Institut für Technische Informatik

Institutsleiter: Univ.-Prof.Dipl.-Inform.Dr.sc ETH Kay Römer

http://www.iti.tugraz.at/

Bachelorarbeiten, Projekte, Masterarbeiten

Seminars/Projects, Bachelor and Master Theses

WS 2022/23

Networked Embedded Systems Group

Contact: Prof. Kay Römer (roemer@tugraz.at)

Overview. Modern embedded systems typically consist of multiple computers that are connected by a wireless or wired network. Sensor networks, Internet of Things, Cyber-Physical Systems are all examples of this type of technology. The Networked Embedded Systems working group, headed by Prof. Dr. Kay Römer, investigates design, implementation, and test of such systems with special emphasis on wireless networking (Assoc.Prof. Carlo Alberto Boano), sensing and embedded machine learning (Assoc.Prof. Olga Saukh), and cognitive embedded systems (Dr. Konrad Diwold). Typical challenges that need to be tackled are the openness and dynamicity of such systems, resource and energy constraints, harsh environmental conditions, and the need for dependable operation despite these difficulties. The working group focuses on experimental research, where concepts are transformed into realistic prototypes that are used in experiments to assess the properties and performance of the concepts.

Research Area 1: Dependable Wireless IoT Systems

(https://teams.iti.tugraz.at/dependable-wireless-embedded-systems/)

Networks of low-power wireless sensors and actuators are becoming an integral part of our daily life: hidden in our homes, cities, and cars, worn on our wrists, integrated in our clothes. They are a fundamental building block of the Internet of Things (IoT) and therefore need to operate efficiently and reliably. The research activities in the "Dependable Wireless Embedded Systems" group aim to analyze and improve the performance of low-power wireless technologies and protocols used to build present and future IoT systems, with the ultimate goal of increasing their dependability and real-world applicability.

Contacts:

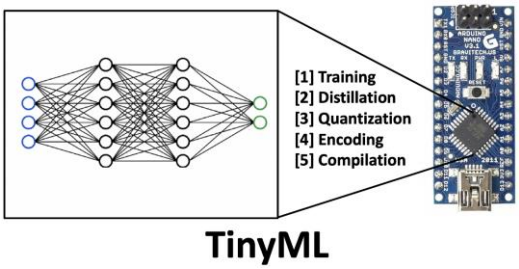
- Prof. Carlo Alberto Boano (cboano@tugraz.at) [Group Leader]
- Prof. Kay Römer (roemer@tugraz.at) [Group Leader]
- Markus Schuß (markus.schuss@tugraz.at) [Focus on Benchmarking IoT Systems]
- Rainer Hofmann (rainer.hofmann@tugraz.at) [Focus on Cross-Technology Communication]
- Michael Stocker (michael.stocker@tugraz.at) [Focus on Ultra-Wideband Localization]
- Maximilian Schuh (schuh@tugraz.at) [Focus on Ultra-Wideband Communication]
- Hannah Brunner (hannah.brunner@tugraz.at) [Focus on Batteryless/Sustainable IoT Systems]
- Elisabeth Salomon (elisabeth.salomon@tugraz.at) [Focus on the Mesh-Cloud Continuum]
- Pei Tian (tian@tugraz.at) [Focus on LoRa Technology and Networks]
- Markus Gallacher (markus.gallacher@tugraz.at) [Focus on Jamming Detection and Mitigation]
- Sonali Deo (sdeo@tugraz.at) [Focus on Resilient Wi-Fi Mesh Networking]
- Mohamed Hassaan Hyder (m.h.mohamedhyder@tugraz.at) [Focus on Testing Large-Scale Networks]

We are always looking for highly motivated and brilliant students interested in doing a project or thesis on our research topics. We typically define the concrete topic after a short meeting with the student, in order to adjust the project/thesis to their interests and skills. If you have any questions, please contact cboano@tugraz.at.

Examples of available topics:

- Evaluating the End-to-End Dependability of Distributed Wireless Systems
- Detecting and Mitigating Coexistence Problems through RF Spectrum Analysis
- Benchmarking the Performance of UWB Platforms under Wi-Fi 6E Interference
- Exploring the Next Generation Ultra-Wideband Transceivers
- Authentication for Dependable IoT Protocols based on Synchronous Transmissions 🔥 (hot topic!) 🔥

Research Area 2: Embedded Information Processing



https://teams.iti.tugraz.at/embedded-information-processing

Today a wide range of sensors integrate with IoT devices to measure their surrounding contexts. As the number of integrated sensors and their complexity grow, so are the amounts of data they produce and the need for this data to be processed. The state-of-the-art computational models that, for example, recognize a face, detect events of interest, track user emotions, or monitor physical activities are increasingly based on deep learning principles and algorithms. Unfortunately, deep models typically exert severe demands on local device resources, and this conventionally limits their adoption within mobile and embedded platforms. Our group works on new sensing concepts based on machine learning models, and on solving the challenges when running machine learning models on resource-scarce embedded devices.

