Teil der BSc Vorlesung Optimierung
(Brox/Diehl)

Nichtlineare Optimierung

3 Wochen (8.1.-22.1.2024)

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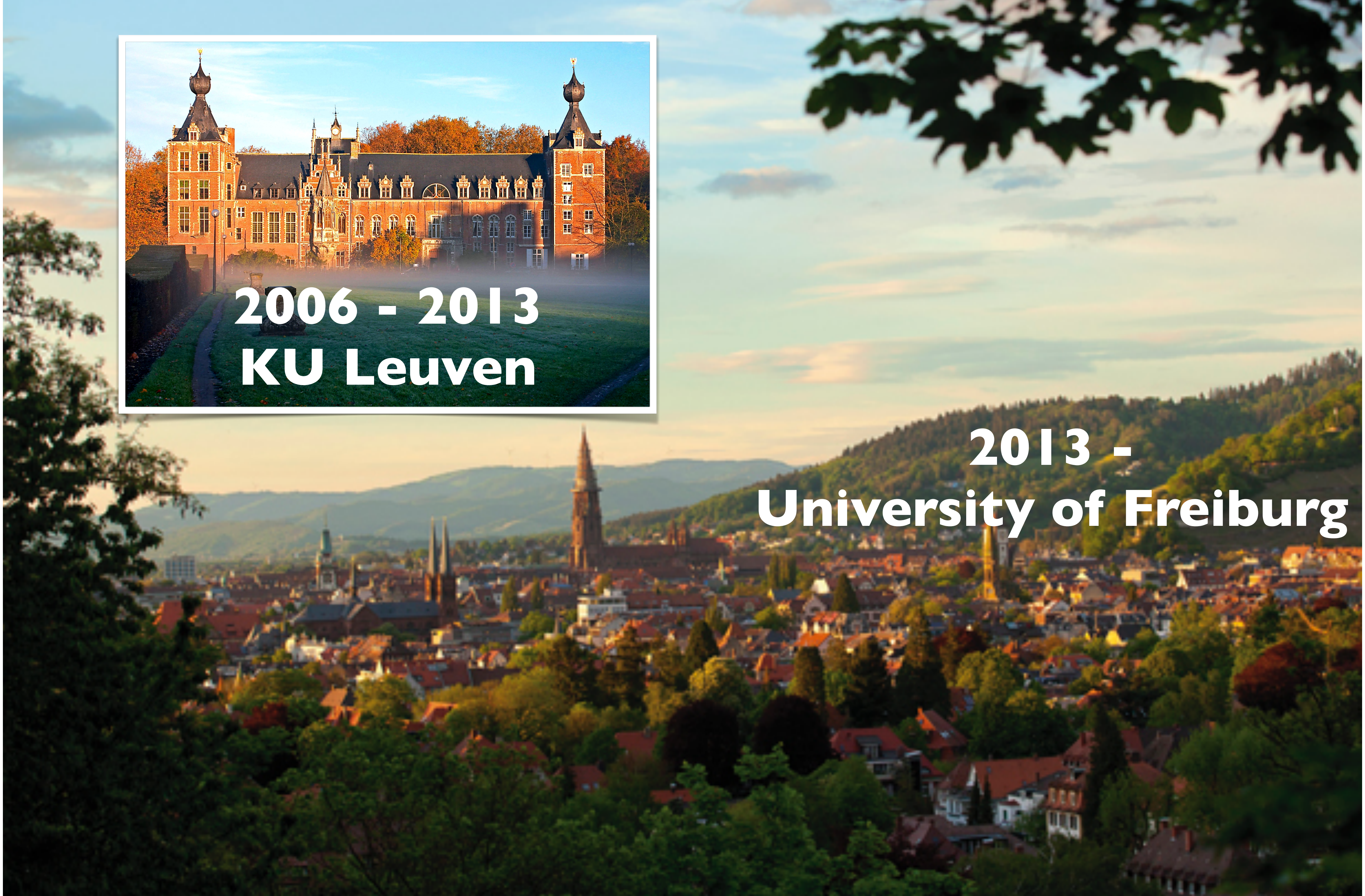
Systems Control and Optimization Laboratory
Department of Microsystems Engineering (IMTEK) &
Department of Mathematics
University of Freiburg

