MODEL PREDICTIVE CONTROL

CONCLUSIONS

Alberto Bemporad

imt.lu/ab
 ✓ Basic concepts of model predictive control (MPC) and linear MPC

 ✓ Linear time-varying and nonlinear MPC

 ✓ MPC computations: quadratic programming (QP), explicit MPC

 ✓ Hybrid MPC

 ✓ Stochastic MPC

 ✓ Data-driven MPC

Course page:

http://cse.lab.imtlucca.it/~bemporad/mpc_course.html
CONCLUSIONS
PREDICTION MODEL AND OPTIMIZATION PROBLEM

Offline QP construction
Online QP solver

LTI model
LTI model
LTI model
LPV model
LTV model
NL model
stochastic model

Offline QP construction and solver

Online QP construction and solver

Sequential QP
explicit MPC
hybrid model

Mixed-integer QP (or MILP)

Online model/QP construction + Sequential QP

"Model Predictive Control" - © A. Bemporad. All rights reserved.
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

Modern vehicles need advanced (MPC) controls
• 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

Hybrid systems


Explicit MPC


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)