Professorship Autonomous Vehicle Systems
Department of Mobility Systems Engineering
TUM School of Engineering and Design

SA/MA

Fusion of RL and MPC for Autonomous Racing at the Vehicle Dynamics Limit

Join us to build the world's most advanced learning-based motion planning and control algorithms for autonomous racing!

Are you passionate about pushing machines to their absolute limits? Do you want to work at the intersection of reinforcement learning, nonlinear model predictive control, and real-world racing systems?

We're developing a self-adaptive, stochastic Nonlinear Model Predictive Controller (NMPC) for high-speed trajectory tracking in the context of autonomous racing—where precision, robustness, and real-time adaptability are not optional, but essential. As part of our research team, you'll work on cutting-edge algorithms that go beyond simulation, with a direct path to deployment on full-scale vehicles.

You'll contribute to high-impact research with a real chance of publication. My former thesis students have published their work at the world's top conferences in robotics and control:

- Chenyang Wang:
  - American Control Conference 2024 (Toronto, Canada): Stochastic NMPC with Uncertainty Horizon
  - IROS 2024 (AbuDhabi, UAE): Adaptive SNMPC with Look-ahead Deep Reinforcement Learning
- Marios Spanakakis: IV 2024 (Jeju Island, Korea): Safe RL-driven WMPC
- João Nunes: IFAC's NMPC 2024 (Kyoto, Japan) (Best Interactive Paper Finalist): R²NMPC with Ellipsoidal Uncertainty Sets



Example Thesis Topics (subject to availability):

Learning-based & Self-Adaptive MPC in Racing

- **Deep Reinforcement Learning** for dynamic MPC weight tuning on high-speed tracks
- **Predictive Safety Filters** and Safe Online learning and parameter estimation for predictive models under racing dynamics
- **Differentiable NMPC** for end-to-end policy refinement and gradient-based optimization
- **Adaptive Stochastic NMPC** under real-world disturbances

Modeling & Uncertainty at the Dynamics Limit

- Online performance monitoring of Stochastic NMPC and degradation cascade detection
- **Physics-Informed Neural Networks (PINNs)** for enhancing vehicle dynamics models and generalization across tire-road interactions
- Integration of motor maps and tire temperature feedback for improved prediction accuracy
- Enhanced ESM (Extended State Monitoring): Predicting slip, understeer, and oversteer in real time

Architectures & System Integration

- Coworking Controller-Planner Interface: Quantifying how much dynamics can be handled by NMPC and when to escalate to the planner
- Modeling and compensation of sensor and actuator delays in high-speed autonomous racing

Prof. Dr.-Ing. Johannes Betz

Supervisor: Baha Zarrouki, M. Sc.

Issue date:_____

Submission date: _____