Freising
- Division EAS (Engineering of Adaptive Systems) of the Fraunhofer Institute for Integrated Circuits IIS, Erlangen
- Project Group ASSID (All Silicon System Integration Dresden) of the Fraunhofer Institute for Reliability and Microintegration IZM-ASSID, Berlin
- Dresden Branch of the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, Sankt Augustin



Customers and Partners

- Research organizations
- Universities
- Industry and economy
- Public institutions
- Transport associations and providers
- Energy suppliers

The complete list of partners is available on the website:



Academic Cooperation

- Technische Universität Dresden
- Technische Universität Bergakademie Freiberg
- Technische Hochschule Ingolstadt

Fraunhofer IVI

ICT Group

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Alliances

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Fraunhofer Traffic and Transportation Alliance

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Fraunhofer Energy Alliance

Spokesperson of the Alliance

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Organization Chart



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Departments



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Vehicle Engineering *Dr. Frank Steinert* | Monitoring and Control Strategies *Dr. Martin Ufert*
Charging Infrastructure *Dr. Sven Klausner*



Traffic Safety and Vehicle Automation

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Vehicle Control and Sensor Systems *Dr. Sebastian Wagner*
Vehicle and Road Safety *Dr. Christian Erbsmehl*



Strategy and Optimization

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Disposition *Dr. Kamen Danowski* | Digital Business Processes *André Rauschert* | Logistics *Denise Hoffeld*



Cognitive and Cooperating Systems

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Cooperative Systems *Dr. Thomas Otto*

Application Center



Connected Mobility and Infrastructure

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Highly Automated Flying *Henri Meeß*

Profile

Fraunhofer IVI employs over 120 research fellows at its two locations in Dresden and Ingolstadt. Its transport-related research work ranges from the field of vehicle and propulsion systems to intelligent transport systems, and it also covers the areas of disposition, logistics and digital business processes.

For more than 20 years, the Fraunhofer IVI has been developing innovations for the intelligent planning, coordination and management of mobility, shaping the digital transformation of public transport with reliable information and assistance systems, platform solutions for mobility data and services as well as electronic ticketing.

Projects investigating autonomous systems are gaining in importance, especially in heavy goods transport and agriculture. The Fraunhofer Application Center »Connected Mobility and Infrastructure« at the TH Ingolstadt was established in 2019. Currently in its start-up phase, the new structural unit focuses on topics of automated and cooperative driving. Besides innovative charging technologies, research and development work in the field of electromobility includes, for instance, solutions for remote battery diagnosis.

In the light of future technological and societal changes, special attention is devoted to security-related topics, covering aspects of civil hazard prevention, the functional safety of vehicle technologies, and developments in the fields of vehicle and road safety as well as accident research.

Intelligent Transport and Mobility Systems

- Mobility services and data
- Ticketing and fares
- Transport planning
- Autonomous driving and cooperative driving maneuvers
- Urban Air Mobility

Vehicle and Propulsion Technologies

- Propulsion technologies
- Multi-axle steering systems and lane guidance
- Mobile work machines
- Thermal management

Vehicle and Traffic Safety

- Functional safety
- Analyses of accident data
- Traffic psychology

Energy Systems

- Autonomous utility systems
- Stationary energy storage systems

Electromobility

- Battery development and recycling
- Charging technologies
- Electric buses and electric commercial vehicles
- Fuel cells / hydrogen technologies

Process Data Analysis

- Transport ecology
- Logistics
- Digital business processes

Civil Protection

- Planning and operation command
- Infrastructure management
- Risk assessment

Facilities and Large Equipment

- Technical center with a vehicle hall and an adjacent test track
- Test vehicles and demonstrators
- Measurement technology
- Test rigs
- Software for Simulation, Big Data, 3D construction and GIS

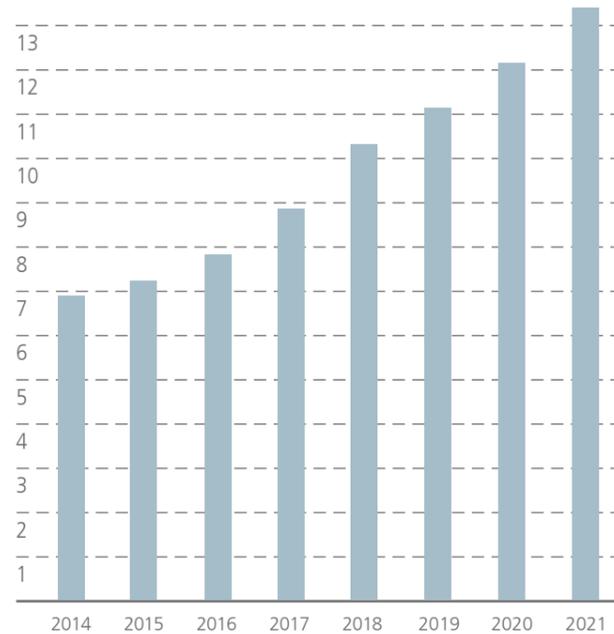
The complete list of facilities and large equipment is available on the website:



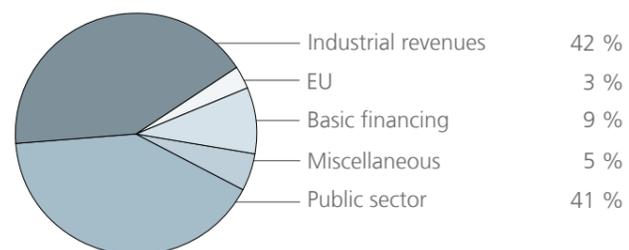
Economic Development

Financial Development

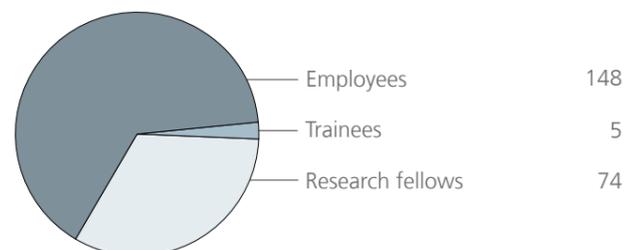
in € million



Operating Budget



Employees



Advisory Board

Members (as of 2021)

Prof. Dr. Thomas Brandmeier,
Scientific Director, Institute of Safety in Future Mobility (ISAFE),
Technische Hochschule Ingolstadt (THI)

Prof. Dr. Viktor Grinewitschus,
Institute for Energy Systems and Energy Business,
Hochschule Ruhr West

Mario Herber,
Senior Chief Superintendent, Head of Department »Central
Services«, Dresden Police Department

MinR Hans-Peter Hiepe,
Head of Division »Innovationsförderung; SprinD; Cluster;
Gaia-X«, Federal Ministry of Education and Research (BMBF)

Prof. Dr. Klaus Janschek,
Managing Director, Institute of Automation,
Faculty of Electrical and Computer Engineering, TU Dresden

Peter G. Nothnagel,
Head of the Staff Unit »Structural Development«,
Saxon State Ministry of Economic Affairs, Labor
and Transport (SMWA)

Prof. Dr. Peter Pickel,
Deputy Director/Manager External Relations,
John Deere GmbH & Co. KG

Dirk Schillings,
Chief Technical Officer Light Rail Vehicles,
Member of the Executive Board, Stadler Rail AG

Nils Schmidt,
Head of Yunex Traffic Germany

Dr. Katharina Seifert,
Head of Group Engineering Strategy and China,
Volkswagen AG

Lars Seiffert,
Board of Operations and Human Resources,
Dresdner Verkehrsbetriebe (DVB) AG

Carsten Utikal,
Consultant – Federal-State Research Institutions,
Saxon State Ministry of Science, Culture and Tourism (SMWK)



Chairman

Prof. Dr.-Ing. Christian Lippold,
Head of planning, construction,
innovation division, Die Autobahn GmbH
of the Federal German Government



Mobility and Digital Services

Alert and Support System Across all Modes of Transport – Rad im Fokus

In the context of automated and connected driving, bicycle traffic often plays a minor role. Within the »Rad im Fokus« (Focus on Bikes) research project, an alert and support system for all transport modes was created with a special focus on bicyclists.



