



FRAUNHOFER INSTITUTE FOR COGNITIVE SYSTEMS IKS

**ANNUAL REPORT**  
2018 / 2019

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# FOREWORD

## Fraunhofer Institute for Cognitive Systems IKS

Fraunhofer ESK has embarked on an exciting new path to the future. On December 1, 2019, the institute officially transitioned to the Fraunhofer Institute for Cognitive Systems IKS. This realignment represents much more than a new name. By refocusing our research activities on software engineering for cognitive systems, we have charted a course for a successful future.

The term cognitive systems refers to machines and equipment that control technical processes by means of learning algorithms, thus opening up completely new opportunities. The applications range from autonomous driving, to Industry 4.0. Given that artificial intelligence (AI) plays a key role in these applications, the central focus of our research activities is making AI safe and at the same time, dependable. The key term here is "Safe Intelligence," which always assumes the capability to react efficiently. It's within these three interconnected issues of safety, dependability and cost that we carry out our research activities as the Fraunhofer Institute for Cognitive Systems IKS.

We are thus on the verge of a new path to a field of research that is highly relevant in today's environment, as well in the future. And we can build on the core expertise of Fraunhofer ESK in the process. Cognitive systems are complex software platforms that encompass aspects such as software architectures, quality assurance and communication mechanisms, which are used to realize connected systems. All of these aspects represent the core expertise of Fraunhofer ESK, which we will expand, enhance and complement with new expertise from the field of artificial intelligence. This combination of software engineering and AI know-how is what makes it possible to realize cognitive systems in the first place.

All of this will require that we build a solid research, organizational and human resources foundation while constantly keeping our eye on the requirements of the market. We will strive to grow quickly and within five years develop into a large institute with 200 employees that will play a correspondingly key role, not only within the Fraunhofer-Gesellschaft, but in Munich and Bavaria.

Discussions are already underway with industry regarding the realignment of the institute. In 2020 we will begin to work with our partners to make a direct and strong transition and ensure a more rapid transfer of AI technologies and cognitive systems from research to industry, thus moving both Bavaria and Germany forward while reinforcing their competitive edge.

This is all based on the prerequisite that our staff is prepared to become an active participant in this interesting but challenging journey. The Fraunhofer Institute for Cognitive Systems IKS boasts a great team of dedicated and highly-qualified employees. Our heartfelt thanks go out to each and every one for their contribution.



*Mario Trapp*

Executive Director



*Rudi Krieger*

Director

# SAFE INTELLIGENCE

# SAFE INTELLIGENCE

## Range of services

Fraunhofer IKS creates intelligent software that makes our lives not only easier, but dependable and safe. To do that, we continually develop software engineering systems for tomorrow's technologies. Despite uncertainties and unpredictable situations, the systems of the future must be agile, fault tolerant and

available at all times. At our institute, safe intelligence means being able to utilize intelligent software functions in products in a safe and dependable manner, and with a development effort that safeguards our industry partners' competitive edge.

### SAFE AUTONOMOUS SYSTEMS

AI-based autonomous systems are susceptible to sporadic errors. Poor weather conditions or unlearned situations can have serious consequences. For this reason, Fraunhofer IKS researches and develops methods for the automated validation of artificial intelligence (AI) technologies and autonomous systems. The goal is to develop the capability to switch to a safe functions path at any time without having to stop or shut down the system, even when expected or unexpected changes occur. Fraunhofer IKS thus develops methods that adequately validate application scenarios in production or logistics environments, materials testing or to support perception monitoring in autonomous vehicles. Our approaches include the intelligent cross-validation of existing sensors to ensure dependable environment models, an assistant for systematically analyzing the safety of AI applications and quality metrics for evaluating the probability of errors in specific AI implementations. These represent important building blocks for the creation of AI safety architectures, and ultimately for the ability to certify AI applications.