Contacts:

- Dr. Olga Saukh (saukh@tugraz.at) [Group Leader]
- Rahim Entezari (entezari@tugraz.at) [Focus on Transfer Learning]
- Franz Papst (papst@tugraz.at) [Focus on IoT Data Privacy]
- Francesco Corti (francesco.corti@tugraz.at) [Focus on Deep Learning for Embedded Dev.]
- Katarina Milenkovic (katarina.milenkovic@pro2future.at) [Focus on Adversarial Robustness]
- Dong Wang (contact saukh@tugraz.at) [Focus on On-device Learning]

Examples of available topics:

- Moving Target Defense Against Adversarial Examples on Embedded Devices (contact saukh@tugraz.at)
- Differential Private Synthetic Data from Hypernetworks (contact papst@tugraz.at)

We are always looking for highly motivated and brilliant students. Please contact saukh@tugraz.at.

Research Area 3: Cognitive Products and Production – "cognify your systems to make them smarter"

Bringing cognition into products requires dependable and low-cost sensing, networking, and software platforms. These building blocks will allow the design and realization of cognitive products, where the "cognition" denotes a product's ability to adapt and its functionality across the whole product lifecycle to maximize customer satisfaction, product quality and sustainability, and to minimize production overheads. We study and investigate technological building blocks for future products and production systems and demonstrate their applicability.

Contacts:

- **Dr. Michael Krisper (michael.krisper@tugraz.at) [Main Contact]**
- Dr. Jesus Pestana (jesus.pestana@pro2future.at) [Drone control & vision]
- Amer Kajmakovic (amer.kajmakovic@pro2future.at) [Automation and Safety]
- Daniel Kraus (daniel.kraus@pro2ufuture.at) [Edge Devices and Backend Communication]
- Elisei Ember (elisei.ember@pro2future.at) [Wireless communication & Localization]

Examples of available topics:

- **REC*AI*CLE**: Machine Learning for Waste Monitoring & Augmentation in Recycling (michael.krisper@tugraz.at)
- **TWIN**: Digital Twins for Safety Automation (amer.kajmakovic@pro2future.at)
- **CORVETTE**: Industrial Sensor and Backend Communication Solution with MQTT (michael.krisper@tugraz.at)
- **VECTO**: Vehicle Simulation for Calculation of CO_2-Emissions (michael.krisper@tugraz.at)
- Generation of Test-Scenarios for Tasks in Real-Time Operating Systems (tanveer.ali-ahmad@pro2future.at)

We are always looking for highly motivated and brilliant students. Please contact michael.krisper@tugraz.at

Embedded Automotive Systems

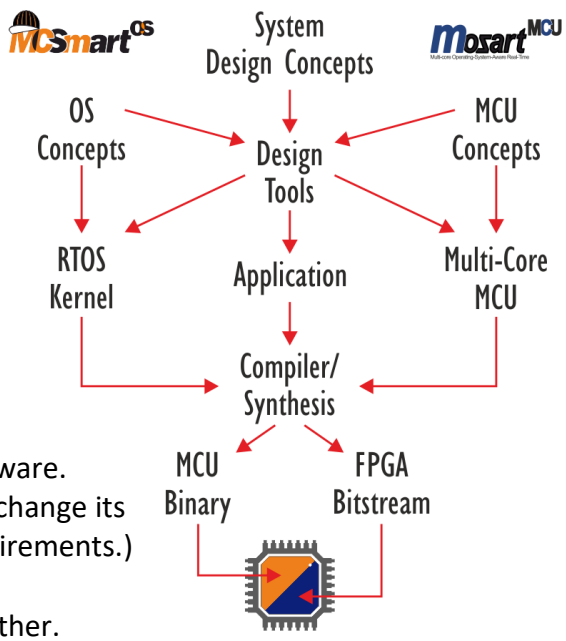
Contact: Prof. Dr. Marcel **Baunach**
Anton **Saikia**
Tanveer **Ali Ahmad**
Leandro **Batista Ribeiro**
Vignesh **Manjunath**
Kristof **Kanics**
Tobias **Scheipel**
Drona **Nagarajan**
Meinhard **Kissich**

