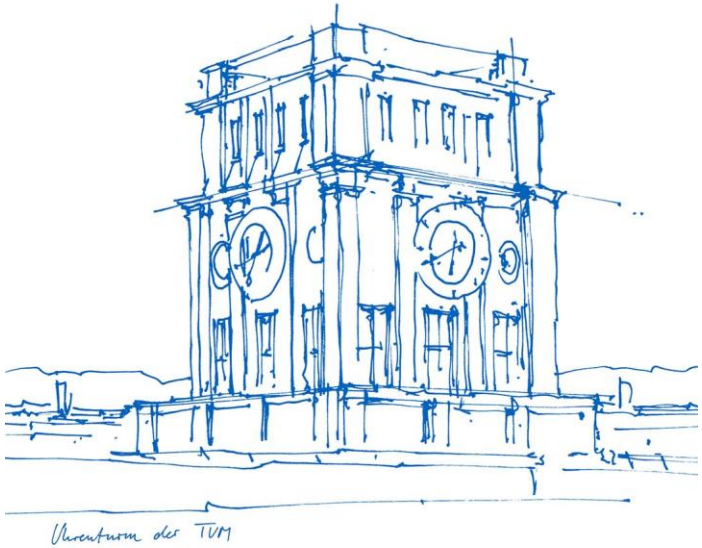
Laboratory for Product Development and Lightweight Design
TUM School of Engineering and Design
Technical University of Munich

Welcome to LPL!

LPL team

Munich, December 17, 2024

LPL

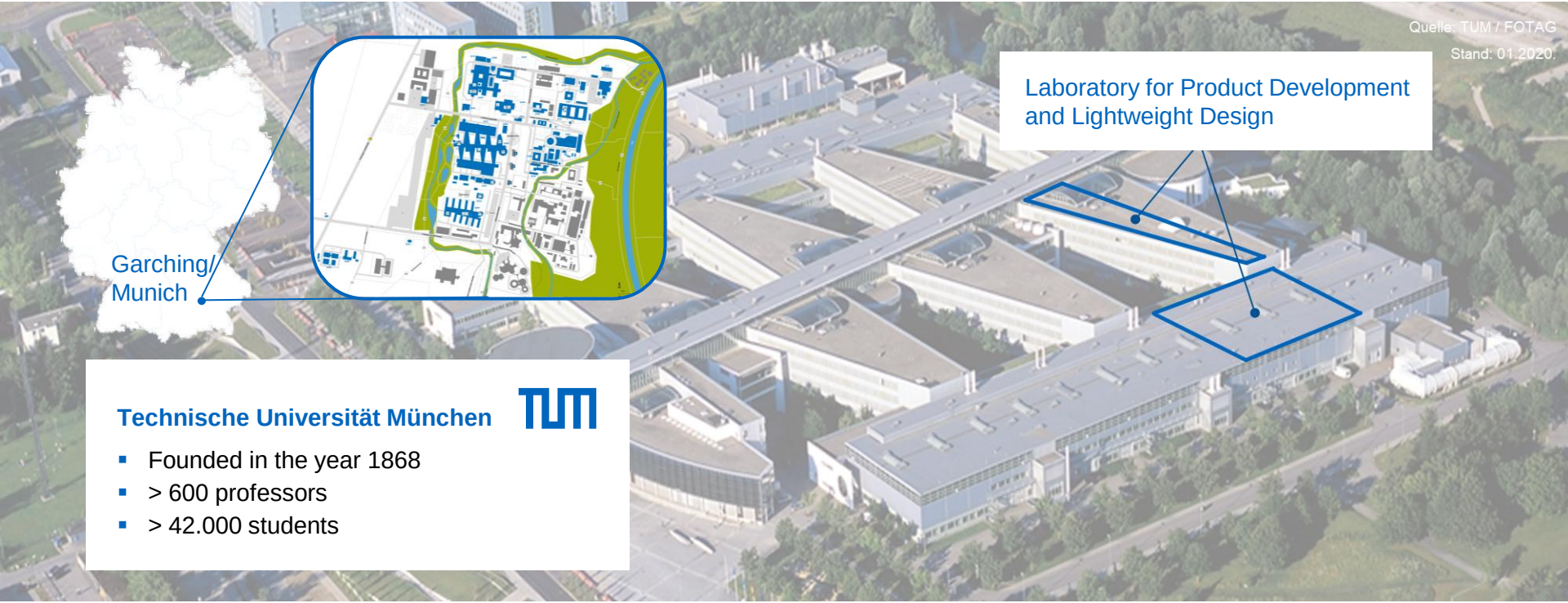


Design and Optimization of Complex Technical Systems

Content

- Laboratory
- Selected Projects
- Collaboration Modes

Technical University of Munich, Campus Garching



Technische Universität München

- Founded in the year 1868
- > 600 professors
- > 42.000 students

LPL team

Lab Management

Prof. Dr. Markus Zimmermann
Dr.-Ing. Markus Mörtl

Associated Lecturer

Dr.-Ing. Stefan Sicklinger
Dr.-Ing. Simon Pfingstl

Administration

Edith Marquard
Marion Riedel
Katja Zajicek
Eva Körner
Robert Weiß

Technical Staff

Manfred Bauer
Karl-Ludwig Krämer
Ruslan Cherednychenko

Research Assistants

Maximilian Amm
Anđela Babaja
Eduardo Della Noce
Felix Endress
Klemens Hohnbaum
Julian Mogk
Sergi Pagés i Diaz
Mahadevan Ravichandran
Jasper Rieser
Akhil Sathuluri
Philipp Schröder
Johannes Soika
Tobias Wanninger
Lucien Zapfe

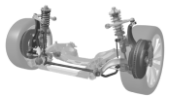
Markus Zimmermann

Academic Training

- TU Berlin, Mechanical Engineering
- University of Michigan, Mechanical Engineering
- Ecole Polytechnique
- MIT, PhD

BMW

- Body design
- Crash design
- Vehicle dynamics
- Interdisciplinary projects



Technical University of Munich

- Since November 13, 2017

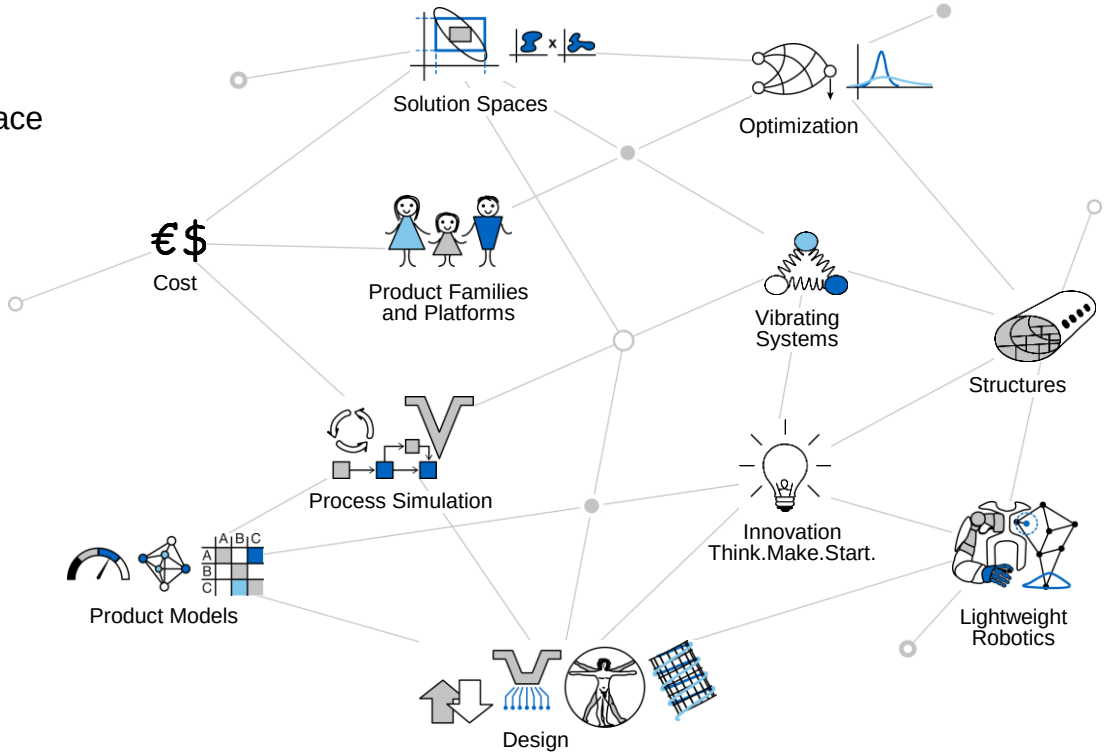
Research

Solution Space Engineering

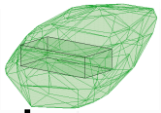
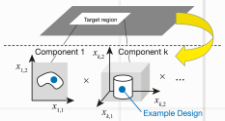
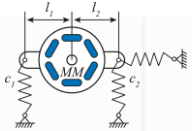
Methods & Processes