### ADAPTIVE AND FLEXIBLE SOFTWARE ARCHITECTURES

For autonomous systems, the ability to adapt to the local environment and current conditions is becoming increasingly important. Our dynamic approaches to adaptive safety management offer more leeway when managing risk, thus making the utilization of unsafe AI methods consistent with guaranteed adherence to safety targets. Adaptive E/E architectures for autonomous driving, as well as highly-resilient Industry 4.0 systems, require not only fault-tolerant embedded platforms, but also adaptive software architectures. In critical situations, or when interruptions occur, these architectures cannot be allowed to simply shut down. Instead, they must safely and dependably maintain the functions. Dependable service-oriented architectures (SoA) for embedded systems enable the necessary flexibility, so that functions can be decoupled from the runtime environment and allocated without violating functional safety requirements. If connectivity is in place, such dynamic functions can be periodically shifted to edge, fog or cloud networks.

### DEPENDABLE CONNECTED SYSTEMS

Dynamic behaviors and quality fluctuations must be taken into account as early as the development phase when numerous individual systems interact within a connected system. At the same time, systems can also collectively enable higher-value functions that must be consistently dependable. In other words, the application must adapt while adhering to all relevant requirements, such as time limits. With this in mind, we research and develop methods for designing dependable end-to-end architectures, as well as comprehensive fail-operational concepts. This allows us to enable the dependable utilization of external services from edge, fog or cloud networks, such as for the dependable control of mixed-criticality applications.

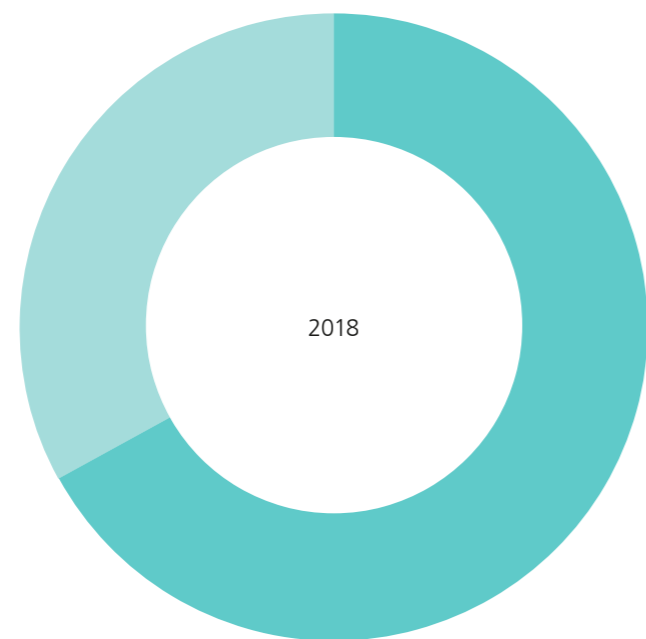
From  
Fraunhofer ESK  
to Fraunhofer IKS.

