MODEL PREDICTIVE CONTROL

CONCLUSIONS

Alberto Bemporad

imt.lu/ab

COURSE STRUCTURE

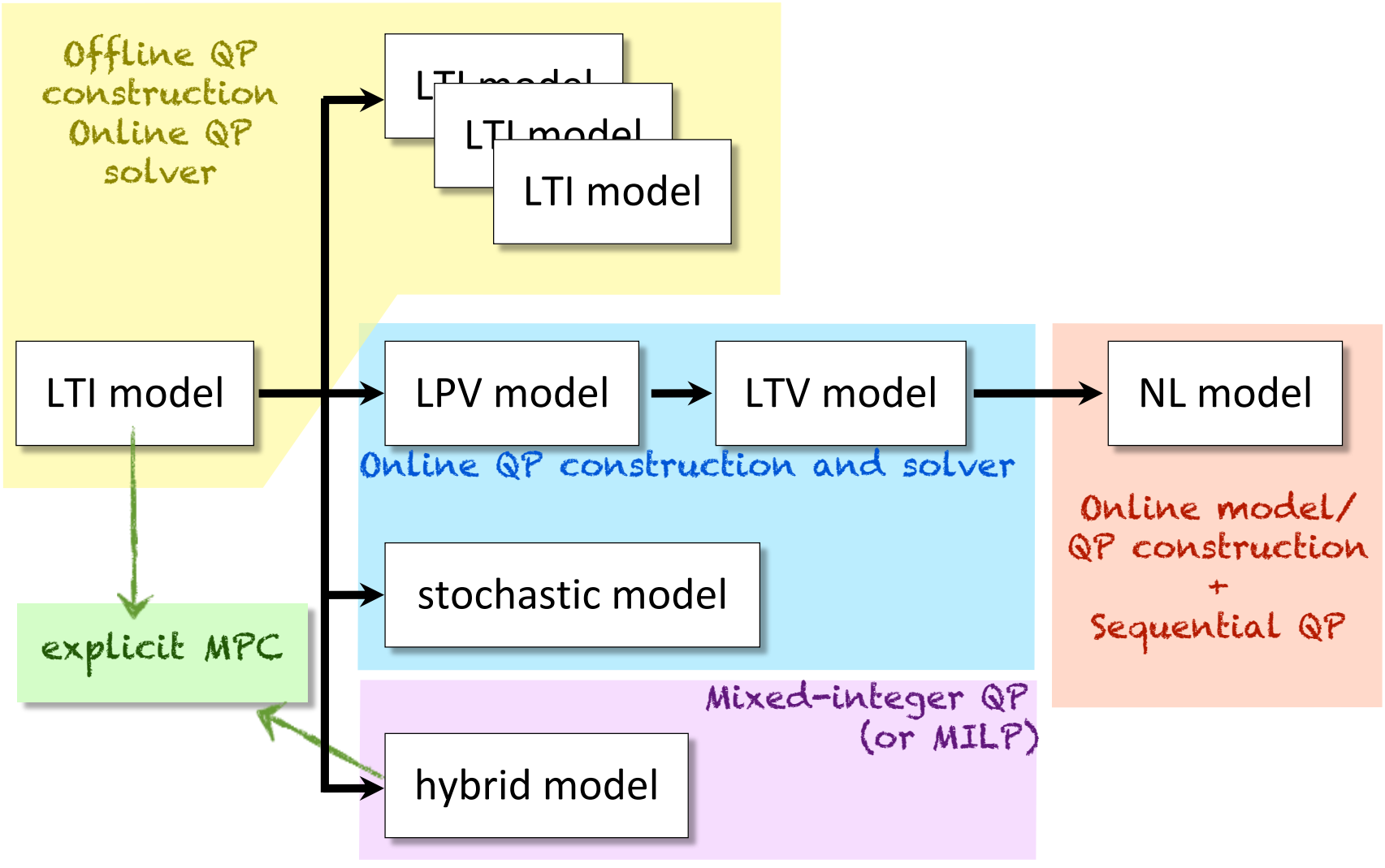
- ✔ **Basic concepts** of model predictive control (MPC) and **linear MPC**
- ✔ **Linear time-varying** and **nonlinear** MPC
- ✔ **Quadratic programming** (QP) and **explicit MPC**
- ✔ **Hybrid** MPC
- ✔ **Stochastic** MPC
- ✔ **Learning-based** MPC

Course page:

`http://cse.lab.imtlucca.it/~bemporad/mpc_course.html`

CONCLUSIONS

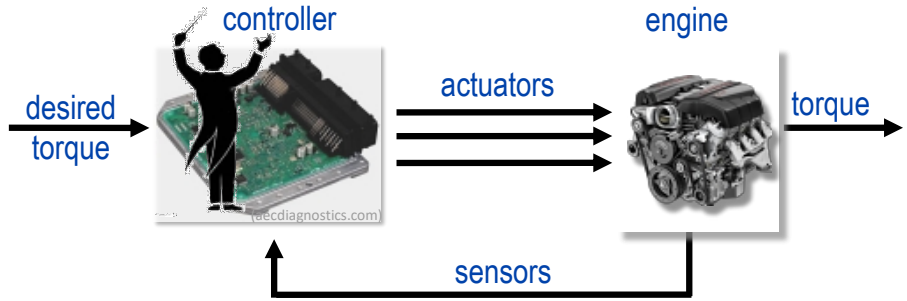
PREDICTION MODEL AND OPTIMIZATION PROBLEM

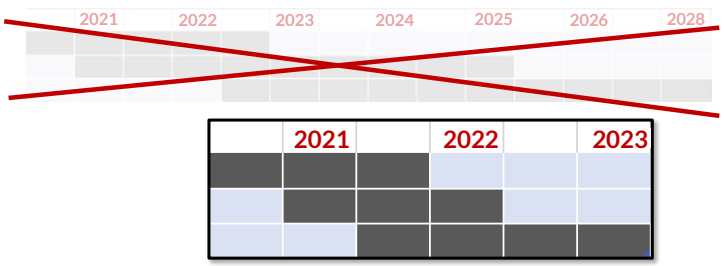


DO WE REALLY NEED ADVANCED CONTROL ?

Perspective of the automotive industry:

- Increasingly demanding **requirements** (emissions/consumption, passenger safety and comfort, …)
- Better control performance only achieved by better **coordination** of actuators:
  - **increasing number** of actuators (e.g., due to electrification)
  - take into account **limited range** of actuators
  - resilience in case of some **actuator failure**

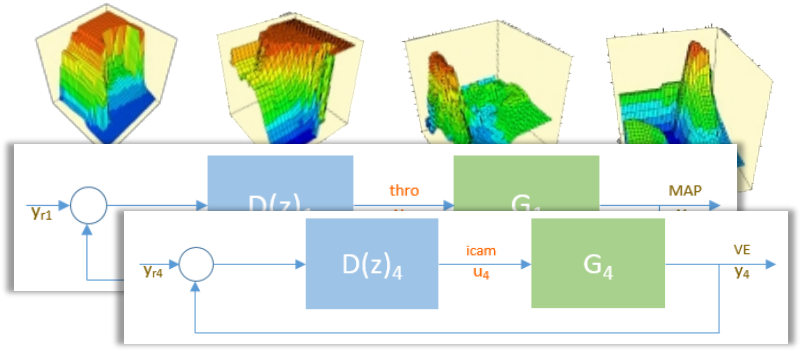


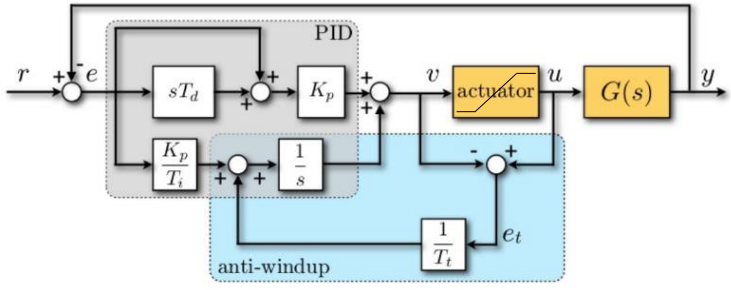


- **Shorter development time** for control solution (market competition, changing legislation)

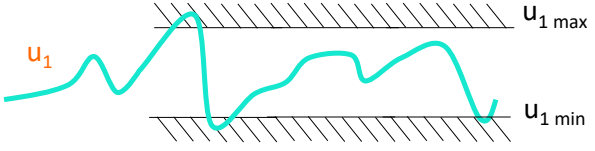
LIMITATIONS OF CLASSICAL CONTROL

- Classical approach:
  - many **single PID loops**
  - **anti-windup** for actuator saturation
  - many **lookup tables**





- Long design & calibration time due to:
  - **complexity** of anti-windup due to **interactions**
  - difficulty to recover from **actuator failure**
  - design space increases **exponentially**
    (e.g.: 5 inputs, 10 values each $\rightarrow 10^5$ entries)
  - hard to **coordinate** multiple actuators optimally
  - design difficult to port to a different vehicle model



(courtesy of J. Verdejo)