The level of interconnection and digitalization in complex transport systems is increasing rapidly. With the help of information and communication technologies, it is possible to organize traffic more efficiently, establish new mobility services and integrate traffic participants more actively. For over 20 years, Fraunhofer IVI has successfully operated in the field of mobility and digital services. The department's work is based on an in-depth collaboration with a multitude of partners such as transport companies and associations as well as industry and public institutions.

The two working groups »Data Systems and Travel Assistance« and »Ticketing and Fares« successfully realize projects in a large variety of research topics, acting in interdisciplinary teams with a broad range of skills and on the basis of experience and know-how gained in practical project work. The staff includes computer scientists, information engineers, transportation engineers as well as automation technicians.

More information



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Range of Services

- Data spaces and platforms for data on transportation and mobility
- Information and navigation applications for conventional and alternative mobility services, as well as for electromobility
- Fare calculator for conventional, electronic and mobile ticketing
- Specific programming language for fares, including development and testing tools
- Fare modeling and simulation
- Software solutions for mobile applications including applications for frontend, backend and the cloud
- Utilization of semantic technologies for data processing and service integration

By incorporating different modes of transport, such as bicycle traffic, individual and public transport, and their integration, safety-relevant aspects can be investigated comprehensively.

The alerts generated in critical situations are based on the fundamental study, classification and modeling of hazardous situations, as well as on a real-time environment analysis (bicycle sensor data, information provided by other traffic participants and traffic lights).

The data is acquired via a broad range of environmental sensors including GPS combined with a specific correction signal for better locating accuracy. With the help of V2X technologies, it was possible to establish reliable fast and direct data exchange between bicycles and cars.

The information gathered is shared on a context-based and user-adaptive level, forming the foundation for support in complex traffic situations. To achieve this, HMI concepts for bicycles were investigated for the first time with the aim of enabling complex context-adaptive and user-adaptive interaction. Different channels of information are used to alert cyclists. For example, haptic signals ensure the fast transmission of alerts and are completed by audio-visual information.

The alert and support system is designed to work both reliably and proactively by transmitting information to cyclists and car drivers in acutely dangerous situations, and doing so in a predictive manner. In the future, the technology can help make traffic safer.

The project was funded within the scope of the »Synchrone Mobilität 2023« research initiative with resources from the European Regional Development Fund (EFRE) and the Free State of Saxony. It was carried out under the leadership of Fraunhofer IVI in collaboration with partners from science and industry.



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Vehicle Systems

The Department »Vehicle Systems« focuses on developing technologies for novel commercial vehicle concepts. Their main focus is on innovative solutions and key technologies in the commercial vehicle and special-purpose vehicle sector. This includes overall vehicle design, construction of components and partial solutions, innovative drive systems, methods for the energy-efficient operation of both main engine and auxiliaries, as well as cutting-edge solutions.

The department contributes their expertise in diverse areas ranging from the development of concepts to the detailed simulation and dimensioning of vehicle systems, and the assembly, set-up and testing of prototypes. This also includes different charging technologies for private and public transport.

More information



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Range of Services

- Design and dimensioning of electric powertrains in commercial and special-purpose vehicles
- Functional safety of commercial vehicles (ISO 26262)
- Electrification and automation of agricultural machinery
- Fast-charging concepts for electric vehicles
- Development of multi-modal energy supply concepts (trams, buses, stationary)
- Modeling and diagnosis of batteries and fuel cells
- Vehicle systems monitoring
- Development of operating strategies for commercial vehicles

New Paths Towards the Electrification of Commercial Vehicles

Electric drive systems have established themselves in both public and private transport as the drive systems of the future. In the commercial vehicles sector, the need for improvement and further development is still great. However, first progress in this area is now becoming discernible.

Supported by:



Only a few years ago, undertakings tackling the electrification of commercial vehicles were looked down upon, but today it is widely accepted that even heavy commercial vehicles can operate electrically. This trend has been demonstrated especially well through developments in the field of electric city buses – today, almost all manufacturers offer series-ready models. Compared to public transport vehicles, the electrification of trucks is a much greater challenge, since they operate much more flexibly and on longer routes. The capacities of currently available batteries are not high enough to replace conventional drives in trucks yet, but they offer large potential for improvement. In addition, there is a variety of new and partly unconventional ideas on how to reduce the time and costs spent at charging stations.

Within the »Lade-PV« project (»PV Charging«), Fraunhofer ISE in collaboration with industry partners and Fraunhofer IVI have developed solar panels and power electronics for integration in commercial vehicles. An electric truck was equipped with a 3.5 kW peak photovoltaic system installed on top of the box body. The solar power harvested on the vehicle's roof can cover between 5 to 10 percent of the energy demand, depending on the route driven. The electric truck is approved for road use and has been in practical operation since 2021.

Electrically driven trucks may disrupt tightly scheduled logistics processes if additional time slots for recharging need to be integrated.

To completely avoid having to pause at charging stations, Fraunhofer IVI and industry partners are developing a new solution within the »CellSwap« project. In this project, an electric truck equipped with a small traction battery is assigned to two or three swap bodies containing large batteries. Only those swap bodies that are currently parked are charged, while the truck picks up a swap body with a fully charged battery and completes its next trip. During the trip, the truck charges its own battery from the swap body. The project team is currently working on a prototype for test operation. If the system proves itself, it can offer numerous application options in the field of heavy-duty logistics.



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Traffic Safety and Vehicle Automation

Extremely long vehicles increase efficiency in the transportation sector, but they also require special infrastructure. The steering systems designed at Fraunhofer IVI improve the maneuverability of these vehicles, thus creating better options for operating them.

Automation in transport and agriculture is an upcoming topic. The application of automated solutions in non-public spaces is an important migration path for which the department has developed the helyOS® management concept. helyOS® coordinates driving tasks, allocates resources to them and computes corresponding paths.

Highly automated and autonomous vehicles require completely new standards for safety and proof of safety. For that reason, the department carries out accident analyses and observes the traffic. The insights gained are used as basis for driving and testing scenarios used in the development and approval of functions for automated and autonomous driving.