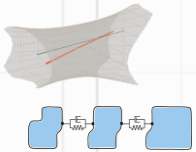
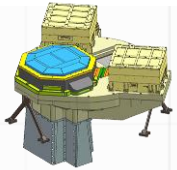
Lightweight Structures

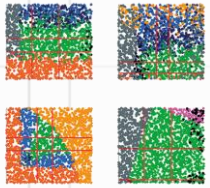
Robot Systems



Research

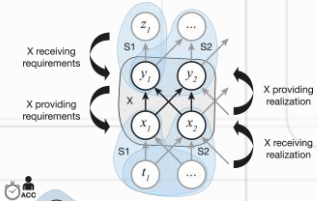
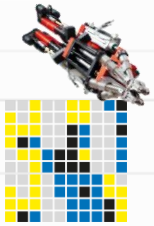
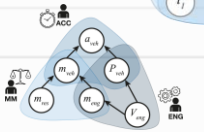
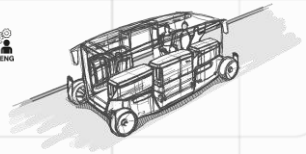


Target region
Component 1
Component k
Example Design

MM

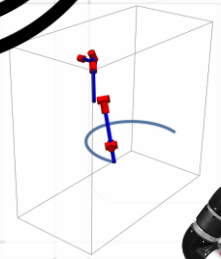




Knowledge
Evaluation
Design
Dependency Graph
Bottom-up mapping
Top-down mapping




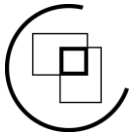



X receiving requirements
X providing requirements
X providing realization
X receiving realization
S1
S2


ACC
MM
ENG




Teaching

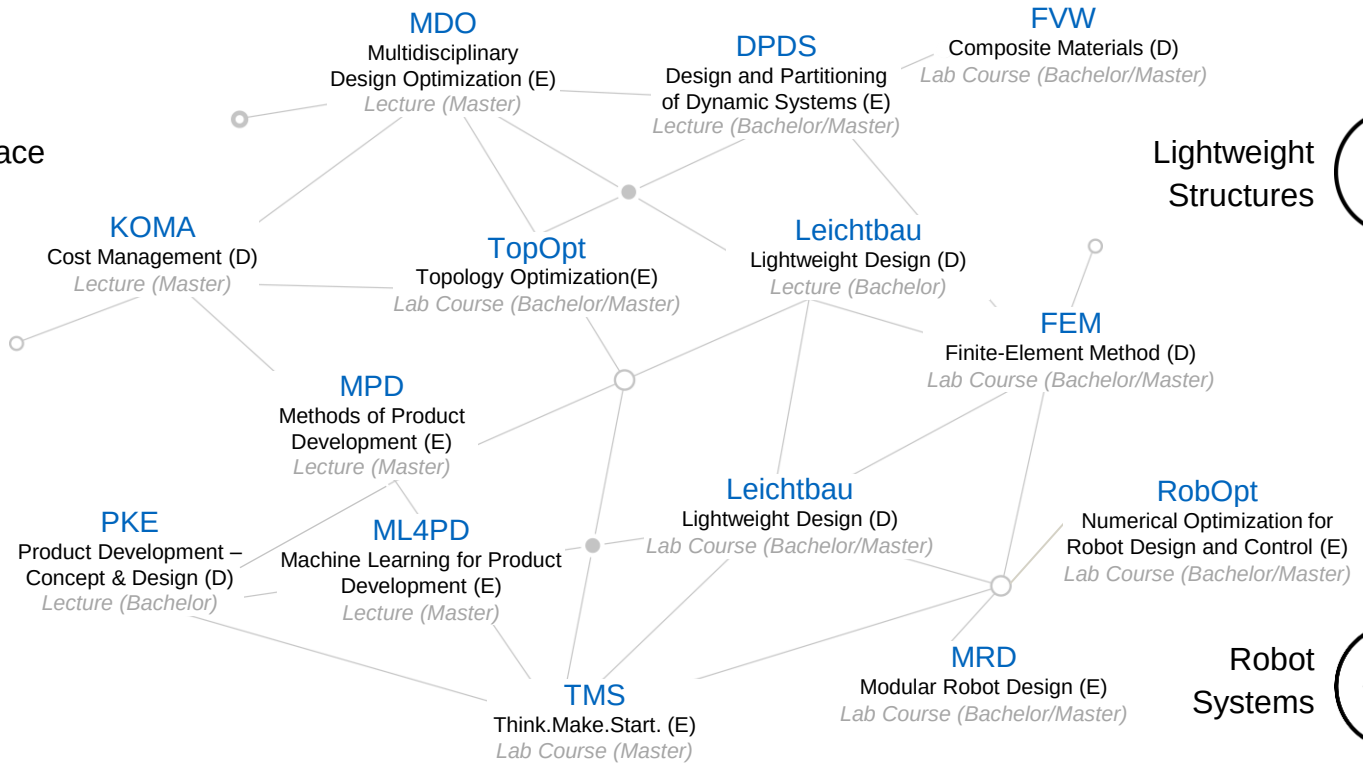


Solution Space Engineering

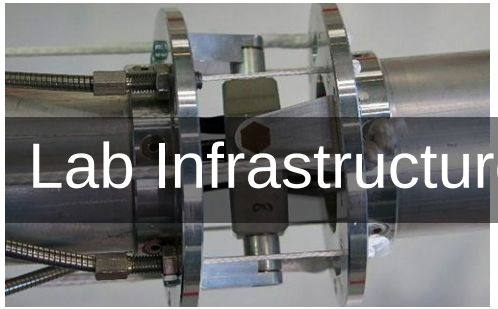
Methods & Processes

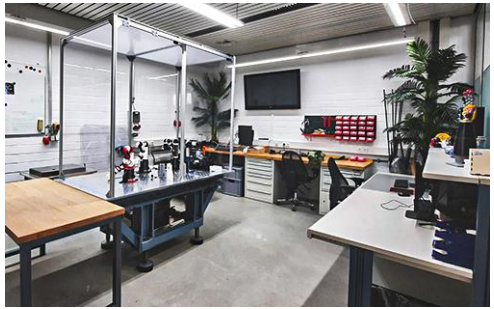
Lightweight Structures

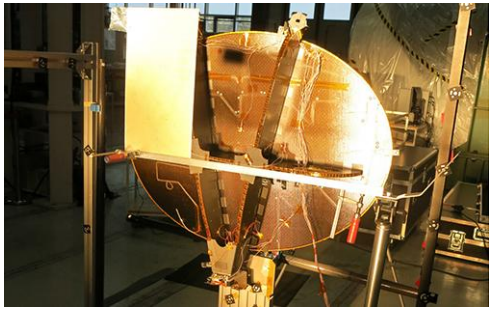
Robot Systems



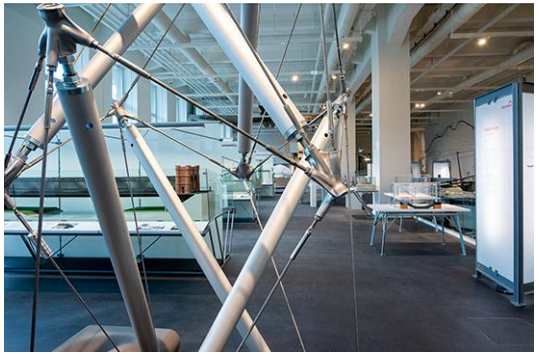
Lab Infrastructure

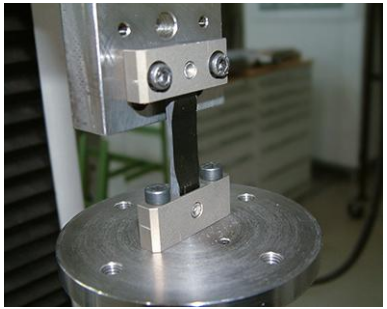






Lab Testing





Testing Machines
Universal testing machines
Ultrasonic testing machine
Vibration table, shock test bench
Thermal chambers, thermal lift,
Tempering oven
Thermal vacuum chamber, humidity chamber
Hydraulic unit Luvra

