Teil der BSc Vorlesung Optimierung
(Brox/Diehl)

Nichtlineare Optimierung
3 Wochen (8.1.-22.1.2024)

Moritz Diehl und Florian Messerer

Systems Control and Optimization Laboratory
Department of Microsystems Engineering (IMTEK) &
Department of Mathematics
University of Freiburg
Anwendungen von Nichtlinearer Optimierung

und Kurzvorstellung der Forschungsgruppe Diehl
History of the Team

2006 - 2013
KU Leuven

2013 -
University of Freiburg
Model Predictive Control (MPC)

Always look a bit into the future

Example: driver predicts and optimizes, and therefore slows down before a curve
Optimal Control Problem in MPC

For given system state $x$, which controls $u$ lead to the best objective value without violation of constraints?
Optimal Control Problem in MPC

For given system state $x$, which controls $u$ lead to the best objective value without violation of constraints?
Model Predictive Control of RC Race Cars (in Freiburg)

Minimize least squares distance to centerline, respect constraints. Use nonlinear embedded optimization software *acados* coupled to ROS, sample at 100 Hz.

[Kloeser et al. 2020]
Time Optimal MPC of a Crane

SENSORS
• line angle
• cart position

MPC

ACTUATOR
• cart motor

Hardware: xPC Target. Software: qpOASES [Ferreau, D., Bock, 2008]
Time Optimal MPC of a Crane

Univ. Leuven [Vandenbrouck, Swevers, D.]
Optimal solutions varying in time

Time optimal path following for crane
Drone Racing with Nonlinear Optimization in Real-Time
(using acados)


Video:  https://www.youtube.com/watch?v=zBVpx3bgI6E

Time-Optimal Online Replanning for Agile Quadrotor Flight

Angel Romero ©, Robert Penicka ©, and Davide Scaramuzza ©

Abstract—In this letter, we tackle the problem of flying a quadrotor using time-optimal control policies that can be replanned online when the environment changes or when encountering unknown disturbances. This problem is challenging as the time-optimal trajectories that consider the full quadrotor dynamics are computationally expensive to generate, on the order of minutes or even hours. We introduce a sampling-based method for efficient generation of time-optimal paths of a point-mass model. These paths are then tracked using a Model Predictive Contouring Control approach that considers the full quadrotor dynamics and the single rotor thrust limits. Our combined approach is able to run in real-time, being the first time-optimal method that is able to adapt to changes on-the-fly. We showcase our approach’s adaptation capabilities by flying a quadrotor at more than 60 km/h in a racing track where gates are moving. Additionally, we show that our online replanning approach can cope with strong disturbances caused by winds of up to 68 km/h.

Index Terms—Aerial systems: Applications, integrated planning and control, motion and path planning.

Supplementary Material
Video of the experiments: https://youtu.be/zBVpx3bgI6E

A. Implementation Details

In order to deploy our MPCC controller, (4) needs to be solved in real-time. To this end, we have implemented our optimization problem using acados [24] as a code generation tool, in contrast to [6], where its previous version, ACADO [25] was used. It is important to note that for consistency, the optimization problem that is solved online is written in (4) and is exactly the same as in [6]. The main benefit of using acados is that it provides an interface to HPIPM (High Performance Interior Point Method) solver [26]. HPIPM solves optimization problems using BLASFEO [27], a linear algebra library specifically designed for
Race Car Control at PhD Seminar at EPFL (Lausanne) (by Florian Messerer et al., also using acados)
Topology Optimization (of a Bridge)

https://youtu.be/UZCc3BkqV_Q
Terminplan

• Montag, 08.01.24
  ◦ Vorlesung 6: *Nichtlineare Optimierung mit Gleichungsbeschränkungen*

• Montag, 15.01.24
  ◦ Übung 5: *Nichtlineare Programmierung und CasADi*
  ◦ Besprechung der Lösung
  ◦ (Das Übungsblatt ist im Abschnitt "Material" verlinkt)

• Montag, 22.01.24
  ◦ Vorlesung 7: *Nichtlineare Optimierung mit Gleichungs- und Ungleichungsbeschränkungen*