4F3 - Predictive Control

Lecture 1 - Introduction to Predictive Control

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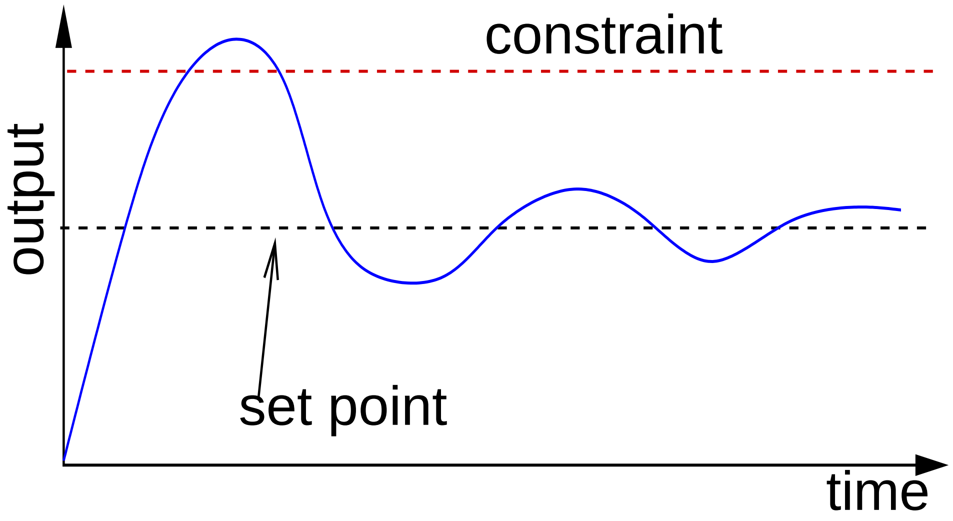
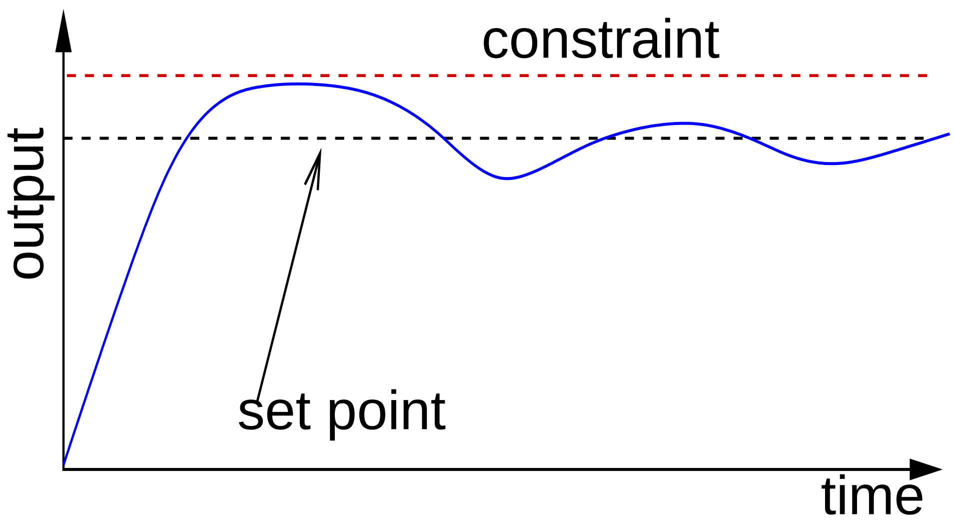
Constraints in Control

- All physical systems have *constraints*:
  - Physical constraints, e.g. actuator limits
  - Safety constraints, e.g. temperature/pressure limits
  - Performance constraints, e.g. overshoot
- Optimal operating points are often near constraints
- Most control methods address constraints *a posteriori*:
  - Anti-windup methods, trial and error

