FORSCHERGRUPPE

„Generierung von optimalen Referenzflugbahnen für autonome Flugsysteme unter Berücksichtigung von Konfigurationsänderungen„

MUNICH AEROSPACE

AUTONOMES FLIEGEN

LEITTHEMA

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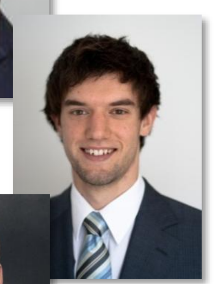

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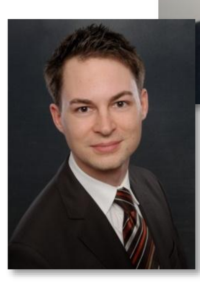

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Motivation

- Flight path optimization: How to control an autonomous flight system for a given task?
- Consideration of configuration changes (gear, flap positions, discrete decisions, choice of routes)
- Efficiency in view of a given objective (mathematical optimization)

Aims

- Investigation of optimal control problems with discrete controls
- Development of efficient methods taking into account switching costs and state dependent control constraints
- Realistic scenarios and validation in trajectory optimization

Approach

- Direct discretization methods (full discretization, shooting methods, gradient based optimization methods (SQP), variable time transformation)
- Methods for vanishing constraints
- Necessary optimality conditions and convergence
- Extensions: model-predictive control, robust optimal control, realtime/onboard optimization and sensitivity analysis

Discrete Control Dependent Constraints

Problem description

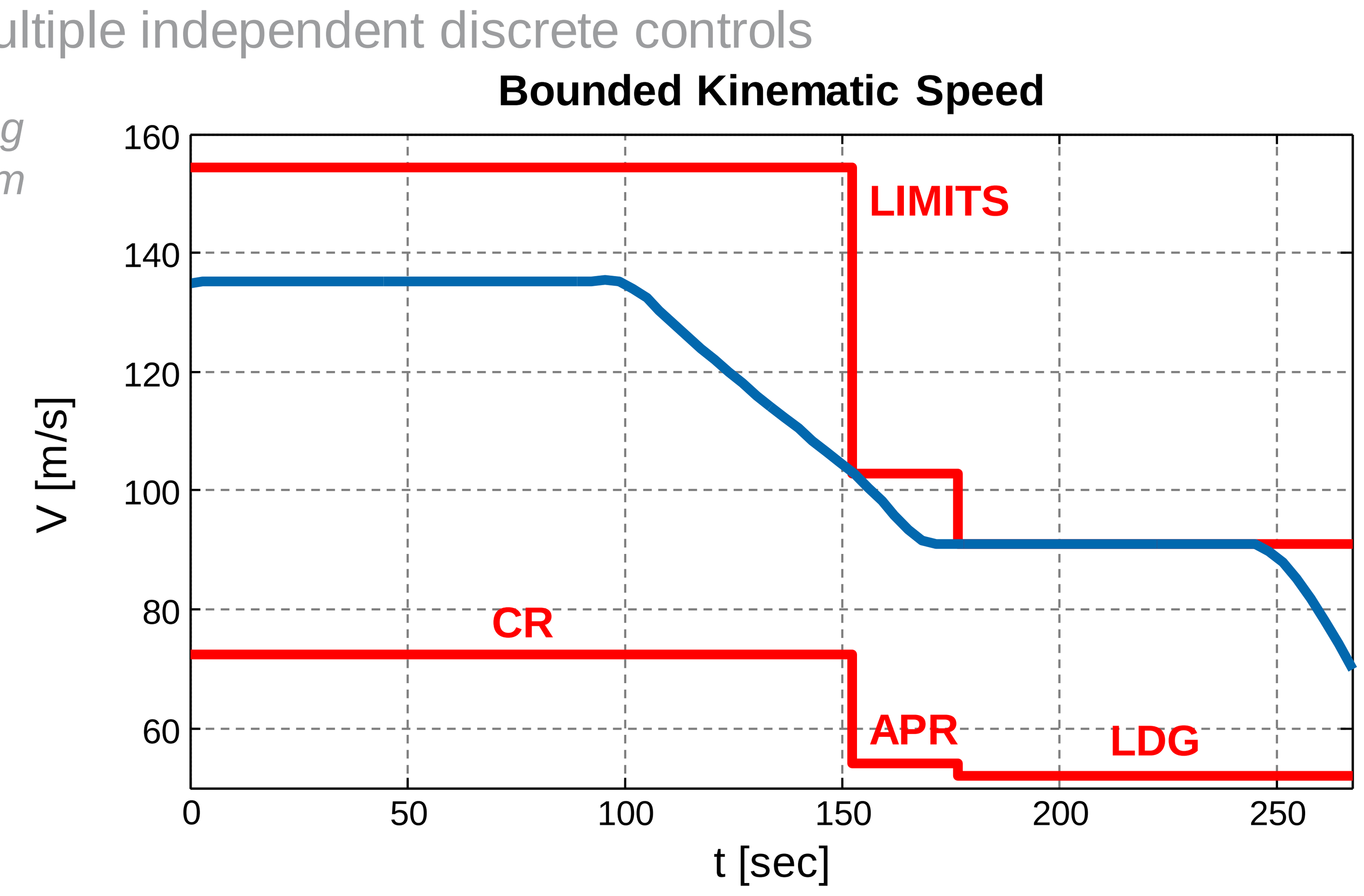
- Gradient based optimization requires translation of discrete controls (e.g. flaps) into continuous optimization problem
- Switching introduces immediate discrete changes in the flight envelope (e.g. speed envelope defined by flap position)

