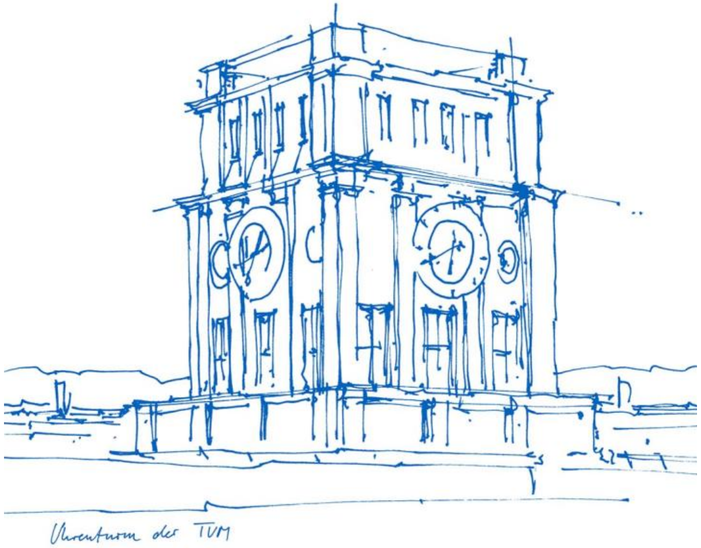
Laboratory for Product Development and Lightweight Design
TUM School of Engineering and Design
Technical University of Munich

Welcome to LPL!

LPL-Team

Munich, June 02, 2025

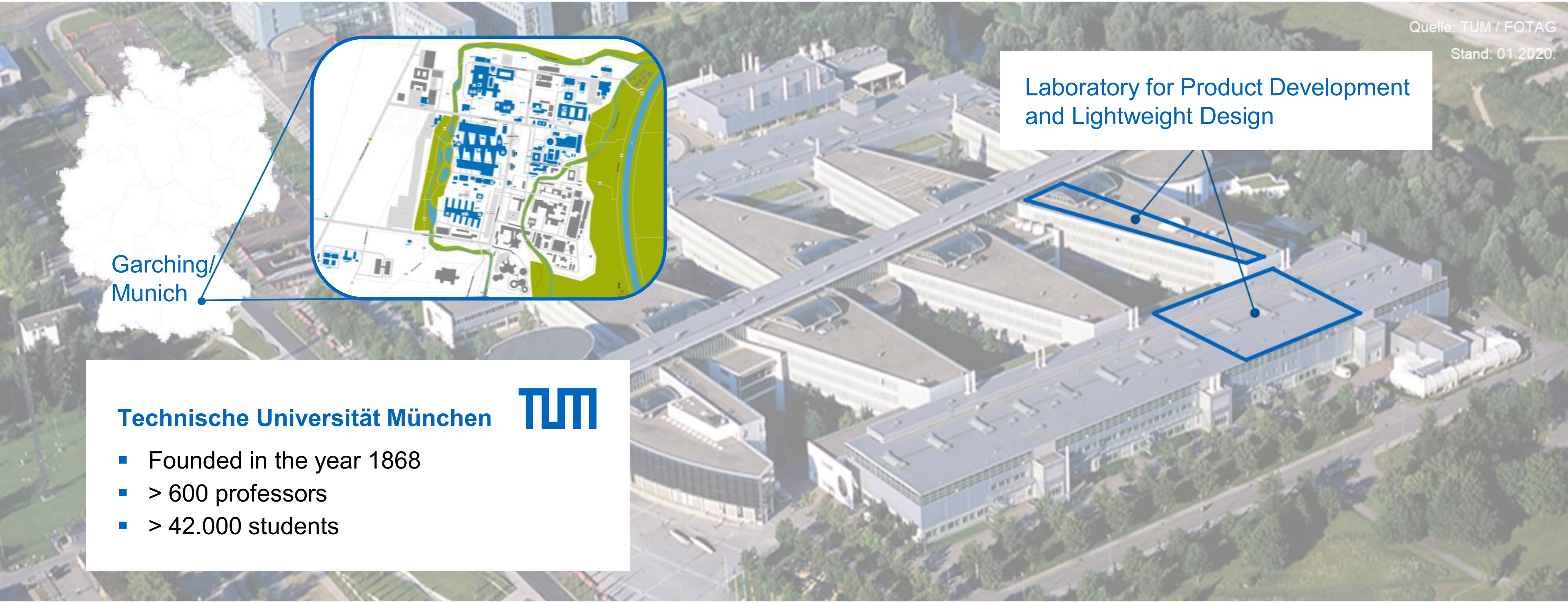
LPL



Design and Optimization of Complex Technical Systems

Content

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
Ruslan Cherednychenko
Andreas Köstler
Karl-Ludwig Krämer

Research Assistants

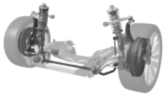
Maximilian Amm
Anđela Babaja
Eduardo Della Noce
Felix Endress
Klemens Hohnbaum
Sergi Pagés i Diaz
Mahadevan Ravichandran
Jasper Rieser
Akhil Sathuluri
Philipp Schröder
Johannes Soika
Tobias Wanninger
Lucien Zapfe

