# Dynamics and Control for Electrified Automotive Systems

## Control Systems group, Dept Electrical Engineering

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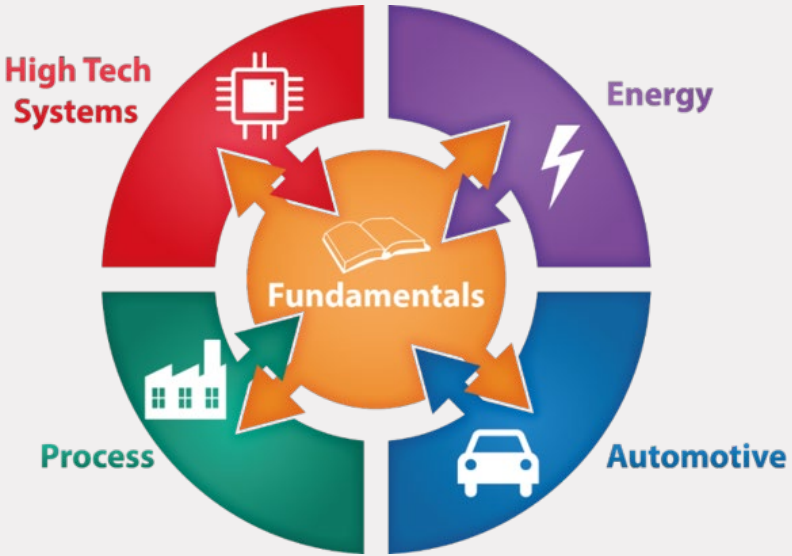
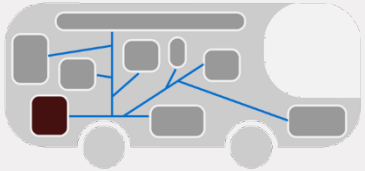
Research:

- Maximize exploitable energy
  - On the vehicle level
  - On the battery level
  - Computationally fast algorithms
- Develop correct-by-design software
  - To merge safety and autonomy
  - Using formal verification methods
- Develop/apply solid control theory

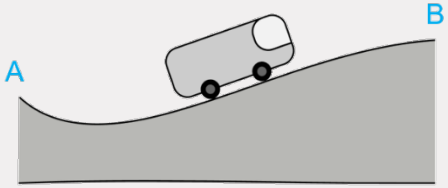


# Complete Vehicle Energy Management

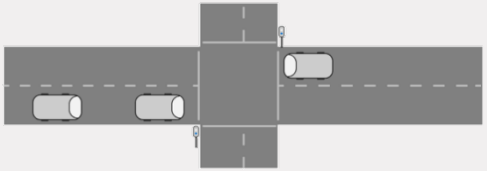
## Complete Vehicle Energy Management (CVEM) / Eco-driving / Eco-routing



Minimization of energy consumption
Distributed optimization




Optimal velocity profiles
Non-convex optimization problems



Optimal velocity profiles
Mixed integer optimization problems

## Optimal control (mixed-integer / scenario-based / nonconvex / distributed / noncooperative )

$$\min_{x(t),u(t)} \sum_{m\in\mathcal{M}} \int_{t_o}^{t_f} g_m(x(t),u(t))\,\mathrm{d}t$$

$$\text{s.t.} \quad \frac{\mathrm{d}}{\mathrm{d}t}x(t) = f(x(t),u(t)),$$
$$x(t)\in\mathcal{X},\ u(t)\in\mathcal{U}$$

# Model-Based Battery Management Systems

Modelling and Parameter Estimation

- to better understand estimation methods
- to better understand battery chemistries

$$\frac{\partial c_s}{\partial t} = \frac{D_s}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial c_s}{\partial r}\right)$$

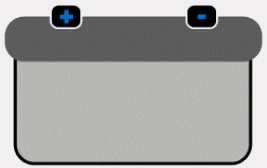
$$\varepsilon_e\frac{\partial c_e}{\partial t} = \frac{\partial}{\partial x}\left(D_e^{\text{eff}}\frac{\partial c_e}{\partial x}\right) + \frac{1-t_+^0}{F}j_{\text{Li}}$$

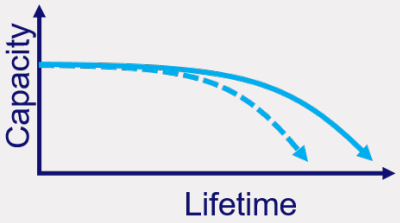
$$0 = \frac{\partial}{\partial x}\left(\sigma^{\text{eff}}\frac{\partial \varphi_s}{\partial x}\right) - j_{\text{Li}}$$

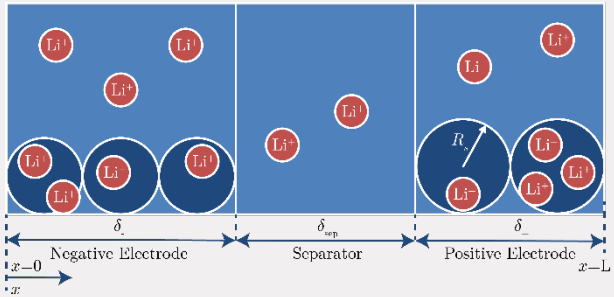
$$0 = \frac{\partial}{\partial x}\left(\kappa^{\text{eff}}\frac{\partial \varphi_e}{\partial x} + \kappa_D^{\text{eff}}\frac{\partial \ln c_e}{\partial x}\right) + j_{\text{Li}}$$

Optimal fast-charging / cell balancing

- tradeoff vehicle range and battery lifetime

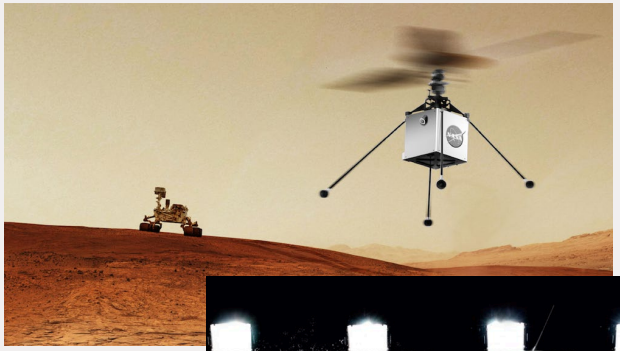




# Merge safety and autonomy

## … Create fundamental theory to solve safety issues




- Automating testing and design of control software
- Formal verification of temporal logic specifications
- Contract-based design
- Control synthesis for probabilistic systems

$$\boldsymbol{C} \,||\boldsymbol{M} \vDash \psi$$

**Required:** Probability theory, control theory, supervisory control

# Control Systems Group

**CS accepts a limited number of AT students**

**Solid background in (mathematical) control theory is needed for MSc projects**

**AT program is super (too) broad, so choose electives to specialize (so no ‘academic writing’ course).**

**For Q2 consider: Energy Management (5XWC0), Control principles for engineered systems (5SMC0), Model Reduction (5LMA0)**

**Contact person**: Prof. Siep Weiland

You will receive an invitation to the **CS in-depth** meeting soon.

*Register at secretariaat.cs@tue.nl*