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UNIVERSITY OF APPLIED SCIENCES

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To all students in the Master program in
Mechatronics

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Studiengangsleitung Mechatronik
Prof. Dr. Klaus-Peter Kämper

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Datum
20.02.2024

Projects in the Master program in Mechatronics

Dear students,

A mechatronics projects is an integrated part of your study program for the Master of Science in Mechatronics.

These projects are to be performed in groups of 5 - 6 students and are running during the complete 2nd and 3rd semester. Each team will be supervised by the professor that contributed the project topic. We are offering you a number of different projects. Please find a list of the proposed projects as an enclosure of this letter.

I ask you to form teams and select a project topic that suits your interests. Of course each project can be only performed by one team. Please contact the responsible professor of your selected project as soon as possible.

In addition I ask you to send me a mail with the names of the members of your team and their e-Mail addresses together with the name of the selected project as soon as possible. Before I have not received this mail you are not registered for the project!

The projects can start immediately or at least directly at the beginning of the summer semester.

I hope that you find an interesting project and wish you all success for the exams in the next weeks and for the new semester.

Yours sincerely

Prof. Dr. Klaus-Peter Kämper

Klaus-Peter Kämper

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List of the project proposals for the Master Mechatronics program in the summer semester 2024

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Project 1: Development of sensors for process monitoring during milling

Prof. Dr.-Ing. Kristian Arntz (arntz@fh-aachen.de)

Task:

In order to characterize and monitor milling processes, complex and expensive force sensors are used in most cases, which also have to be integrated into the direct force flow. However, there are also other signals that can be measured and used to characterize the processes. These include acceleration and acoustic emissions in particular. The aim of this project is to develop a measuring system based on inexpensive sensors and evaluation units.

This means in particular:

- Development of a requirement and functional specification
- Development of a concept for the implementation of sensor technology, machine integration and evaluation system
- Design of the overall mechatronic system
- Obtaining offers and carrying out the procurement
- Setting up the system and integrating it into a milling machine in the mechanical workshop at Goethestrasse
- Carrying out machining tests to evaluate the system
- Documentation

The task must be completed in a team and documented accordingly. In addition, each participant must keep a project diary showing the scope and type of activities carried out.

Team:
2-4 students

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Contact

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Dipl.-Ing. (FH) R. Sander
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Project 2: Development of an IMU Based Robot-Controlling Hand-Wrist-Device

Prof. Dr. rer. nat. Felix Hüning (huening@fh-aachen.de)

To create a more ergonomic and user-friendly working environment, machinery is used to transfer heavy lifting away from human employees. But often, it is still required to reposition a component, and in most cases, a human employee has to make adjustments that still require unergonomic movements.

The idea is to solve this problem by attaching heavy components to a robot arm that can make the adjustments for the human but still give the employee a way to make adjustments to the heavy component without unergonomic heavy lifting.

The goal of the project is to create a device that anyone can strap around their hand, which is able to pass the orientation of the hand to a robot arm. The robot arm's end effector then should rotate accordingly to the hand's movement. Additional tasks can be added based on the number and expertise of students.

This project is suitable for up to 8 students with a high motivation to work on sensor systems, development of robot functions as well as information technology.

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Project 3: De-powdering system for 3D printed components manufactured using LPBF

Prof. Dr.-Ing. Sebastian Bremen (bremen@fh-aachen.de)

Topic

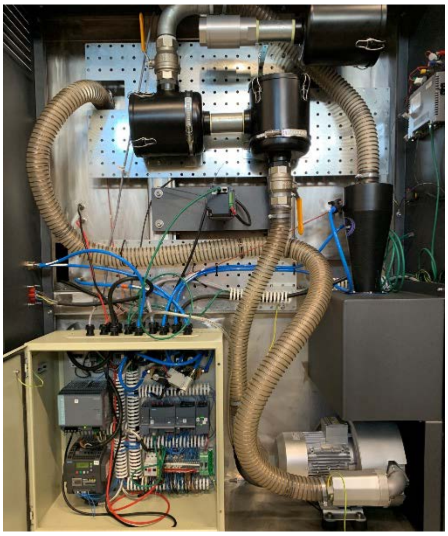
In Laser Powder Bed Fusion (LPBF), components are built up layer by layer through the targeted melting of metal powder using laser radiation. This allows complex internal structures to be realized, among other things. The unmelted powder remains in the component and must be removed after completion.

As part of a project at the GoetheLab, a system for removing powder from components was developed. The aim of this system is to be able to rotate and swivel the components using a motorized platform and also to transmit vibrations to the component via a vibration turbine in order to loosen the powder. It should also be possible to extract powder using an integrated vacuum cleaner. As reactive material is one of the materials used, the entire process takes place in a protective gas atmosphere, which is monitored by an oxygen sensor.

In manual mode, the user should be able to control all functions of the system via an HMI. In addition, depowdering cycles are to be programmed that automatically execute the axis movements, vibrations and protective gas control within the framework of the mechanical boundary conditions. The system is equipped with a PLC (Siemens Simatic S7-1200), which is programmed via the TIA Portal software.

Optionally, the project can be extended to include the implementation of a 3D scanner in the system.

Your tasks are



- Assembly of the final hardware components
- Control of the motors (CANopen)
- Setting up manual operation
- Programming various automatic programs
- Optimization/troubleshooting
- Commissioning and testing of the system
- Creation of documentation including operating instructions

Please contact us for a more detailed presentation of the areas of responsibility.