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

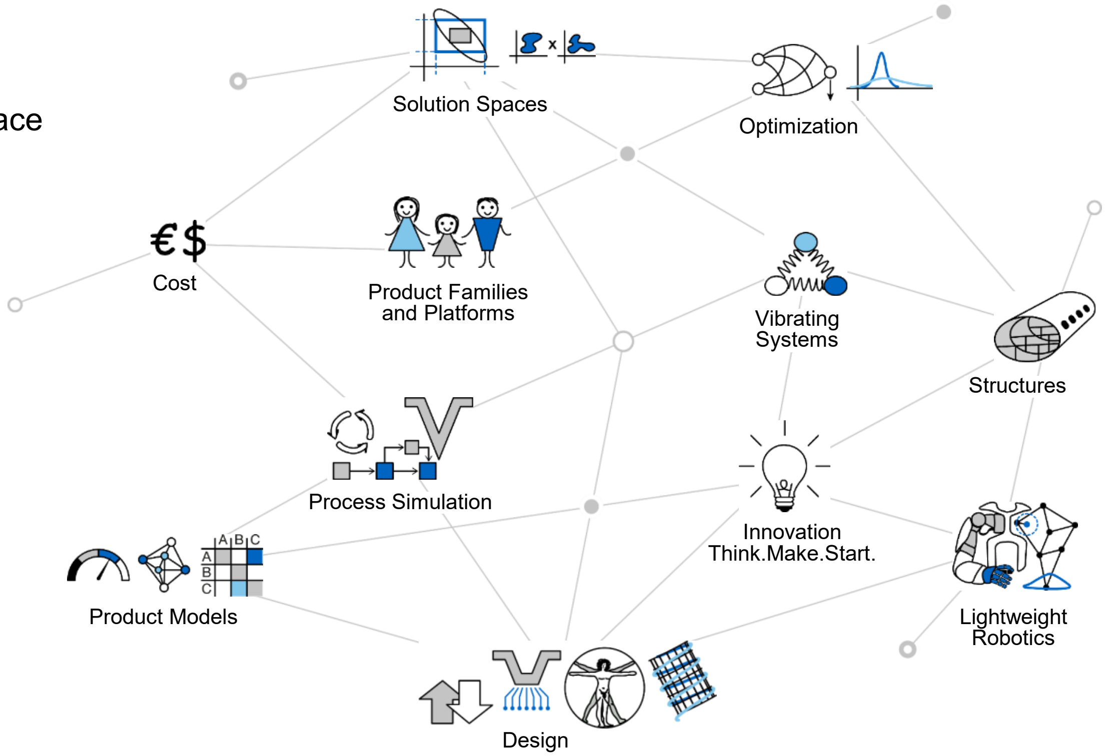
Technical University of Munich

- Since November 13, 2017

Research

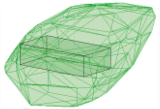
Solution Space Engineering

Lightweight Structures

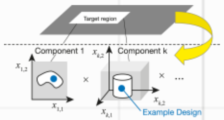


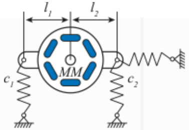
Methods & Processes

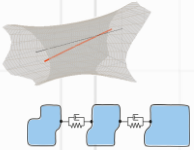
Robot Systems

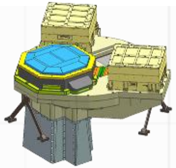


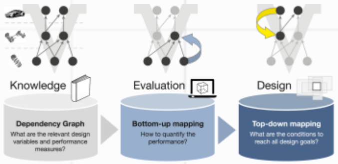
Research

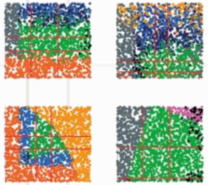

Target region
Component 1
Component k
Example Design

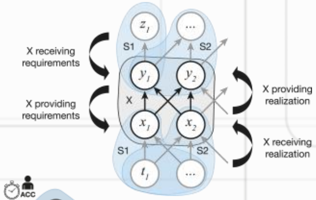

MM

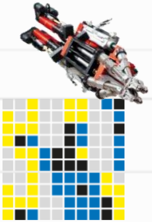


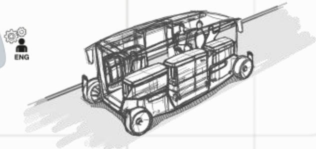


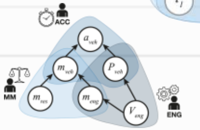

Knowledge
Evaluation
Design
Dependency Graph
What are the relevant design variables and performance measures?
Bottom-up mapping
How to quantify the performance?
Top-down mapping
What are the conditions to reach all design goals?

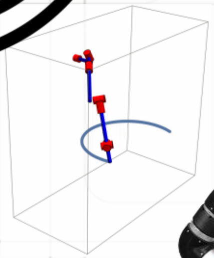


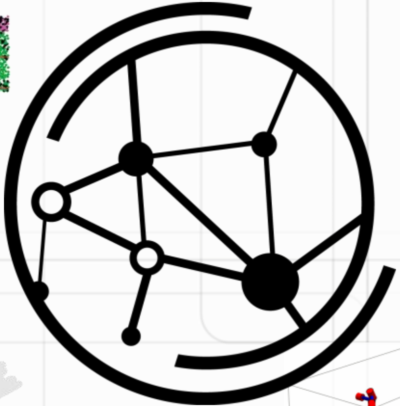

X receiving requirements
X providing requirements
X providing realization
X receiving realization
S1
S2
X






ACC
MM
ENG





Teaching

Solution Space Engineering

Lightweight Structures

Methods & Processes

Robot Systems

MDO
Multidisciplinary Design Optimization (E)
Lecture (Master)

DPDS
Design and Partitioning of Dynamic Systems (E)
Lecture (Bachelor/Master)

FVW
Composite Materials (D)
Lab Course (Bachelor/Master)

KOMA
Cost Management (D)
Lecture (Master)

TopOpt
Topology Optimization(E)
Lab Course (Bachelor/Master)

Leichtbau
Lightweight Design (D)
Lecture (Bachelor)

FEM
Finite-Element Method (D)
Lab Course (Bachelor/Master)

MPD
Methods of Product Development (E)
Lecture (Master)

PKE
Product Development – Concept & Design (D)
Lecture (Bachelor)

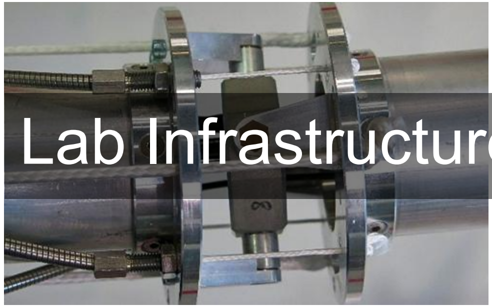
ML4PD
Machine Learning for Product Development (E)
Lecture (Master)

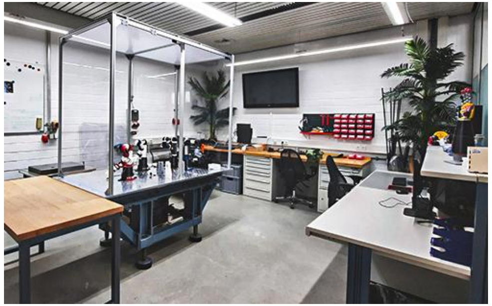
SMM
Structural Mechanics Modeling (D)
Lecture (Bachelor)

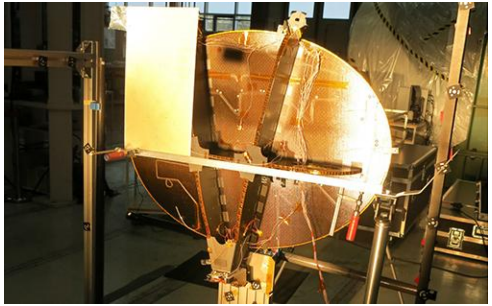
RobOpt
Numerical Optimization for Robot Design and Control (E)
Lab Course (Bachelor/Master)

TMS
Think.Make.Start. (E)
Lab Course (Master)