Optimal Operation and Constraints

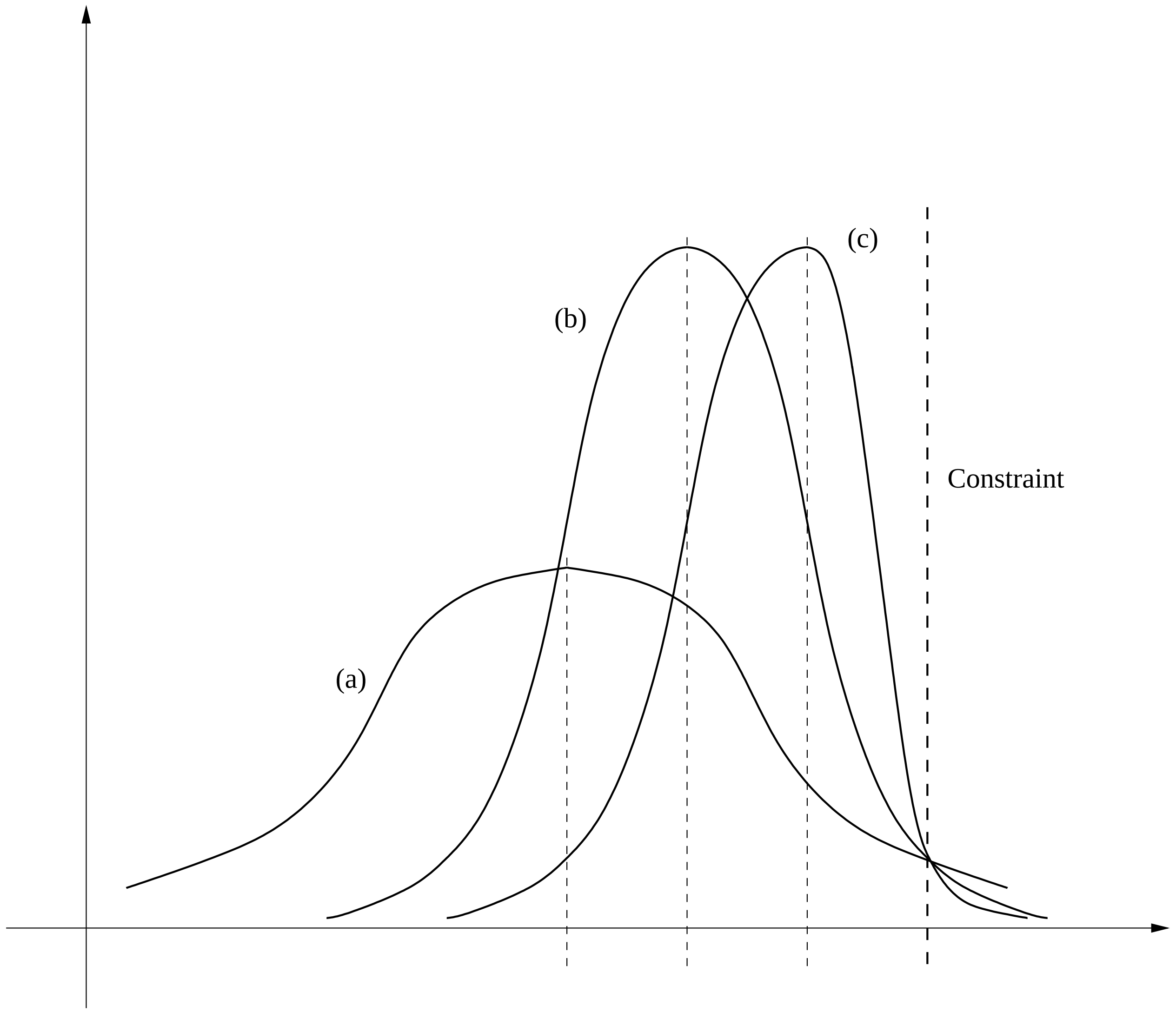


- Classical Control
  - No knowledge of constraints
  - Set point far from constraints
  - Suboptimal plant operation