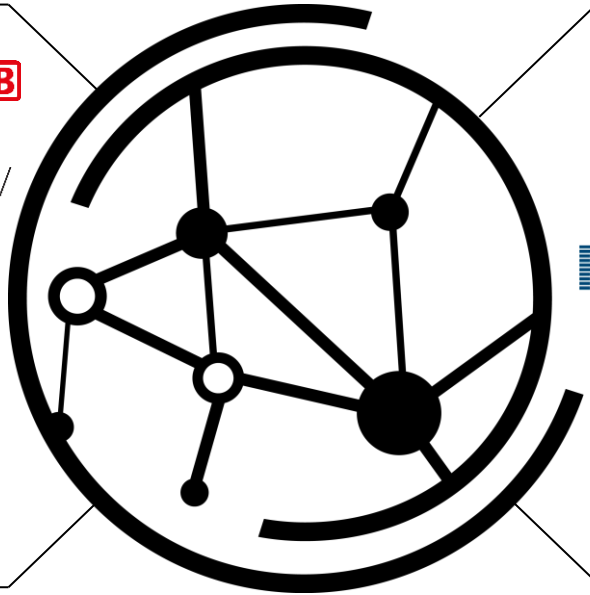
Measurement Technology
GOM Aramis
Photogrammetry equipment, thermography
Measurement systems (Flex, Cronos,
Micromysics)

Manufacturing
Turning, milling, drilling, grinding, welding,
sawing, bending
Calcination furnace
Sandblasting, water cutting
Autoclave, CNC prepreg cutter,
RTM equipment

Partners

Industry Partners

Academic Partners



Startups & Initiatives

Content

- Laboratory
- Selected Projects
- Collaboration Modes

PLUTO

Processor Localization and Utilization for Thermal Optimization

Funding | Partner: Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie | EMM engineering minds munich

Contact: Sergi Pagés i Diaz, M.Sc.

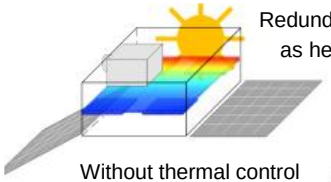
Scope: LPL and EMM GmbH are jointly developing a thermal management system for cubesats by using a digital twin as well a concept for distributed computation within the satellite. Therefore, the position of the computation units are optimized.

Anticipated results:

(1) Optimized placement of the components within the cubesat concering thermal management

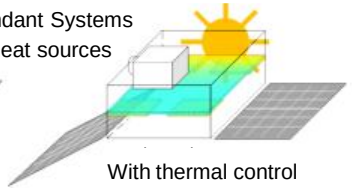
(2) Digital twin for thermal management

(3) Validation of the procedure using a prototype

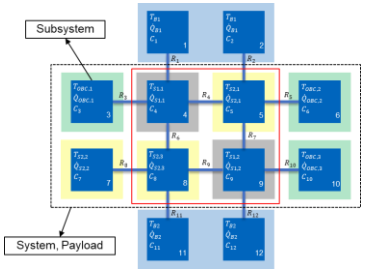


Redundant Systems as heat sources

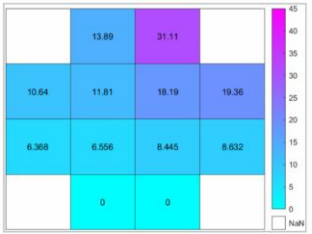
Without thermal control

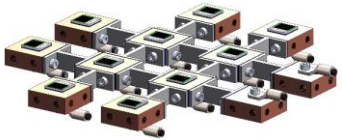


With thermal control

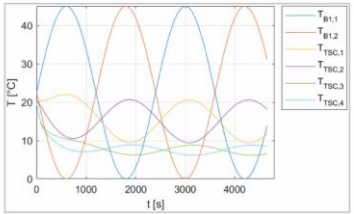


Abstraction





Prototyping & Testing



Modelling

Plattner, Radecker, Kreiner, Fassi, Frank, Zimmermann: *Satellite Payload Design for Optimized Thermal Management using a Distributed Processor System*. Proceedings of the 2023 Forum for Specification and Design Languages (FDL). September 13-14, 2023, Turin, Italy

Completed 2022

SysDeNoR

System Design of Vibration and Noise Reduction

Funding: Zeidler Forschungs Stiftung

Contact: Duo Xu, M.Sc.

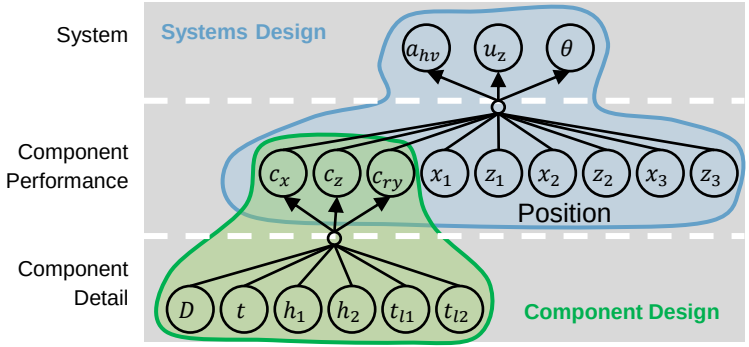
Scope: In this project, a top-down development method for the design of vibrating mechanical systems was developed that decomposes the overall system requirement into component level requirements based on Solution Space Engineering.

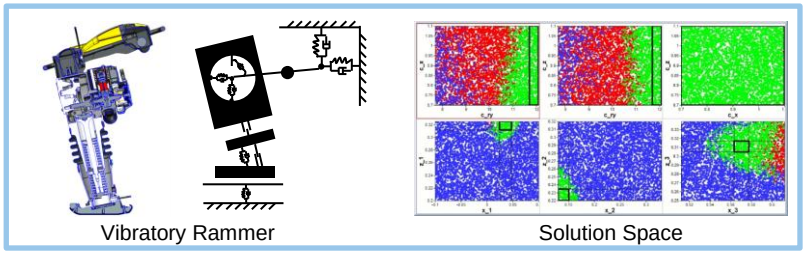
Results:

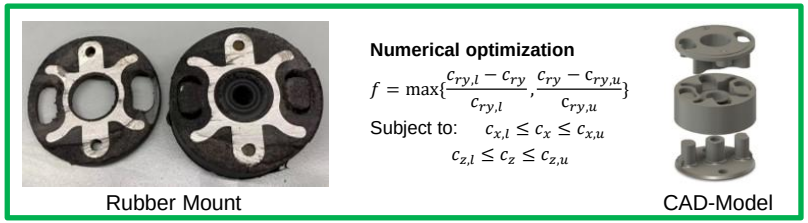
(1) Systematic top-down design method for vibrating systems to avoid iterations,

(2) Tools for precise derivation of quantitative component requirements.

(3) Three demonstrators including a real-world soil compaction device.







SOLID – Smart Soil Compaction Devices

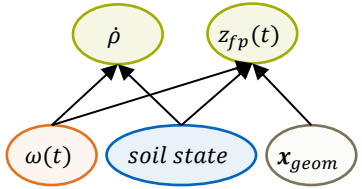
Employing Digital Twins for Optimizing Design and Operation of Vibrating Systems

Funding | Partners: Bayerische Forschungsstiftung | Wacker Neuson Group | Zentrum Geotechnik

Contact: Anđela Babaja, M.Sc.

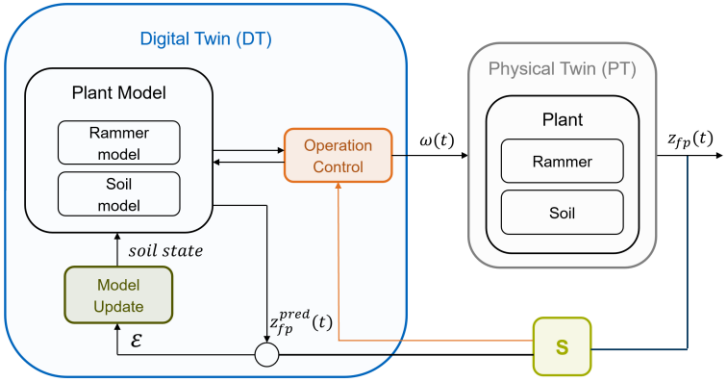
Scope: Establishing product requirements in product design is crucial to construct an attribute dependency graph (ADG). Utilizing simulation-based framework and solution space engineering methods enhances product design optimization based on the abovementioned ADG. With a simulation model for the soil compaction process, including the vibratory rammer, performance can be enhanced while mitigating dynamic loads on the operator. Moreover, evolving simulations into a digital twin (DT) allows for continuous updates and optimization in response to real-world data and conditions. Therefore, this project proposes a systematic approach to designing a requirements-compliant and robust vibratory rammer safe for the operator while optimizing real-time machine operation via a DT.

Anticipated Results: A prototype of an optimized vibratory rammer virtualized via a DT for optimal performance control.



Attribute dependency graph (ADG)

Vibratory rammer
Wacker Neuson AS68e



Concept of digital twin (DT) for optimal perfomance control

Solution Spaces

Towards the Theoretical Limit of Optimal Requirement Decomposition Using Solution Spaces for Complex Systems Design

Funding: DFG Deutsche Forschungsgemeinschaft

Contact: Eduardo Rodrigues Della Noce, M.Sc.