Anwendungen von Nichtlinearer Optimierung

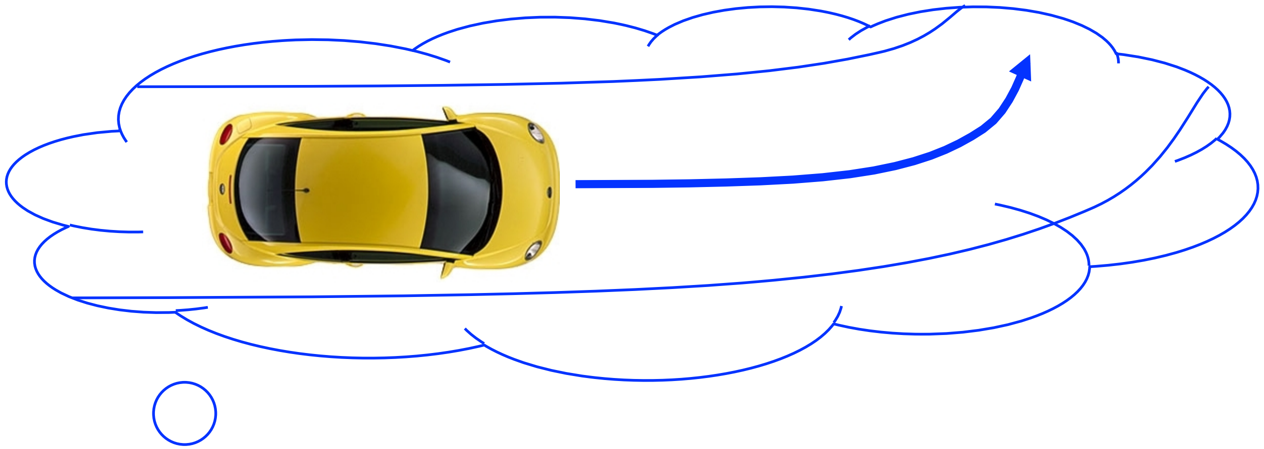
und Kurzvorstellung der Forschungsgruppe Diehl

History of the Team



Model Predictive Control (MPC)