→ *Aim of research project:*
Taking into account discrete control dependent constraints in an optimization problem solvable by gradient based optimizers

Additional requirements

- Implementation of switching logics (CRUISE→APPROACH→LANDING)
- Multiple independent discrete controls

Landing problem



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Optimal Control with Switching Costs

Motivation

- Penalize frequent control changes
- Real models require smooth or constant behavior of the control

Difficulties

- Non existence of proper theory
- Lack of suitable formulation for cost penalization

Tasks

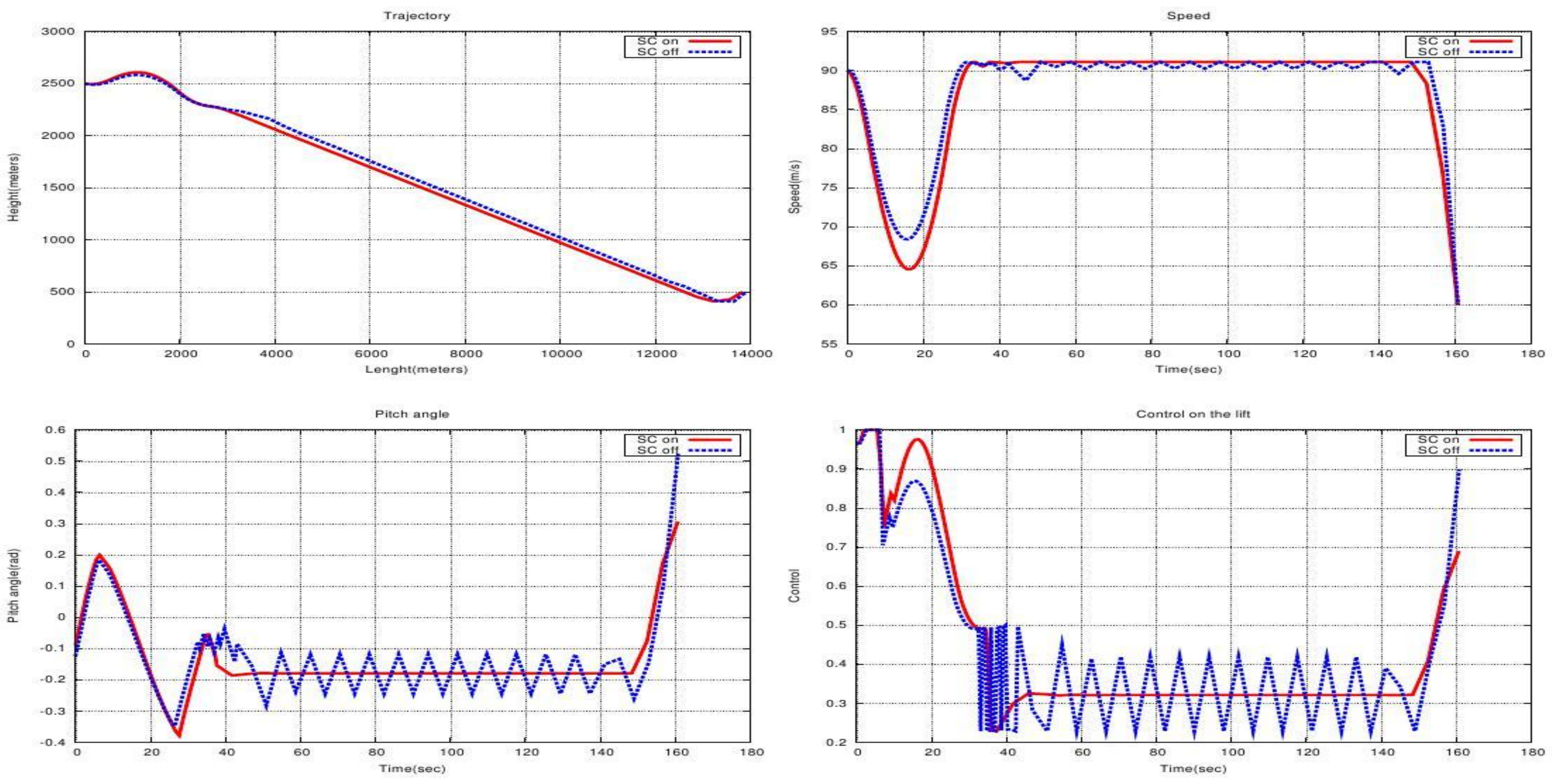
- Problem reformulation
- Investigation of necessary conditions
- Direct discretization methods
- Convergence of the discretized problem