Scope: Dividing a large system into smaller parts may reduce design complexity and enable concurrent engineering. The key idea of this project is to compute and maximize *generalized component solution spaces* to enable said division. If properties of all components are realized within their respective component solution spaces, the overall design goal will be reached, while designers are still allowed to work independently with maximum design freedom.

Anticipated Results: Tools for Systems Design, Solution Space Engineering and Optimization

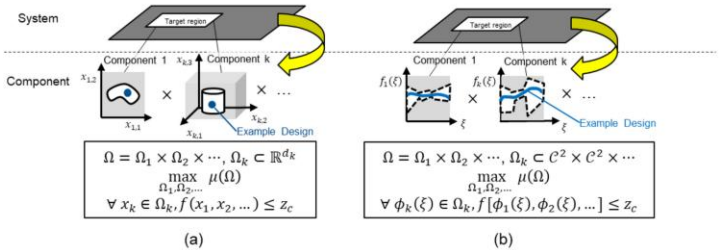


Fig. 1: Solution spaces for components that are characterized by (a) finite dimensional design vectors and variables and (b) functions.

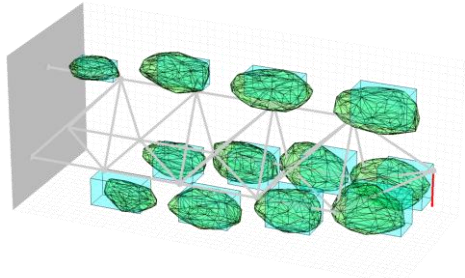


Fig. 2: Solution spaces for nodes of a truss

Rodrigues Della Noce, Zimmermann: *Optimizing Requirements for Maximum Design Freedom Considering Physical Feasibility*. Proceedings of the Design Society. 2023;3:2865-2874.

Completed 2024

PrintYourLab

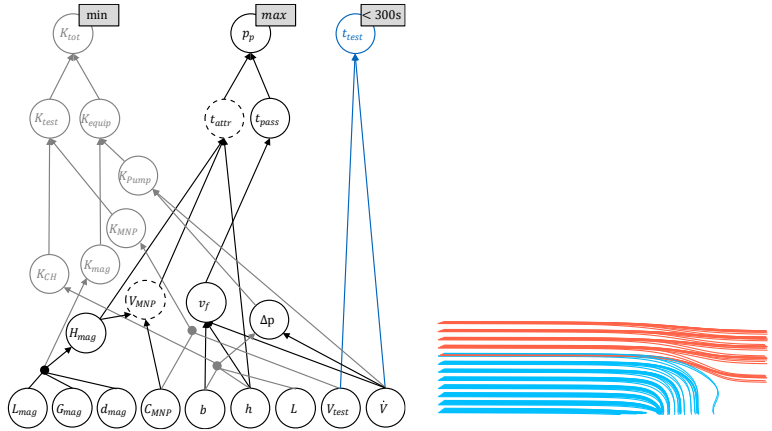
Optimizing Millifluidic Structures for Medical Applications

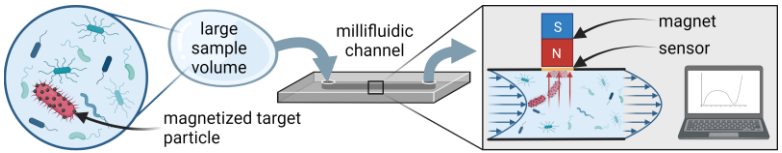
Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action | domatec Einfach sicher sein. | Steinbeis

Contact: Johannes Soika, M.Sc.

Scope: The goal of the project is to develop a handheld device that can perform water analysis regarding contamination with pathogenic microorganisms on site and within a short period. The development of suitable millifluidic structures is required to perform the rapid test and detect specific microorganisms. The structure is to be automatically designed and optimized by a topology optimization method based on target cell specific requirements.

Results: Fast simulation model for the prediction of number of particles trapped by magnetic field.





Workflow of the water analysis: 1. magnetize target particles, 2. collect large sample, 3. guide through channel, 4. separate from flow onto sensor, 5. analyse sensor signal

Soika, Wanninger, Muschak, Schwaminger, Berensmeier, Zimmermann: *Designing lab-on-a-chip systems with attribute dependency graphs*. Proceedings of the Design Society, 2024, 4, 785-794.

Soika, Wanninger, Muschak, Schwaminger, Berensmeier, Zimmermann: *Efficient Numerical Modelling of Magnetophoresis in Millifluidic Systems*. Royal Society of Chemistry, 2024, Lab-on-a-Chip.

PROVING

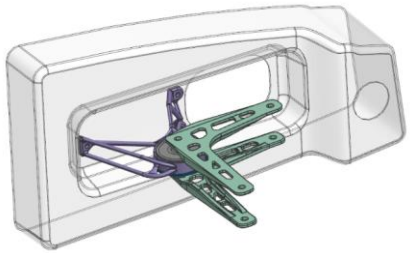
Aircraft Structure Design for Additive Manufacturing

Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action; BAM Bundesanstalt für Materialforschung und -prüfung; BOEING; EASA; EES Zeppelin Engineering Solutions; IABG; MSC Software; oerlikon; RS.aero A REINER STEMME COMPANY; Technische Universität Berlin

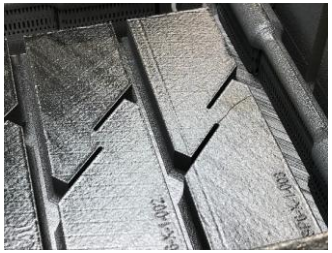
Contact: Felix Endress, M.Sc. M.Sc.

Scope: For aerospace applications metal additive manufacturing bears potentials for lightweight design and cost-effective low volume productions. Yet, the development and design of mechanical systems is complex, due to great influences of the build process (anisotropic material behaviour, failure modes, etc.) and various DfAM principles and opportunities. Therefore, Additive Manufacturing characteristics are investigated and fed back into the development process.

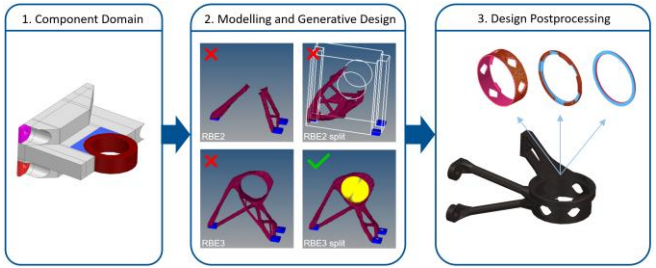
Anticipated results: Approaches for the optimization-driven product development of aircraft structures are being developed, considering process, material and design characteristics of metal additive manufacturing. Reduction of physical testing and improved optimization and simulation results.



Assembly of AM components



Testing the strength of AM specimen



Design and optimization of AM components

Endress, Kipouros, Zimmermann: *Distributing Design Domains for Topology Optimization in Systems Design*, Proceedings of the ASME 2023, International Design Engineering Technica, Conferences and Computers and Information in Engineering Conference IDETC-CIE2023, August 20-23, 2023, Boston, Massachusetts
Endress, Zimmermann: *Designing Variable Thickness Sheets for Additive Manufacturing Using Topology Optimization with Grey-Scale Densities*, in C. Klahn et al. (Eds.): AMPA 2023, STAM, pp. 63–76, 2024.

FORAnGen

Generative Design by Topology Optimization Considering Assembly and Manufacturing

Funding | Partners:

Contact: Johannes Soika, M. Sc.

Scope: Highly optimized lightweight components are typically subject to many requirements on their performance and restrictions imposed by manufacturing and assembly. Often, requirements and restrictions are not available as explicit constraints and cannot be included in tools that automatically generate design proposals. Also, there are no methods available for optimal load path design of mechanical connections.

Anticipated results: Methods and tools for automatically generating (1) feasible lightweight designs with a particular focus on additive manufacturing and (2) optimal load paths for connecting interfaces. The methods will be applied to demonstrator parts from industry partners.