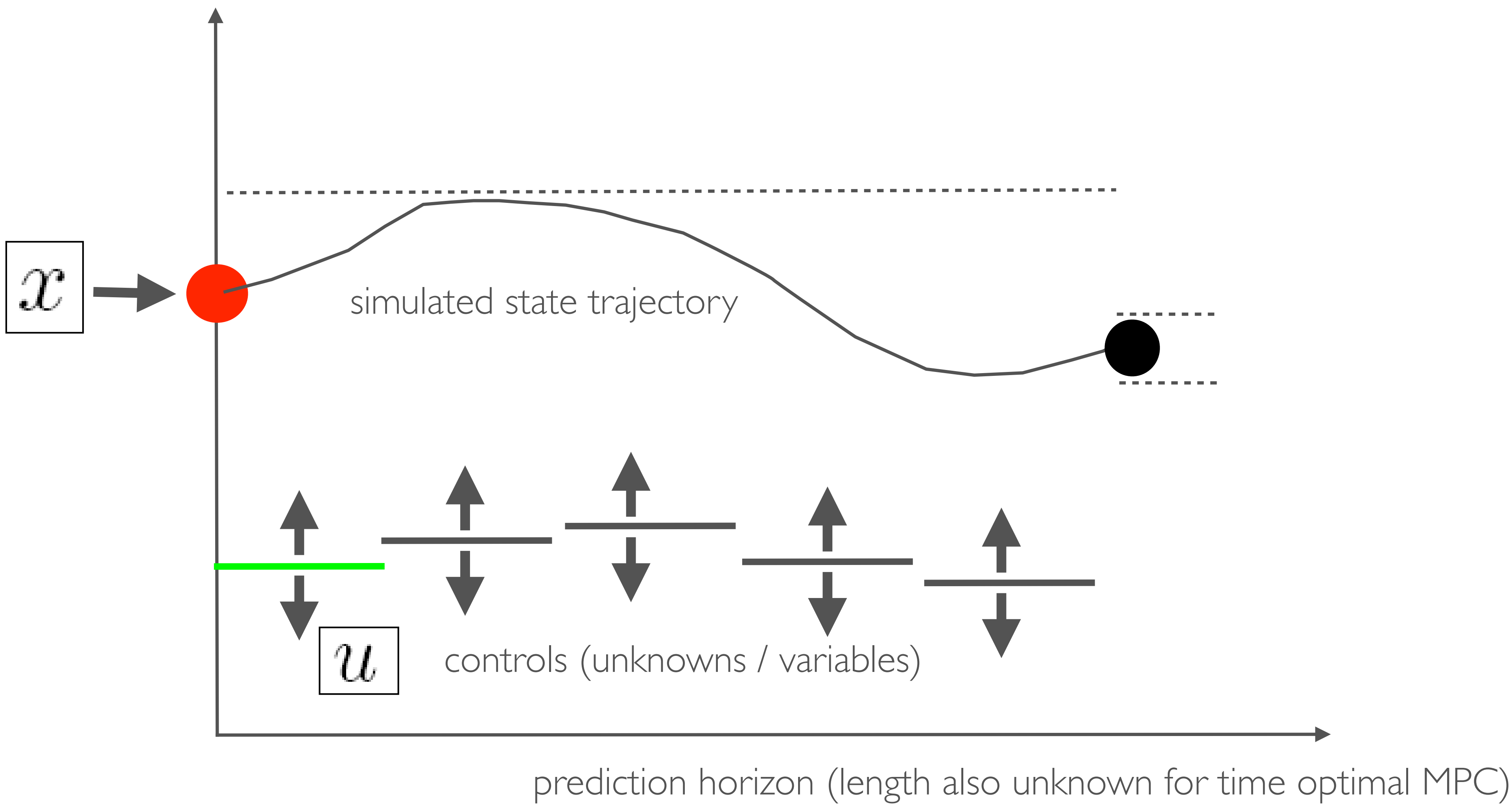
Always look a bit into the future



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

