Trajectory Optimization for Car-Like Vehicles in Structured and Semi-Structured Environments

Clemens Nietzschmann, Sebastian Klaudt, Christoph Klas, Devid Will, Lutz Eckstein
Institute for Automotive Engineering (ika), RWTH Aachen University, Germany

Trajectory Optimization

- OCP with an objective function which should be minimized for the prediction horizon $t_f$
- Problem is discretized with the direct multiple shooting approach
- Quadratic cost function
- Kinematic single track model is used as system model

Environment Representation

- Generic interface by using ordered sampled points
- All static obstacles need to be included in the boundaries
- Smoothed cubic spline interpolation
- Vehicle shape approximated by circles
- Road Users & VRUs are modeled as scalar potentials
- Prediction assuming a constant velocity and is matched to lanes (wherever possible)

Trajectory Reference Information

- Hybrid A* for path planning (parking & retrieving the vehicle)
- Boundary extraction from grid map
- Path & Boundaries are used as input for the trajectory optimization
- Urban Driving Scenario on public streets with round-about and other road users
- Reference path and boundaries are derived from map data
- Map data is created with aerial imagery

Implementation & Testing

- Implementation of OCP in C++11
- Prediction horizon $t_f$ up to 8.0 s with 0.1 s or 0.2 s steps
- Single-threaded without dynamic memory allocations
- Planning frequency set to 10 Hz
- ACADO Toolkit for code generation
- qpOases used as solver
- tailored C-code for integrating the system model and solving the discretized optimization problem
- The partial derivatives of the objective function are expressed analytically and are passed as custom C-function
- Tested in ika’s automated research vehicle for both scenarios

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Contact

Sebastian Klaudt, M.Sc.
Institute for Automotive Engineering (ika)
RWTH Aachen University, Germany
sebastian.klaudt@ika.rwth-aachen.de