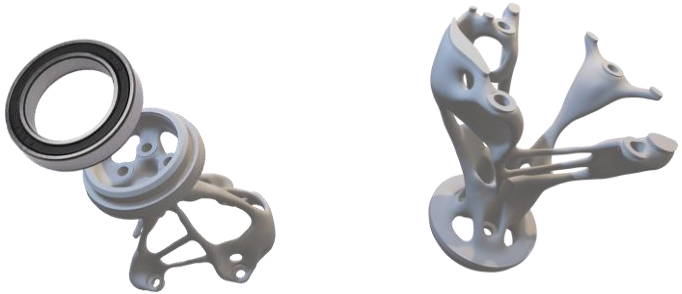


Fig 1: Optimized structures considering connections with a roller bearing (left) and screw connections (right)

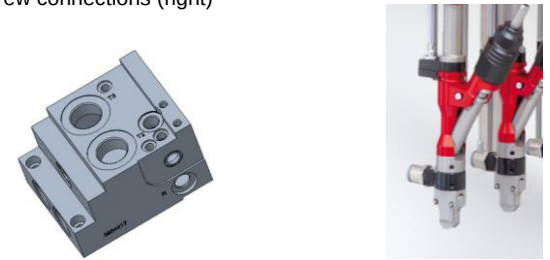


Fig 2: Application problems: Hydraulic valve block from ZF Friedrichshafen AG (left) and automatic screwdriver from Stöger Automation (right)

TopOpt Connections

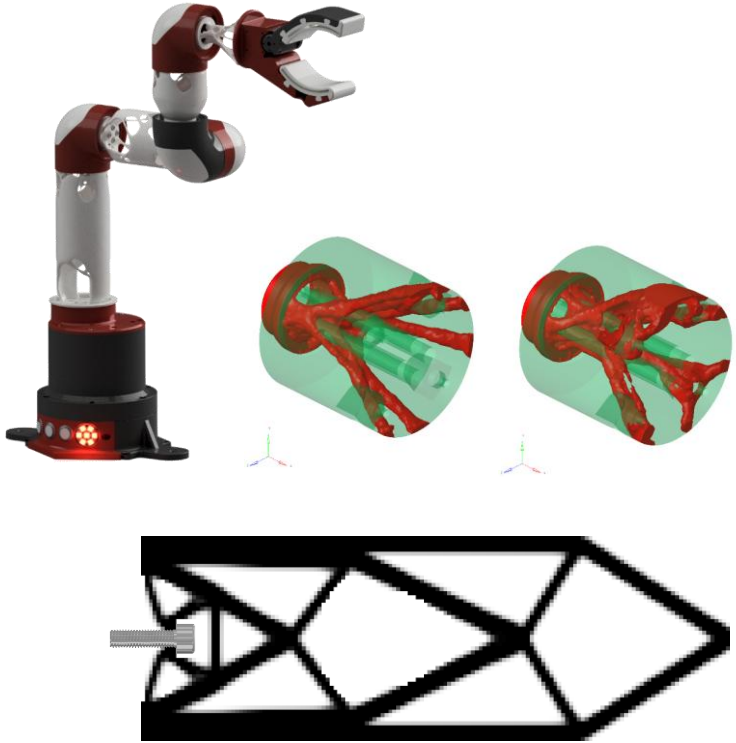
Screw Connection Design for Topology Optimization

Funding | Partner: LPL

Contact: Tobias Wanninger, M.Sc.

Scope: Connections in topology optimization with screws are typically considered as fixed boundaries on the contact surface of the screw heads. By doing so, the boundary of the optimization is limited, and the design space cannot be fully exploit. The formulation here utilize the force coming from the screws to apply pressure on structural parts which are connected to the boundary. The approach is carried out in a two-step procedure where at first the best attachment points of the global loads are calculated. The second step involves both global loads and screw loads to determine the final structure.

Anticipated Results: Computational methods to simultaneously optimize structural load paths and screw connections.



Wanninger, Frank, Zimmermann: *Topology optimisation of multiple robot links considering screw connections*. Proceedings of the Design Society, 2024, 4, 1879-1888.

FCC

Support Structure for Next Generation Muon Detector at CERN

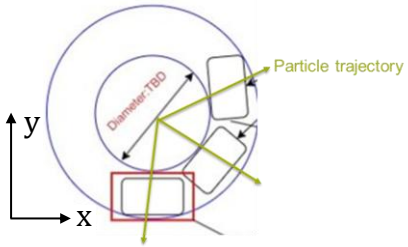
Funding: Bavarian-Czech Academic Agency (BTHA)

Partners:

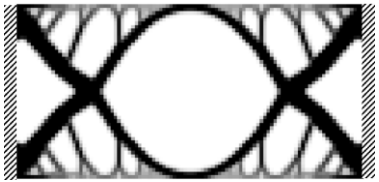
Contact: Mahadevan Ravichandran, M.Sc.

Scope: Muon detectors are to be huge components to be arranged in vertical circles to detect particles in the Future Circular collider at CERN. These detectors are to be supported by a structure that meets the accuracy and stiffness requirements on the detectors. The project aims to develop a method to design the support structures.

Anticipated Results: A method to develop the support structure design for different boundary conditions



Circular collider with detectors
in different boundary conditions



Optimal topology results with external and self-weight loads

Current generation muon detector tubes

Completed 2022

OptProLaS

Component Optimization Considering the Process Influences during Laser Beam Melting

Funding | Partners: KME | iwb | STÖGER AUTOMATION | MTU Aero Engines | vectoflow measurements in fluids

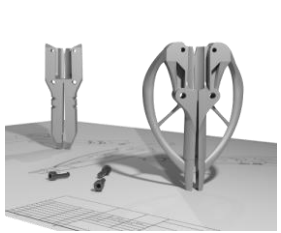
Contact: Jasper Rieser, M.Sc.; Jakob Trauer, M.Sc.

Scope: Selective laser melting is a complex and relatively expensive additive manufacturing (AM) process. Geometrical deviations, residual stresses and build failure often pose challenges for users in practice. The aim of this project was to investigate how complex metallic components must be designed to better meet the special requirements AM while fully exploiting the great potentials of this powerful manufacturing techniques.

Results:

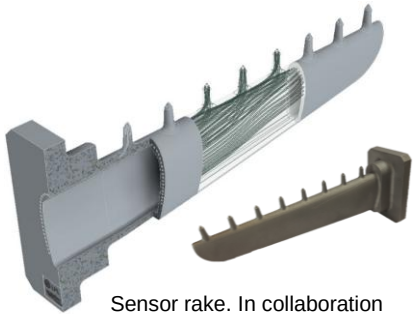
(1) A *procedure model* for the design of AM parts covering all essential steps from requirement elicitation to the final printed part.

(2) Three demonstrator parts: a customized *screw gripper*, a *gas turbine engine emissions rake* with internal pressure channels and a light-weight aero engine *bracket*.



Gripper for a handheld screwdriver by STÖGER AUTOMATION GmbH: The support-free redesign (right) provides mass savings of 30% compared to the conventional design (left).

Aero engine bracket with optimized topology. In collaboration with MTU aero engines AG.



Sensor rake. In collaboration with vectoflow GmbH.

KREATIVE

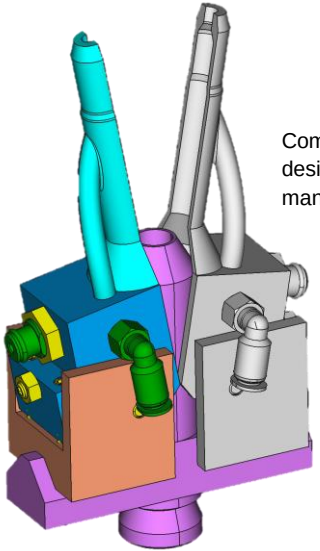
Konstruktionsmethodik für die hybride Additive Fertigung

Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action | iwis | iwb | STÖGER AUTOMATION

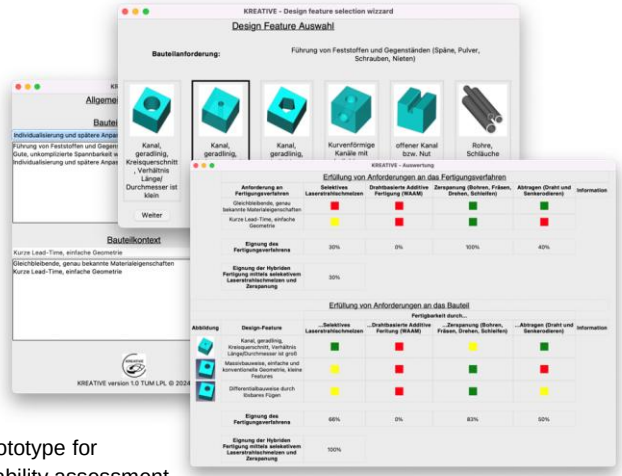
Contact: Jasper Rieser, M.Sc.

Scope: Additive manufacturing (AM) is widely considered as the Swiss army knife among the existing manufacturing techniques. With AM it is possible to manufacture parts with fairly complex geometries from many different materials. However, the cost of AM are often still too high for series production, thus limiting its use to merely prototyping. To overcome this, AM can sometimes be combined with another manufacturing technique leading to a hybrid additive manufacturing approach. The research project KREATIVE aims at exploring how parts must be designed to properly take advantage of the individual strengths of the different manufacturing techniques while also considering their weaknesses and limitations.

Anticipated Results: A design methodology for hybrid additive manufacturing.