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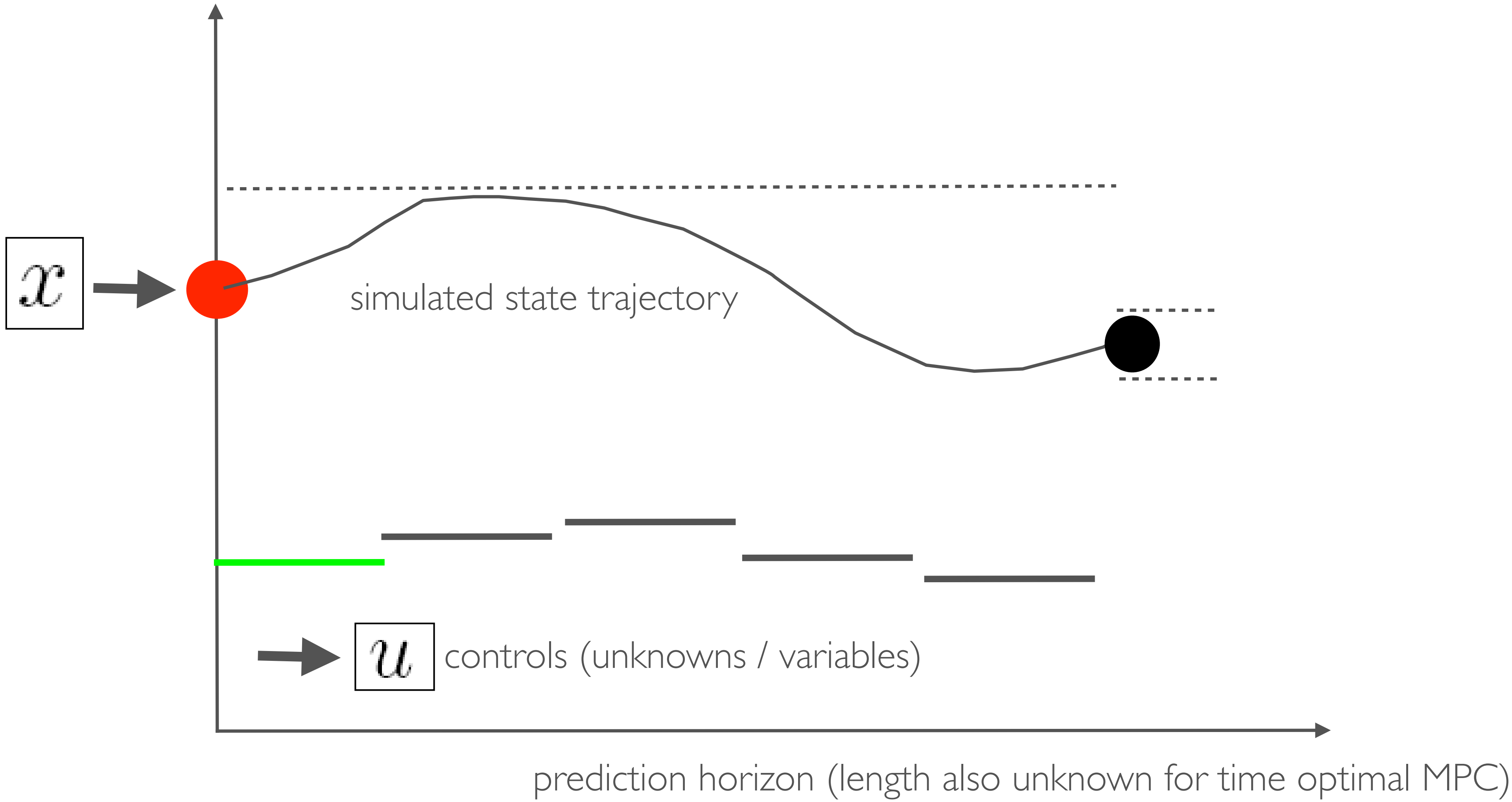
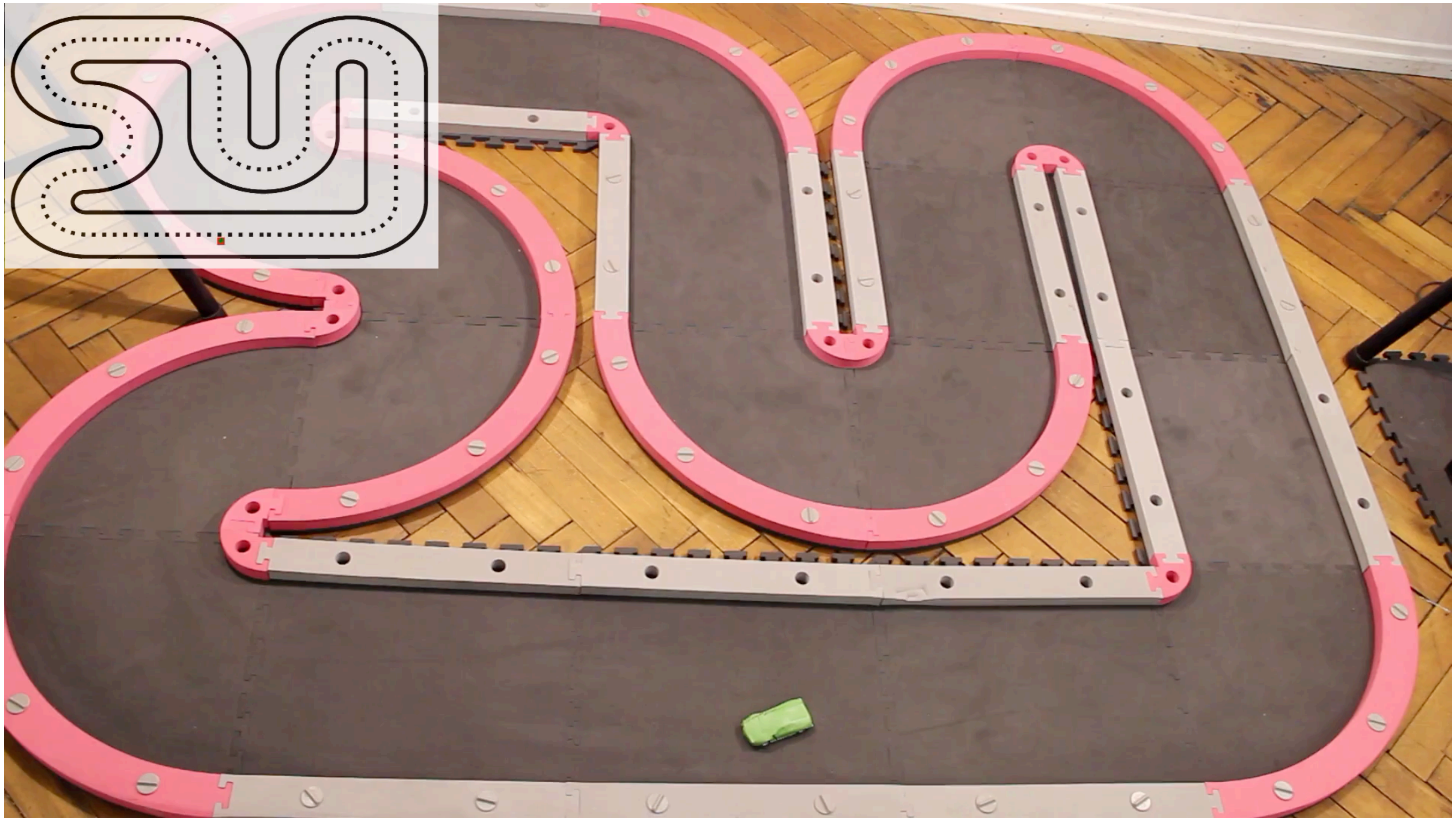