We offer you

- Practical example of real product development (comparable systems on the market cost around €90,000)
- All required hardware and software resources
- Insight into the future technology of additive manufacturing
- Close cooperation in the motivated team of the GoetheLab for Additive Manufacturing
- Independent work with great freedom of action

Contact

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Tobias Rehfeld
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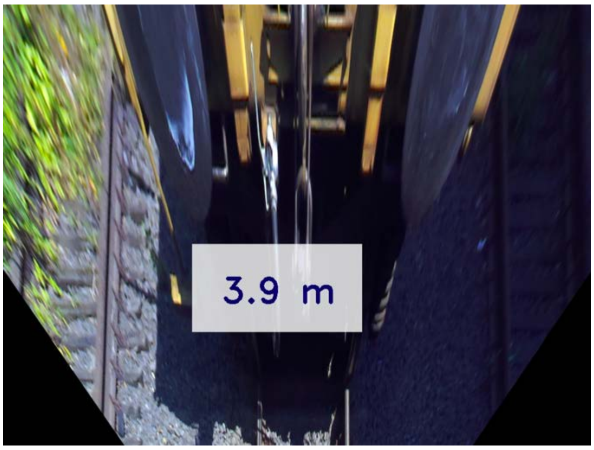
Project 4: Low cost advanced driver assistance system (ADAS) for railways

Prof. Dr. Raphael Pfaff (pfaff@fh-aachen.



- **Technology:**
    - Monocular (Basler or AlliedVision) or stereo cameras (Stereolabs ZED 2i)
    - NVIDA Jetson platform (Nano or Xavier, Orin possible)
    - LIDAR Optional (Ouster, Blickfeld or RoboSense)
    - OpenCV, PyTorch, PIL
- **Project aims:**
    - Create Birds eye view (360°) around locomotive
    - Mark objects
    - Create abstract view for driver
    - Judge freedom of movement

Testing on real locomotive in shunting environment can be arranged (at Henkel, Düsseldorf or Reuschling, Hattingen). A number of ROS bags from shunting scenes is available. Also open data sets can be used.

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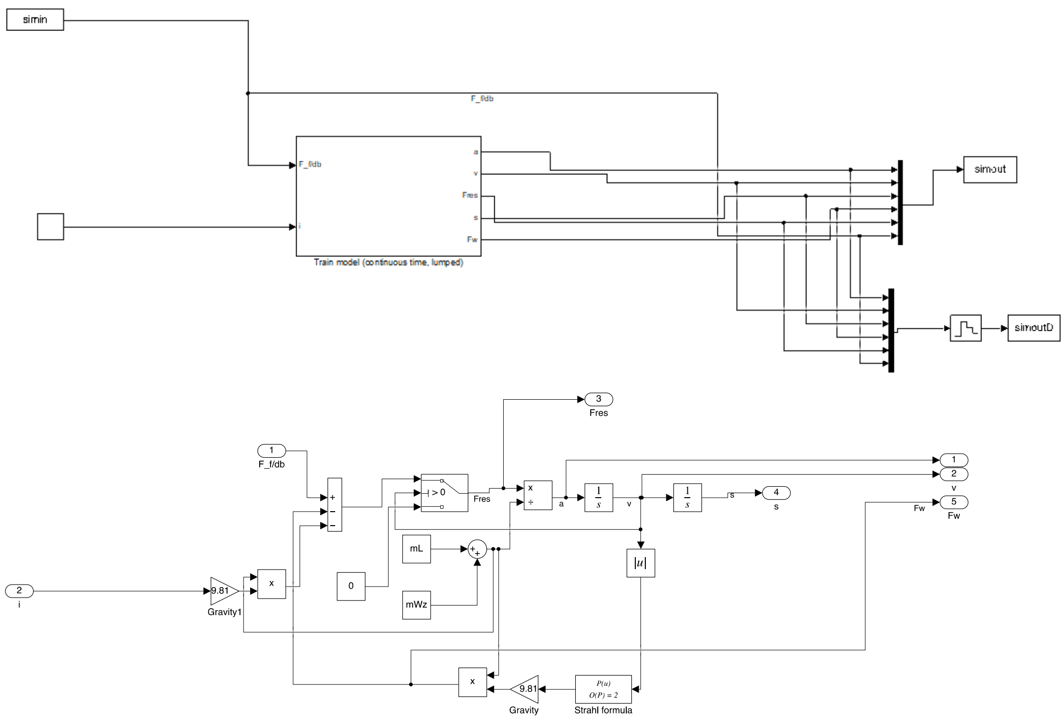
Project 5: Detailed Matlab/Simulink/SimScape-Model of Locomotive Drive System

Prof. Dr. Raphael Pfaff (pfaff@fh-aachen.



- **Technology:**
  - Matlab/Simulink
  - Simscape Multi-Domain physical simulation
  - Batteries (LTO/LFP)
  - Motors (BLDC)
- **Project aims:**
  - Develop model of drive train including
    - Train dynamics
    - Motor control
    - Batterie behaviour

The model shall be based on the railway challenge locomotive Molly.