Component of a screw driver designed for hybrid additive manufacturing



Software prototype for manufacturability assessment

LCL Robots

Low-Cost Lightweight Robots on Demand

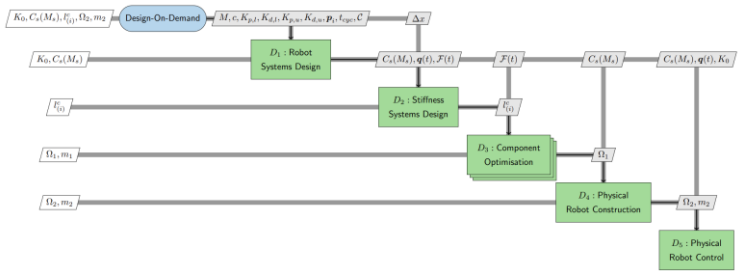
Funding: Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

Partners: voxeljet, MiMed, HAWE HYDRAULIK

Contact: Akhil Sathuluri, Maximilian Amm, M.Sc.

Scope: LPL and the Institute of Micro Technology and Medical Device Technology (MIMED, Prof. Lüth) are jointly developing a process for the semi-automatic design of task-specific low-cost lightweight robots. The project deals with the multidisciplinary computational design process by combining optimisation sub-problems of several sub-systems. It ties together modular robotics, structural optimisation, additive manufacturing with innovative design processes to realise customisable robots with minimal development time.

Anticipated results: Hardware and software tools for the automatic robot design with its concurrent structural optimisation



Sathuluri, Sureshbabu, Frank, Amm, Zimmermann: *Computational Systems Design of Low-Cost Lightweight Robots*. Robotics 2023, 12, 91.

Completed 2023

DIVA

Intuitive Design in Contrast to the V-model and its Analysis

Funding: State of Bavaria

Contact: Akhil Sathuluri, M.Sc.; Maximilian Amm, M.Sc.

Scope: Experience driven **bottom-up** design processes have been effectively used for humanoid robot design. On the other hand, this project aims at evaluating an alternative **top-down** design strategy for developing robots. This involves a cascaded optimization strategy resulting in constructing the so-called *solution spaces.* This enables us to interpret and trade-off different design variables in the design process.

Results: Computational design methodology for the top-down development of robot systems. Comparison of the different design philosophies.

1. Modeling and optimization

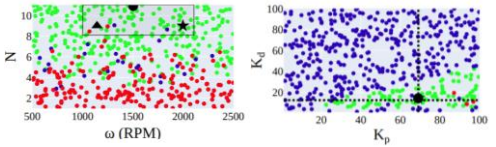
Problem-1:

$$\min_{\boldsymbol{x}} \ \phi(\mathrm{t_{cyc}}, \mathrm{L}), \quad \text{subject to,} \ \ h(\boldsymbol{x}) = 0, \quad \boldsymbol{x}_l \leq \boldsymbol{x} \leq \boldsymbol{x}_u$$

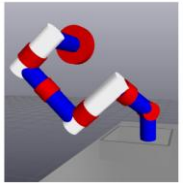
Problem-2:

$$\max_{\boldsymbol{\zeta}} \ \mu(\Omega(\boldsymbol{\zeta})), \quad \text{such that,} \ \ \mathrm{t_{cyc}} \leq \mathrm{t_{cyc}}(\boldsymbol{x}_p), \quad \mathrm{L} \leq \mathrm{L}(\boldsymbol{x}_p)$$

2. Top-down mapping



3. Physically-feasible design



Simulation

Reality

Robot resulting from V-model vs intuitive design

Sathuluri, Vazhapilli Sureshbabu, Zimmermann: *Robust co-design of robots via cascaded optimisation.* 2023 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2023.

DSL4RAS

Domain Specific Language for Robot-like Systems

Funding: DFG Deutsche Forschungsgemeinschaft

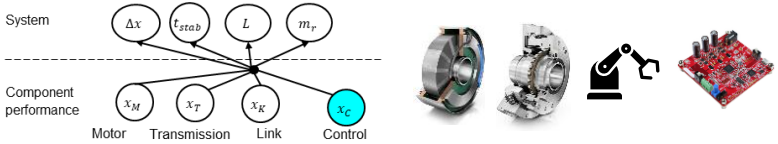
Partners: Institute of Machine Elements (FZG),
Institute of Automation and Information Systems (AIS)

Contact: Akhil Sathuluri

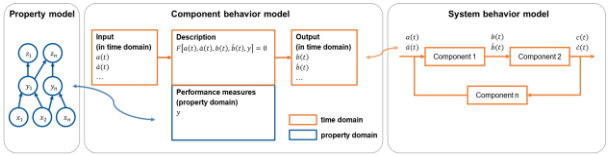
Scope: Designing robot-like systems involves several domains. DSL4RAS aims at developing domain specific languages that are compatible with each other. With them, co-design of mechanical elements, like gears, mechatronic elements, like motors, control logic and sensor design shall be enabled. A particular focus lies on quantitative detail modelling of mechanical characteristics of gears, in particular on degradation effects. Three TUM labs work together in a DFG-supported project.

Anticipated Results: Design languages for all relevant components of robot-like systems, modelling procedures, procedure model for systems design and product family design

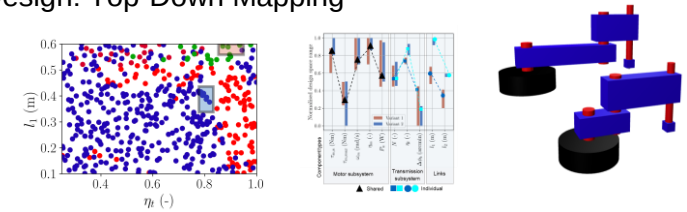
1. Framing: Problem and requirement definition



2. Modelling: Establishing bottom-up mappings



3. Design: Top-Down Mapping



Ziegler et al.: *MBSE incorporating time-dependent behavior for the design of robot-like systems*. Proceedings of the Design Society 3 (2023): 2585-2594.
Ziegler et al.: *Computing solution spaces for gear box design.* Proceedings of the Design Society 4 (2024): 3041-3050.

SSO-DT

Solution Space Optimization with Disturbance Tolerances

Funding: DAAD

Contact: Akhil Sathuluri

Scope: The combined optimisation of different robot sub-systems as a co-design problem has been shown to identify better-performing robot designs. However, classical optimisation methods result in point-optimum solutions that may not ensure physical feasibility or robust performance. The proposed method retains the design flexibility of the robot while improving the tolerance to disturbances.

Results:

(1) A *top-down* based computational systems design approach to improve the robustness of a humanoid robot walking.

(2) Improved tolerance to disturbances of 20% higher magnitude.

(3) A suggestion of product family of joint actuation components and their sizing.

1. Modeling and optimization

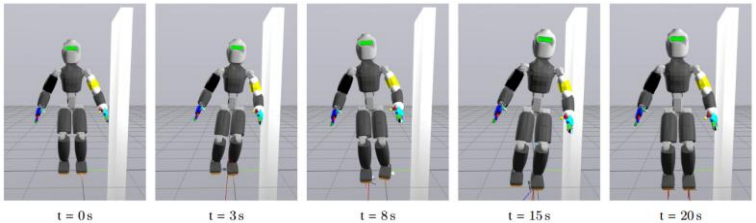
Problem-1:

$$\begin{aligned} \min_{\boldsymbol{x}} \quad & L(\boldsymbol{x}), \\ \text{subject to,} \quad & h(\boldsymbol{x}, \boldsymbol{\xi}) = 0, \\ & g(\boldsymbol{x}, \boldsymbol{\xi}) \leq 0, \\ & \boldsymbol{x}_l \leq \boldsymbol{x} \leq \boldsymbol{x}_u, \end{aligned}$$

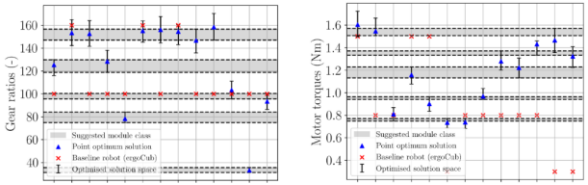
Problem-2:

$$\begin{aligned} \max_{\boldsymbol{\zeta}_A} \quad & \mu(\Omega(\boldsymbol{\zeta}_A))\ \mu(\Omega(\boldsymbol{\Xi})), \\ \text{subject to,} \quad & \forall\ \boldsymbol{x}_A \in \Omega(\boldsymbol{\zeta}_A) \text{ and } \boldsymbol{\xi} \in \Omega(\boldsymbol{\Xi})\ \exists\ \boldsymbol{x}_C \text{ such that,} \\ & h(\boldsymbol{x}_A, \boldsymbol{x}_C, \boldsymbol{\xi}) = 0, \\ & g(\boldsymbol{x}_A, \boldsymbol{x}_C, \boldsymbol{\xi}) \leq 0. \end{aligned}$$