More information



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Range of Services

- Innovative steering systems for extremely long road vehicles with multiple steered axles
- Control center for autonomous driving in non-public areas
- Fully automated maneuver planning for road-bound transport vehicles
- Analyses, surveys and development work in the field of vehicle and traffic safety
- Traffic psychology – behavior analyses of various groups of traffic participants
- Modeling and testing of driving scenarios with the help of motion platforms
- Implementation concepts for electric buses and fuel cell buses
- Charging infrastructure for bus depots and logistics yards

Energy and Cost-Efficient Freight Transport – AEROFLEX

To achieve a more sustainable mobility, freight transport must also be considered. The solutions created within the AEROFLEX project increase the energy and cost-efficiency, as well as the safety and comfort of trucks.



This project has received funding from the European Union's Horizon2020 research and innovation programme under grant agreement No 769658.

Long-distance freight transport represents a significant proportion of traffic on roads. Hence, it is a necessary factor to consider in the attempts to change mobility and improve the conditions on roads and highways. This, exactly, was the target of the AEROFLEX consortium.

Renowned stakeholders from industry, science and the OEM sector count among the 23 consortium partners. One of their main objectives was the development and implementation of novel technologies and concepts in the field of freight transport. The solutions were to improve the vehicles' cost and energy efficiency, as well as their safety and comfort. In addition, they needed to be flexibly adaptable so as to fulfil the diverse requirements of clients and service providers in the field of intermodal freight transport.

The approaches followed within the project regarded the vehicle as a whole and covered various different subject areas. Some of the many targets were the development of an extended energy management system for a hybrid drive system concept distributed throughout the entire semitrailer, as well as the lowering of air resistance with the help of improved aerodynamics components. In the logistics sector, the creation of so-called Smart Loading Units lead to a 38 percent increase in trailer loading efficiency.

The topic of traffic safety was also addressed. With a view to vulnerable road users, the partners investigated vehicle design options that lower the effects of accidents involving pedestrians as well as bicycle and motorcycle riders.

Fraunhofer IVI researchers supported the project through their expertise in the field of hybrid drivetrains and were the essential contributing partners in the development of an electrified dolly. This dolly helps reduce CO₂ emissions by providing electric drivetrain support and recovering braking energy. In addition, it enables locally emission-free autonomous shunting without a conventional tractor unit.



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Strategy and Optimization

MePol – Modern Communication and Operations Control for the Police

Since 2019, Fraunhofer IVI and Saxony's police administration office (Polizeiverwaltungsamt, PVA) have been developing an innovative messenger service – MePol – for daily use in police operations. After only two years, the technology was transferred to the Saxon police cloud. The service is highly available and scalable, allowing secure and high-performance access to sensitive data.

The department consists of three working groups and offers a wide array of services in the research areas of security, business process analysis, logistics planning and infrastructure management. The interdisciplinary team includes computer scientists, geoscientists as well as mathematicians with both professional expertise and practical knowledge.

Application-oriented research and development projects are focused on decision support for an optimized planning and control of resources. The core competencies of the department comprise the development of novel optimization processes and algorithms as well as the design and implementation of complex systems. In the age of digitalization, it is not only the controllability of data that counts but the creation of data value as a business benefit.

More information



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Range of Services

- Systems for operational and tactical mission control for firefighters, rescue services, emergency services and police
- Analyses and risk assessment in hazard prevention: planning of fire safety requirements and rescue service zones, optimization of site concepts
- Robust distributed systems with analysis tools from data mining, machine learning and natural language processing on the basis of big/smart Data
- Data-driven process optimization using AI methods
- Predictive and prescriptive analyses for decision support systems
- Integrated optimization of production processes and cargo spaces
- Condition-based maintenance planning

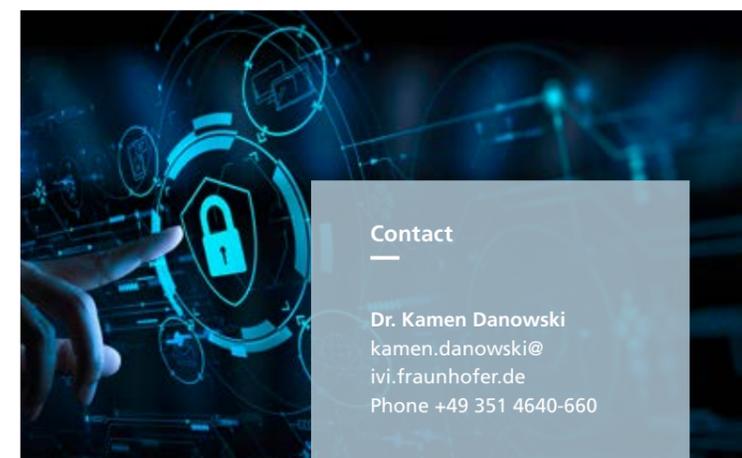
MePol is a comprehensive communication technology for the secure transfer of data-protected police information. It is based on the SE-Netz/EKUS mission control and communication system which was developed at Fraunhofer IVI in collaboration with Saxony's state criminal police office (Landeskriminalamt, LKA). By now established as a nationwide standard, SE-Netz/EKUS was awarded the 2020 Joseph von Fraunhofer Prize.

The key functionalities of MePol include, among others:

- Exchange of mission-specific messages – texts, images, audio, video and files,
- Networked location display – real-time locations of patrol officers and units, marked addresses, objects, lines, areas and others,
- Storage area for digital mission documents,
- Intelligent algorithms for the optimal allocation of personnel and resources,
- Role and rights management, and many more.

So far, more than 4000 smartphones have been equipped with MePol. Police officers use the software in their daily routine work, as well as in large-scale operations. With the PVA Saxony, which is a central authority and service provider for all information and communication needs of the Saxon police force, Fraunhofer IVI has an experienced and competent partner and client at its side.

The technology, which has become indispensable for its end-users, is flexible and contains numerous networked components, including different servers, browsers and mobile apps. »Next to range of functionality, an additional decisive factor for high acceptance levels is good usability. Also, the recommendations and wishes of the people who use the system on a daily basis are taken up and implemented quickly.« – says Jan Hentschel, head of the information and communication department of the PVA Saxony. The system will be improved continuously and shall be available to all police officers in the future. In addition, Saxony's police is seeking to establish the system as a standard all across Germany.



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Connected Mobility and Infrastructure



Data-Protection-Compliant Sensor Systems for Infrastructure

Road side units employed for infrastructure-based detection and protection of traffic participants consist of several sensors, such as different types of cameras, as well as radar and LiDAR systems, an embedded hard drive computer system, and a modem for V2X communications. Data is exchanged in compliance with data protection regulations via the Mobility Data Space.

The Fraunhofer Application Center »Connected Mobility and Infrastructure« at Technische Hochschule Ingolstadt (THI) focuses on current and future topics of automated and cooperative driving. By means of roadside protection systems and high-performance car-2-infrastructure communication, the safety risks of partially and fully automated traffic flows will be reduced, and overall traffic will become more efficient.

In the long term, the exploitation of mobility's third dimension will facilitate the shipping of goods as well as passenger transport. To achieve this, diverse competences in the fields of sensor technology, communications and artificial intelligence are combined, fostering synergies with local industry and promoting close cooperation with the city of Ingolstadt and its partners.