Model Predictive Control of RC Race Cars (in Freiburg)



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

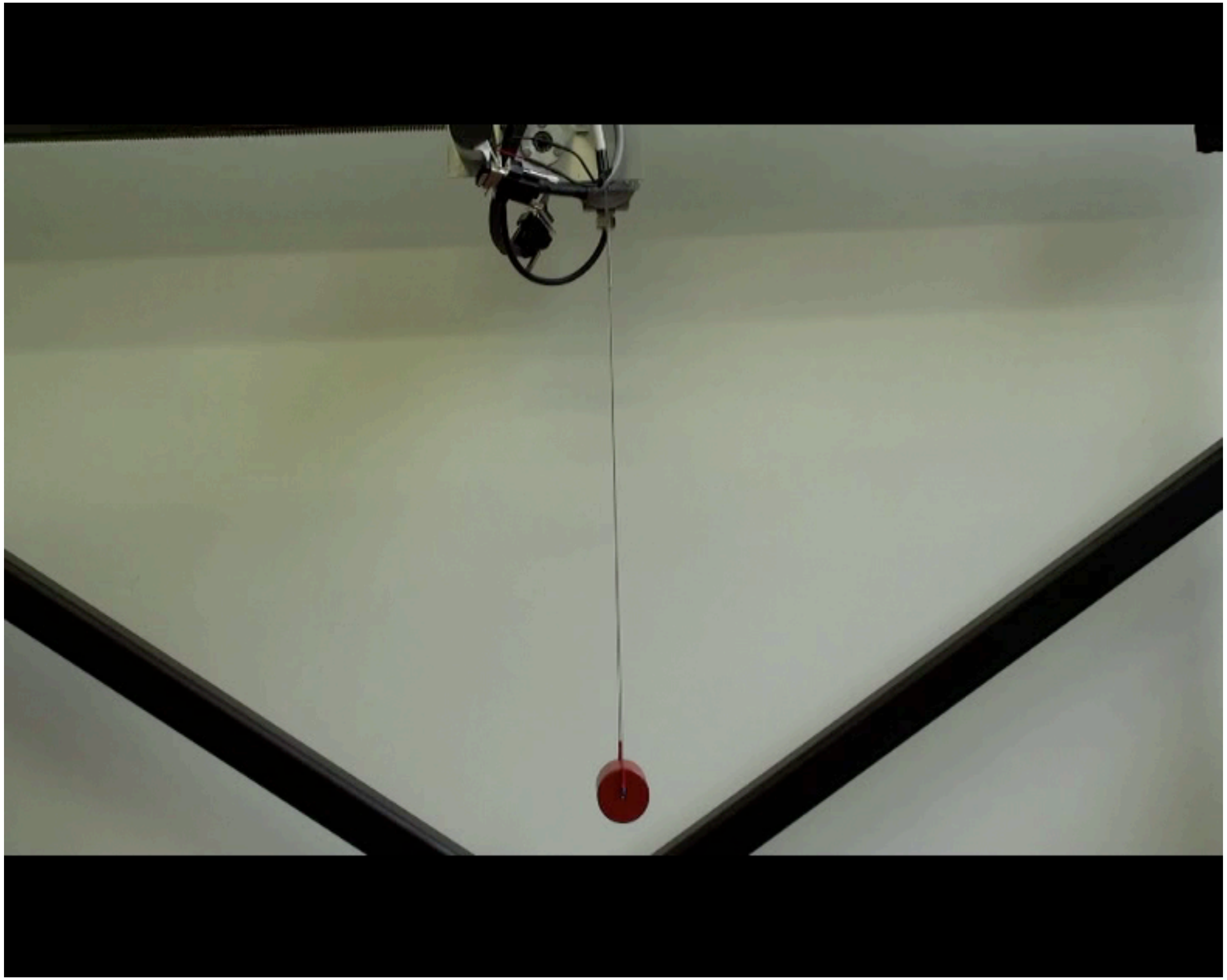
ACTUATOR

- cart motor