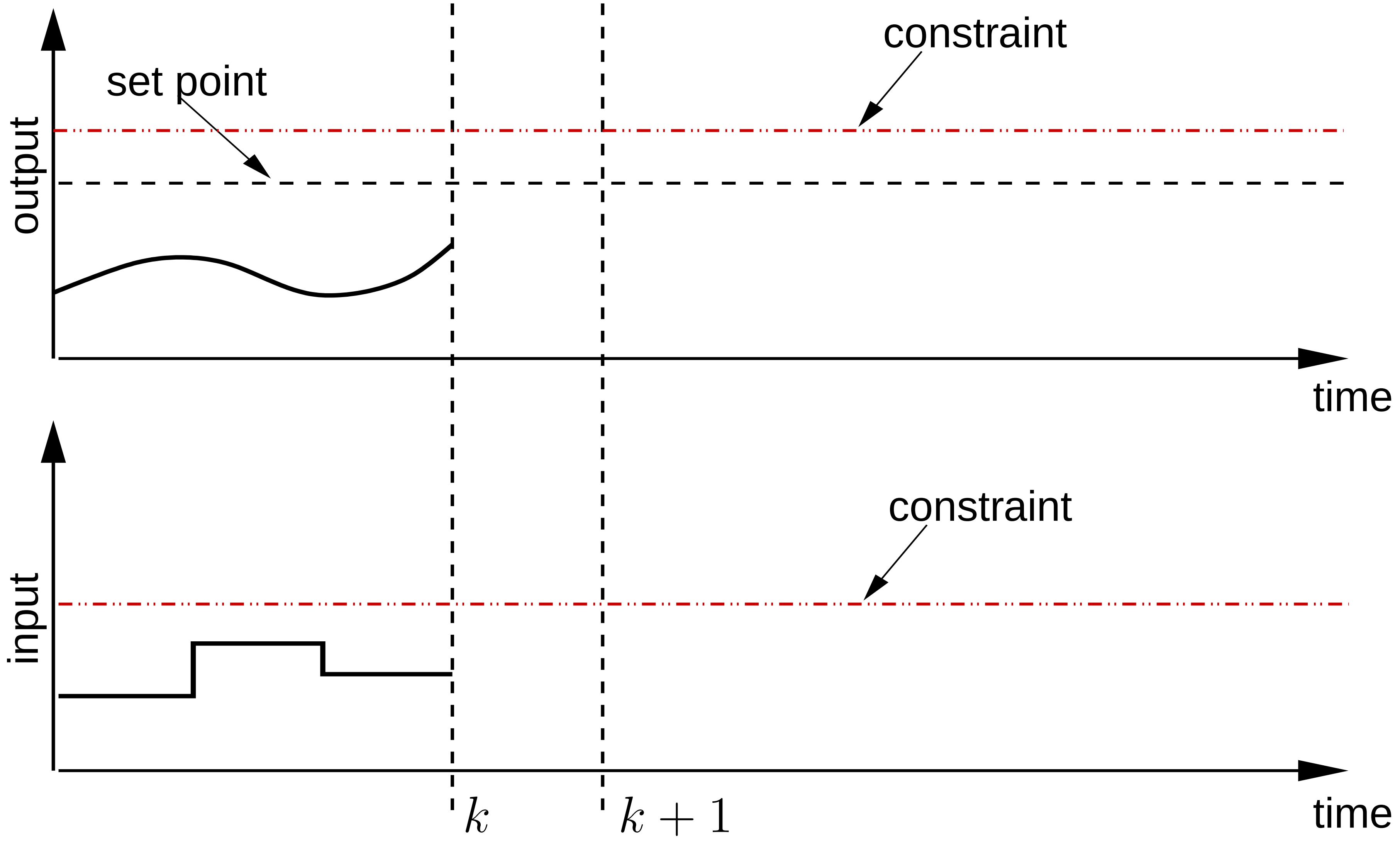


- Predictive Control
  - Constraints included in design
  - Set point closer to optimal
  - Improved plant operation