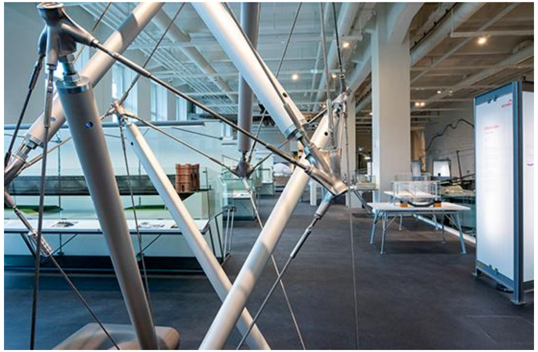
Lab Infrastructure

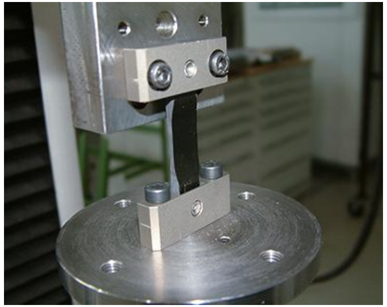






Lab Testing





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

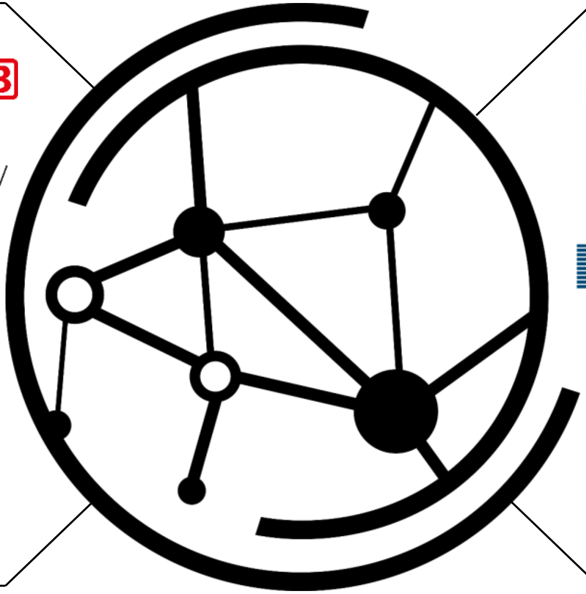
Sandblasting, water cutting

Autoclave, CNC prepreg cutter, RTM equipment

Partners

Industry Partners

Academic Partners



Startups & Initiatives

Content

- Laboratory
- Selected Projects
- Collaboration Modes

Completed 2025

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.

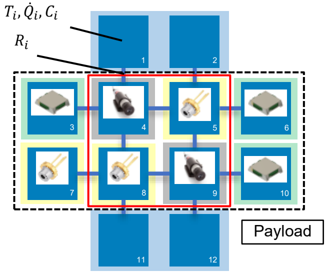
Scope: LPL and EMM GmbH are jointly developing a thermal management system for CubeSats by using a digital twin, as well as a concept for distributed computation within the satellite. Therefore, the position of the computation units are optimized. The satellite's thermal requirements are managed using a model-predictive control loop, enhanced by an automated routine for parameter update.

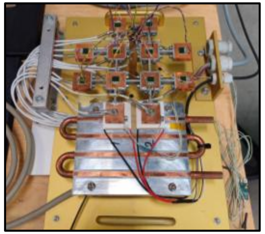
Anticipated results:

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

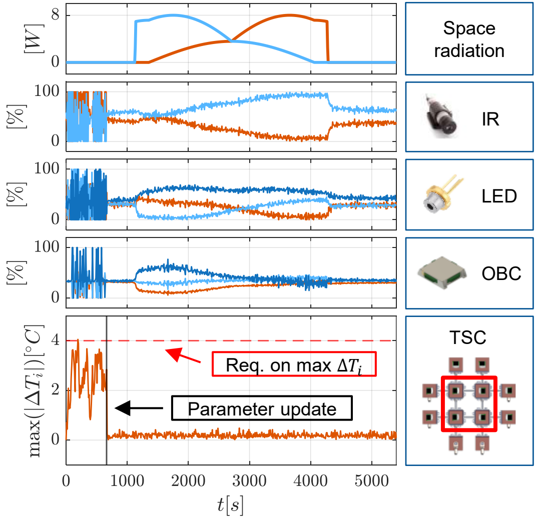
(2) Digital Twins for thermal management

(3) Validation of the procedure using a prototype





Design, Prototyping and Testing



Orbit Simulation and Thermal Control

Completed 2022

SysDeNoR

System Design of Vibration and Noise Reduction

Funding: ZEIDLER FORSCHUNGS STIFTUNG

Contact: Duo Xu, M.Sc.

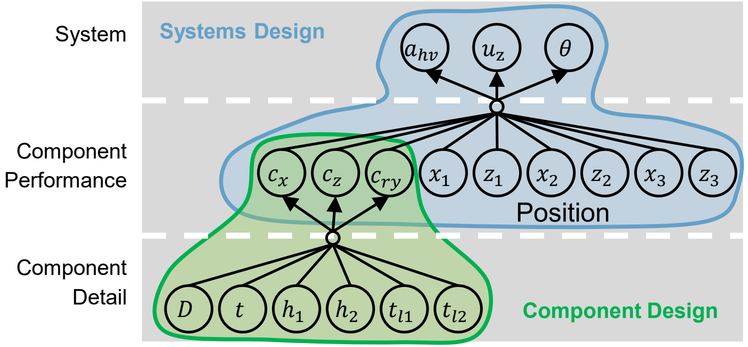
Scope: In this project, a top-down development method for the design of vibrating mechanical systems was developed that decomposes the overall system requirement into component level requirements based on Solution Space Engineering.

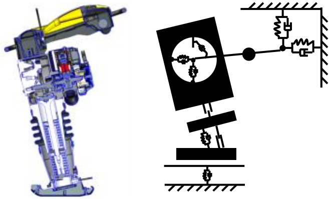
Results:

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

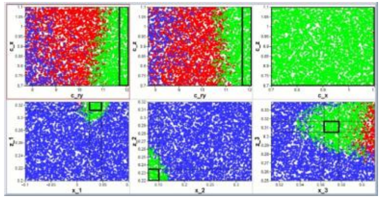
(2) Tools for precise derivation of quantitative component requirements.

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





Vibratory Rammer



Solution Space

Rubber Mount

Numerical optimization

$$f = \max\{\frac{c_{ry,l} - c_{ry}}{c_{ry,l}}, \frac{c_{ry} - c_{ry,u}}{c_{ry,u}}\}$$

Subject to: $c_{x,l} \leq c_x \leq c_{x,u}$

$c_{z,l} \leq c_z \leq c_{z,u}$

CAD-Model

SOLID – Smart Soil Compaction Devices

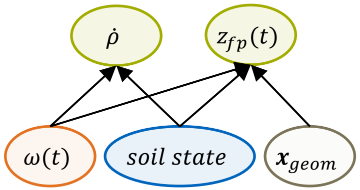
Employing Digital Twins for Optimizing Design and Operation of Vibrating Systems

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

Contact: Anđela Babaja, M.Sc.