Overview. The EAS group aims on fundamental and applied research in highly dependable embedded systems with mixed real-time demands. Examples include electronic control units for smart, networked and autonomous vehicles, advanced robotics, or the Internet of Things. These application domains are also expected to bring forth the most disruptive core technologies for the next decade. Considering the design, implementation, test, and maintenance of such systems, a holistic view on the hardware (processor architectures), software (operating systems/applications), and networks (interfaces) reveals a large variety of exciting challenges and projects.

Research Area 1
Hardware / Embedded Processor Architectures

This area offers the opportunity to get a deep understanding in the design and implementation of MCU architectures, including single-core and multi-core as well as FPGA-based soft cores (e.g., RISC-V) and standard ASICs (e.g., Aurix, ARM, etc.):

- Hardware accelerators for application-specific processors
- Code and logic synthesis in hardware and software
- Self-reconfiguring logic & partial reconfiguration at runtime
- Special hardware support for low-level software (OS)
- Security and resource sharing for multi and many-core
- MCU self-supervision and runtime profiling
- Design of flexible hardware/software interfaces



Keywords: MCU/FPGA, HDL, C/C++/Scripting, RISC-V/*mosart*MCU

Open topics:

- **Self-modifying Processors:**
  Tomorrow's hardware will be updatable similar to today's software.
  > Support us in developing our own RISC-V processor that can change its own logic and features at runtime (in case of bugs or new requirements.)
- **Hardware support for OS features:**
  Future basic software and processors will be tailored to each other.
  > Work together with experienced OS developers to accelerate kernel features through novel hardware concepts.
- **Optimization of processor runtime characteristics in software**
  Software has a significant impact on various runtime characteristics of the hardware.
  > Support us in understanding the effects in detail and optimize software to reduce energy consumption, avoid power peaks and cross-core implications, or optimize temperature profiles.

RISC-V

Research Area 2

Software / Embedded Operating Systems

This area allows you to dig deep into operating systems kernels and basic software concepts for embedded real-time systems. Support us in creating a versatile kernel or work closely together with our partners to develop new concepts for various application domains:

- Design and implementation of a novel embedded operating system
- Multi-core concepts and software partitioning for handling dynamic workloads
- Support for self-reconfigurable processors
- Model based OS development for automatic porting to various MCU architectures
- Verification concepts for OS kernels and low-level software
- Automatic interfacing of synthesized hardware extensions
- Basic software and systems generation for automotive and IoT applications

Keywords: C/C++/Assembly/Scripting, formal methods, *Smart*OS/AUTOSAR, MCU/FPGA, IoT/ADAS/CPS

Open topics:

- **Contribute to *Smart*OS:**
  *Smart*OS is the basic software developed by the EAS Group for research and teaching. It supports preemptive multitasking and various features for developing complex applications for different hardware platforms (e.g., RISC-V). A previous version of SmartOS is used in the automotive industry and a more recent version is used in embedded systems onboard of a rocket of the ASTG. As a next step, we seek to provide a new implementation as open-source.
  > Become part of the team and contribute your ideas and expertise to our kernel, services, drivers, …

- **Provably correct and portable System Software:**
  System software like OS kernels or drivers provide the base for complex applications on plenty of target architectures. To guarantee their correctness and availability for new (or even reconfigurable) processors, we work on special design and implementation concepts. This includes modeling and formal verification of code and requirements, like timing, security, liveness, energy, etc.
  > Support our team and external experts in implementing system software that is provably correct.

- **Dynamic Composition of Embedded Systems:**
  Future embedded systems for robots, vehicles, etc. will contain complex application software that is composed of tens or hundreds of components. These components are independently developed and tested, but need to coexist on few hardware platforms and interact dependably in any situation and under all circumstances.
  > Involve yourself in developing new concepts to modularize systems and prove their correctness.

CompEAS

Elektrobit

Infineon

More topics for both research areas can be tailored to your interests. Just contact us!

Depending on the topics, theses can also be offered within industry cooperation projects.