Getting closer to constraints



The Receding Horizon Principle



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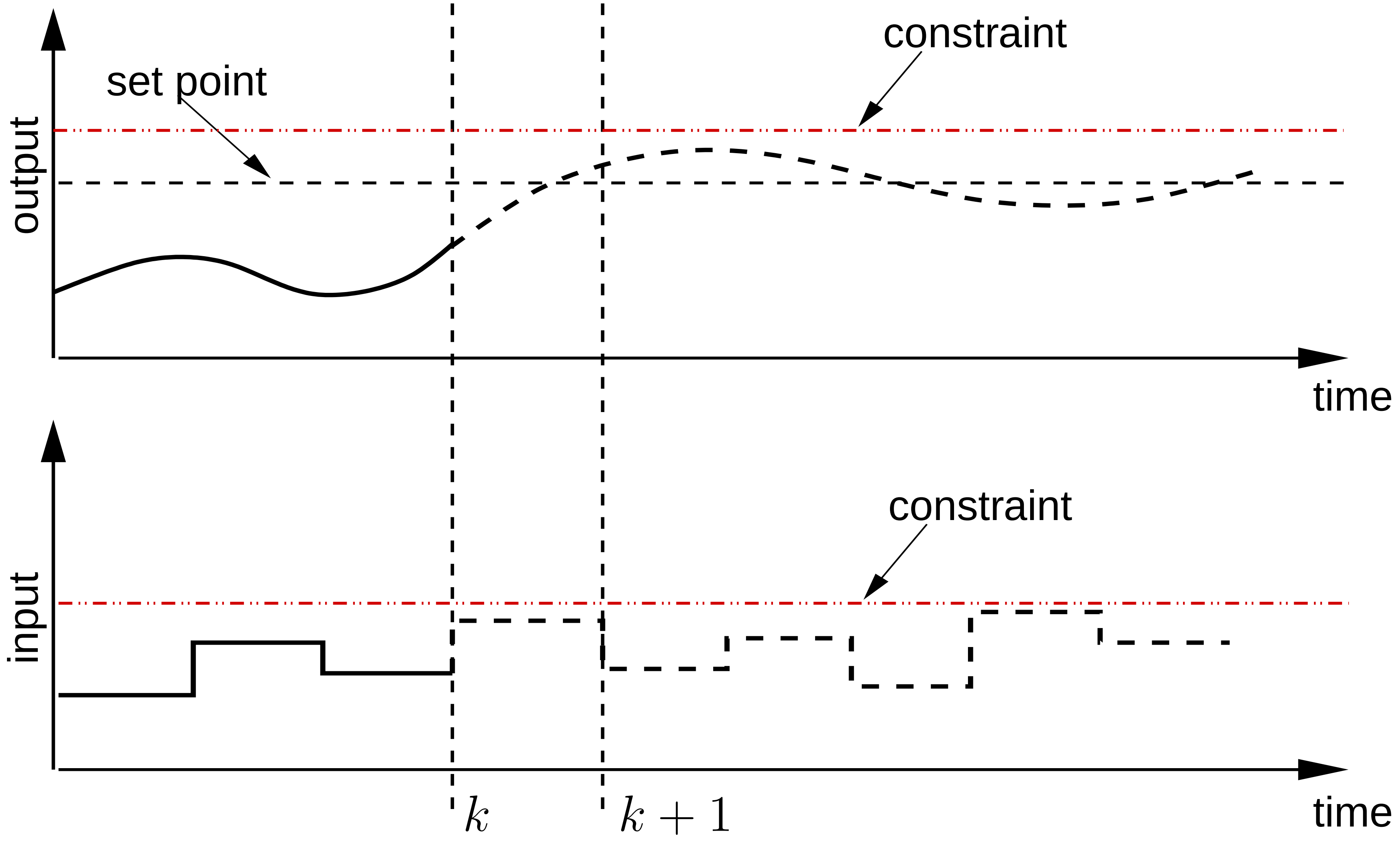
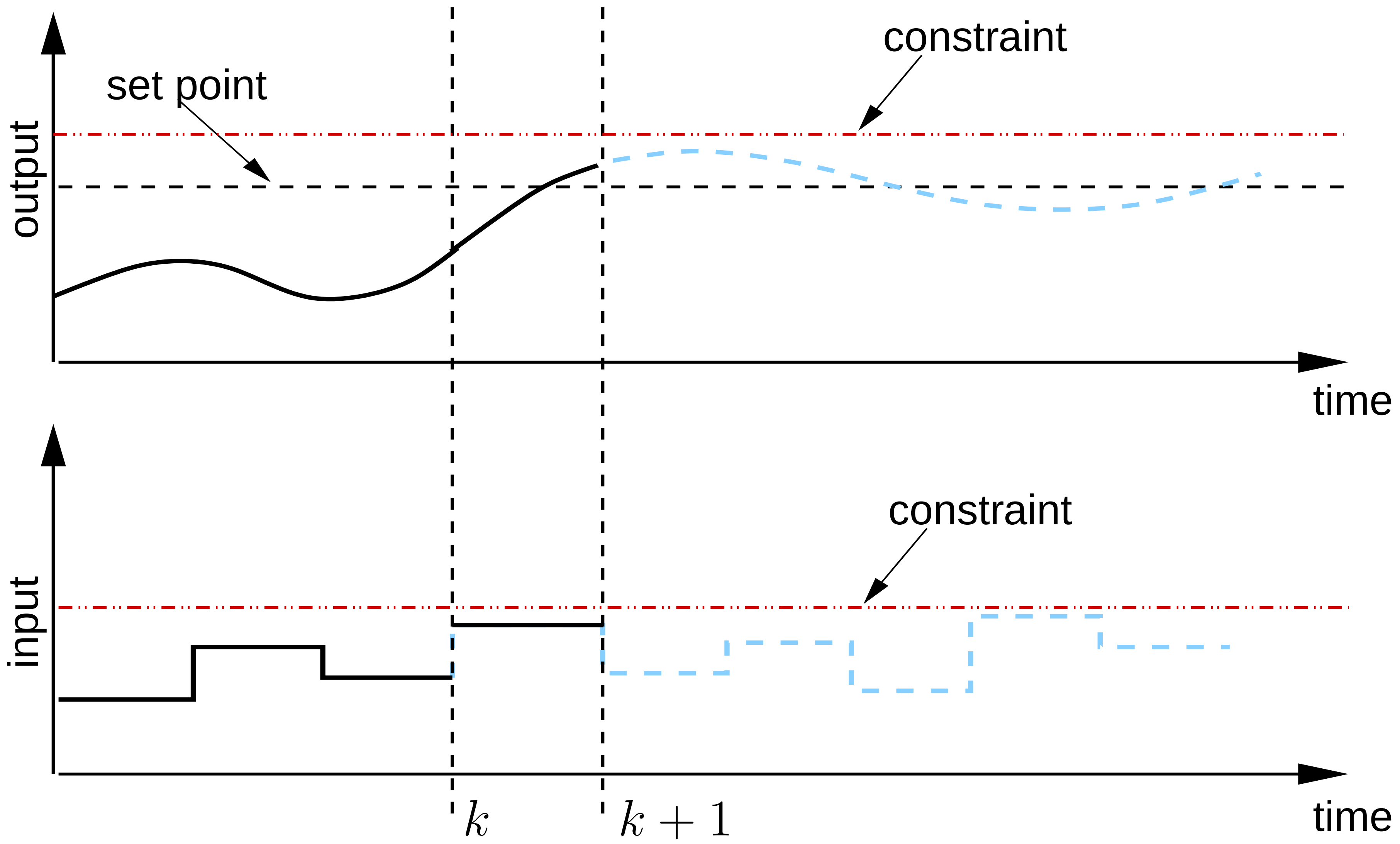
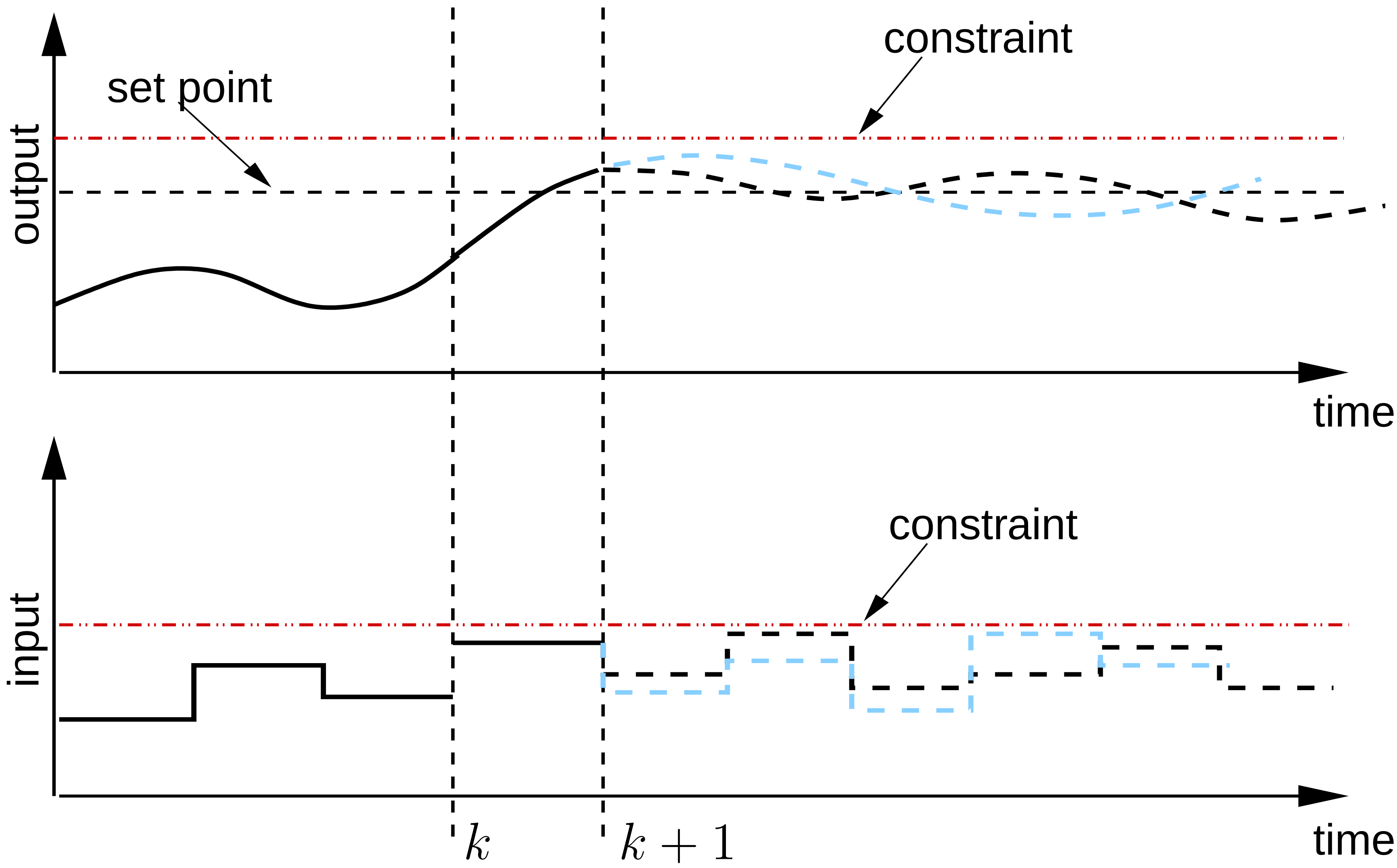