## FRAUNHOFER IKS PROFILE

# FACTS & FIGURES

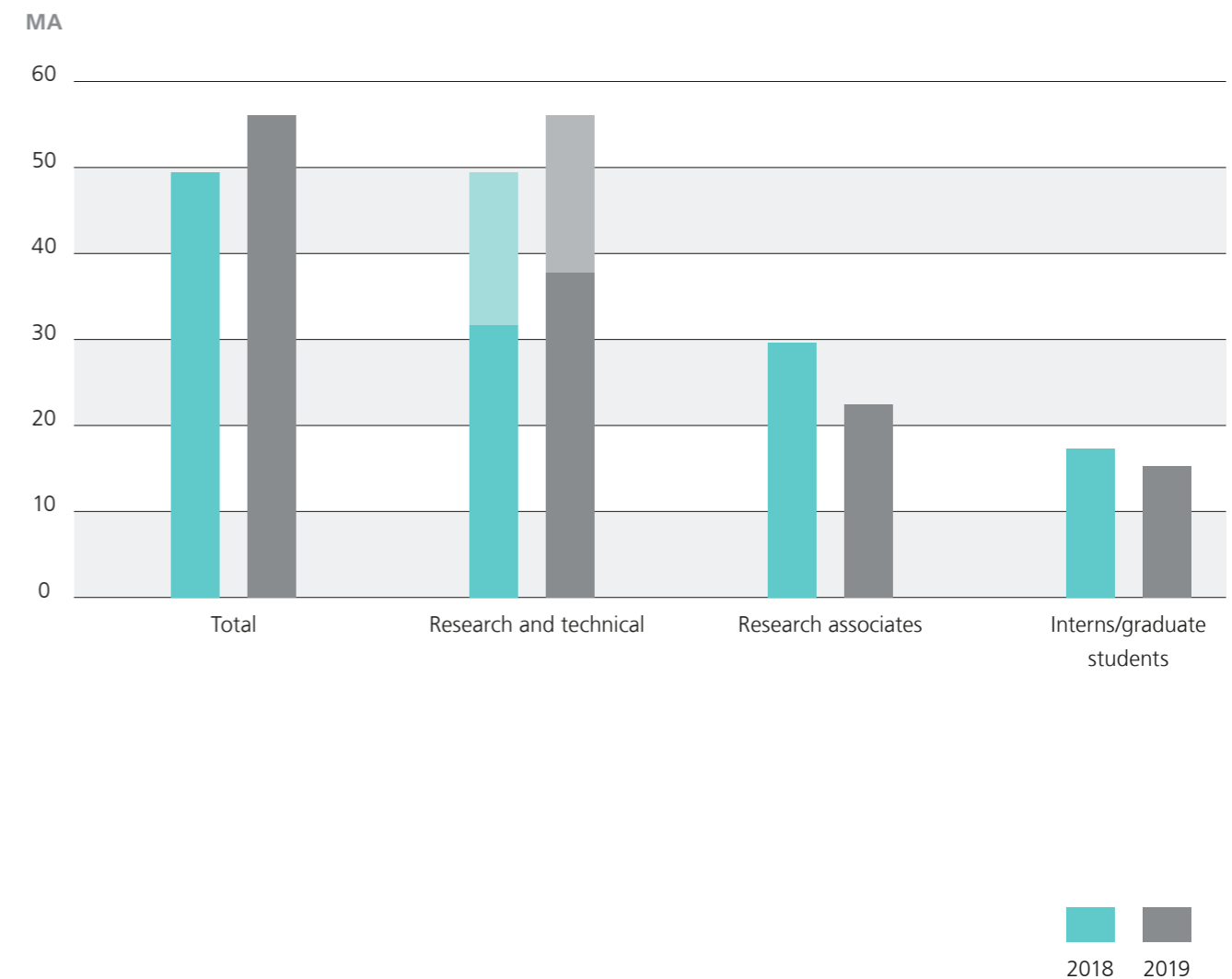
## Total operating budget

In 2018, the total operating budget for Fraunhofer ESK was approximately 5.8 million euros (2017: 5.5 million), of which 3.9 million euros (2017: 3.8 million) was related to personnel expenditures and 1.9 million euros (2017: 1.6 million) to non-personnel expenditures. Research revenues from industrial contracts reached 1.4 million euros in 2018 (2017: 1.1 million), representing 24.2 percent of the total budget.



## Personnel

On August 31, 2019, Fraunhofer ESK employed a staff of 55 (2018\*: 49), of which 37 were active in the research and technical area (2018: 31). These qualified scientists and engineers were supported by a staff of 22 research assistants (2018:29). Over the course of the year, 15 university students worked at the institute acquiring know-how and transferring their knowledge into scientific activities.