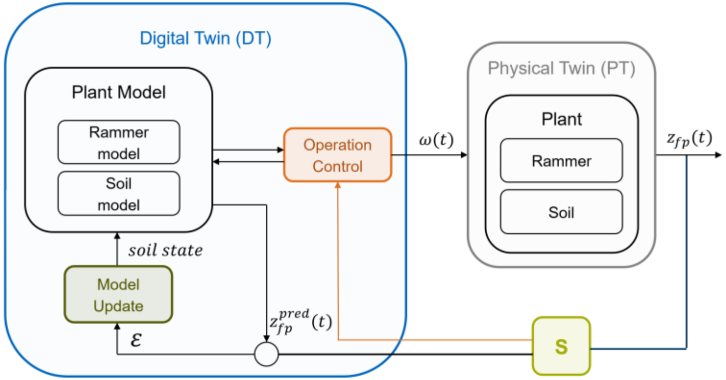
Scope: Establishing product requirements in product design is crucial to construct an attribute dependency graph (ADG). Utilizing simulation-based framework and solution space engineering methods enhances product design optimization based on the abovementioned ADG. With a simulation model for the soil 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

Completed 2025

Solution Spaces

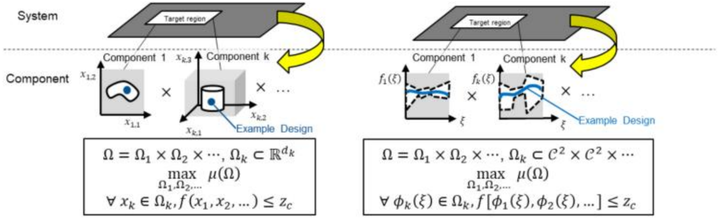
Towards the Theoretical Limit of Optimal Requirement Decomposition Using Solution Spaces for Complex Systems Design

Funding: DFG Deutsche Forschungsgemeinschaft

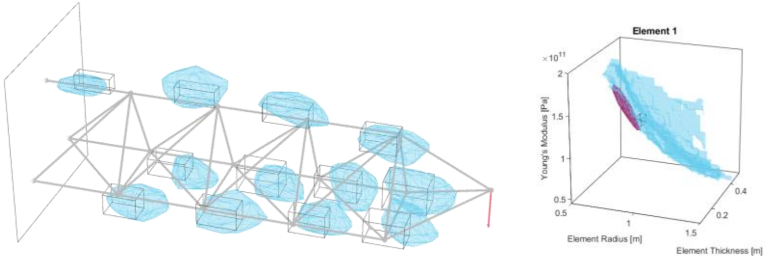
Contact: Eduardo Rodrigues Della Noce, M.Sc.

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.

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



Component solution spaces for (left) finite-dimensional design vectors and (right) functions.



Solution spaces for nodes of a truss (left) and component properties (right)

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

Completed 2023

PrintYourLab

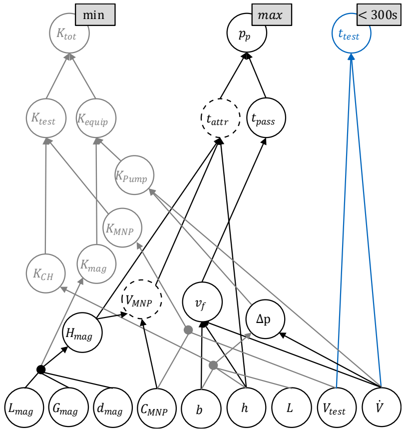
Optimizing Millifluidic Structures for Medical Applications

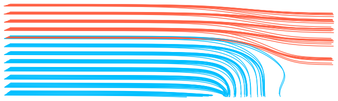
Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action | domatec Einfach sicher sein. | Steinbeis

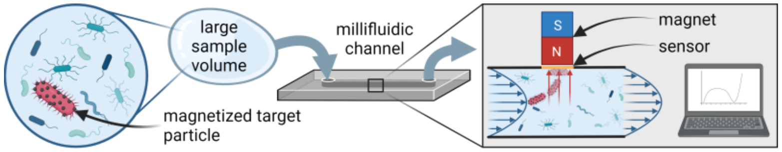
Contact: Johannes Soika, M.Sc.

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.

Mu-Flash GEN 2

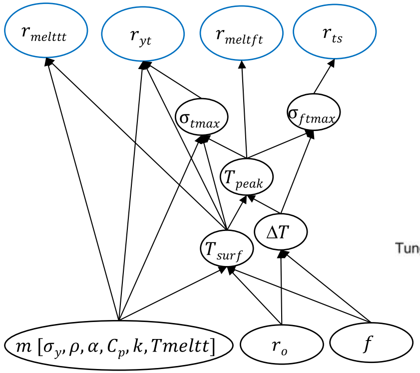
X-Ray Anode Design for Tumor Therapy with Micro Beams

Funding | Partners: IAS | MRI

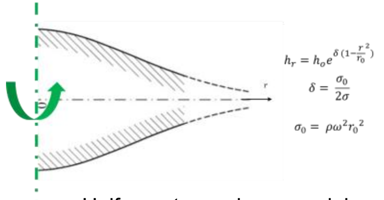
Contact: Mahadevan Ravichandran, M.Sc.

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.

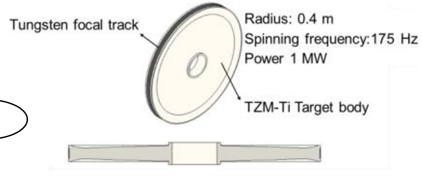
Anticipated Results: A Validation method for extreme thermo-mechanical loads in component design, Feasibility of using the concept in the clinical microbeam therapy system X-ray system



Attribute Dependency Graph



Uniform stress shape model



Prototype design

Validation test set-up and tested tungsten surface

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

Completed 2025

PROVING

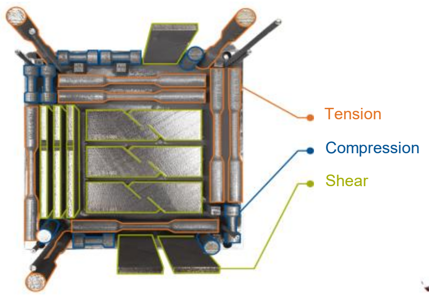
Aircraft Structure Design for Additive Manufacturing

Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Energy | BAM Bundesanstalt für Materialforschung und -prüfung | BOEING | EASA | EES Eppinger Engineering Solutions | IABG | MSC Software | oerlikon | RS.aero | Technische Universität Berlin

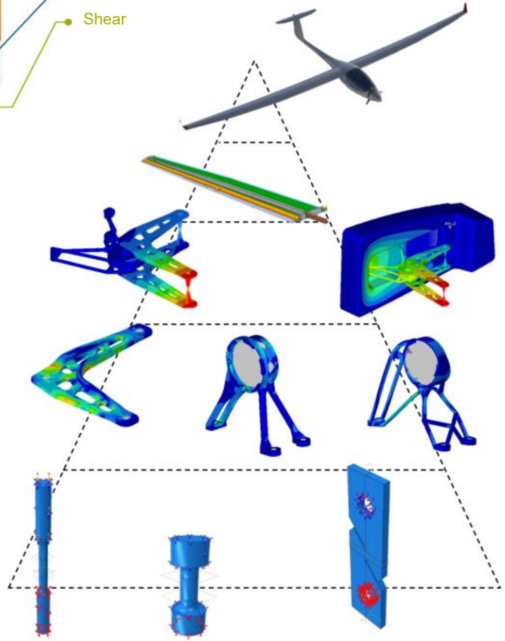
Contact: Felix Endress, M.Sc. M.Sc.