2. Improvement in robustness to obstacles



3. Product family design



Completed 2022

DESIM

Simulation of Distributed Design Processes

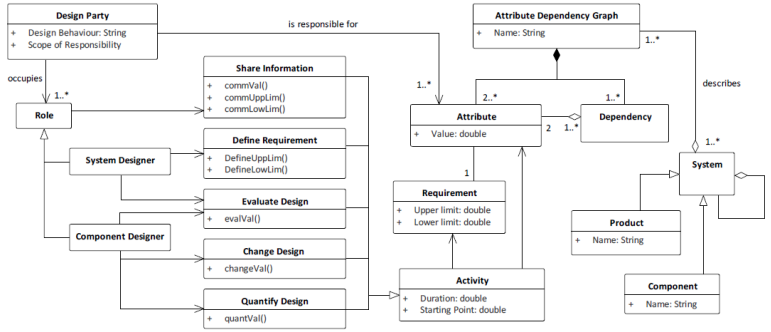
Funding:

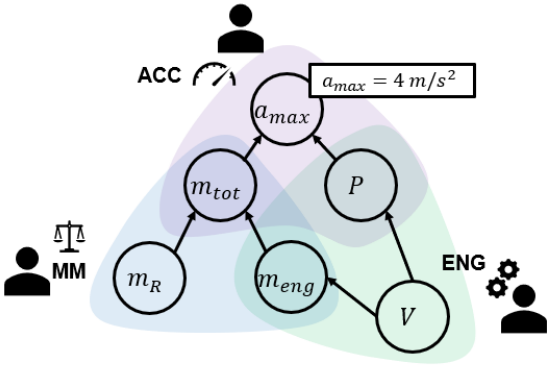
Contact: Ferdinand Wöhr, M.Sc.

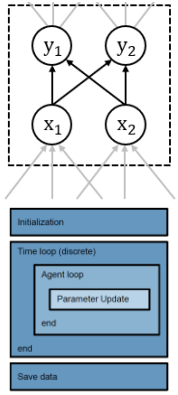
Scope: Development of an agent-based simulation model to evaluate distributed design processes with respect to product quality, development time and design flexibility. Key elements are:

- Time-discrete simulation algorithm
- Mathematical process description
- Data model including all aspects
- Multi-scale model validation

Results: Combined agent-product-process model and simulation tool for improvement of organizations and development processes.







Completed 2022

Product Family Design

Modular Product Family Design for Screw Driving Systems

Funding: STÖGER AUTOMATION

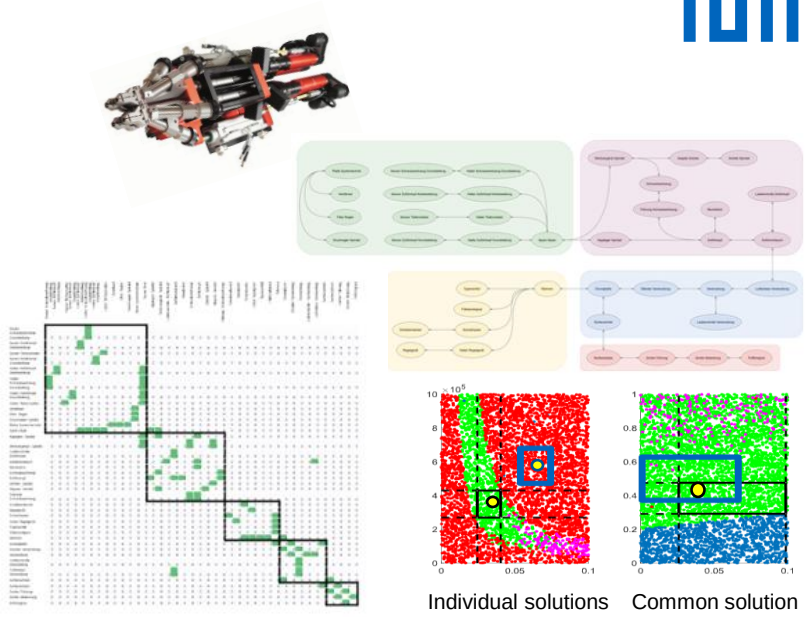
Contact: Sebastian Rötzer, M.Sc.

Scope: In the competitive market of highly automated screwdriving and fastening systems, companies need new methods for systematic product development for *specific customer requirements*. Modular product family design and customer orientation are key to extending mechanical excellence with digital functionality.

Results:

(1) A *method* for the design of product family architecture, connecting customer-oriented functions with specific product components.

(2) One *demonstrator* = a product architecture with full transparency about important design decision.



Top: example of screwdriving system. Bottom: Eight steps of the procedure applied in this project

BUENA

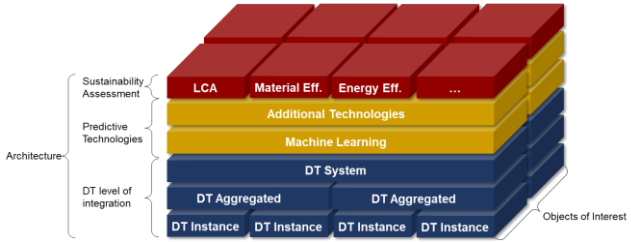
Cross-sector Industrialization of Additive Production

Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action | IABG | VOITH | BOEING | FIT | iwb | nebumind | Fraunhofer IAPT | Bergische Universität Wuppertal

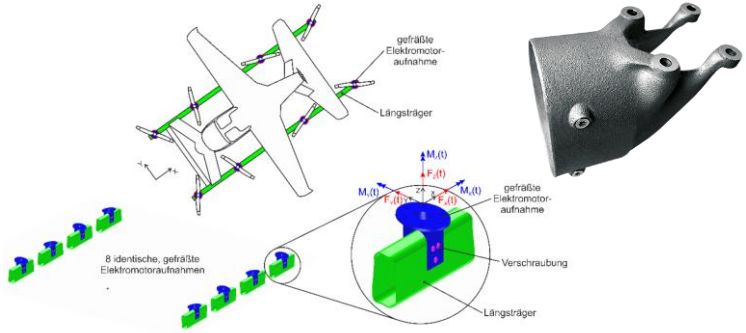
Contact: Philipp Schröder, M.Eng.

Scope: BUENA's project consortium has identified several issues as barriers to additive manufacturing (AM). In order to resolve these, the aim is to industrialize AM across all sectors. In this way, it is intended to contribute to the promotion of material- and energy-efficient lightweight construction. The project will be limited to the widely used laser powder bed fusion and direct energy deposition processes. Within this framework, the project aims to map or predict the costs and emissions of an AM component holistically over its life cycle. The technological realization of the project is carried out by a digital twin.

Anticipated Results: A digital twin including cost and emission model. Using this the costs and emissions of the life cycle can be included early in the development process.



Structure of a digital twin concept for carbon emission reduction



Motor bracket developed for additive manufacturing

Kos, Schröder, Trauer, Endress, Mörtl, Zimmermann: *Improving sustainability of additive manufacturing processes based on digital twins – a case study,* Proceedings of the Design Society 2024.

TuWAs

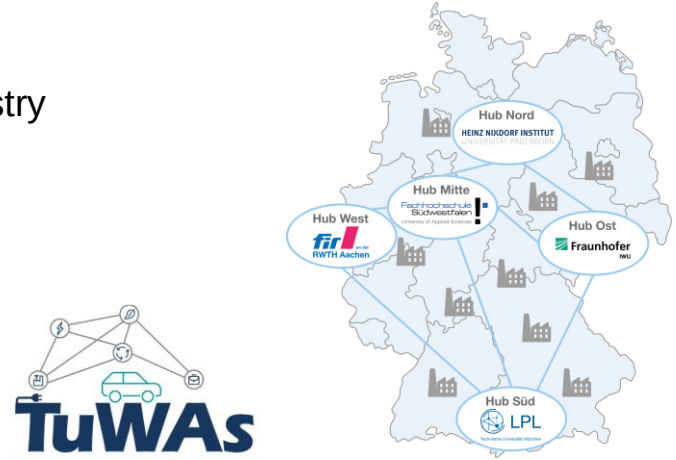
Transformation Hub for Powertrain Value Chains in Forming Industry

Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action | Fraunhofer IWU | fir an der RWTH Aachen | HEINZ NIXDORF INSTITUT UNIVERSITÄT PADERBORN | Fachhochschule Südwestfalen University of Applied Sciences

Contact: Lucien Zapfe, M.Sc.; Klemens Hohnbaum, M.Eng.

Scope: The project focuses on the transformation process of the automotive powertrain value chain in the forming industry due to the e-mobility. The objective is the successful transformation of the companies and to provide important impulses for the preservation of jobs, know-how and manufacturing networks in Germany and Europe.