\* As of December 31, 2018

# PATENTS

## Patents at a glance

### PATENT FILINGS:

- Nitsche, T.; Roscher, K.: A method to classify a neighbor in an ad-hoc network, a classification device, a vehicle comprising a classification device and a computer program (EP)
- Roscher, K.: Method, apparatus and computer program for routing data packet (EP)
- Methods for estimating the current quality of a communications channel and for predicting the future quality of a communications channel

### REGISTERED PATENTS:

- Bittl, S.: Safeguarding of data exchange (EP)
- Chen, Y.; Hussmann, C.: Method, device and computer program for determining the probability that a received signal was modulated with a tested modulation method
- Chen, Y.: Device and method for identifying a modulation method for a symbol transmitted via a selected subcarrier
- Manderscheid, M; Eilers, D.: State-based planning and validation of resources
- Eilers, D.; Weiß, G.: Device for creating a marked reference data stream (EP)

One patent was filed in 2018.

# COOPERATION GROUPS

## Well-connected

The research activities of the Fraunhofer-Gesellschaft are conducted by 72 institutes and research units at locations throughout Germany. Institutes with a similar technical focus are organized within research alliances and operate jointly in the research and development market. The Fraunhofer Institute for Cognitive Systems IKS actively participates in the Information and Communication Technology Alliance, as well as the Microelectronics Alliance.

At the ENARIS® Think Lab (ENgineering and Architectures for Resilient Intelligent embedded Systems), the Fraunhofer Institute for Cognitive Systems IKS works closely together with Fraunhofer IESE based in Kaiserslautern, Germany. The Think Lab's research activities are focused on the field of resilient intelligence.

The Fraunhofer Institute for Cognitive Systems IKS also actively participates in technology and industry committees outside of the Fraunhofer-Gesellschaft.

## Groups, Committees, Alliances

- 5G Alliance for Connected Industries and Automation
- 5G Automotive Association
- aitiRaum Augsburg
- ASQF e. V. – Working Group for Software Quality and Training/Education
- AUTOSAR
- BICCnet
- Bitkom e. V.
- CAR2CAR Communication Consortium
- CAST e. V. – Competence Center for Applied Security Technology
- Mechatronics & Automation Cluster
- EAST-ADL Association
- ETSI – European Telecommunications Standards Institute
- Fraunhofer Information and Communication Alliance
- Fraunhofer Microelectronics Alliance
- German Society of Informatics e. V.
- IEEE – Institute of Electrical and Electronics Engineers
- IEEE 802.1 Drafts
- ITG Group 5.2.5 Access and Home Networks
- ITS Bavaria – Gesellschaft für Verkehrstelematik Bayern
- ITS mobility e. V.
- OpenAirInterface Software Alliance
- Open Alliance Special Interest Group
- Round Table: “Autonomous Driving” - Federal Ministry of Transport and Digital Infrastructure (BMVI)
- VDA Automotive Engineering Standards Committee – Working Group for Functional Safety, Software and Processes
- VDE – Association of Electrical, Electronic & Information Technologies
- VDI – Association of German Engineers
- VDI - Association of Vehicle and Transportation Engineering
- ZD.B – Bavarian Center for Digitalization: Working Group for Digital Production Platforms

VISION

**LIVING  
IN A DEPENDABLE  
WORLD**

MISSION

**DEPENDABLE  
SOFTWARE TECHNOLOGIES  
FOR PEOPLE**



# PUBLICATIONS

## Selection of scientific publications and lectures/ presentations

Bittl, Sebastian ; Seydel, Dominique ; Pfeiffer, Jakob ; Jiru, Josef:

### **Evaluation Methodology for Cooperative ADAS Utilizing Simulation and Experiments.**

In: Smart Cities, Green Technologies, and Intelligent Transport Systems : 6th International Conference, SMARTGREENS 2017, and Third International Conference, VEHITS 2017, Porto, Portugal, April 22-24, 2017, Revised Selected Papers Cham: Springer International Publishing, 2019, S.333-353  
DOI: 10.1007/978-3-030-02907-4\_17

