

MODEL PREDICTIVE CONTROL

CONCLUSIONS

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COURSE STRUCTURE

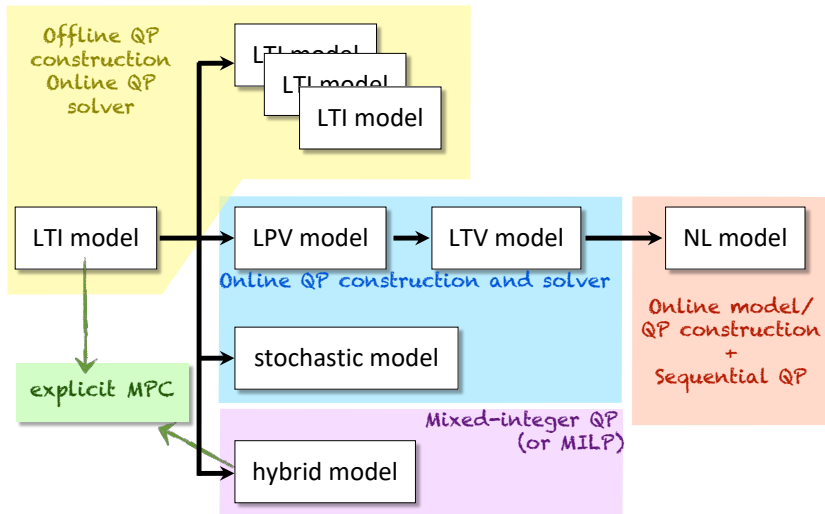
- ✓ Basic concepts of model predictive control (MPC) and linear MPC
- ✓ Linear time-varying and nonlinear MPC
- ✓ Quadratic programming (QP) and explicit MPC
- ✓ Hybrid MPC
- ✓ Stochastic MPC
- ✓ Learning-based MPC

Course page:

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

CONCLUSIONS

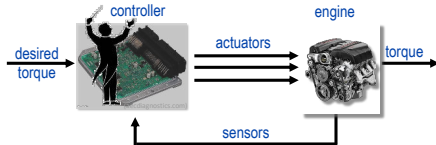
PREDICTION MODEL AND OPTIMIZATION PROBLEM



DO WE REALLY NEED ADVANCED CONTROL ?

Perspective of the automotive industry:

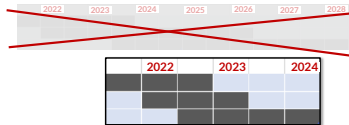
- Increasingly demanding **requirements** (emissions/consumption, passenger safety and comfort, ...)
- Better control performance only achieved by better **coordination** of actuators:



- **increasing number** of actuators (e.g., due to electrification)
- take into account **limited range** of actuators
- resilience in case of some **actuator failure**

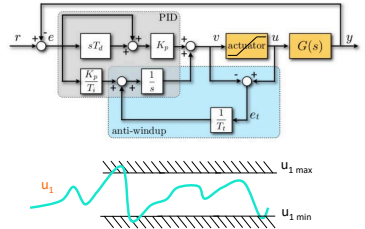
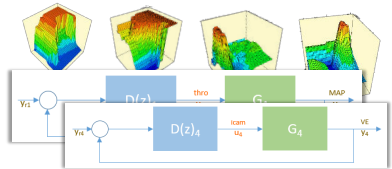


- Shorter development time** for control solution (market competition, changing legislation)



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

General references on MPC




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Hybrid systems

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-  V. Breschi, D. Piga, and A. Bemporad, "Piecewise affine regression via recursive multiple least squares and multcategory discrimination," Automatica, 73, pp. 155–162, 2016

Explicit MPC

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-  A. Bemporad, "A multiparametric quadratic programming algorithm with polyhedral computations based on nonnegative least squares," IEEE Trans. Autom. Cont., 60(11), pp. 2892–2903, 2015
-  F. Borrelli, M. Baotic, A. Bemporad, and M. Morari, "Dynamic programming for constrained optimal control of discrete-time linear hybrid systems," Automatica, 41(10), 2005

The End



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