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.

Results: Approaches for the optimization-driven product development and certification of aircraft structures, considering process, material and design characteristics of metal additive manufacturing. Reduction of physical testing for certification via improved simulations.



Testing the stiffness and strength of AM specimen



Testing pyramide for additively manufactured metals

Endress, Kipouros, Zimmermann: *Distributing Design Domains for Topology Optimization in Systems Design*, ASME IDETC-CIE Conf. 2023, August 20-23, 2023, Boston, MA, USA.
Endress, Zimmermann: *Designing Variable Thickness Sheets for Additive Manufacturing Using Topology Optimization with Grey-Scale Densities,* AMPA Conf. 2023, Lucerne, Switzerland.
Endress, Tiesler, Zimmermann: *Technical cleanliness of additively manufactured Inconel 718: a comparative study of surface treatment methods*, Rapid Prototyping Journal, Emerald Publishing Limited, 2024.

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

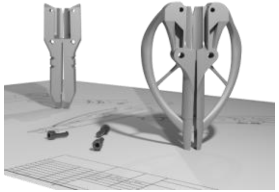
Contact: Jasper Rieser, M.Sc.; Jakob Trauer, M.Sc.

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:

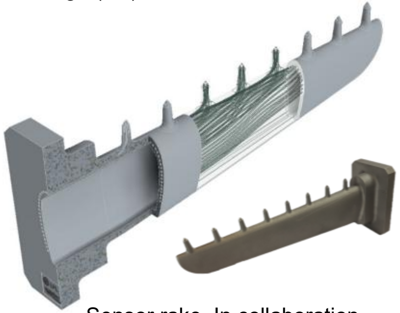
(1) A *procedure model* for the design of AM parts covering all essential steps from requirement elicitation to the final printed part.

(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

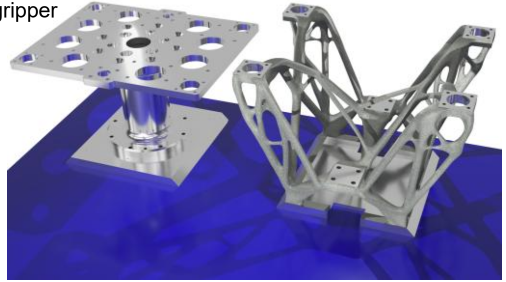
Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Energy | iwis | iwb | STÖGER AUTOMATION

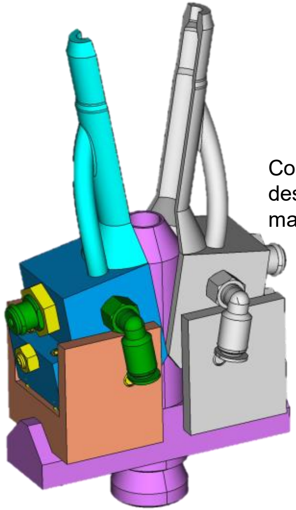
Contact: Jasper Rieser, M.Sc.

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.

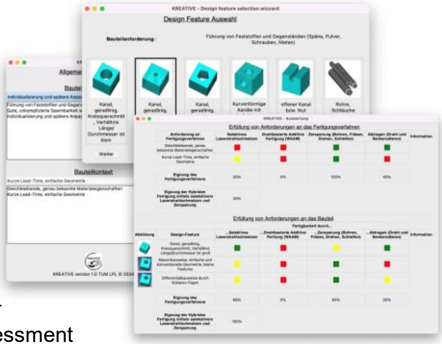
Anticipated Results: A design methodology for hybrid additive manufacturing.

Support structure for an injection molding gripper





Component of a screw driver designed for hybrid additive manufacturing

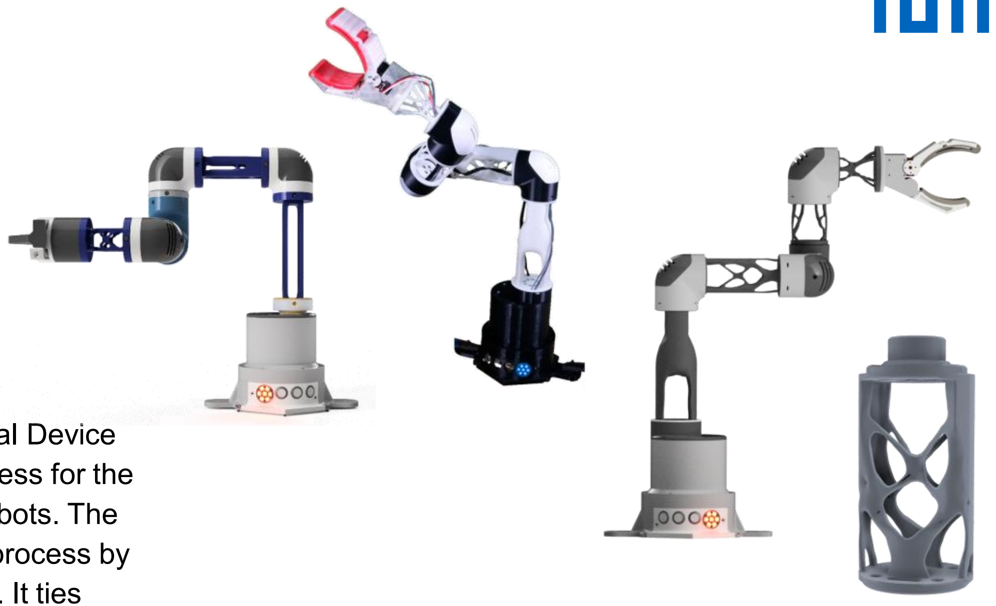


Software prototype for manufacturability assessment

Completed 2024

LCL Robots

Low-Cost Lightweight Robots on Demand



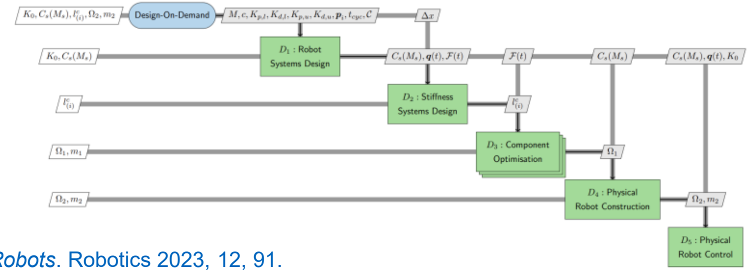
Funding: Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

Partners: voxeljet MiMed HAWE HYDRAULIK

Contact: Akhil Sathuluri, M.Sc.; 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.

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.

FORAnGen

Generative Design by Topology Optimization Considering Assembly and Manufacturing

Funding | Partners: Bayerische Forschungsstiftung | Universität Bayreuth, FAU Friedrich-Alexander-Universität Erlangen-Nürnberg, Fraunhofer IGCV, ZF, Audi, Stöger Automation

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.