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Project 6: LED Controller with EtherCAT Interface

Prof. Dr.-Ing. Markus Schleser (schleser@fh-aachen.de)

LaVa-X GmbH specializes in laser welding in vacuum. Founded with the help of FH Aachen, the company has been working together closely with the university ever since. Along with the highly innovative laser welding process, specialized machines are developed to enable said process.

Laser welding machines are equipped with a Camera to monitor process and workpiece which requires an LED light source in order to work. Goal of this project is to develop a LED driver circuit with an EtherCAT Fieldbus interface which is to be integrated into our custom light unit.

Requirements

- Interest in developing electrical hardware
- Basic knowledge in Embedded Systems
- Independent way of working
- Motivation to work in an interdisciplinary environment
- Interest in working on a hands-on development project

What you can expect

Working at LaVa-X, you get the chance to work on cutting edge laser welding machines. Through development work on our systems, you can make a significant contribution with your project and help shape state-of-the-art technology, while working together with a young and interdisciplinary team.

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Tel.: +49 2407 953898 72

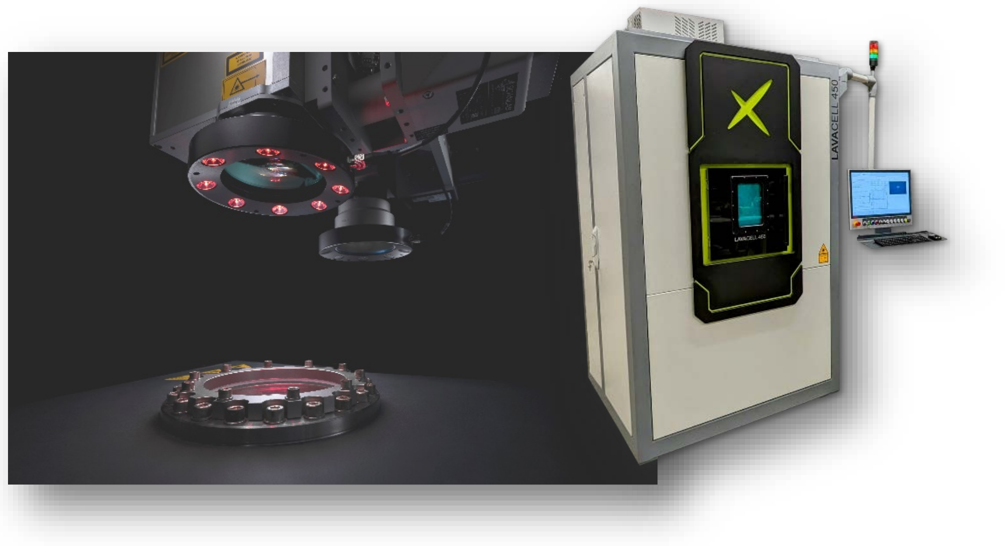
LaVa-X GmbH
Kaiserstraße 100
52134 Herzogenrath

Project 7: Construction and development of a lightweight vacuum laser beam welding machine

Prof. Dr.-Ing. Markus Schleser (schleser@fh-aachen.de)

LaVa-X GmbH specializes in laser welding in vacuum. Founded with the help of FH Aachen, the company has been working together closely with the university ever since. Along with the highly innovative laser welding process, specialized machines are developed to enable said process.

To show our process at fairs, we want to develop a lightweight welding machine for easy transport and setup. The project requires work on electrical as well as mechanical concepts and final construction based on our existing machines. The Engineers at LaVa-X will fully support you during this endeavor.



Requirements

- Interest in electrical construction (Eplan)
- Basic knowledge in mechanical construction (preferably Autodesk Inventor or Fusion)
- Independent way of working
- Motivation to work in an interdisciplinary environment
- Interest in working on a hands-on development project

What you can expect

Working at LaVa-X, you get the chance to work on cutting edge laser welding machines. Through development work on our systems, you can make a significant contribution with your project and help shape state-of-the-art technology, while working together with a young and interdisciplinary team.

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Project 8: Data acquisition for predictive maintenance of vacuum laser beam welding machines

Prof. Dr.-Ing. Markus Schleser (schleser@fh-aachen.de)

LaVa-X GmbH specializes in laser welding in vacuum. Founded with the help of FH Aachen, the company has been working together closely with the university ever since. Along with the highly innovative laser welding process, specialized machines are developed to enable said process.

Laser welding machines need a variety of sensors to monitor and control the welding process. Goal of this project is to finalize a database system based on a master thesis to acquire the sensor readings into a data pool. Finally a concept can be developed to use the gathered data to monitor and predict maintenance intervals.

Fig. 1: Source LaVa-X

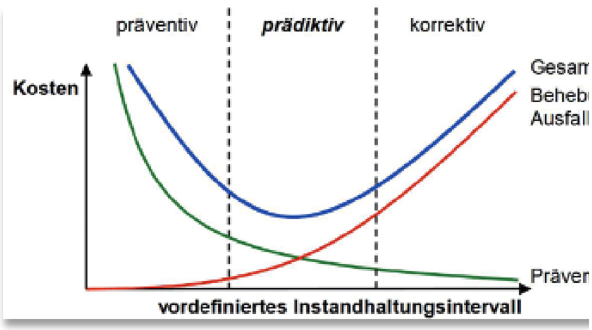

Fig. 2: (Source: TU Darmstadt)

Requirements

- Interest in PLC programing and Databases
- Independent way of working
- Motivation to work in an interdisciplinary environment
- Interest in working on a hands-on development project

What you can expect

Working at LaVa-X you get the chance to work on cutting edge laser welding machines. Through development work on our systems, you can make a significant contribution with your project and help shape state-of-the-art technology, while working together with a young and interdisciplinary team.