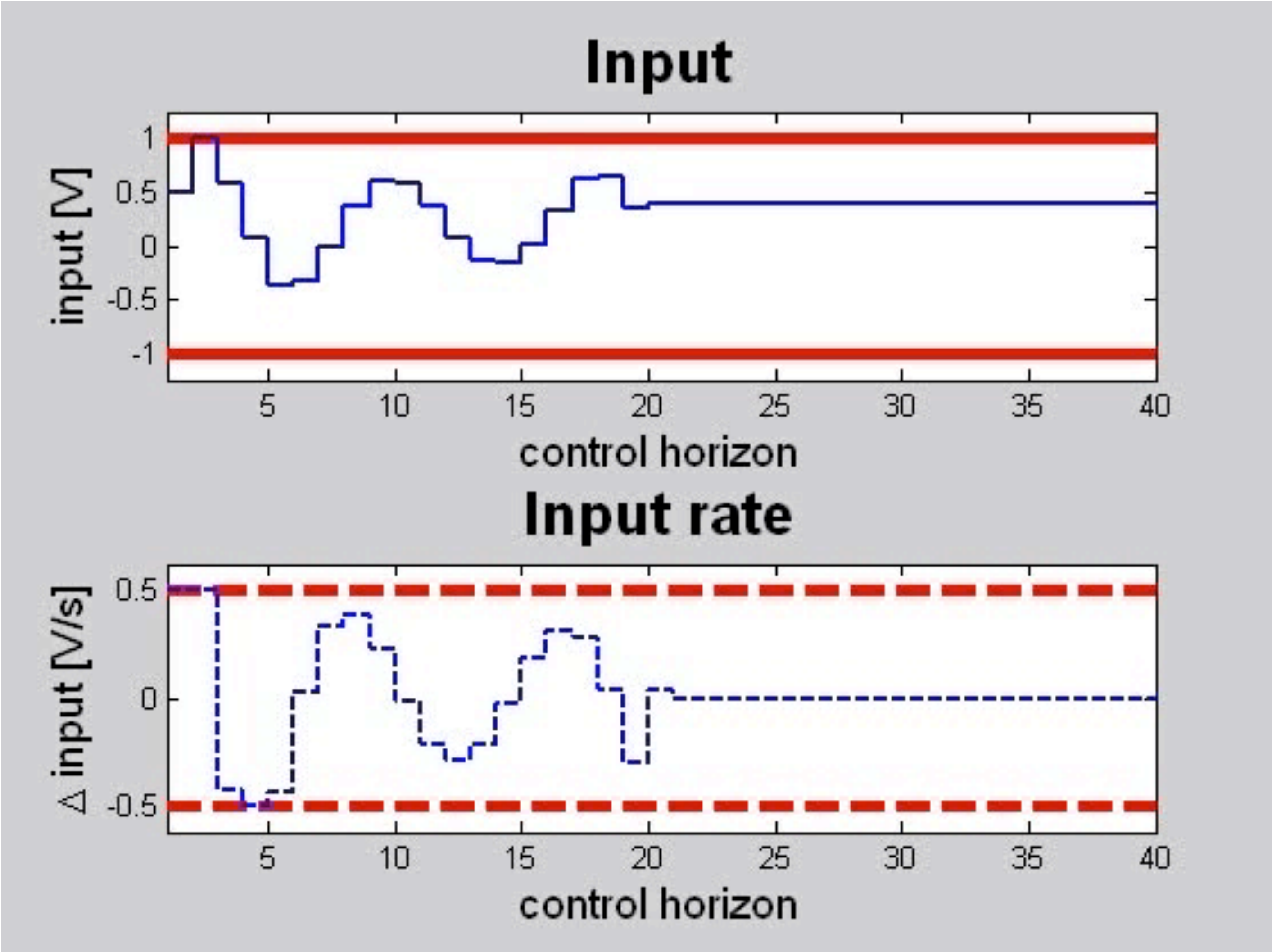
Hardware: xPC Target. Software: qpOASES [Ferreau, D., Bock, 2008]

Time Optimal MPC of a Crane

Univ. Leuven [Vandenbrouck, Swevers, D.]