OCP with Riemann-Stieltjes cost functional

$$\text{Minimize} \quad \varphi(x(T)) + \int_0^T f_0(x(t), u(t))du(t)$$

$$\begin{aligned} \text{s.t.} \quad x'(t) - f(x(t), u(t)) &= 0_{\mathbb{R}^n} && \text{a.e. in } [0, T] \\ g(x(t), u(t)) &\leq 0_{\mathbb{R}^k} && \text{a.e. in } [0, T] \\ x(0) - \eta_0 &= 0_{\mathbb{R}^n} \\ \psi(x(0), x(T)) &= 0_{\mathbb{R}^s} \end{aligned}$$

Application to aircraft landing model (w/o switching costs):



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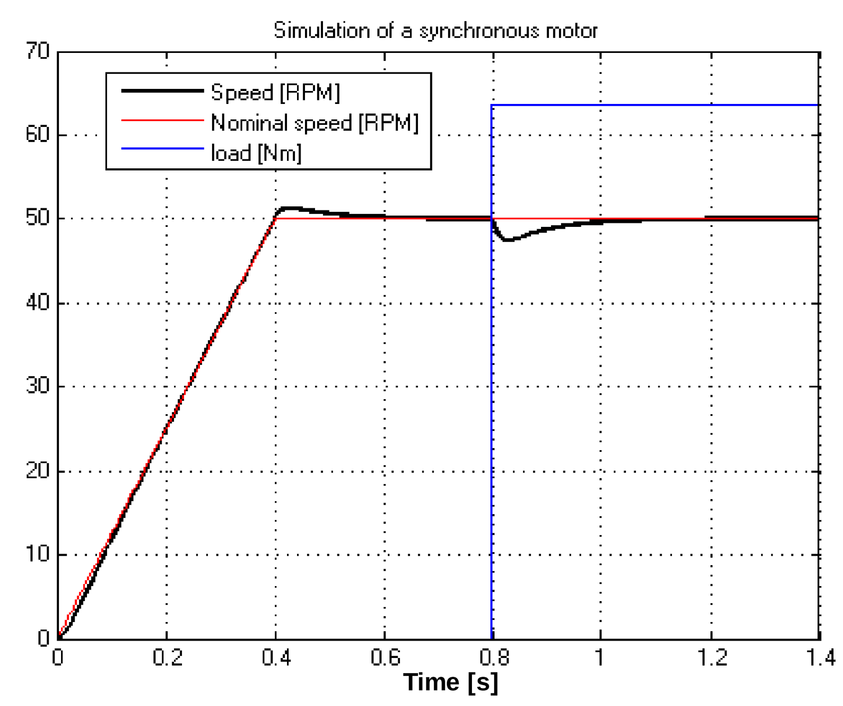
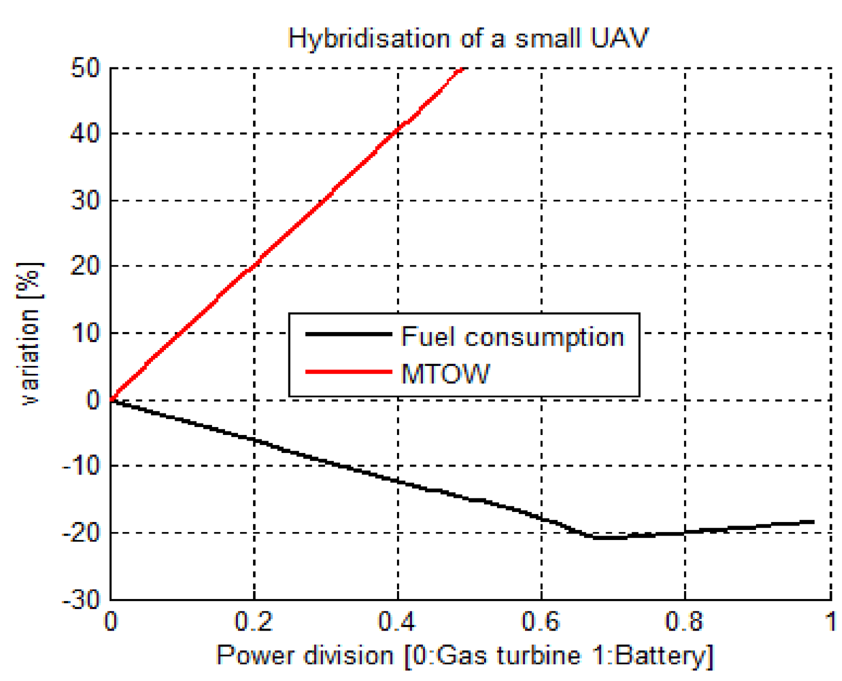
Hybrid propulsion for highly agile UAVs

Improved agility using hybrid engines

- Characterization and optimization of dynamic behavior of hybrid propulsion systems
- Examination of limits of flight stabilization and flight maneuvering by electric propulsion
- Impact of electric motors on instationary fan performance





More endurance with hybrid engines

- Idea: Endurance improvement by combined thermodynamic cycles (i.e. gas turbine and fuel cell)
- Idea: Endurance improvement by temporary energy buffer and down scaling of core engine
- Characterization depending on mission profile

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