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Project 9: Talpa - autonomous garden robot

Prof. Dr.-Ing. Jörg Wollert (*wollert@fh-aachen.de*)

In this project the sensor-plattform for the x-by-wire-equiped Jansen MSK-800X electrical wheelbarrow will be performed. Goal is to develop a concept and a application prototyp based on the IFM 3d-sensor-technology for a self-driven vehicle based on ROS3.

1. Making a risk analysis based on all relevant norms concerning self-driving construction and agricultural vehicles.
2. Developing a concept for a cost-effective Sensor-System based on the IFM toolset.
3. Implementing a prototype based on the IFM Sensor family and ROS.
4. Preparing a presentation for IFM with the needs and cost-estimation for the retrofit of construction vehicles with self-driving technology.

The project is finished, if the prototype of the system is well documented and running. In the first step an autonomous driving of the MSK-800X would be fine, but it is not evident. The project outcome is:

1. Risk-analysis concerning the ISO 12100 and any relaying C-norms for the described use-cases (agricultural and construction machines)
2. Prototype setup concerning the necessary safety-levels with a clear safety-concept. Using the IFM products for the realization.
3. Fitting the MSK-800X with the technical equipment and testing the basic functionality with ROS.

This project is done in cooperation with the company IFM and is one part of an holistically approach to develop a retrofit platform

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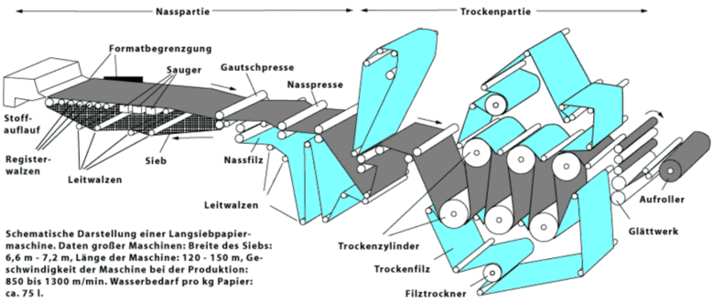
Project 10: Virtual paper factory - Part 1: Building a virtual paper factory

Prof. Dr.-Ing. Jörg Wollert (*wollert@fh-aachen.de*)

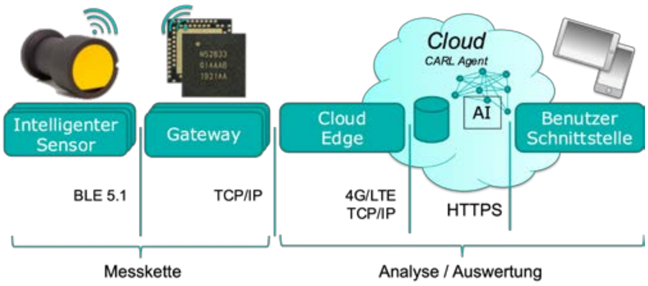
Based on a research project (CARL) we currently helping the company CKS in the digitalization of rollers. One important issue is the modelling of a virtual testing environment for the paper-industry.

In the fabrication of paper a lot of rollers are used for different process stages.



With our CARL-technology we are able to supervise all rollers for production, logistic and maintenance issues. For the long-term test we are locking for students which are interested in modelling the virtual paper factory. The demands on the projects are:

1. Modelling a paper-machine with all necessary parts. Figuring out the relevant use-cases on the different roller.
2. Making a concept for the implementation of intelligent CARL-sensors in CNC machines for the simulation of the paper process.
3. Defining the installation strategy together with the company and putting in operation of the CARL-Sensors
4. Supervision of the behavior of the sensors and analysis of the virtual factory.



This project is done in cooperation with the company CKS and is one part of a holistically approach on the digitalization of a SME.

Contact:

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Project 11: Driving Simulator

Prof. Dr.-Ing. Jörg Wollert (wollert@fh-aachen.de)

Project description:

At the IaAM, a beach buggy was converted into a driving simulator. By reading the telemetry data from the racing simulation, the gateway was developed in the form of a master's thesis, the design was implemented and a functional racing simulator was created.

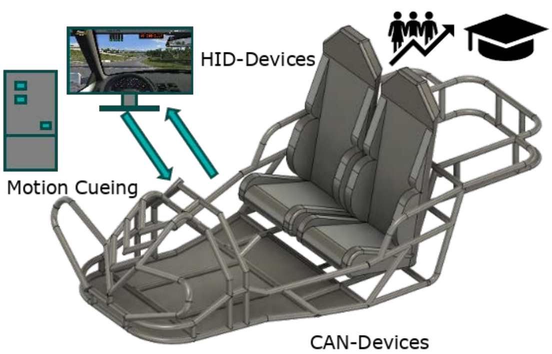
What is waiting for you?

We strive to develop a practical digitalization strategy. Specifically, it is about the design and implementation of a CAN board network. Add-on parts such as multifunction levers, brake lights, headlights and other components should be controlled via CAN. This project offers you the chance to delve deep into the world of the automotive-relevant CAN protocol. Not only will you learn the software and hardware aspects of the CAN protocol, but you will also master the intricacies of careful system architecture in terms of scalability and reliability.