Hardware/Software-Codesign Group

Contact: Dr. Christian Steger - steger@tugraz.at
Markus Feldbacher - m.feldbacher@tugraz.at
Fikret Basic - basic@tugraz.at
Gernot Fiala - gernot.fiala@tugraz.at

Overview. The HW/SW codesign group at the Institute for Technical Informatics deals with embedded systems, HW/SW codesign, and power awareness. The design of embedded systems can be subject to many different types of constraints, including timing, security, power consumption, reliability, and cost.

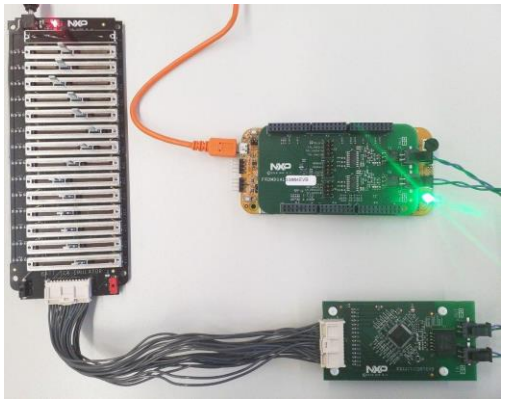
SEAMAL BMS

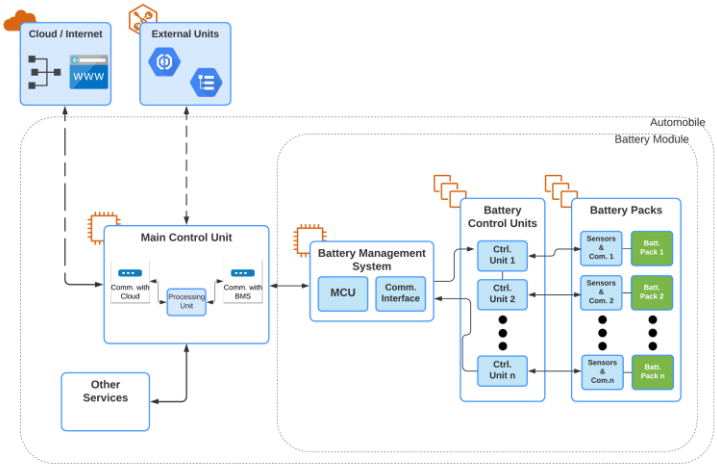
Security-related Topics in the domain of Battery Management Systems

(in cooperation with NXP Semiconductors)

Fikret Basic, Christian Steger

Battery Management Systems (BMS) are control systems present in many safety-critical environments, e.g., in vehicles, where they are used to monitor the health status, as well as the load/unload of battery cells. They present a relatively new and open research field. TU Graz, together in cooperation with NXP Semiconductors, is interested in devising novel solutions in the area of module communications, i.e., switching from wired to wireless technology, anti-counterfeiting authentication solutions, security provisioning, and secure logging handling. This opens many new possibilities, which include wireless updates and configurations, better sensor coverage, easier module maintenance, deployment in distributed architectures, etc. The goal is to allow the integration of new communication technologies while at the same time ensuring the protection of the BMS data confidentiality, integrity, and authenticity.





Project Topics:

- HW/SW extensions on the RFID setup for the inter-BMS module communication
- Security extensions on the BMS security architecture

Sensor SoC

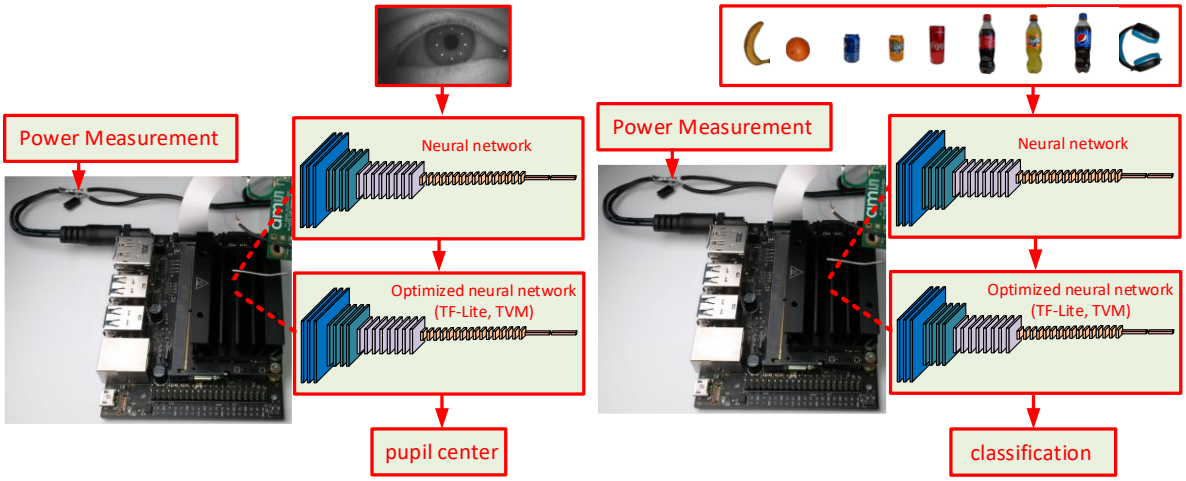
SoC topic in the area of image processing