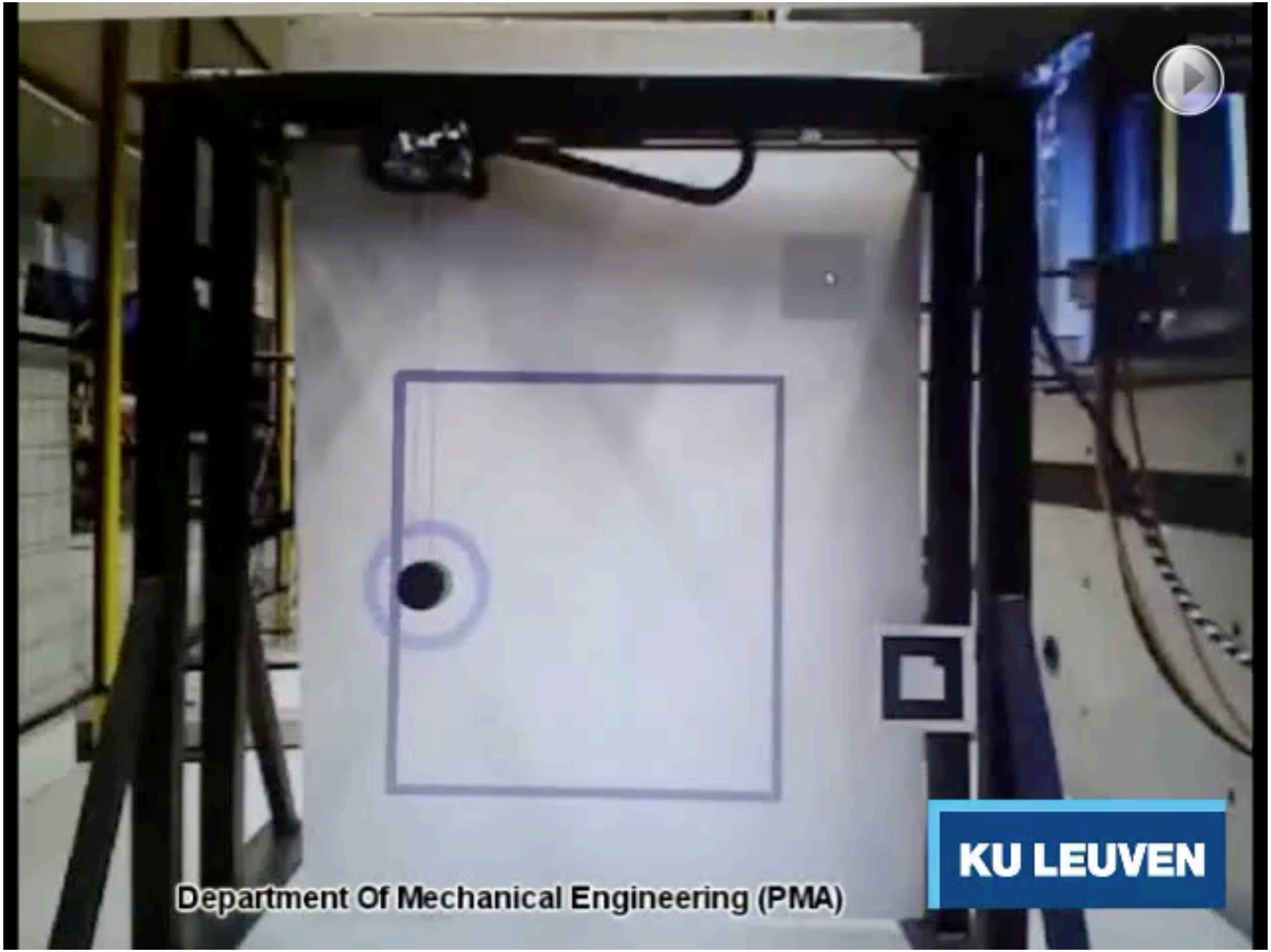


Optimal solutions varying in time



Solver qpOASES [PhD H.J. Ferreau, 2011], [Ferreau, Kirches, Potschka, Bock, D. , A parametric active-set algorithm for quadratic programming, Mathematical Programming Computation, 2014]

Time optimal path following for crane



Drone Racing with Nonlinear Optimization in Real-Time (using acados)

Paper: https://ieeexplore.ieee.org/abstract/document/9805699

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

7730 IEEE ROBOTICS AND AUTOMATION LETTERS, VOL. 7, NO. 3, JULY 2022

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 adaption 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