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

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

Completed 2024

TopOpt Connections

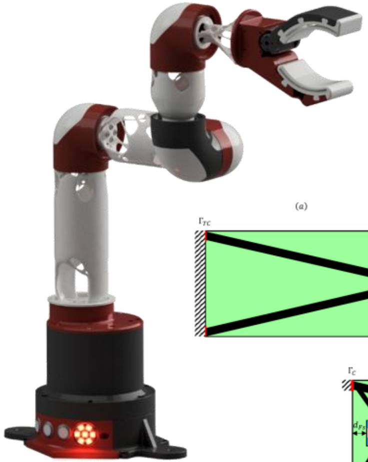
Screw Connection Design for Topology Optimization

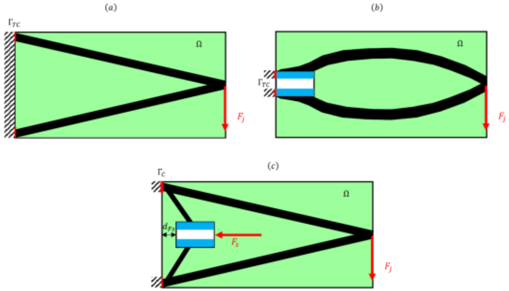
Funding | Partner:

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.

Tailored Stiffness Components

Optimizing structures for spatial stiffness requirements

Funding | Partner: LPL | TUM

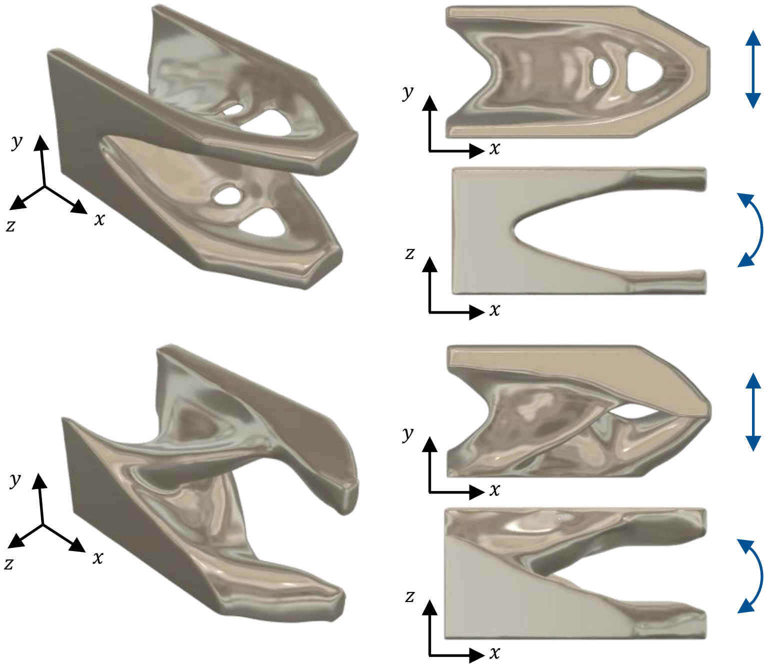
Contact: Tobias Wanninger, M.Sc.

Scope: The MK-Problem deals with the optimization of structures with two interfaces that are subject to specific stiffness constraints. Application examples for requirements on interface stiffness contains the decoupling of systems, uncertain loading conditions, or vibrating structures. This approach allows for efficient optimization of the structure while ensuring that the stiffness constraints are met.

$$\min_{\mathbf{x}} m(\mathbf{x})$$

$$\text{s.t.}: \quad \lambda_i\left(\tilde{\mathbf{K}}(\mathbf{x}) - \tilde{\mathbf{K}}_c\right) \geq 0 \quad \forall i$$

Anticipated Results: Algorithm to compute mass optimal structures for given limit interface stiffness



Wanninger, Soika, Zimmermann: *Optimizing 3d structures with two interfaces subject to constraints on the interface stiffness matrix*. Presented at WCSMO-16 in Kobe, Japan (2025-05-20).

TUM Bike

Demonstrator for methods and teaching @LPL

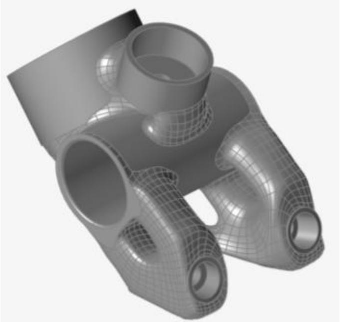
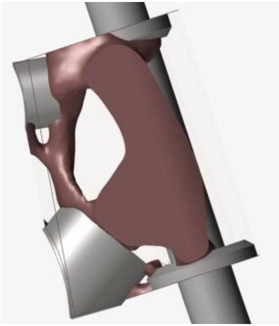
Funding I Partner: LPL | TUM

Contact: Tobias Wanninger, M.Sc.

Scope: The TUM Bike project aims to develop and build a functional bicycle that serves as both an exhibit and a method carrier for research at the Chair of Product Development and Lightweight Design (LPL). The focus of the core development is on the bicycle frame, emphasizing stiffness, lightweight design, and user comfort. The goal is to develop a modular frame that allows various methodologies developed at the chair to be applied and demonstrated. The modularity also enables individual components to be replaced and further developed over time, ensuring the method carrier remains relevant and can be used as a continuous practical example in teaching.

Anticipated Results: Functional prototype of a modular bicycle frame



Completed 2023

DIVA

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

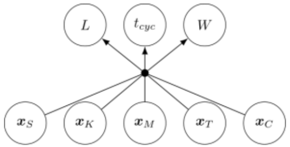
Funding: State of Bavaria

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

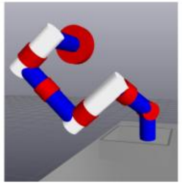
Scope: Experience driven **bottom-up** design processes have been effectively used for humanoid robot design. On the other hand, this project aims at evaluating an alternative **top-down** design strategy for developing robots. This involves a cascaded optimization strategy resulting in constructing 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. Design variables and quantities of interest

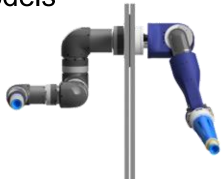


2. Bottom-up modeling, simulation models



Simulation

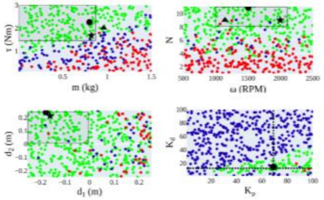
Reality



Robot resulting from V-model vs intuitive design

3. Top-down mapping

$$\min_{\boldsymbol{X}} -\mu(\Omega_{\boldsymbol{X}})$$
$$\text{s.t. } \boldsymbol{g}(\boldsymbol{x}) \leq \boldsymbol{0}, \boldsymbol{h}(\boldsymbol{x}) = \boldsymbol{0}$$



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

Completed 2025

DSL4RAS

Domain Specific Language for Robot-like Systems

Funding: Deutsche Forschungsgemeinschaft (DFG)

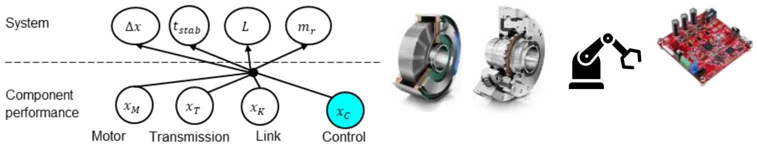
Partners: Institute of Machine Elements (FZG), Institute of Automation and Information Systems (AIS)

Contact: Akhil Sathuluri, M.Sc.