Drabek, Christian ; Weiß, Gereon ; Bauer, Bernhard:

### **Resumption of Runtime Verification Monitors: Method, Approach and Application.**

In: International Journal on Advances in Software 11 (2018), Nr.1&2, S.18-33  
<http://publica.fraunhofer.de/documents/N-503842.html>

Fanucchi, Dario ; Staehle, Barbara ; Knorr, Rudi:

### **Network Formation for Industrial IoT: Evaluation, Limits and Recommendations.**

In: IEEE 23rd International Conference on Emerging Technologies and Factory Automation, ETFA 2018. Proceedings : Politecnico di Torino, Torino, Italy, 04-07 September 2018 Piscataway, NJ: IEEE, 2018, S.227-234  
<http://publica.fraunhofer.de/documents/N-531398.html>  
DOI: 10.1109/ETFA.2018.8502509

Franze, Juliane ; Seydel, Dominique ; Weiß, Gereon ; Haspel, Ulrich:

### **Evaluation of Traffic Control Systems as ITS Infrastructure for Automated Driving.**

In: Intelligent Transport Systems. From research and development to the market uptake : First International Conference, INTSYS 2017, Hyvinkää, Finland, November 29-30, 2017, Proceedings Cham: Springer International Publishing, 2018, S.205-214  
DOI: 10.1007/978-3-319-93710-6\_22

Fröhlich, Georg ; Stiller, Michael ; Shekhada, Dhavalkumar ; Morgade, Javier:

### **Resource-adaptive mobile assistance system for complex agriculture machines**

In: Informatics in agriculture, forestry and food industries. Focus: Digitalization for agricultural operations in small-structured regions – a paradox? Referate der 39. GIL-Jahrestagung, February 18-19, 2019, Wien Bonn: Köllen, 2019, S.59-64  
<http://publica.fraunhofer.de/documents/N-541131.html>

Gschwend, Tobias ; Preisinger, Markus ; Schelter, Christian ; Haller, Gabriele ; Trägler, Thomas ; Rodler, Rainer:**Requirements for IT-/OT safety when planning and operating Industry 4.0 systems**

Garching : Sicherheitsnetzwerk München, 2019  
<http://publica.fraunhofer.de/documents/N-552076.html>

Heinrich, Patrick:

### **Adaptive, connected embedded systems: modeling energy consumption**

München : Verlag Dr. Hut, 2018  
(Zugl.: Augsburg, Univ., Dissertation, 2018)

Henne, Maximilian ; Schwaiger, Adrian ; Weiß, Gereon:

### **Managing Uncertainty of AI-based Perception for Autonomous Systems.**

In: Workshop on Artificial Intelligence Safety, AISafety 2019. Proceedings : Co-located with the 28th International Joint Conference on Artificial Intelligence, IJCAI 2019; Macao, China, August 11-12, 2019  
CEUR, 2019, S.57-60  
<http://publica.fraunhofer.de/documents/N-555261.html>

Hincapie, Daniel ; Saad, Ahmad ; Jiru, Josef:

### **Collaborative and Distributed QoS Monitoring and Prediction: A Heterogeneous Link Layer Concept towards always Resilient V2X Communication.**

In: VEHITS 2019, Proceedings of the 5th International Conference on Vehicle Technology and Intelligent Transport Systems : May 3-5, 2019, Heraklion, Crete, Greece Setubal: SciTePress, 2019, S.601-608  
URL: <http://publica.fraunhofer.de/documents/N-555477.html>  
DOI: 10.5220/0007801706010608

Hincapie, Daniel ; Leibiger, Mathias ; Oswald, Erik:

### **Roll-out of Giga-bit Copper : Impact-Analysis of Deploying G.fast in FTTC Access Networks.**

In: Providing broadband in Germany: 12. ITG Conference, April 18-19, 2018, Berlin: VDE Verlag, 2018, 6 S.