More information



Head of Application Center

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Range of Services

- Testing of connected automated driving within the Digital Testbed Ingolstadt/Bavaria
- Backend and cloud applications for cooperative systems
- Infrastructure sensors and assistance
- Environment perception and maneuver control for autonomous drones
- High-precision locating for indoor and outdoor areas
- AI-based environment perception and driving functions
- V2X communications (ETSI ITS-G5, C-V2X, 5G), C-ITS facilities and applications
- Traffic monitoring, management and control
- Sensor monitoring, malfunction detection as well as sensor re-calibration and control

In several projects of the Fraunhofer Cluster of Excellence Cognitive Internet Technologies (CCIT), the application center collaborates with the Fraunhofer institutes FHR, IIS and IAIS to develop a road side unit (RSU) combining radar technology with an infrared camera. While the radar sensor is weather resilient and determines the locations and speeds of traffic participants, the infrared camera is able to record image data at virtually any time of day.

A major advantage of combined sensors over simple RGB cameras is the fact that no personal data is acquired. Instead, the data is largely anonymous due to the measuring method. This facilitates the RSU's flexible use and simplifies the required data protection concepts. The implementation of algorithms anonymizing image data acquired by RGB cameras is not necessary. Currently, the radar sensor and the infrared camera execute object detection as well as the tracking and classification of traffic participants independently from each other using AI-based methods.

Data from publicly accessible databases as well as from proprietary measuring campaigns are the basis for algorithm training. The EfficientDet neural network architecture is used for the infrared camera. The radar raw data is preprocessed for better classification of cyclists and pedestrians with the help of the Micro-Doppler effect. The fusion of object lists is achieved using a Kalman filter, which improves classification precision.

Through this double data classification, even temporarily hidden traffic participants can be detected, especially in bad weather conditions. At the same time, the overall object classification process becomes more robust because the weaknesses of the individual sensors are compensated.

The next step is data fusion on a raw data level. This means that a multidimensional convolutional neural network is trained using infrared, Micro-Doppler, speed and distance data. The aim is to investigate whether object detection in bad weather conditions can be further improved.



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Strategic Development

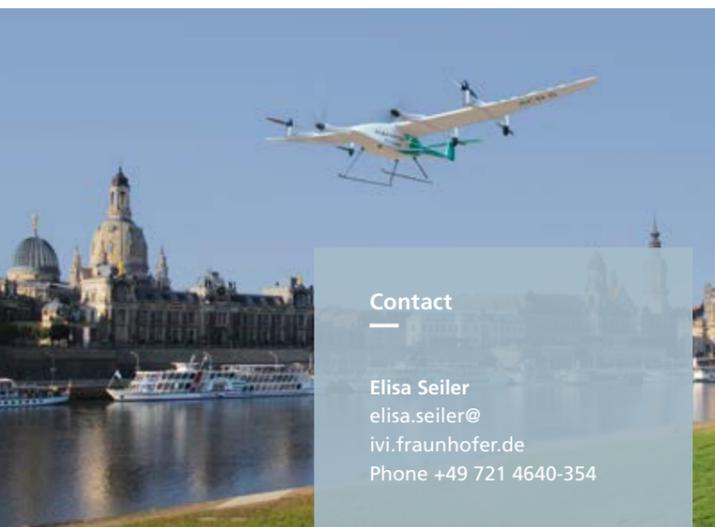
ALBACOPTER® – Flying Like a Bird

Implementing visionary ideas long before their actual market maturity – this often seems inconsistent with the ambition that Fraunhofer institutes set for themselves. They rather intend to have the success of their application-oriented research work measured by the probability of its immediate transfer to industry. On the other hand, visionary imagination provides particularly great motivation in the human pursuit of scientific knowledge.

By introducing the Fraunhofer Lighthouse Projects in the past few years, the Executive Board has launched a well-funded research program that allows Fraunhofer institutes to exploit synergies in joint initial research work, build scientific competencies of outstanding excellence and develop cutting-edge technologies for emerging markets at a very early stage.

One of these research projects kicked off in 2021 is the Fraunhofer ALBACOPTER® Lighthouse Project, in which six institutes led by Fraunhofer IVI are aiming at creating an electrically driven aircraft capable of autonomous flight. This aircraft is supposed to combine the energy efficiency of a gliding albatross with the vertical take-off and landing capabilities of a multicopter.

To a considerable degree, Fraunhofer IVI has derived its economic strength from projects that had been five or ten years ahead of their time. The ALBACOPTER® Lighthouse Project is perfectly aligned with this strategy, combining the positive experience gained in the past with future-oriented collaboration across several institutes. The overall project management, parts of the research and development work, the acquisition of future projects, as well as the transfer and exploitation of results all fall under the responsibility of the »Strategic Development« Working Group, which has been established as an independent sector within the institute.



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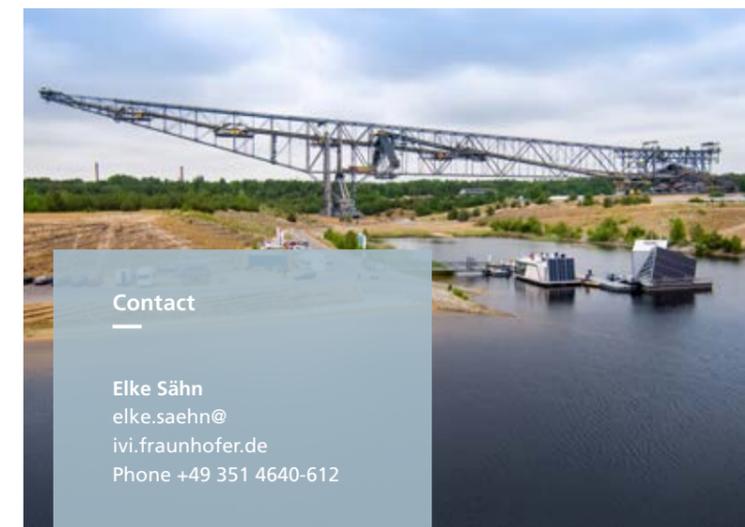
aquaforum – Design Ensemble at Lake Bergheide

For Leonardo DaVinci, combining scientific and aesthetic features in a modern way was an obvious method for achieving success. Primarily known as a painter, sculptor and architect, he was also a skilled musician, and was interested in biology, mechanics and philosophy as well. Unlike any other personality of his time, he embodies the unity of art and science.

Design as an interdisciplinary field that works within technical, ergonomic and creative framework conditions has been gaining importance in the research sector. Project results usually reflect the achieved level of technology readiness. The integration of design processes can improve the users' experience with development results, thus facilitating the transfer to practical application. The Fraunhofer IVI researchers have realized that taking aesthetic and user-centered aspects into account during the acquisition, development and commercialization of new technologies brings great added value, and they take a pioneering role within the Fraunhofer Gesellschaft.

In addition to creating print media, videos and animations – from the idea to the finished product –, the »Science Communication and Design« team is responsible for topics in the field of product and vehicle design, as well as interior and exterior design.

Fraunhofer IVI participated in developing the aquaforum seminar ship powered by solar energy and two electric engines. Together with the floating autartec® house, it forms an ensemble at the foot of the F60 former overburden conveyor bridge in the Lusatian Lake District. In addition to drafting a technical concept for the ship, the institute's task was to emphasize the ensemble's unity. To achieve this, a design aesthetic was developed based on the architecture and interior of the autartec® house that makes both objects appear like a single unit despite their different utilization concepts.