(in cooperation with ams-OSRAM AG)

Gernot Fiala, Christian Steger

Embedded image processing and analysis close to the image sensor is gaining more and more momentum since it allows to reduce required communication bandwidth to the next layer of the processing hierarchy. This saves energy and enables significant efficiency improvement for different use cases.

Here, the focus is on pupil detection for AR/VR applications and shape/object detection for industrial applications, which are integrated into a smart image sensor with limited resources. Image processing in a smart image sensor not only comes with benefits but also includes technical challenges regarding processing time, area, and power.



Project Topics:

- Power consumption comparison of non-optimized/optimized DNN for object/shape classification
- Power consumption comparison of non-optimized/optimized DNN for pupil center detection

DiSel

Digitalisierung von Services, Equipment und Logistik

(in cooperation with Innofreight Solution GmbH, Office Graz)

Christian Steger

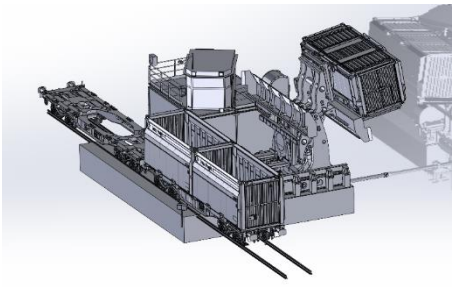
A stationary unloading machine (SUM) as an unloading system allows a cost-efficient operation. It also offers work safety, process reliability and supply security at the highest level and state-of-the-art technology. They present a relatively new approach of logistics within the train sector. Innofreight together in cooperation with TU Graz has the aim to raise the automation level of this machines. For this, specific tasks in the area of robotics, image recognition and condition monitoring are necessary.

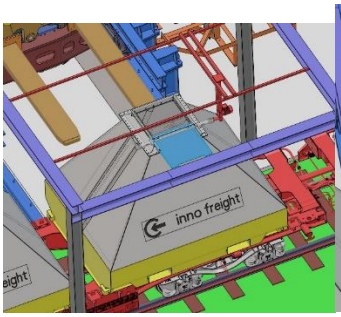
Topic 1:

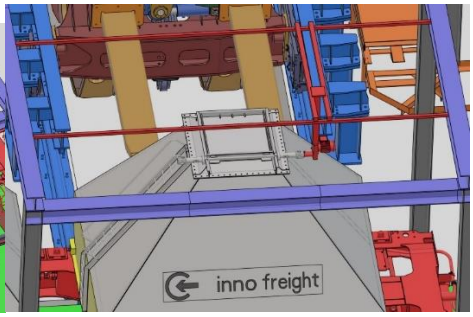
After an unloading sequence the operator of the SUM has to put the container back onto the wagon. Therefore, it is necessary to check if all pins, for load safety, are in the right position. In the area of image recognition, we want to automatically detect and count the pins at the waggons during the unloading process. Goal of this project should be a design and implementation of a prototype of an image recognition system running in the laboratory. With an outlook how to extend this to the real world.

Topic 2:

For special goods, special containers are needed. Some of those containers have a cover, which has to be opened before unloading. In this specific case we have a sliding cover. The goal of this project is to design and implement a prototype of a system to detect the opener and manoeuvre an arm onto it.