Langmann, Reinhard ; Stiller, Michael:

### **Cloud-Based Industrial Control Services : The Next Generation PLC.**

In: Online Engineering & Internet of Things : Proceedings of the 14th International Conference on Remote Engineering and Virtual Instrumentation, REV 2017, held 15-17 March 2017, Columbia University, New York, USA Cham: Springer International Publishing, 2018, S.3-18  
DOI: 10.1007/978-3-319-64352-6\_1

Langmann, Reinhard; Stiller, Michael:

### **The PLC as a Smart Service in Industry 4.0 Production Systems.**

In: Applied Sciences (2019), Nr.18, art.nr.3815  
DOI: 10.3390/app9183815

Lefèvre, Gert ; Wieland, Thomas ; Steffens, Petra:

### **Digital transformation in the county of Bergstraße**

In: The County 89 (2019), Nr.5, S.266-267

Manderscheid, Martin:

### **Performance verification of network architectures in embedded systems from the point of view of runtime variability.**

München : Verlag Dr. Hut, 2018  
(Zugl.: Augsburg, Univ., Dissertation, 2018)

Manderscheid, Martin ; Weiß, Gereon ; Knorr, Rudi:

### **Verification of Network End-to-end Latencies for Adaptive Ethernet-based Cyber-physical Systems.**

In: Journal of systems architecture 88 (2018), S.23-32  
<http://publica.fraunhofer.de/documents/N-512721.html>  
DOI: 10.1016/j.sysarc.2018.05.004

Mejía Rodriguez, Catalina:

**Design and Evaluation of Hybrid Communication Systems for Cooperative Driving Based on Reinforcement Learning.**

Presentation at 52. Meeting of VDE/ITG Working Group 5.2.4 on the topic of vehicle communications, March 15, 2018, Herzogenrath  
<http://publica.fraunhofer.de/documents/N-534522.html>

Oleinichenko, Oleg ; Sevilmis, Yagmur ; Roscher, Karsten ; Jiru, Josef:

**Time-Controlled Neighborhood-driven Policy-based Network Selection Algorithm for Message Dissemination in Hybrid Vehicular Networks.**

In: VEHITS 2018, 4th International Conference on Vehicle Technology and Intelligent Transport Systems. Proceedings : Funchal, Madeira, Portugal, 16-18 March 2018  
 SciTePress, 2018, S.141-155  
 URL: <http://publica.fraunhofer.de/documents/N-494024.html>  
 DOI: 10.5220/0006705901410155

Petreska, Neda ; Al-Zubaidy, Hussein ; Knorr, Rudi ; Gross, James:

**Bound-based power optimization for multi-hop heterogeneous wireless industrial networks under statistical delay constraints.**

In: Computer Networks 148 (2019), S.262-279  
 DOI: 10.1016/j.comnet.2018.09.009

Petreska, Neda:

**Performance Analysis of Wireless Industrial Networks - Challenges and Trends.**

ETAI 2018 Conference, September 20-22, 2018, Struga, Macedonia  
<http://publica.fraunhofer.de/documents/N-519663.html>

Pöcheim, Simon:

**Decentral Runtime Adaptation for Fault Tolerance in Distributed Industrial Systems.**

(München, TU, master's thesis, 2019)

Pöhn, Daniela ; Wessel, Sascha ; Fischer, Felix ; Braunsdorf, Oliver ; Wenninger, Franz ; Seydel, Dominique ; Weiß, Gereon ; Roscher, Karsten:

**A Rapid Innovation Framework for Connected Mobility Applications : High Performance Center Connected Secure Systems. Fraunhofer AISEC, EMFT & ESK.**

München : Fraunhofer ESK, 2018  
<http://publica.fraunhofer.de/documents/N-487489.html>

Qi, Xiaoting:

**Performance Enhancement Using Sensor Data Fusion for an Indoor Localization System Based on Ultra-wideband.**

(München, TU, master's thesis, 2018)

Saad, Ahmad:

**On Coexistence of Wireless Systems in Unlicensed Bands Using Cognitive Medium Access.**

München : Verlag Dr. Hut, 2019  
 (Zugl.: Augsburg, Univ., Dissertation, 2019)

Saad, Ahmad ; Staehle, Barbara ; Knorr, Rudi:

**Predictive Medium Access Control for Industrial Cognitive Radio.**

In: 15th IEEE Annual Consumer Communications & Networking Conference, CCNC 2018 : 12-15 January 2018 in Las Vegas, NV, USA; Proceedings  
 Piscataway, NJ: IEEE, 2018  
 DOI: 10.1109/CCNC.2018.8319193

Saad, Ahmad ; Schepker, Henning F. ; Staehle, Barbara ; Knorr, Rudi:

**Whitespace Prediction Using Hidden Markov Model Based Maximum Likelihood Classification.**

In: IEEE 89th Vehicular Technology Conference, VTC-Spring 2019. Proceedings : Kuala Lumpur, Malaysia, 28 April-1 May 2019  
 Piscataway, NJ: IEEE, 2019  
 DOI: 10.1109/VTCSpring.2019.8746327

Salvi, Aniket:

**Semi-automated Unsupervised Learning from System Traces.**

VDI Presentation Evening „Artificial Intelligence in Automation Technology“, October 15, 2018, Fraunhofer Institute for Embedded Systems and Communication Technology ESK, München.  
<http://publica.fraunhofer.de/documents/N-531706.html>

Schelter, Christian:

**Transfer to Industry 4.0 interface using two industrial application examples.**

In: Automation 2018. 19 : Seamless Convergence of Automation & It; July 3-4, 2018, Baden-Baden  
 Düsseldorf: VDI-Verlag, 2018, S.225-234  
<http://publica.fraunhofer.de/documents/N-506689.html>

Schepker, Henning ; Saad, Ahmad:

**Accurate QoS Prediction for CSMA/CA Systems with Uncorrelated Interference.**

In: IEEE 90th Vehicular Technology Conference, VTC-Fall 2019. Proceedings : Honolulu, Hawaii, 22-25 September 2019  
 Piscataway, NJ: IEEE, 2019  
 DOI: 10.1109/VTCFall.2019.8891184

Seydel, Dominique ; Weiß, Gereon:

**Rapid Innovation Toolkit for the Development of Dependable Cooperative Applications.**

In: Forum Safety & Security 2018. Proceedings : 12.-13. September 2018, Sindelfingen  
 Kissing: WEKA Fachmedien, 2018  
<http://publica.fraunhofer.de/documents/N-515205.html>

Seydel, Dominique ; Weiß, Gereon ; Pöhn, Daniela ; Wessel, Sascha ; Wenninger, Franz:

**Safety & Security Testing of Cooperative Automotive Systems.**

In: Embedded world 2018 Exhibition and Conference. Proceedings : ...it's a smarter world; 27 February - 1 March 2018, Nuremberg, Germany  
 Haar: WEKA Fachmedien, 2018  
<http://publica.fraunhofer.de/documents/N-497369.html>

Shekhada, Dhavalkumar ; Stiller, Michael ; Salvi, Aniket:  
**A Comparison of Current Web Protocols for Usage in Cloud Based Automation Systems.**  
 In: Communications and Image Processing in Automation: Selected contributions from the KommA and BVAu 2016 anniversary of the inIT Institute for Industrial Information Technology  
 Berlin: Springer Vieweg, 2018, S.54-72  
 DOI: 10.1007/978-3-662-55232-2\_5