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Identification and Assessment of Factors Influencing Risk Detection for UAS Flights Beyond Visual Line of Sight



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Unmanned Aerial Systems (UAS) are gaining in importance especially for operations beyond visual line of sight (BVLOS). Flights of this kind, however, have higher risks and therefore require pre-flight risk assessment. Within the scope of the Master's thesis, the existing methods were extended and an approach for their future automation was developed.

In order to guarantee safe flight, the SORA (Specific Operations Risk Assessment) risk assessment process assigns UAS operations with a risk category including accompanying measures to be taken. The SORA-GER (Specific Operations Risk Assessment Germany) approach investigated in this thesis has so far been a rather rigid method. It takes into account only a limited number of influence factors and has to be executed manually for all planned UAS flights in BVLOS operations.

To extend potential influence factors within SORA, several data sets, systems and technologies were investigated and – after being divided into ground risks and air risks – attributed to the existing risk categories. Geodata are the most important data to be studied for an assessment of ground risks because they provide information on obstacles, areas in which crowds might potentially gather, and the existence of critical infrastructure. The distinction between settled and unsettled areas to be flown over, combined with further differentiation according to the density of settlement could therefore improve risk assessment.

Using a web-based UAS traffic management system with interfaces to the systems of public authorities, additional dynamic influence factors can be included. This way, temporary and regionally limited safety-critical information can be integrated in the risk assessment process.

The extended SORA approach was applied for two exemplary flights carrying medical blood samples in the Dresden area. With the help of geoinformation software, buffer zones were established around the flight routes. In addition, the layers containing geodata relevant for the ascension of UAS were correlated. The result was a table listing the attributes of all safety-critical objects within the buffered flight route, which provided a first approach towards automation.

The findings presented above were submitted as a Master's thesis to the »Friedrich List« Faculty of Transport and Traffic Sciences at TU Dresden.

With special thanks to Prof. Dr.-Ing. habil. Hartmut Fricke and Dipl.-Ing. Robert Brühl, TU Dresden, Institute of Logistics and Aviation, Vanessa Eidel B. A. and Alexander Tummes, Droniq GmbH Frankfurt/Main, as well as Dr.-Ing. Christian T. Erbsmehl and Dipl.-Ing. Susanne Günther, Fraunhofer IVI Dresden.

Development of a Global Path Planning Tool for Automated Weed Removal via Robot Swarms on Complex Field Geometries



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The use of automated field robots and modern sensor technology in agriculture allows sustainable, plant-specific farming and reduces negative effects on the environment such as soil compression and ground water pollution by fertilizers and pesticides.

The thesis brought forward a global path planning tool for automated weed control in sugar beet farming. This tool was designed to allow the treatment of complete rows of plants on fields with complex geometries. The course of the individual plant rows is calculated from the previously recorded driving maneuvers of the seed drill. With the help of a nearest neighbor classification process, neighboring seed rows can be identified and compiled into reference paths for the field robots according to their weed removal tools' operating width.

During sowing, headland areas are created along the field limits in which the plant rows run orthogonally to those of the main field. As a result, the field consists of several subfields with parallel plant rows. A path network compiled through extrapolating the previously driven tracks allows to visit all subfields consecutively. This way, the robots can work efficiently without damaging the plants. The path network is abstracted into a weighted graph and the Dijkstra algorithm is then applied to determine the shortest transfer route between any desired subfields. Taking into account the field robots' specified initial and final positions, the work sequence and driving direction on the subfields are optimized with the help of a genetic algorithm to minimize the overall driving distance.

Knowing the optimal sequence of subfields and transfer routes, individual paths that in sum cover the entire field are calculated for the robots. To achieve this, the tracks along neighboring plant rows are connected by constructing turnaround paths between them. In the next step, the transfer paths between the subfields are smoothed out under consideration of the vehicles' kinematic models. An optional feature is the scheduling of trips to a mobile charging trailer depending on the field robots' ranges.

First test runs within a simulation environment have already been successful. Within the scope of the Fraunhofer »Cognitive Agriculture« Lighthouse Project, the path planning tool will be tested in practical application.

The results were submitted as a Diploma thesis to the Faculty of Electrical and Computer Engineering at TU Dresden.

With special thanks to Felix Keppler M.Sc., Fraunhofer IVI, as well as Prof. Dr. techn. Klaus Janschek, TU Dresden, Institute of Automation.

Robust Background Estimation for Traffic Monitoring with Cameras Using Singular Value Decomposition



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Autonomous driving is subject to strict safety requirements. A viable option for increasing the coverage and reliability of autonomous traffic participants' sensor systems in spatially restricted areas such as the AutoTruck® and helyOS® fields of application (e.g., ports, factory yards or logistics yards) is to supplement the vehicles' sensors with infrastructure-based solutions. One example of this approach is obstacle detection in the footage of stationary security cameras. The aim of a Diploma thesis was to develop a system module for robust background estimation.

Principal component analysis by singular value decomposition is a well-suited approach for separating frequently occurring shapes of the static background in video footage from the dynamic effects happening in the foreground. Using a sufficiently diversified set of data, this approach makes it possible to train a model that represents the image background under different weather and lighting conditions, thus allowing the estimation of the background images of live camera footage.

To investigate the robustness of the background estimation process under environmental influences, the system was trained using camera data recorded at a large intersection in Dresden, and later evaluated with the help of an appropriate procedure. During the training, the slow movement of shade cast by stationary background objects as well as frequently appearing, similar-looking foreground elements (e.g., dark cars before the stop lines of traffic lights) were identified as critically disruptive factors, among others.

Building on these results, methods for dissolving the previously determined disruptive factors were developed. Extending the background estimation system by a novel dual model structure consisting of a short-term and a long-term model allows the correct incorporation of hard shadow edges into the background estimation process. Interference caused by reappearing foreground elements can be eliminated by applying the robust principal component analysis (RPCA) procedure.

As a final step, the resulting algorithm was validated using footage from the institute's own test track. During the validation process, the targeted improvement of background estimation robustness was observed for the previously identified disruptive situations. The results from the Diploma thesis are used as basis for further research.

The results were submitted as a Diploma thesis to the Faculty of Electrical and Computer Engineering at TU Dresden.

With special thanks to Prof. Dr. techn. Klaus Janschek and Dr.-Ing. Sergey Dyblenko, Institute of Automation, TU Dresden, as well as to Prof. Dr.-Ing. Matthias Klingner, Dr.-Ing. Sebastian Wagner, Dr. Michael Klöppel-Gersdorf and Dipl.-Ing Friedrich Trauzettel, Fraunhofer IVI.

Implementation of a Process for Developing a User Interface for Geodata Processing



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The access to large amounts of geodata creates various opportunities. The steps necessary for processing this data, however, are often very complex. Within this thesis, a graphical user interface was developed that makes the process of creating complex configuration files significantly easier. With its help, different configurations can be visualized, edited and validated.

The Fraunhofer IVI researchers develop, among others, operational command and communication systems, as well as modules for risk evaluation and prevention. One crucial data basis for these systems are geodata from heterogeneous sources. The information available usually presents itself in various formats. To be able to work with them, the geodata needs to be adapted to the data structures and formats used by the Fraunhofer systems through a process tailored to the respective sources.

To this end, a command-line-based geodata management tool was developed in the past. This tool is able to read, process and export all relevant geodata formats. A configuration file written in a defined XML dialect is used to specify the processing procedure for this data. The software tool can read the configuration details and execute the respective conversion steps automatically. However, manually editing a file of this sort takes a lot of time and requires deeper knowledge of its internal structures. Even if the editing person is very experienced, the configuration process is complex and therefore error-prone.