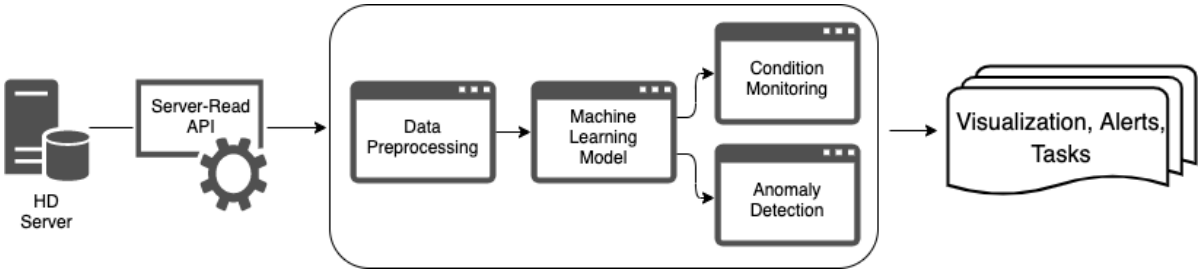






Topic 3:

In order to improve the lifetime and optimize the overall SUM, Innofreight is monitoring the whole system and gathering the data. Due to this condition monitoring a lot of steps are necessary which can be improved, extended or developed. Due to this wide range of topics form condition monitoring to web-applications, any further work can be discussed in detail.



Industrial Informatics

Contact: **Dr. Georg Macher** georg.macher@tugraz.at
Jürgen Dobaj juergen.dobaj@tugraz.at
Thomas Krug t.krug@tugraz.at

Overview. The Industrial Informatics working group closely cooperates with industry to tackle the needs and challenges in technology, process improvement, and new compulsory standards. While the complexity increases in products and solutions for the automotive, automation, and IT domains, development cycle times continuously shrink. System development by singular domain specialists is no longer sufficient. Systems have to be engineered in integrated design processes across distributed supply chains, keeping track of changes in an agile manner. The group focuses on general functional viewpoints and system-wide feature thinking.

Area: Communication Technologies for Distributed Embedded Real-Time Systems
(Contact: juergen.dobaj@tugraz.at)

- **Task**: Create a reliable industrial IoT communication system by utilizing smart contracts, arbitration, and network management tools.
- **Task:** Explore the integration of AI in safety-critical (autonomous) applications (e.g., driving, robots, manufacturing, drones, …)
- **Task**: Build a demonstrator platform to evaluate distributed industrial control algorithms based on ARM/X86 processor architectures running real-time Linux.
- **Task**: Analyze and compare the features of modern industrial & automotive real-time network technologies (e.g., EtherCAT, Time-Sensitive Networking, TTEthernet, Profinet, Sercos III, …).

Area: Service-Based Automation of Critical Distributed Embedded Real-Time Systems
(Contact: t.krug@tugraz.at)

- **Task**: Build a demonstrator for industrial IoT (IIoT) systems with a miniature industrial system.
- **Task:** Explore the integration feasibilities of AI in safety-critical real-time applications for attack mitigation
- **Task**: Build a real-time demonstrator of an IIoT system with runtime adaptation
- **Task**: Build a robot arm demonstrator with runtime safety cocoons
- **Task**: Analyze and compare industrial service-based approaches for the feasibility of application in a dependable industrial system context

Area: Methods, Tools & Industrial Informatics Applications (Contact: georg.macher@tugraz.at)

- **Task**: Check/test the cybersecurity measures of a series embedded automotive system.
- **Task**: Built up a demonstrator of an automotive battery management system.
- **Task**: Support in designing a Cyber-Security educational program.

- **Task**: Mining and describing best practices and patterns for industrial Cyber-Security, Safety, and Risk Estimation.

Area: MacGyver Projects – *Invent something extraordinary!* (Contact: georg.macher@tugraz.at)
These topics are not bound to a specific industry project but can be freely explored to do something highly innovative and creative. Either you **come up with your own crazy or unusual ideas**, or be inspired by some of ours:

- **Task:** IoT Cyber Security: Try hacking tools available in the world wide web
- **Task:** Automotive Cyber Security: Try out hacking and service tools available for automotive communication
- **Task:** Automotive Cyber Security: Reverse engineer an embedded automotive system
- **Task:** Machine Learning/AI for Self-Driving Cars: Build (an AI-driven) self-driving car in CARLA or in real
- **Task:** Machine Learning/AI in Dependable Systems: Use your knowledge of AI for increasing safety and security of dependable systems.
- **Task:** Home Automation: Create some crazy home automation with IoT
- **Task:** Drones: Develop an self-flying drone with an adaptive safety cocoon
- **Task:** Medical Devices: Develop a wearable measurement system for humans (including wearables and synchronous storing)
- **Task:** WAP ("*Wild-and-Provocative*") Digitalization Project: Build a hardware demonstrator of your interest that evaluates/improves/changes/enhances the current state of industry practice and science.