Important:

The willingness to learn new things and be hands-on is essential! In the simulator on the Nürburgring or on the A4 towards Aachen in a driving school car or Audi R8... system tests could be more boring!

In the future, the driving simulator will serve as a test environment for various research approaches to the gamification of autonomous driving systems and offer a risk-free field for experimentation. Several leading German automobile manufacturers are already pursuing similar approaches - you too can be part of this innovative field of research!



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Project 12: Gamified digital workingstation

Prof. Dr.-Ing. Jörg Wollert (wollert@fh-aachen.de)

Project description:

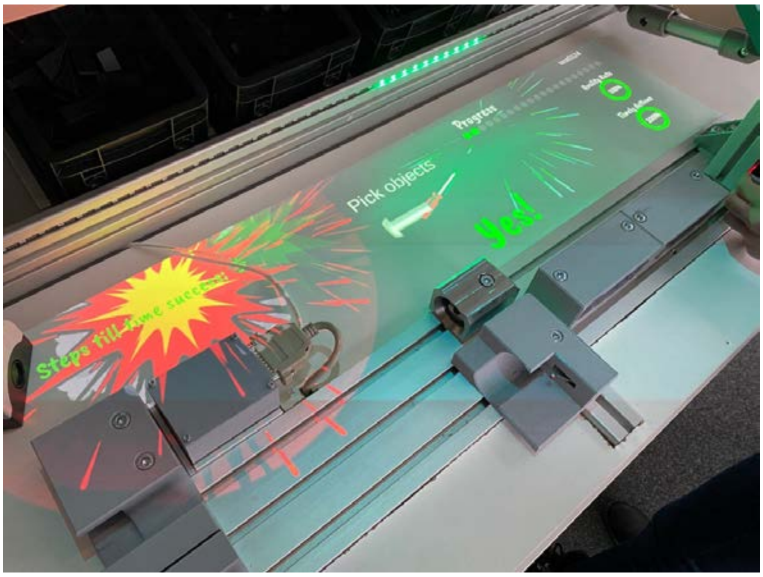
As part of the digitization of industrial processes, we are looking for support in the development of a gamification system that can be directly integrated into digitized manual workstations. The aim is to increase work motivation through playful elements and to improve the efficiency and quality of work processes and to analyze interactions from an ergonomic perspective.

What is waiting for you?

> Conception and development of a gamification system in Unity and Python.
> Analysis and processing of incremental performance and quality data.
> Creative freedom to design game mechanics that fit the work environment.
> Test and validation of the system in real production by our project partner!
> A project at the interface of gaming and Industry 4.0.

Important:

We want to create a workplace where every move counts and is visualized and rewarded through the gamification system. This is intended to increase productivity and continuously improve the quality of work results. The project has a direct influence on current research projects!



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Project 13: Toolchain for system integration with Microsoft Power BI and Azure

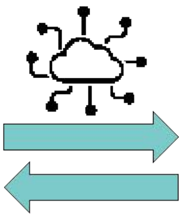
Prof. Dr.-Ing. Jörg Wollert (*wollert@fh-aachen.de*)

Project description:

The digital transformation of industry presents companies with the challenge of making their production processes more efficient, flexible and transparent. The use of modern IT technologies such as OPC-UA for industrial communication and integration using the Microsoft tool chain for data processing and analysis offers innovative approaches.

What is waiting for you?

> You will explore the various components of the Microsoft toolchain, including Azure IoT Hub, Azure Stream Analytics, Power BI, and more, in terms of their applicability to monitoring and controlling assembly processes.
> Experimentally validate integration options for OPC-UA and IO-Link.
> Automation mechanisms for developing dynamic UIs, business processes and guided assistance in the work context.
> Development of your own data management and data analysis services
>



Important:

> Interested in practical implementation of your own services under Microsoft.
> Don't be afraid to learn different programming languages.

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Project 14: Intelligent tool management

Prof. Dr.-Ing. Jörg Wollert (*wollert@fh-aachen.de*)

Project description:

The digitalization of industrial manufacturing processes offers enormous potential for increasing efficiency, accuracy and flexibility. As part of this project, the degree of digitalization of assembly processes is to be significantly increased through the development of intelligent tool holders that are equipped with modern embedded systems and corresponding software. The aim is to make a direct contribution to Industry 4.0 through the digitalization of tool holders by better tracking, controlling and optimizing tools and their use.

What is waiting for you?

> Design and development of physical prototypes for intelligent tool holders. This includes selecting suitable materials, taking ergonomic aspects into account and ensuring robustness for use in industrial environments.

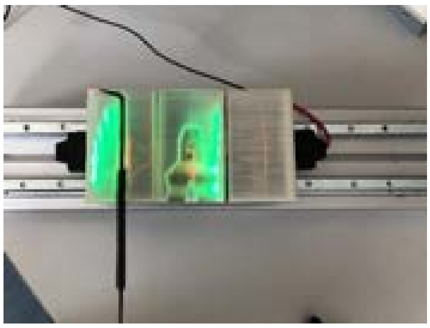
> Development and implementation of embedded systems for intelligent tool holders. This includes the selection of microcontrollers, sensors and other components, the design of circuit boards (PCB design) and the integration of communication technologies for data transmission.
Programming the firmware for the embedded systems as well as developing software solutions for data analysis, monitoring and control of the intelligent tool holders.