The Receding Horizon Principle



The Receding Horizon Principle



Summary of Predictive Control

Receding Horizon Control (RHC) $\Leftrightarrow$ Model Predictive Control (MPC)

- At each time instant, a predictive controller:

  1) Takes a measurement of the system state/output

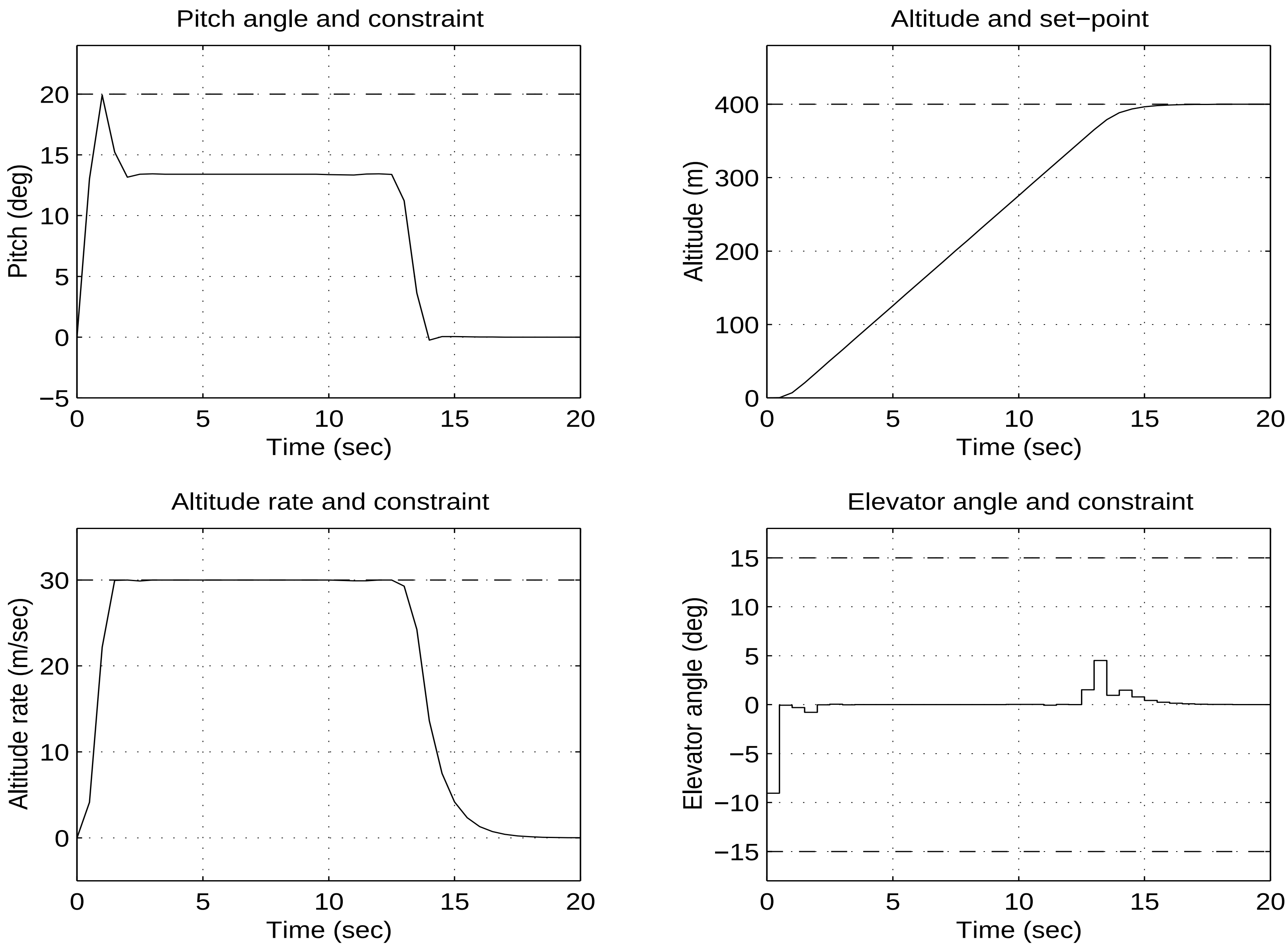
  2) Computes a finite horizon control sequence that

