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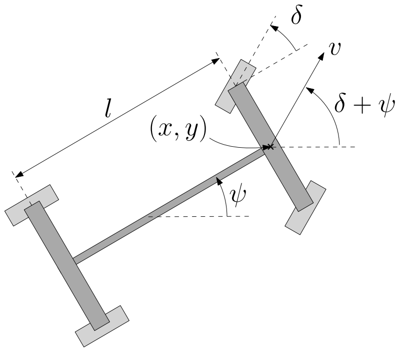
Optimization – Project 3 – WS 21/22

Multi-Objective Optimal Control of a Mobile Robot with CasADi

Consider a mobile robot with the dynamics

$$\frac{\mathrm{d}}{\mathrm{d}t} z = \frac{\mathrm{d}}{\mathrm{d}t} \begin{pmatrix} x \\ y \\ v \\ \psi \\ \delta \end{pmatrix} = \begin{pmatrix} v\cos(\psi+\delta) \\ v\sin(\psi+\delta) \\ u_1 \\ \frac{v}{l}\sin(\delta) \\ u_2 \end{pmatrix}$$



where $l = 1$. At $t = 0$, the robot is faced south-west and is standing still at position $(0, 0)$. We want to control the robot to transition from this initial position to $(7, 5)$ and for it to face north there in time T.
The following constraints must be satisfied:

- The absolute steering angle δ is bounded by 45°.
- The absolute steering angle speed $\dot{\delta}$ is bounded by $20°/s$.
- The velocity is lower bounded by -0.2m/s.
- The position in x is upper bounded by 7.1m.
- The acceleration is lower bounded by -10m/s^2 and upper bounded by 5m/s^2.
- The car should reach the final position in at most 20 s

There are two objectives to be minimized: 1) the energy consumption $\frac{1}{2}\int_0^T u_1^2$ and 2) the transition time T.
This multi-objective optimal control problem is to be solved with the use of CasADi in MATLAB.

Project task 3.1 – Optimal Control with Opti Stack

In this task, you will implement an optimal control for the Mobile Robot as a first milestone for your project.

a) Download CasADi for your MATLAB version on `https://web.casadi.org/get/`, the template `simulate_car_template.m` and the CasADi cheat sheet.

b) In this template, you can find parts that are marked with "`...`" that you have to fill in. These include the energy cost function, the constraints and the ODE.

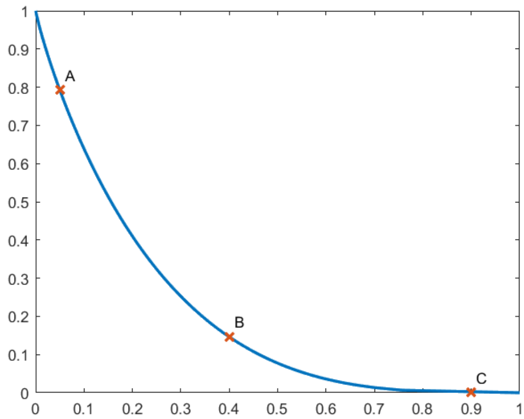
Project task 3.2 – Multi-Objective Optimization and Analysis

In this task, you analyze the optimal control problem with one of the multi-objective optimization techniques presented.

a) The second milestone of this project is implementing a multi-objective optimization technique to get a **parameterized** optimal control problem, parameterized in the Pareto parameters (e.g. epsilons, weights, ...).

b) Using the results from the previous subtask, calculate the Pareto front of the problem. You can store all of the solution objects in separate variables to access their corresponding decision variable and cost values afterwards.

c) Milestone 3 consists of plotting all computed Pareto optimal points in the objective space and the input u and the path driven by the vehicle for three different Pareto optimal solutions. These three points (A, B, C) could for example be points like the ones shown in the following exemplary Pareto front.



Please send your solutions to these tasks to matthias.hoffmann@uni-saarland.de by 07.02.2022 zipped in a file named "firstname_lastname_matrikelnr_3.zip". You can only pass if you work on all tasks and describe your problems in unsolved subtasks.