Prior to designing the graphical user interface, several other examples from related subjects were studied in detail and their design concepts evaluated. The solutions investigated include ArcGIS Modelbuilder, QGIS Model Designer, GRASS GIS Graphical Modeler and FME Workbench. As a result of the analysis, general requirements for the configuration software were specified, as well as functionalities for individual implementation. The knowledge gained was compiled in a preliminary design and implemented as a JavaFx demonstrator. The latter is the basis for full implementation, which will be carried out after completion of the thesis. As a result, time will be saved and efficiency will be improved in the creation of different configurations for geodata processing.

This thesis was submitted to the Faculty of Spatial Information at HTW Dresden.

With special thanks to Dipl.-Ing. Ines Schwarzbach, HTW Dresden and Dipl.-Inf. Patrick Brausewetter, Fraunhofer IVI.

Highlights



June 9, 2021 | Meeting of the Advisory Board

Due to the Corona pandemic, the meeting was held as a hybrid event for the first time. In addition to presentations on the state of the Fraunhofer-Gesellschaft and the institute's annual financial statements, the focus was on two current research topics. The first presentation was dedicated to ALBACOPTER®, a Fraunhofer Lighthouse Project dealing with the development of a flying experimental platform, and the second was about the Mobility Data Space, an open data space for the secure exchange of sensitive traffic data that ensures data sovereignty for all parties involved.



June 28, 2021 | Minister of State Prof. Dr. Wöller at Fraunhofer IVI

Saxony's State Minister of the Interior, Prof. Dr. Roland Wöller, visited Fraunhofer IVI together with the President of the State Office of Criminal Investigation, Sonja Penzel, and the President of the Police Administration Office, Dr. Jörg Michaelis. In addition to the State Office of Criminal Investigation, representatives of the fire department, the rescue services and the police attended the event as further partners of the institute and presented current joint developments to improve security in the civilian sector.



August 6, 2021 | Trial Studies TRYING of TU Dresden

Three female students interested in taking up studies in the field of engineering were able to learn about scientific topics of the institute during an excursion to Fraunhofer IVI.

A special highlight were the rides on the test track with an electric bicycle from the »Rad im Fokus« project (Focus on Bikes), which warns of critical traffic situations through its networking with other road users.

September 5-11, 2021 | Fraunhofer Summer Camp

Under the motto »Design & Research vs. Pandemic«, the 2021 summer camp – a creative event with competitive character – was held at the Fraunhofer research campus in Waischenfeld, Bavaria. In addition to an excellent research infrastructure, it offered twelve students and six researchers an inspiring atmosphere in a Franconian picture-book landscape. First place went to a team for developing a garment with built-in sensors for detecting health problems.



September 15, 2021 | Saxon State Minister Dulig Visits the Institute

As part of his annual »Kreativwirtschaftstour« (creative economy tour), Martin Dulig, Minister of the Saxon State Ministry for Economic Affairs, Labor and Transport (SMWA) visited, among others, Fraunhofer IVI. His main interest lay in the Fraunhofer »Science, Art and Design« Network. In his role as speaker of the network's design department, institute director Prof. Dr. Matthias Klingner presented the network along with its activities and programs.



September 23, 2021 | Field Day »LANDNETZ Meets Feldschwarm® – Agriculture of Tomorrow, Experienced Today«

Since 2019, scientists from TU Dresden have been researching new technologies for comprehensive wireless data transmission and networking as part of the LANDNETZ experimental field together with the Saxon State Office for Environment, Agriculture and Geology (LfULG) and Fraunhofer IVI. The consortium organized a field day in Naundorf/Saxony, where they presented new digital applications in agriculture as well as the final results of the BMBF-funded Feldschwarm® project.





September 28, 2021 | Expert Day 2021 »Testing Cooperative Driving Maneuvers«

Numerous guests attended the event in Ingolstadt, hosted by the Application Center »Connected Mobility and Infrastructure« of Fraunhofer IVI and Technische Hochschule Ingolstadt (THI) together with the Research and Test Center for Vehicle Safety CARISSMA, AB Dynamics Europe GmbH and GeneSys GmbH. Experts in the fields of automotive testing and connected driving discussed future innovations by combining the two areas.



September 28, 2021 | AEROFLEX Final Event

In the fall, the final event of the EU-funded AEROFLEX project was held at the ZF Group test track in Jeveresen. More than 80 people experienced live demonstrations of the hybrid drivetrain consisting of towing vehicle, trailer and dolly – an electrically driven chassis with autonomous driving functions. In addition, about 200 guests from all around the world joined the event remotely and followed the presentations via online streaming.



October 4, 2021 | 5G Campus Network Goes Live

The 5G campus network has been put into operation at the Köllitsch Teaching and Research Farm of the Saxon State Office for the Environment, Agriculture and Geology (LfULG).

The new digital infrastructure enables the testing of technologies based on 5G and real-time data transmission. Innovative solutions for communication between humans, machines and sensors can be tested in order to align agricultural processes even more specifically with the needs of plants, animals and the environment.

October 4-8, 2021 | Week for the Promotion of Young Scientists

Fraunhofer IVI, together with MINT-EC (Society of mathematical and scientific excellence centers at schools) organized a talent school. Ten students from all over Germany aged 16 to 18 had qualified as participants in the event by going through a general selection process. Their task was to develop a concept for making mobility safer for children and teens as pedestrians, bikers, and e-scooter drivers. To this end, Fraunhofer IVI experts made them aware of the dangers in road traffic.



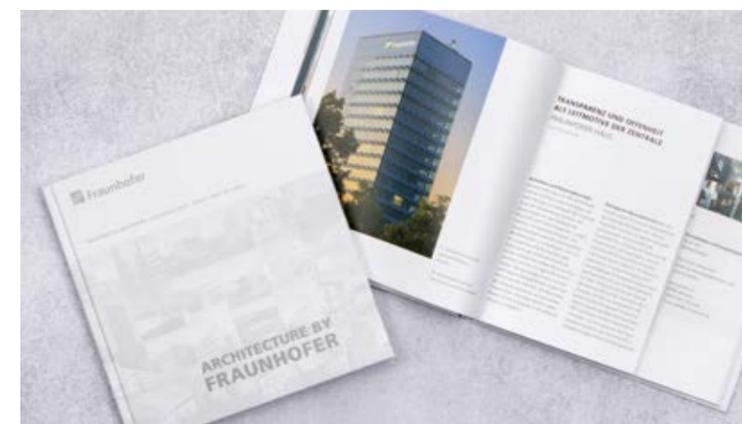
October 11-15, 2021 | Joint Event on Long Buses with Hübner

Under the motto »For your Eyes only«, Hübner GmbH & Co. KG and Fraunhofer IVI invited several European bus manufacturers to Dresden, where they received information on the current status of the joint development of steering control systems for long multi-unit vehicles. In addition to elaborate demonstrations on the test bench and accompanying presentations, there were numerous opportunities for intensive discussion and technical exchange.