That are your skills:

> Basics in object-oriented programming.

> Interested in developing PCB designs according to high industry standards.

> Basics in industrial communication



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Project 15: Digitization of a coffee machine for intelligent energy monitoring using AI and cloud managemen

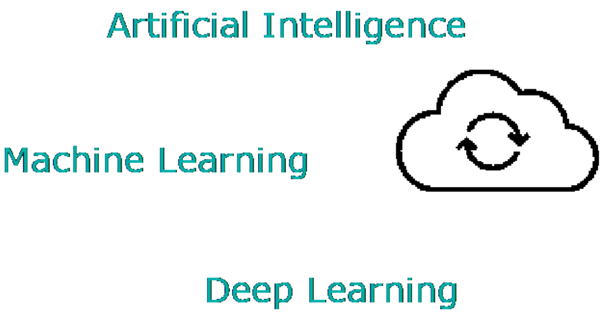
Prof. Dr.-Ing. Jörg Wollert (*wollert@fh-aachen.de*)

Project description:

In today's world of smart devices, it is important to digitize machines, systems and devices in order to realize energy efficiency, operational data and intelligent analytics. This project aims to transform a standard coffee machine into a smart device that monitors and analyzes its energy consumption and automatically evaluates operational data through the use of 3D printing technology, PCB design, artificial intelligence and cloud computing.

What is waiting for you?

> Design and creation of 3D printed attachments equipped with sensors and electronic components for energy monitoring.
> Developing machine learning algorithms hosted in the cloud to analyze the collected data and identify patterns in energy consumption.



That are your skills:

> Basics in object-oriented programming.
> Interested in IoT topics
> Interested in PCB design

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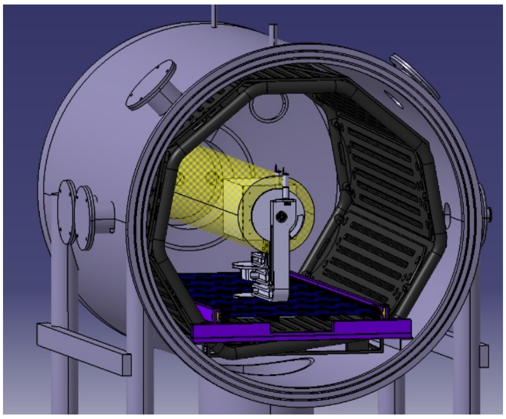
Project 16: Orbit Simulator Motor Control System

Prof. Dr.-Ing. Markus Czupalla (*czupalla@fh-aachen.de*)

Project Overview:

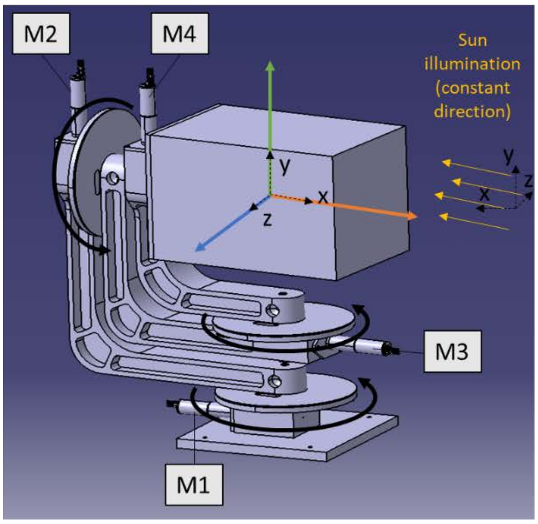
Orbit simulators play a vital role in spacecraft testing, providing controlled dynamic test cases for evaluating, e.g. the thermal and electric performances. These simulators can replicate different thermal load cases and solar power availability caused by different spacecraft orientations relative to the sun occurring during the orbit. As the sun is fixed in the testing facility, the spacecraft specimen itself needs to be rotated to provide the correct orientation.

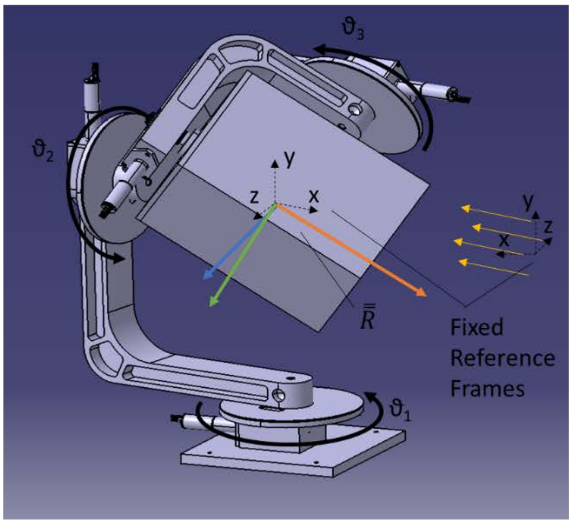
A mechanical design of such an orbit simulator for CubeSat testing was developed at FH Aachen. Based on a cardanic suspension, leaving the volumetric centre of the specimen aligned with the rotation axes, the system can rotate the test object into any orientation. To accomplish the rotation, the three arms, making up the suspension, can be individually rotated by sperate motors.