     (a) Uses an internal model to predict system behavior
     (b) Minimizes some cost function
     (c) Doesn't violate any constraints

  3) Implements the first part of the optimal sequence

- This is a feedback control law

Example of MPC: What not How



Properties of MPC technique

- Is this a new idea?
  - No – Standard finite horizon optimal control.
  - Yes – Optimization in the loop, in ‘real time’.
- The main problems:
  - Optimization needs to be fast enough.
  - The resulting control law might not be stable.
- The main advantages:
  - Systematic method for handling constraints.
  - Flexible performance specifications.
  - Easy to understand.

Computational Speed and Applications

- Historically, MPC has been used on ’slow’ processes:
  - Petrochemical and process industries, *pulp and paper*
  - Sample time of seconds to hours
- Major advances in hardware and algorithms
  - Computation of 1 minute in 1990 $\Rightarrow$ now less than 1s
- MPC now being proposed for ’fast’ processes:
  - Automotive traction and engine control
  - Aerospace applications
  - Autonomous vehicles
  - Electricity generation and distribution

Also Known As...

Other Names in Industry and Academia:

- Dynamic Matrix Control (DMC)
- Generalised Predictive Control (GPC)
- $\vdots$

Generic names:

- Model Predictive Control (MPC)
- Model Based Predictive Control (MBPC)
- Receding Horizon Control (RHC)

Books

- *Predictive Control with Constraints*, J.M. Maciejowski, Prentice-Hall, 2002, **QC254**.
- *Model predictive control*, E. Camacho and C. Bordons, Springer, (2004), **QC264**.
- *Model Predictive Control: Theory and Design*, J.B. Rawlings and D.Q. Mayne, Nob Hill Publishing, 2009, (not in CUED Library yet).

What is in this course?

- In
  - Linear systems with constraints
  - Linear inequality constraints on states and outputs
  - Discrete-time
  - Continuous state/input systems
  - Ensuring stability with predictive control
  - Case study: Paper making
- Out
  - General nonlinear systems
  - Robust predictive control
  - Discrete states and hybrid systems

Course Outline

- Introduction to predictive control
- Discrete-time state space control theory — handout only
- Predictive control without constraints
- Predictive control with constraints
- Stability and feasibility in predictive control
- Setpoint tracking and offset-free control
- Industrial case study – Dr Paul Austin – ***Fri. 5 March***
- Examples Class – 2 Examples Papers – ***Tue. 9 March***