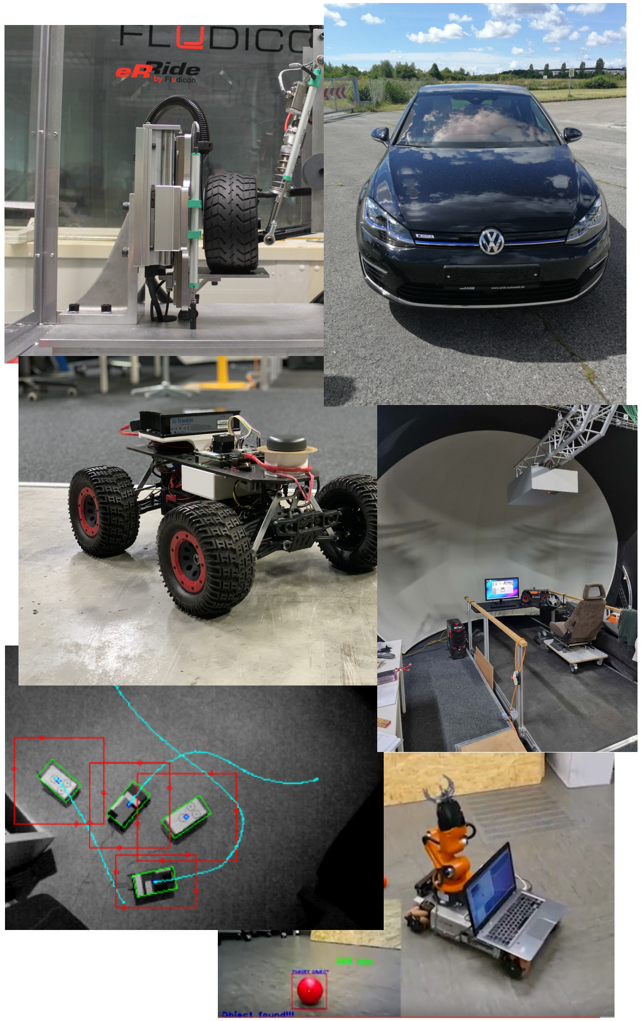
Demonstrators

Our lab allows to implement and to test optimal control algorithms and real-time control algorithms in practice. The lab comprises autonomated vehicles (eGolf, Vehicle-in-the-loop on the basis of two Audi A6), mobile robot platforms, a quarter car testbench for chassis control, a KUKA®YOUBOT, and a KINOVA®JACO® robotic arm.

Various sensors (dGPS, GNSS, IMU, laser scanner, rotation sensors, stereo camera, HTC Vive, Nexonar, Nikon Metrology iGPS) are used to locate the robots and to detect obstacles.



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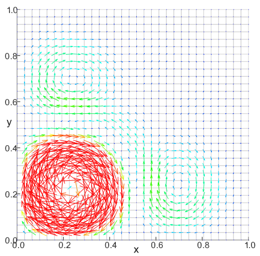
Research Topics

Our main fields of research are

- optimization and optimal control
- parametric sensitivity analysis
- model-predictive control and real-time optimization
- coordination of interacting systems
- vehicle simulation, virtual test-driving, driver assistance, collision avoidance, automated driving
- trajectory optimization in aerospace engineering and robotics

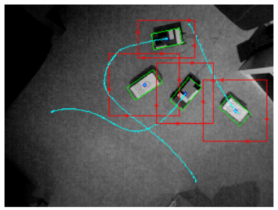
Optimal control and parameter identification with ordinary differential equations, differential-algebraic equations, and partial differential equations

Our research focuses on development and analysis of numerical discretization methods for control and state constrained optimal control and parameter identification problems. In particular, shooting methods and semismooth Newton methods are investigated. Sample applications: flow control with Navier-Stokes equations (bottom right), robot control (top right).



Realtime optimal control

Time critical problems require algorithms, which are capable of providing approximations for optimal solutions in realtime. We use model-predictive control and parametric sensitivity analysis to achieve this goal.



Mixed-integer optimal control

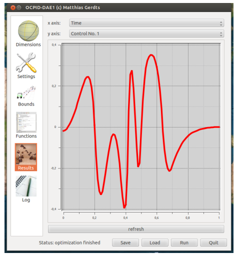
Mixed-integer optimal control problems contain discrete-valued controls that can be used to model time dependent decision and switching processes, for instance the choice of gear shifts in cars or discrete flap positions in aircrafts. We use direct discretization methods based on a time transformation techniques to solve such problems.

Nonlinear programming

The main focus is on the development of software products for small and dense as well as large-scale and sparse nonlinear optimization problems. This software can be used standalone or to solve discretized optimal control problems.

Software and Visualization

Software packages OCPID-DAE1 and SQPFILTERTOOLBOX for optimization and optimal control problems have been developed by the Engineering Mathematics Group. The software is free for academic use. Commercial licenses are available upon request. In addition we develop visualization and simulation tools using the unreal engine and Qt3D and the robot operating system ROS.



Teaching

We offer courses in optimization, optimal control, numerical analysis, flight path optimization, and mathematics for engineers.

References:

- M. Gerdts, F. Lempio: *Mathematische Optimierungsverfahren des Operations Research*, DeGruyter, 2011, ISBN 978-3-11-024994-1.
- M. Gerdts: *Optimal Control of ODEs and DAEs*, DeGruyter, 2011, ISBN 978-3-11-024995-8.

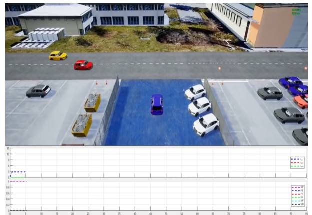
Applications

Our research is supported by DFG, BMBF, BMWi, EU, AFOSR, dtec.bw, Munich Aerospace, ESA, and industry to transfer the methods to practice. A particular focus is on the exploitation of structures and on the development of suitable models and tailored solution methods.

Automated Vehicle-in-the-loop (A-VIL):

The A-VIL combines virtual and real driving in one platform on the base of an Audi A6. It allows to safely investigate automated driving scenarios, even in emergency situations.

Path planning and tracking for automated vehicles:

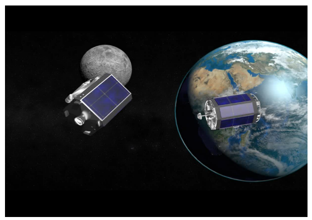


Optimization-based path tracking and planning is a core technique in automated driving. We use model-predictive control techniques and validate them on test vehciles.

Path planning and collision avoidance for UAVs:

Automatic path planning methods for UAVs with collision avoidance are developed and simulated in a virtual environment using ROS and the unreal engine.

Docking maneuvers in space:



Space debris removal and in-orbit servicing require computational tools for docking trajectories. Next to gradient-based optimization we explore reinforcement learning techniques.