November 29, 2021 | Book »Architecture by Fraunhofer« Published

In cooperation with the Fraunhofer institutes and the Headquarter's building department, selected institute buildings were recorded and described in terms of their architectural features. The framework for this was provided by the Design Faculty of Coburg University of Applied Sciences and Arts, who conducted accompanying research on the effect of scientific buildings on human perception. The result is the second volume of a book series dealing with design, architecture and art in the context of research work at Fraunhofer.





Trade Fairs

October 7-9, 2021 | FLORIAN Dresden

At the FLORIAN 2021, the trade fair for Fire Brigades, Civil Protection and Disaster Control in Dresden, Fraunhofer IVI once again presented solutions in the field of civil protection and security. The technologies introduced at the fair effectively support complex strategic and operational-tactical decisions in risk prevention.



Fraunhofer IVI researchers presenting their developments.

September 7-12, 2021 | IAA Mobility Munich

The Fraunhofer Application Center »Connected Mobility and Infrastructure« presented itself at the redesigned IAA Mobility 2021 trade fair. Together with Technische Hochschule Ingolstadt and CARISSMA Research and Test Center, the application center showcased challenges and solutions for the mobility of the future at the joint booth of the Ingolstadt Mobility Region.

Comprehensive and reliable environment perception is one of the key issues of connected automated mobility. Vehicles are increasingly equipped with sensors, which, however, do not realize sufficient observation of traffic in all situations due to poor weather conditions and limited visibility. Equipping the traffic infrastructure with sensors can improve the range and reliability of environment perception. Challenges lie in networking and processing as well as fusing data from different types of sensors.

An automated vehicle and a roadside unit were on display at the booth, each using its sensors to observe the environment and detect trade show visitors. The vehicle and the roadside unit are connected, fuse their data in real time and display it live.

October 11, 2021 | ITS World Congress Hamburg

Fraunhofer IVI is the application institute for the field of mobility in the Fraunhofer Cluster of Excellence Cognitive Internet Technologies CCIT. At the ITS World Congress in Hamburg, the institute presented two current key topics at the Fraunhofer joint booth. In addition to the Mobility Data Space, an open data space that enables the secure exchange and access of real-time traffic data as well as sensitive mobility data and connects existing data platforms with each other, a special focus lay on the Smart Intersection.

For this purpose, a so-called Smart Intersection was installed in Hamburg's city center on the test track for automated and connected driving. The intersection records the movements of road users and processes the information in a trustworthy manner so that partially automated vehicles can safely pass critical areas for accidents. Innovative algorithms are used to protect against the risks of manipulating cognitive functions. Through this, the aspect of critical infrastructure protection measures is comprehensively considered. Thanks to a direct connection, visitors were able to experience how traffic can be controlled in the future with the help of security systems along the road and high-performance Car2Infrastructure communication.



Booth at the ITS World Congress 2021.

November 23-25, 2021 | PMRExp Cologne

Together with the software developer Vivasecur, Fraunhofer IVI participated in the PMRExp. The leading European trade show for secure communication offers international exhibitors and visitors the opportunity to exchange information about the latest technologies in various fields.

At the joint booth, the institute's »Strategy and Optimization« department presented the modular MobiKat® system and showed current trends and solutions centered around the topics of safety and security.

Life at Work and Beyond

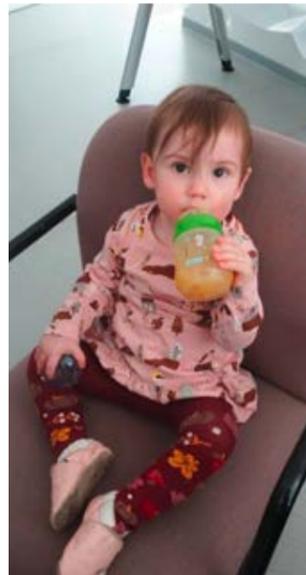
Once again, the Covid pandemic has had a significant impact on everyone's worklife this year. Many planned events had to be cancelled, such as the hiking day appreciated by the whole staff and the annual Christmas meeting. However, all employees of the institute have shown more than impressively how one manages to maintain social contacts during such crazy days and how to develop together as a team despite the distance. Many obstacles, including kindergarten and school closures and even the remoteness of the workplace, were overcome and the year 2021 turned out to be a wonderfully varied and colorful one. The following lines and photos show a small insight into the employees' very personal life at the institute.



Despite the restrictions that have now lasted for almost two years, togetherness at the institute is very important. The small barbecues in the summer not only offered the opportunity to meet and exchange ideas far away from the virtual space, but they were also a good opportunity to get to know new colleagues.«



I have experienced a colorful mix of working from home, office hours, shared lunch breaks in the sun, outdoor meetings, digital and physical business trips, and I am looking forward to spending another day at my »real« desk again tomorrow.«



Whenever I'm taking care of my little Thalia, I at least have company in the Kids Office. Unfortunately, it doesn't help when she cleans out all the trash cans or spreads all the pillows, books, and other toys around the room. And I can take the little one to the cafeteria for lunch.«



As a new employee, I particularly enjoyed the outdoor breaks with the team, as we were able to get to know each other better. Small tokens of appreciation also contributed to making me feel welcome and at ease right from the start.«



I have never been able to soak up as much sun and fresh air as I did in 2021. In the Feldschwarm® project, it was often possible to work outside on my laptop in the summer, which prompted many a counterpart in the Teams meetings to ask whether I was sitting by an outdoor swimming pool with a blurred video image. But it was »only« the stairs behind the technical center.«



Within the FuSi Articulation System project, exciting driving tests were carried out in which the maneuvers performed with conventional articulated city buses put looks of amazement on the drivers' faces. My usual office screen tan was thus definitely passé in the outdoor working year of 2021.«



Announcing construction work is rather unpopular with employees, as it is always accompanied by noise and dirt. Thanks to the new freedom of being able to work on a mobile basis, both spatially and temporally, this problem no longer exists. Colleagues were able to »escape«, and companies had the freedom to build. Small happiness in difficult times.«

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Academic Output

- Publications
- Teaching Engagements
- Final Theses
- Public Body Membership
- Patents
- Certificates
- Trademarks



Publications

Articles and Presentations

Agrawal, S.; Elger, G.: **Concept of Infrastructure Based Environment Perception for IN2Lab Test Field for Automated Driving**. IEEE International Smart Cities Conference ISC2, virtual event, September 7-10, 2021, presentation: S. Agrawal
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In: Proceedings. ADAC Stiftung; Hochschule Kempten (eds.), Göttingen, Cuvillier Verlag, 2021, p. 185-200, ISBN: 978-3-7369-6445-7

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Otto, T.: **Smart Intersection Approach for Automated-Assisted Driving**. 27th ITS World Congress, Hamburg, October 11-15, 2021

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Otto, T.; Partzsch, I.; Klöppe-Gersdorf, M.; Zimmermann, A.; Purschwitz, A.: **C-ITS Service »Traffic Signal Priority« via ETSI G5 (CAM and SREM/SSEM)**. 27th ITS World Congress, Hamburg, October 11-15, 2021, presentation: T. Otto

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Schmid, M.; Bhogaraju, S. K.; Elger, G.: **Characterization of Copper Sintered Interconnects by Transient Thermal Analysis**. 15th International Conference on Electronics Packaging ICEP, Tokyo, Japan, Mai 12-14, 2021, presentation: M. Schmid
In: *Proceedings. Piscataway, NJ, USA, IEEE*, p. 71-72, ISBN: 978-4-9911-9111-4, DOI: 10.23919/ICEP51988.2021.9451966

Schmid, M.; Elger, G.: **Reliability of SAC+ Solders for LED Packages**. 27th IEEE International Workshop on Thermal Investigations of ICs and Systems, virtual event, September 23, 2021, presentation: G. Elger
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Senel, N.; Udupa, S.; Elger, G.: **Sensor Data Preprocessing in Road-Side Sensor Units**. 38th FISITA World Congress, virtual event, September 14-16, 2021, presentation: N. Senel

Sfetos, A.; Giroud, F.; Clemencau, A.; Varela, V.; Freissinet, C.; LeCroart, J.; Vlachogiannis, D.; Politi, N.; Karozis, S.; Gkotsis, I.; Eftychidis, G.; Hedel, R.; Hahmann, S.: **Assessing the Effects of Forest Fires on Interconnected Critical Infrastructures under Climate Change. Evidence from South France**.