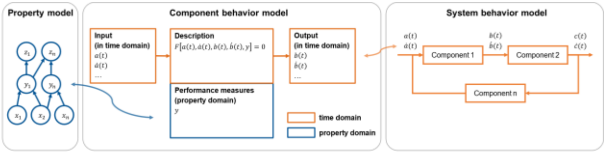
Scope: Designing robot-like systems involves several domains. DSL4RAS aims at developing domain specific languages that are compatible with each other. With them, co-design of mechanical elements, like gears, mechatronic elements, like motors, control logic and sensor design shall be enabled. A particular 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.

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

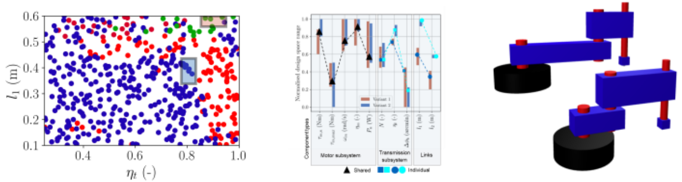
1. Framing: Problem and requirement definition



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, M.Sc.

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.

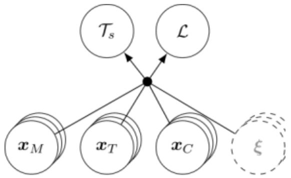
Results:

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

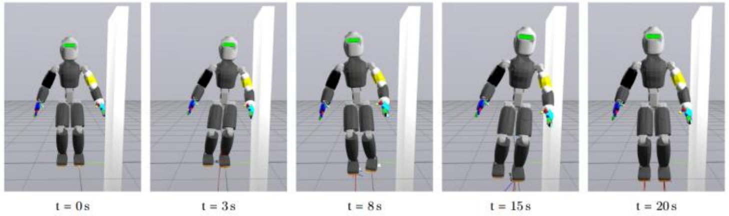
(2) Improved tolerance to disturbances of 20% higher magnitude.

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

1. Design variables and quantities of interest

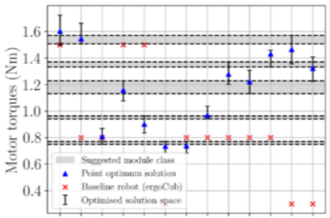


2. Bottom-up models, simulation models



3. Top-down mapping

$$\min_{X_A} -\mu(\Omega_{X_A \Xi})$$
$$\text{s.t. } \forall \boldsymbol{x}_A \in \Omega(\boldsymbol{X}_A) \text{ and } \boldsymbol{\xi} \in \Omega(\Xi) \ \exists \ \boldsymbol{x}_C,$$
$$\boldsymbol{h}(\boldsymbol{x}_A, \boldsymbol{x}_C, \boldsymbol{\xi}) = \boldsymbol{0}, \boldsymbol{g}(\boldsymbol{x}_A, \boldsymbol{x}_C, \boldsymbol{\xi}) \leq \boldsymbol{0}$$



Completed 2022

DESIM

Simulation of Distributed Design Processes

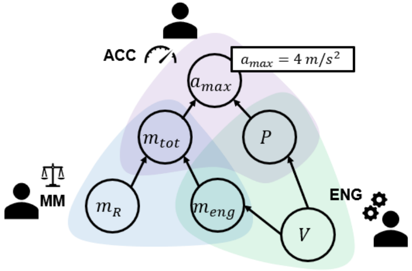
Funding:

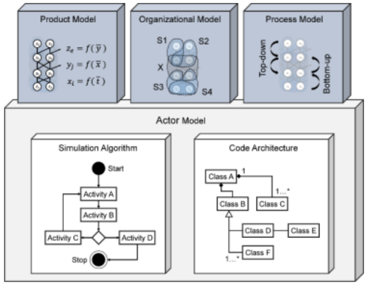
Contact: Ferdinand Wöhr, M.Sc.

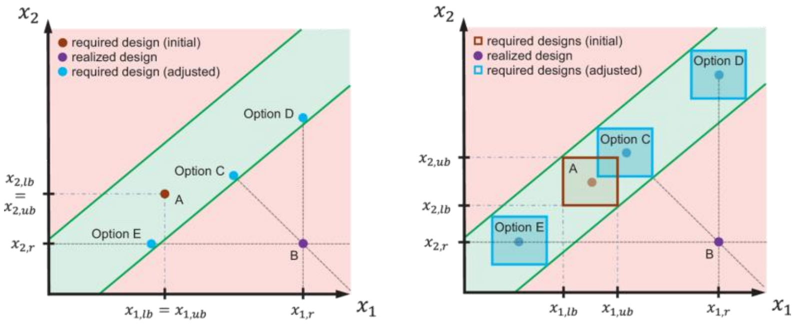
Scope: Development of an agent-based simulation model to evaluate distributed design processes with respect to product quality, development time and design flexibility. Key elements are:

- 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.







(a) (b)

Wöhr, Königs, Stanglmeier, Zimmermann: *A quantitative model of hierarchical product design*. Design Science. 2025

Completed 2022

Product Family Design

Modular Product Family Design for Screw Driving Systems

Funding: STÖGER AUTOMATION

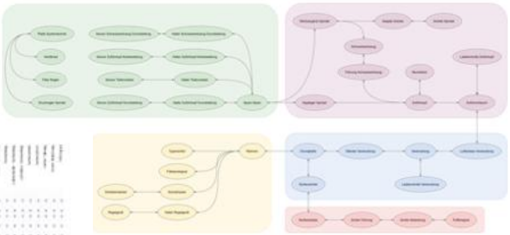
Contact: Sebastian Rötzer, M.Sc.

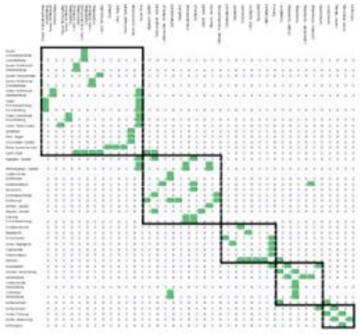
Scope: In the competitive market of highly automated screwdriving and fastening systems, companies need new methods for systematic product development for *specific customer requirements*. Modular product family design and customer orientation are key to extending mechanical excellence with digital functionality.

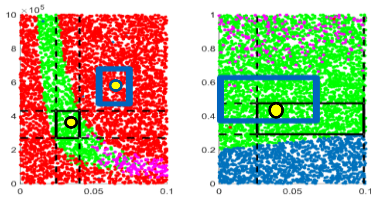
Results:

(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.