Anticipated Results: Establishing of a transformation hub that enables companies in the forming industry managing the challenges presented by major future trends.



Mu-Flash GEN 2

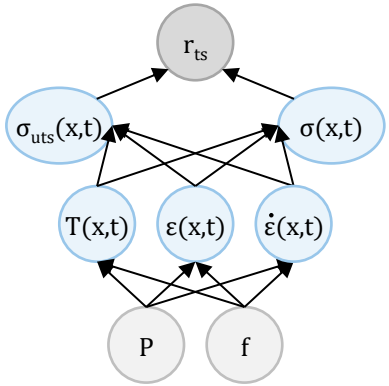
X-Ray Anode Design for Tumor Therapy with Micro Beams

Funding | Partners: IAS | MRI

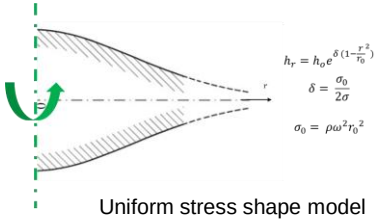
Contact: Mahadevan Ravichandran, M.Sc.

Scope: Microbeam radiation therapy is novel and highly promising technique for cancer treatment. It relies on high-intensity, high-dosage micrometer-scale X-ray beams produced by electrons hitting a fast-rotating body called X-ray anode. It is to be designed and optimized to withstand 1.5 MW of heat load to suit human treatment. To verify this never-seen-before heat flux loads, an equivalent prototype is to be built and tested to validate the design.

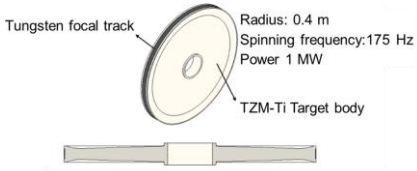
Anticipated Results: A Validation method for extreme thermo-mechanical loads in component design, Feasibility of using the concept in the clinical microbeam therapy system X-ray system



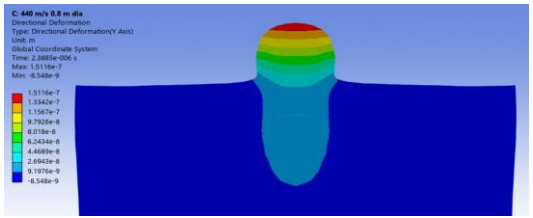
Attribute Dependency Graph



Uniform stress shape model



Prototype design



Validation test modelling

Prototype X-ray anode GEN 1

Ravichandran et al.: *Material selection for extreme thermo-mechanical loads using design space projection*, DS 118: Proceedings of the DesignSociety 2022
Ravichandran et al.: *Design and Validation Strategy for an X-Ray Target Subject to Ultra-High Heat Flux Loading*, Summer Heat Transfer Conference 2024

MeViPeP

Evaluation Methods and Metrics for Monitoring and Strategically Expanding the Degree of Virtualization of a Passenger Car Development Process

Funding:

Contact: Julian Mogk

Scope: The development of complex systems is facilitated by modern virtual methods. Virtual Product Creation (VPC) methods are of high importance to the development efficiency and product quality of automobiles and their software. To strategically advance the use of VPC methods and thereby enhance the development of the most innovative products, it is necessary to establish metrics for the degree of virtualization. Consequently, new metrics and methodologies are developed and evaluated within the development department of AUDI AG.

Anticipated results: New methods and metrics to measure the degree of virtualization of a development process are needed. This should enable Audi to enhance both the efficiency and quality of the development process.

This image was created using Microsoft Copilot

Completed 2024

STEAM

Solutions for Transport Networks with Electric Advanced Mobility

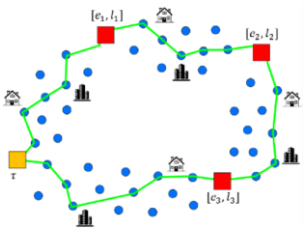
Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action; CLUSTERS 4 FUTURE Innovationsnetzwerke für unsere Zukunft; BAIS; BMW GROUP; MAN; SWM; Stanglmeier Touristik

Contact: Nuno Miguel Martins Pacheco, M.Sc.

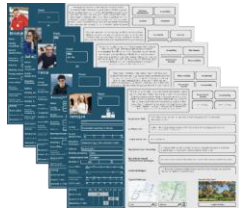
Scope: We aim to rethink Munich's urban transport by optimizing bus systems with innovative technologies and data analysis. The project includes three aspects: (1) Adjust routes based on traffic data and occupancy, (2) Integrate passenger and parcel transport to reduce traffic, emissions, costs, and (3) Create adaptable interiors for passengers and freight, using citizen and stakeholder feedback.

Results: A **concept for an integrated bus system** for public transport in Munich for passenger and parcel transport. This is designed with accessibility features for all passengers and uses flexible interiors to adapt to different travel needs. Parcels are transported through an autonomous **parcel locker robot**. The system was realized as a **VR Demonstrator**, where one can experience the system. In addition, **multiple living labs** with citizen involvement were hosted to get feedback.







Content

- Laboratory
- Selected Projects
- Collaboration Modes

Kooperationsformate

F&E Projekt	Gefördertes Projekt	Schulungs-Projekt	Studienarbeiten
3 Monate – 5 Jahre	1 – 4 Jahre	Individuell	Bis 6 Monate
Ab ca. 160 k€ / Jahr	0 € (Firma erhält evtl. Zuwendungen)	6k – 10k € pro Tag (nach Vorbereitungsaufwand)	0 €
Forschung ergebnis-offen, individuell und evtl. in Kooperation mit anderen Partnern	Forschungsantrag ggfs. mit weiteren Partnern	Standardaufgaben ohne Forschungsinhalte	Betreuung durch Lehrstuhl- und Firmen-Mitarbeitende
Mitarbeiter*in vor Ort	Mitarbeiter*in vor Ort	Mitarbeiter*in vor Ort	Keine Mitarbeiter*in vor Ort
Übertragung der Rechte an Firma möglich	Öffentlich, bei KME verbandsintern	Urheberrechte beim Dozenten	Rechte beim Studierenden

Collaboration Modes




R&D project	**Funded project**	**Training project**	**Student research project**
3 months – 5 years	1 – 4 years	Individual	Up to 6 months
>aprox. 160 k€ / year	0 € (Company receives fundings)	6k – 10k € a day (according to effort)	0 €
Research solution neutral, individual and possibly in cooperation with other partners	Research proposals, possibly with further partners	Standard tasks, no research	Supervision by chair and company employees
Employee on site	Employee on site	Employee on site	No employee on site
Transfer of rights to company possible	Public, internal to KME	Copyright with the lecturer	Rights belong to the student

Contact

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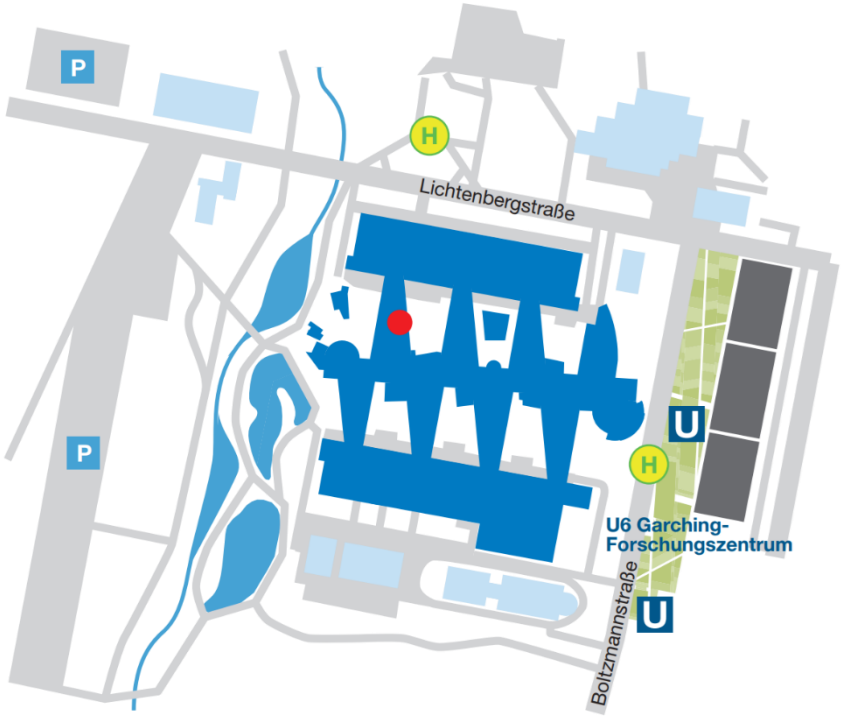

Thank you for your attention!

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