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Song, R.; Festag, A.: **Analysis of Existing Approaches for Information Sharing in Cooperative Intelligent Transport Systems – SENSORIS and V2X Messaging**. 38th FISITA World Congress, virtual event, September 14-16, 2021, presentation: R. Song

Strauzenberg, N.; Erbsmehl, C. T.; Pohle, M.: **Fraunhofer Accident Prevention School (FAPS)**. 10. Jahrestagung GMTTB, hybrid event, Konstanz, October 21-22, 2021, presentation: N. Strauzenberg

Streck, E.; Schmok, P.; Schneider, K.; Erdogan, H.; Elger, G.: **Safeguarding Future Autonomous Traffic by Infrastructure Based on Multi Radar Sensor Systems**. 38th FISITA World Congress, virtual event, September 14-16, 2021, presentation: E. Streck

Tavakolibasti, M.; Meszmer, P.; Böttger, G.; Kettelgerdes, M.; Elger, G.; Erdogan, H.; Seshaditya, A.; Wunderle, B.: **Thermo-Mechanical-Optical Coupling within a Digital Twin Development for Automotive LiDAR**. 22nd International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems (EuroSimE), virtual event, April 19-21, 2021, presentation: M. Tavakolibasti
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Theissler, A.; Pérez-Velázquez, J.; Kettelgerdes, M.; Elger, G.: **Predictive Maintenance Enabled by Machine Learning: Use Cases and Challenges in the Automotive Industry**.

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In: *Proceedings. Piscataway, NJ, USA, IEEE*, p. 1049-1056, ISBN: 978-1-7281-9142-3, DOI: 10.1109/ITSC48978.2021.9564783

Wagner, H.; Gründel, T.: **3. PKM-Praxistreffen**. Virtual event, May 5, 2021, presentation: H. Wagner, T. Gründel

Wagner, H.; Gründel, T.: **PKM News**. 69. Kontiki-Konferenz »Mobilitätsplattformen – Hype, Geschäftsmodell oder Beitrag zur Verkehrswende?«, virtual event, June 10-11, 2021, presentation: H. Wagner, T. Gründel

Wittig, H.; Engasser, J.; Glavinic, A.: **AEROFLEX – Distributed Hybrid Drivetrain for Long Haul Freight Vehicles**. 7th International VDI Conference Drivetrain Solutions for Commercial Vehicles, hybrid event, Bonn, October 13-14, 2021, presentation: H. Wittig
In: *21st Dritev / 7th International VDI Conference Drivetrain Solutions for Commercial Vehicles*. VDI Wissensforum, Düsseldorf, VDI Verlag, 2021, *VDI-Berichte 2381*, p. 593-607, ISBN 9783180923819

Teaching Engagements

Bartholomäus, Ralf

Optimale Steuerung kontinuierlicher Prozesse. TU Dresden, Faculty of Electrical and Computer Engineering, Institute of Control Theory, SS 2021

Robuste Regelung. TU Dresden, Faculty of Electrical and Computer Engineering, Institute of Control Theory, SS 2021

Vernetzte Energiespeicher. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, SS 2021

Elger, Gordon

Elektronische Bauelemente. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2020/21, WS 2021/22

Computer Aided Engineering. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, SS 2021

CAE für die Elektrotechnik. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2021/22

Electronics, Measurement and Systems. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, SS 2021

Festag, Andreas

Kommunikationssysteme. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, SS 2021

Projektmanagement. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2020/21

car2X-Kommunikation. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2020/21, WS 2021/22

Einführung in die Car2X-Kommunikation. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2021/22

Software-Entwicklung für sicherheitskritische Systeme. TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2020/21, WS 2021/22

Group project (Master Program Automatisiertes Fahren, International Automotive Engineering). TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2020/21, WS 2021/22

V2X Services (Master of Applied Research). TH Ingolstadt, Faculty of Electrical Engineering and Information Technology, WS 2021/22

Kertzscher, Jana

Berechnung elektrischer Maschinen. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, SS 2021

Einführung in die Elektrotechnik. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2020/21, WS 2021/22

Elektrische Energiewandler. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, SS 2021

Elektrische Maschinen und Antriebe. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2020/21

Elektrische Maschinen. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2021/22

Einführung in die Elektromobilität. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2020/21, WS 2021/22

Energietechnik. (Lecture series) TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2020/21

Grundlagen der Elektrotechnik. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, SS 2021

Elektrische Antriebe I. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, SS 2021

Theorie elektrischer Maschinen. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2020/21, WS 2021/22

Klingner, Matthias

Elektroenergiesysteme. TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, SS 2021

Systemtheorie in der Anwendung. (Block event) TU Freiberg, Faculty of Mechanical, Process and Energy Engineering, Institute of Electrical Engineering, WS 2020/21, WS 2021/22

Knote, Thoralf

Straßenverkehrstechnik. TU Dresden, »Friedrich List« Faculty of Transport and Traffic Sciences, Institute of Transport Planning and Road Traffic, WS 2020/21, WS 2021/22

Fahrzeugsicherheit automatisierter Fahrzeuge. TU Dresden, »Friedrich List« Faculty of Transport and Traffic Sciences, Institute of Transport Planning and Road Traffic, SS 2021

Rauschert, André

Ideen-, Innovations- und Change Management. Gründungsmanagement. HS Mittweida (FH), Faculty Industrial Engineering/Media Faculty, WS 2020/21, SS 2021, WS 2021/22

Final Theses

Doctoral Candidates

Keiner, Jan

Experimental investigation and modeling of the thermal behavior of intelligent battery cells and modules under electric vehicle conditions. TU Berlin

Diploma Students

Dunkelberg, Nils

Efficient Multi-Robot Path Planning for Autonomous Weed Control on Complex Field Configurations. TU Dresden

Friedemann, Max

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Public Body Membership and Patents

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– JUG Saxony e.V.

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– SafeTRANS e.V.

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– ETSI European Telecommunications Standards Institute

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– »Dresden – Stadt der Wissenschaften« Network
– Exzellenzstiftung Ingolstädter Wissenschaft – Ignaz Kögler
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– Fraunhofer Network »Science, Art and Design«
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Otto, Thomas

– Road and Transportation Research Association (FGSV), Working Group 3.2.1 »Sensor fusion and artificial intelligence for situation/event detection and prognosis«

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– Fraunhofer Big Data and Artificial Intelligence Alliance
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