Project Scope:

The scope of this project encompasses the development of a motor control system that ensures the correct manipulation of individual motors within the orbit simulator. The proposed control system is expected to calculate and deliver the precise motor inputs required to achieve the desired orientation of the test specimen. To accomplish this, the project might explore the application of inverse kinematics methods, a mathematical approach known for determining the required joint angles to achieve a specific end-effector position.
Possibly critical aspects such as angle anomalies, maximal arm rotation capabilities, rotation velocities and undesirable concealment of the solar radiation beam shall also be considered in the control.





Key Tasks and Deliverables:

1. System Analysis and Requirements Gathering

- Conduct a thorough analysis of the orbit simulator system architecture.
- Identify the specific requirements for achieving precise orientation control.

2. Inverse Kinematics Implementation

- Investigate and implement appropriate inverse kinematics algorithms.
- Develop a robust mathematical model for calculating motor inputs based on desired specimen orientation.

3. Motor Control System Design

- Design a centralized motor control system architecture.
- Specify communication protocols and interfaces for seamless integration with individual motors.

4. Motor Controller Implementation

- Develop motor controllers capable of interpreting the calculated inputs.
- Ensure real-time communication between the control system and individual motors.

5. Demonstration

- Demonstration of the functionality of the motor control system either by software or even hardware if possible (3D-printing, etc.)

Expected Outcomes:

The successful completion of this project will result in an advanced motor control system for orbit simulators, enabling precise control of the relative orientation of test specimens with respect to the fixed sun system. The control system shall be capable of processing user input defining the demanded orientations.

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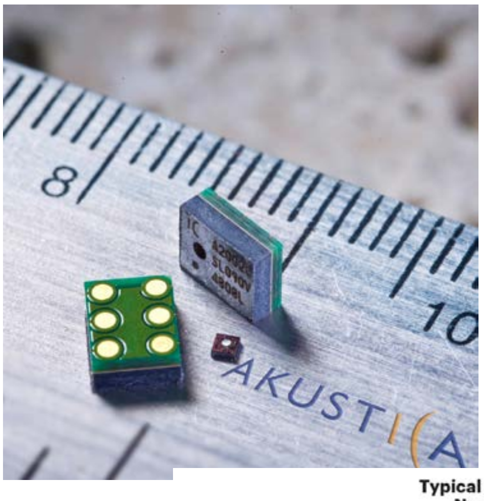
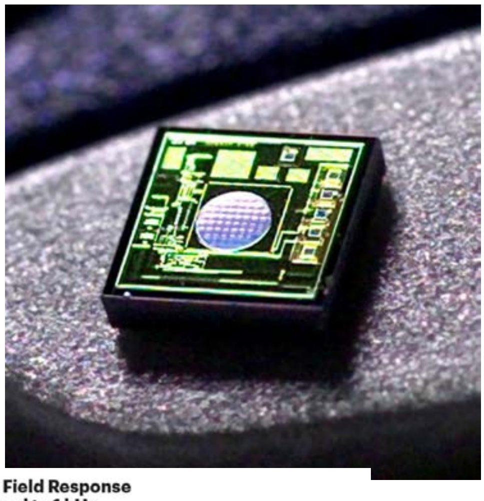
Project 17: Development of an acoustic direction finder using an array of MEMS microphones

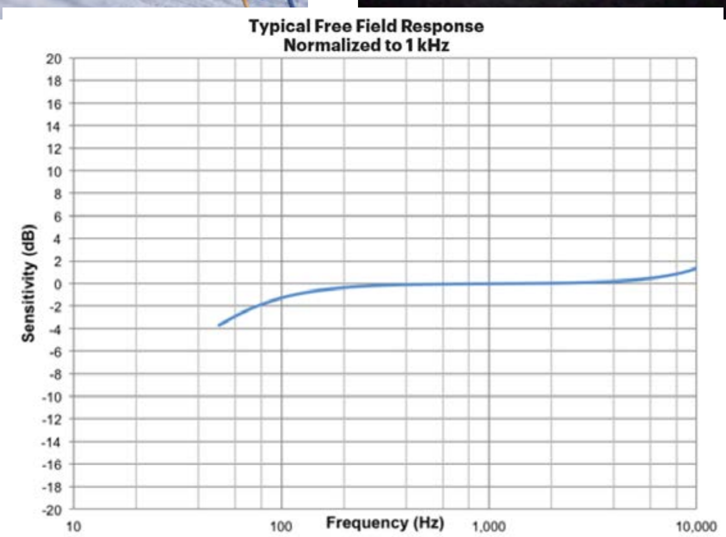
Prof. Dr. Klaus-Peter Kämper (kaemper@fh-aachen.de)

Modern MEMS based microphones combine good acoustic properties with a small package, very low costs and excellent uniformity and reproducibility. Thus, they allow the design of new acoustic measurement set-ups based on arrays of MEMS microphones. Due to the extremely reproducible acoustic properties, measurements based on phase differences between microphones sensing the same acoustic signal at different locations have become possible.

The goal of this project is the use of a circular array of 6 or more MEMS microphones to measure the direction from which an acoustic signal is coming. Furthermore, the output signals of the different individual microphones can be combined in a phase sensitive way to yield a microphone set-up with an adaptive directional characteristic.