Individual solutions   Common solution

1 Functional structure | 2 Market analysis | 3 Physical structure | 4 Product architecture

5 Defining modules | 6 Documenting modules | 7 Designing modules | 8 Leading innovation by modules

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

BUENA

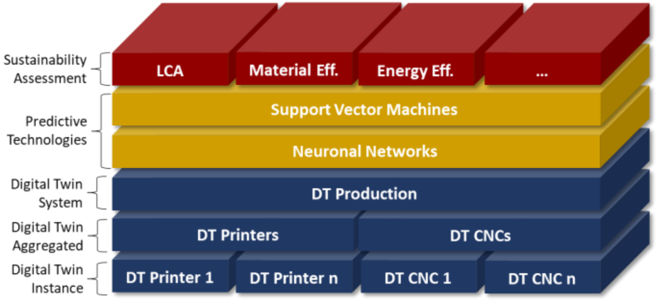
Cross-sector Industrialization of Additive Production

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

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

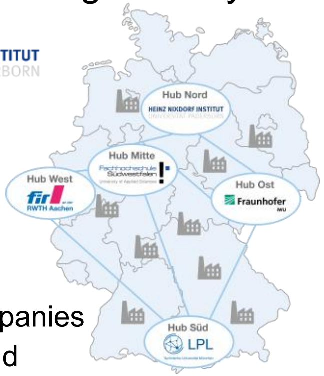
Use case and to be developed motor bracket for additive manufacturing

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

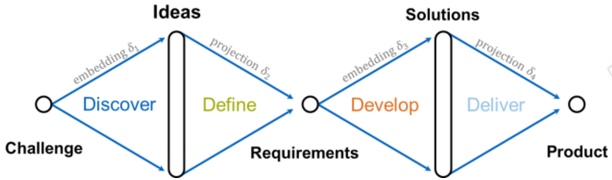
Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Energy | Fraunhofer IWU, fir an der RWTH Aachen, HEINZ NIXDORF INSTITUT UNIVERSITÄT PADERBORN, Fachhochschule Südwestfalen University of Applied Sciences



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 preserving jobs, know-how, and manufacturing networks in Germany and Europe.

Results: A transformation hub was established among all partners. LPL contributes, i.a., with a Product Transformation Workshop that applies design thinking to derive product and business model innovations from asset and market analyses.



Completed 2024

STEAM

Solutions for Transport Networks with Electric Advanced Mobility

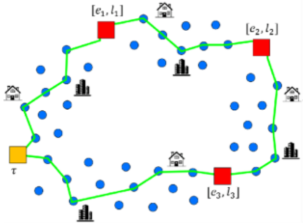
Funding | Partners: Supported by: Federal Ministry for Economic Affairs and Climate Action | CLUSTERS 4 FUTURE Innovationsnetzwerke für unsere Zukunft | BAIS | vt | BMW GROUP | MAN | SWM | Stanglmeier Touristik

Contact: Nuno Miguel Martins Pacheco, M.Sc.

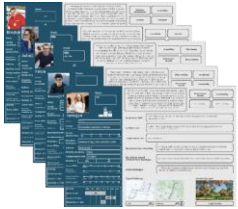
Scope: We aim to rethink Munich's urban transport by optimizing bus systems with innovative technologies and data analysis. The project includes three aspects: (1) Adjust routes based on traffic data and occupancy, (2) Integrate passenger and parcel transport to reduce traffic, emissions, costs, and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

- 3 Monate – 5 Jahre
- Ab ca. 160k € / Jahr
- Forschung ergebnis-offen, individuell und evtl. in Kooperation mit anderen Partnern
- Mitarbeiter*in vor Ort
- Übertragung der Rechte an Firma möglich

Gefördertes Projekt

- 1 – 4 Jahre
- 0 € (Firma erhält evtl. Zuwendungen)
- Forschungsantrag ggfs. mit weiteren Partnern
- Mitarbeiter*in vor Ort
- Öffentlich, bei KME verbandsintern

Schulungs-Projekt

- Individuell
- 6k – 10k € pro Tag (nach Vorbereitungsaufwand)
- Standardaufgaben ohne Forschungsinhalte
- Mitarbeiter*in vor Ort
- Urheberrechte beim Dozenten

Studienarbeiten

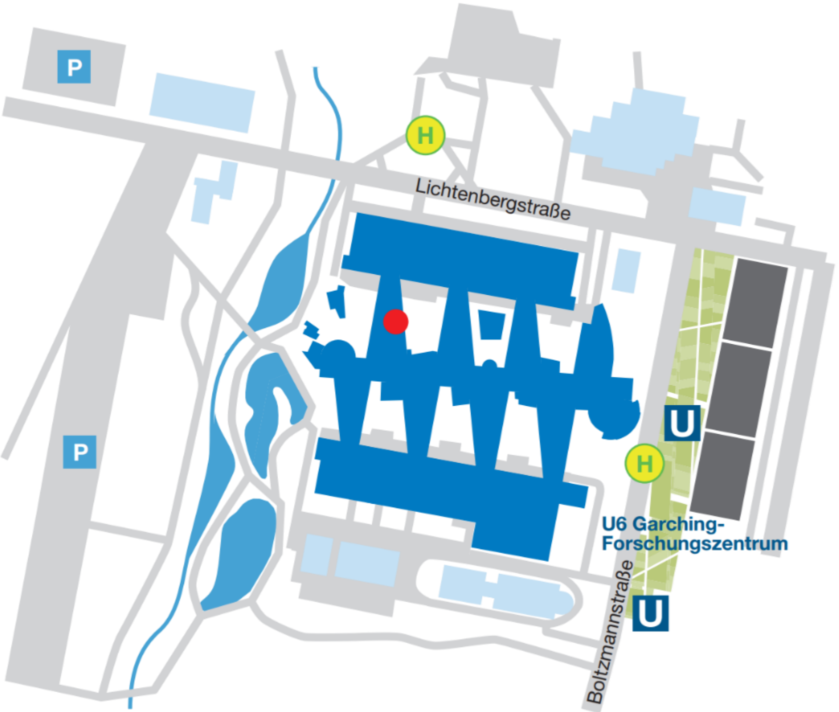
- Bis 6 Monate
- 0 €
- Betreuung durch Lehrstuhl- und Firmen-Mitarbeitende
- Keine Mitarbeiter*in vor Ort
- Rechte beim Studierenden

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. 160k € / 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

- Technical University of Munich
  TUM School of Engineering and Design
  Department of Mechanical Engineering
  Laboratory for Product Development and Lightweight Design
  Boltzmannstr. 15
  D-85748 Garching b. München
- Building 6, 2nd floor
- Website: **www.mec.ed.tum.de/lpl**
- Contact: **zimmermann@tum.de**
- Phone: +49 89 289-15150



Thank you for your attention!

LPL

Design and Optimization of
Complex Technical Systems