Steffens, Petra:  
**Less red tape through rules-based software architectures: Findings from the p23R pilot projects and their implications for the diffusion of a rules-based E-government infrastructure.**  
 Baden-Baden : Nomos Verlagsgesellschaft, 2019  
 (Zugl.: Berlin, TU, Dissertation, 2017)

Stiller, Michael:  
**Industrial cloud services. From current services to future solutions with the Industry 4.0 interface.**  
 Smart Automation Workshop. Cloud-based control services and applications, January 11, 2018 at Fraunhofer ESK, München.  
<http://publica.fraunhofer.de/documents/N-512724.html>

Stiller, Michael:  
**Keeping robots in line: real-time analysis and monitoring for ROS.**  
 Automatica 2018, June 198, 2018, München <http://publica.fraunhofer.de/documents/N-507015.html>

Stiller, Michael ; Salvi, Aniket:  
**Error-free ROS applications with DANA**  
 In: SPS-Magazin (2018), Nr.3, S.22-24

Stiller, Michael:  
**Why use mobile edge computing at the edge of the field? An introduction to the INVIA project.**  
 VDI seminar, agriculture technology, mobile edge computing for teleservices in agriculture, Julyx 18, 2019, Weihenstephan  
<http://publica.fraunhofer.de/dokumente/N-561678.html>

Sunkum Rammurthy, Abhishek:  
**Experimental evaluation of statistical delay bound for IEEE 802.15.4 TSCH networks**  
 (München, TU, master's thesis, 2018)

Trapp, Mario ; Hess, Steffen:  
**Digital villages. How digital ecosystems are structured and what they provide.**  
 In: Biologische Transformation  
 Berlin: Springer Vieweg, 2019, S.371-387  
 DOI: 10.1007/978-3-662-58243-5\_18

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**Towards dynamic safety management for autonomous systems**  
 In: Engineering Safe Autonomy : Proceedings of the 27th Safety-Critical Systems Symposium,  
 Bristol, UK, February 5-7, 2019  
 Heslington: SCSC, 2019, S.193-204  
<http://publica.fraunhofer.de/documents/N-546215.html>

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**Towards safety-awareness and dynamic safety management**  
 In: 14th European Dependable Computing Conference, EDCC 2018 : Iași, Romania, 10-14 September 2018  
 Piscataway, NJ: IEEE, 2018, S.107-111  
<http://publica.fraunhofer.de/documents/N-518517.html>  
 DOI: 10.1109/EDCC.2018.00027

Wardenburg, Eva von:  
**What factors influence decision making during the job application process? Evaluation of the success factors in job advertisements for computer scientists at the Fraunhofer-Gesellschaft.**  
 (Elmshorn, Nordakademie, master's thesis, 2019)

Weiß, Gereon ; Schleiß, Philipp ; Schneider, Daniel ; Trapp, Mario:  
**Towards integrating undependable self-adaptive systems in safety-critical environments**  
 In: SEAMS 2018, 13th International Symposium on Software Engineering for Adaptive and Self-Managing Systems : May 28-29, 2018, Gothenburg, Sweden  
 New York: ACM, 2018, S.26-32  
<http://publica.fraunhofer.de/documents/N-497208.html>  
 DOI: 10.1145/3194133.3194157

## Imprint

### **PUBLISHER**

Fraunhofer Institute for Cognitive Systems IKS  
Hansastraße 32  
80686 München

+49 89 547088-396  
pr@iks.fraunhofer.de

### **EDITORIAL STAFF**

M.A. Hans-Thomas Hengl  
Press  
M.A. Eva von Wardenburg  
Head of PR & Technology Marketing

Fraunhofer Institute for Cognitive Systems IKS  
Hansastraße 32  
80686 München  
+49 89 547088-396  
pr@iks.fraunhofer.de

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### **IMAGES**

Fraunhofer Institute for Cognitive Systems IKS  
Hansastraße 32  
80686 München

+49 89 547088-396  
pr@iks.fraunhofer.de

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www.x-height.de

### **PRINTING**

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