Source: Acoustica, Knowles

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Project 18: Development of a magnetic shape memory alloy actuator and a corresponding test bed

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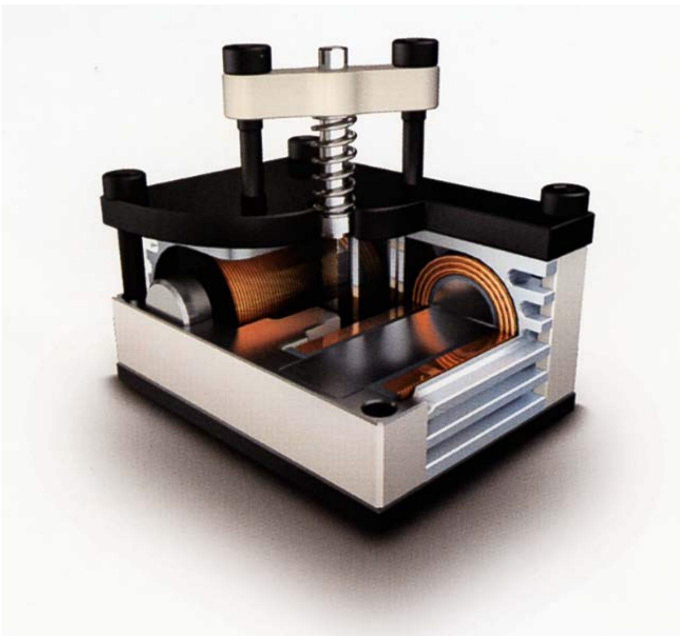
Magnetic shape memory actuators (MSM) are a very new class of solid state actuators. Compared to piezoelectric and magnetostrictive actuators they offer much larger strokes and thus open up a large variety of new mechatronic applications. Compared to thermal shape memory alloys they offer much faster switching speeds since they are controlled by magnetic field and not by a temperature change.

In a previous project a small MSM actuator using a rod from the magnetic shape memory alloy Ni-Mn-Ga has been developed. The design of an improved version of this MSM actuator, that allows to thoroughly characterize it, has been started, but needs to be completed and to be put into operation.

An additional task of this project is the development of a suitable testbed for this MSM actuator and a corresponding control, test and measurement software. It should enable the measurement of the stroke of the MSM actuator with very high accuracy (i.e. in the nm range) under static and dynamic conditions (up to 1 kHZ).



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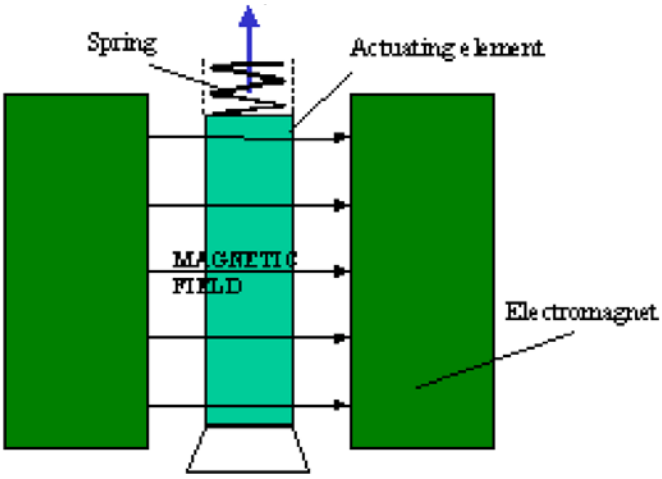

The stroke can be measured by an optical triangulation sensor. Since the stroke of an MSM actuator also depends on the mechanical prestress, the test bed should also allow the measurement of the force generated by a prestress spring.

A further extension of the testbed could include the possibility to measure the actuator performance under variable mechanical loads, provided e.g. by a miniaturized pneumatic actuator.

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Project 19: Design of an advanced personal activity tracker with the Bosch Sensortec BNO 055 and or the ST LSM6DSO inertial sensors

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The goal of the project is the design of an advanced personal activity tracker using the new possibilities offered by the Bosch Sensortec BNO 055 sensor and the ST LSM6DSO sensor

Source: Microsoft

The Bosch sensor BNO 055 is a relatively new combo sensor, that combines an advanced triaxial 16bit angular rate sensor, a versatile, leading edge triaxial 14bit accelerometer, a triaxial geomagnetic sensor and a 32-bit cortex M0+ microcontroller in a very small package. For the first time an intelligent fusion of the sensor data is implemented on the microcontroller in the same LGA package with a form factor of just 5.2 x 3.8 x 1.1 mm^3. Thus the user has direct access to the absolute orientation of the sensor in space in form of quaterions, Euler angles or rotation matrices. In addition the linear acceleration values, the inclination, the angular rates and the magnetic field data are provided. The data are provided by I^2C and UART interfaces.

Source: Bosch

Source: Bosch

In a previous project we have gathered first experience in handling and calibrating the sensor based on two platforms (LabView plattform with an I^2C interface and an Arduino based platform), including the measurement of steps and step width.

The ST sensor LSM6DSO also includes a 3D acceleration sensor and a 3D angular rate sensor. It contains even more advanced signal processing functionalities than the Bosch sensor, also employing artificial intelligences technologies, e.g. for recognition of different activities from the movement signals.

The goal of the project is to use these new sensors to implement new functionalities in an advanced fitness and activity tracker.

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