Modern vehicles need advanced (MPC) controls

CONCLUSIONS

- MPC is a **universal control methodology**:
  - different **models** (linear, nonlinear, hybrid, stochastic, …)
  - **optimize** closed-loop performance subject to **constraints**
  - intuitive to **design** and **calibrate**, easy to **reconfigure**
- **MPC research**:
  1. Linear, uncertain, explicit, hybrid, nonlinear MPC: **mature theory**
  2. Stochastic MPC, economic MPC: **still open issues**
  3. Embedded optimization methods for MPC: **still room for many new ideas**
  4. System identification for MPC: there is **a lot to "learn"** from machine learning
  5. Data-driven MPC: still **a lot of open issues**
- **MPC technology**: mature enough for widespread use in industrial applications

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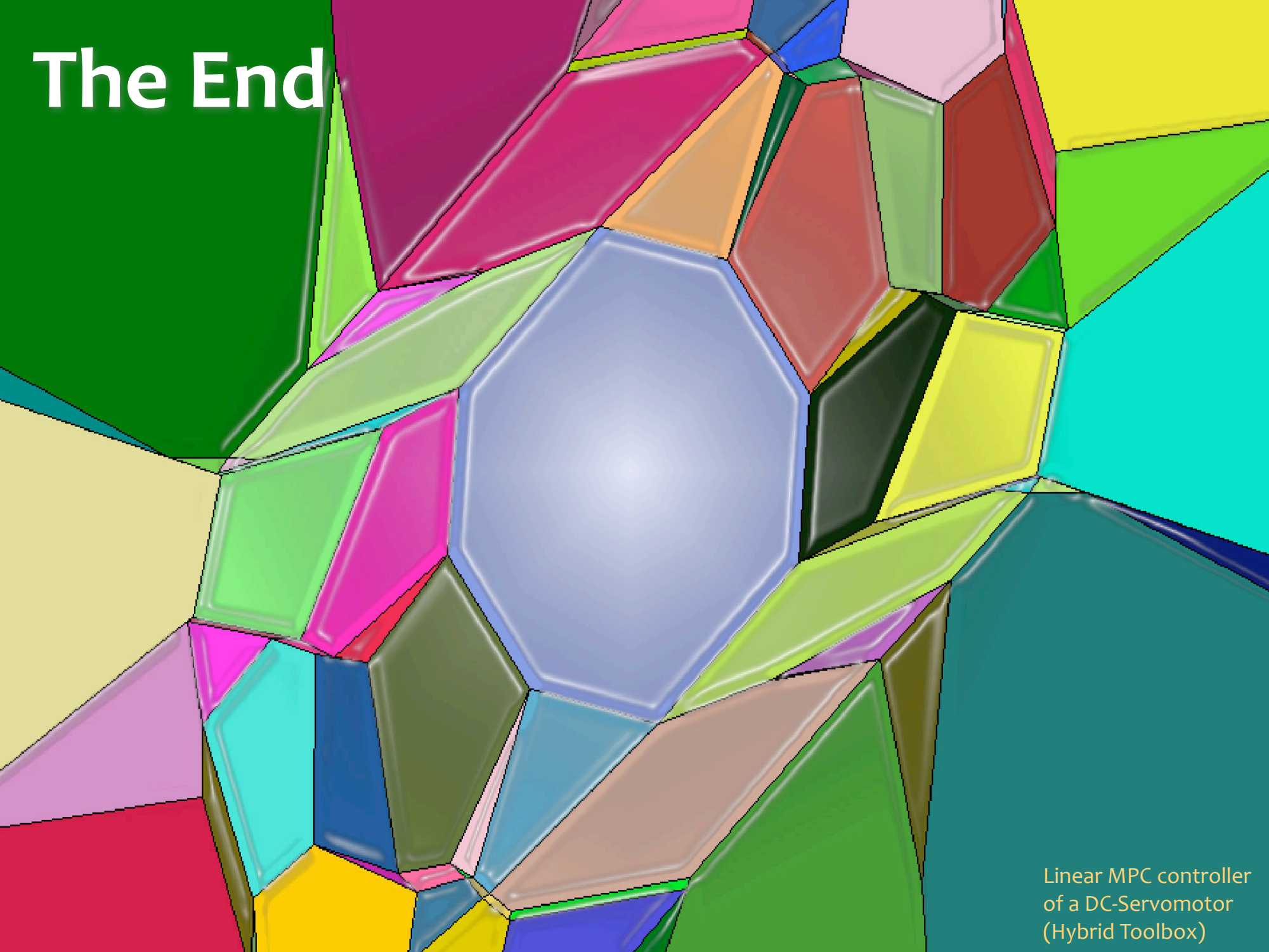

Linear MPC controller
of a DC-Servomotor
(Hybrid Toolbox)