

# MODEL PREDICTIVE CONTROL

## CONCLUSIONS

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# COURSE STRUCTURE

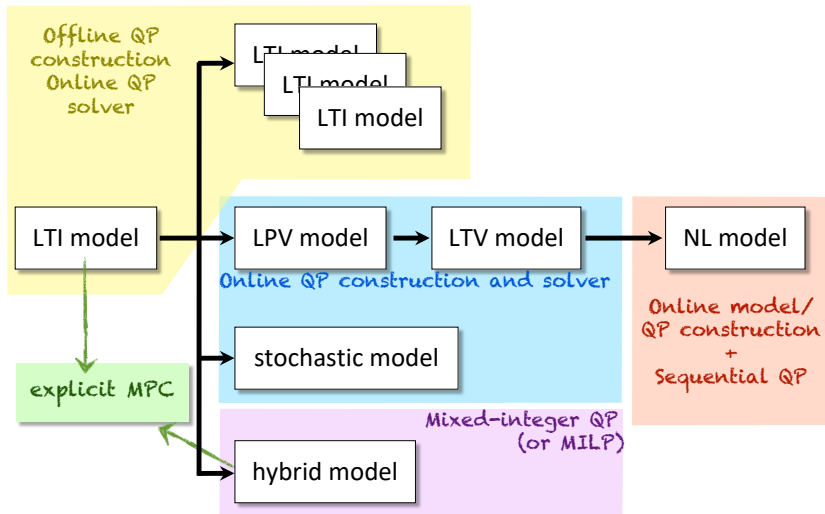
- ✓ Basic concepts of model predictive control (MPC) and linear MPC
- ✓ Linear time-varying and nonlinear MPC
- ✓ MPC computations: quadratic programming (QP), explicit MPC
- ✓ Hybrid MPC
- ✓ Stochastic MPC
- ✓ Data-driven MPC

## Course page:

[http://cse.lab.imtlucca.it/~bemporad/mpc\\_course.html](http://cse.lab.imtlucca.it/~bemporad/mpc_course.html)

## CONCLUSIONS

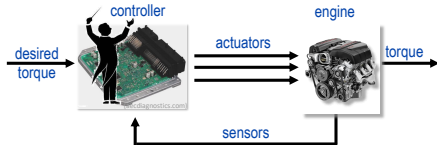
# PREDICTION MODEL AND OPTIMIZATION PROBLEM



# DO WE REALLY NEED ADVANCED CONTROL ?

## Perspective of the automotive industry:

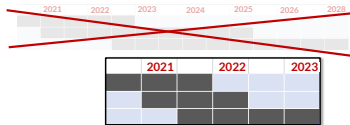
- Increasingly demanding **requirements** (emissions/consumption, passenger safety and comfort, ...)
- Better control performance only achieved by better **coordination** of actuators:



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

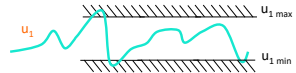
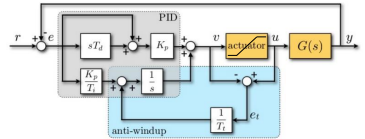
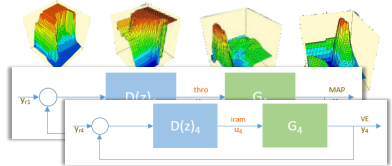


- Shorter development time** for control solution (market competition, changing legislation)



# 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**






- 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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-  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)