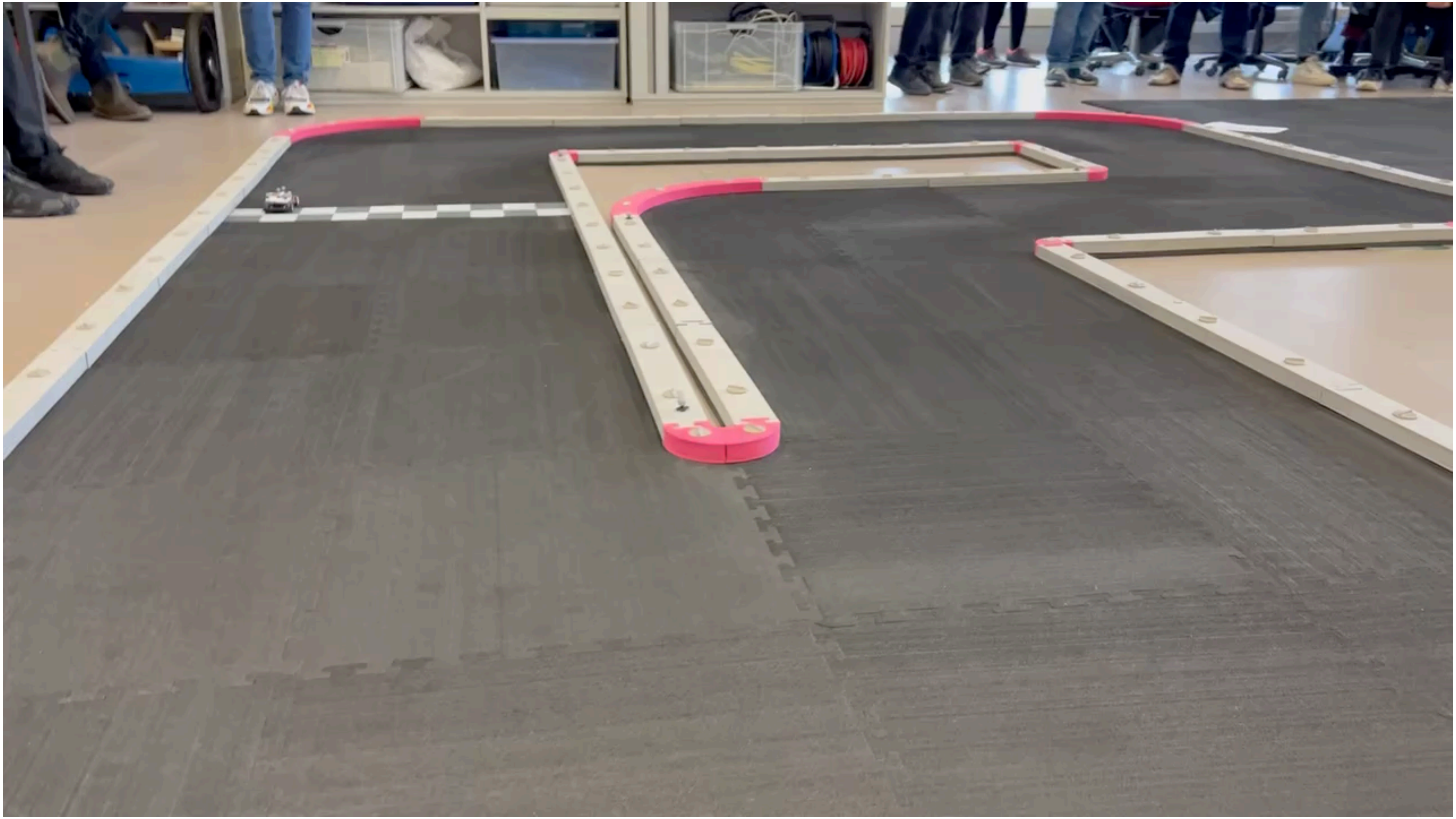
Video of the experiments: https://youtu.be/zBVpx3bgI6E

Fig. 1. The proposed algorithm is able to adapt *on-the-fly* when encountering unknown disturbances. In the figure we show a quadrotor platform flying at speeds of more than 60 km/h. Thanks to our online replanning method, the drone can adapt to wind disturbances of up to 68 km/h while flying as fast as possible.

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*
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