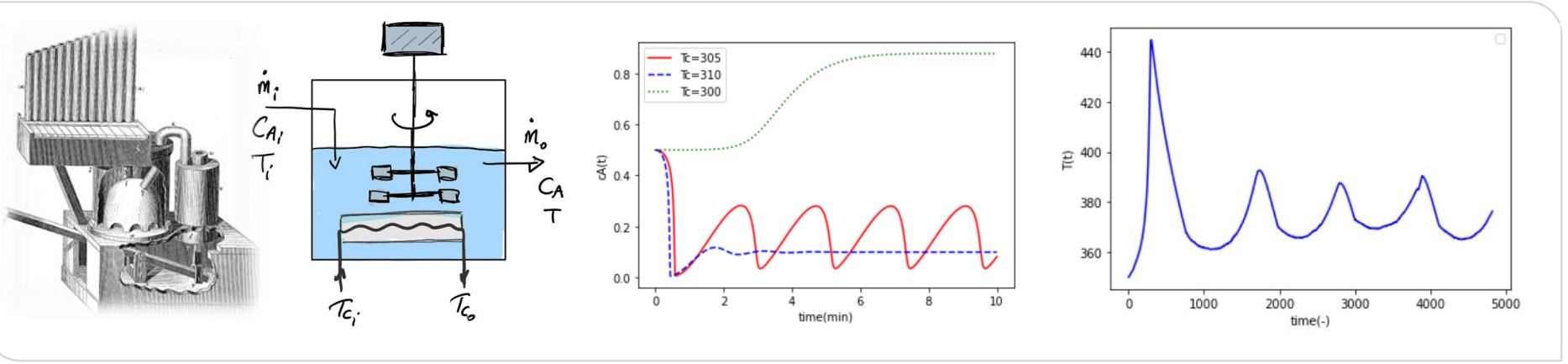
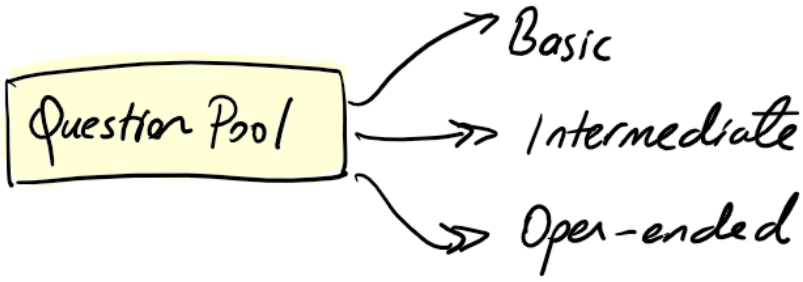
Data Driven Engineering II: Advaced Topics

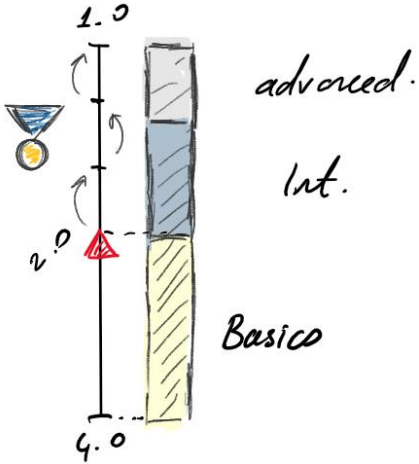
Genetic programming for data driven control

Institute of Thermal Turbomachinery
Prof. Dr.-Ing. Hans-Jörg Bauer



Outline of the oral exam:

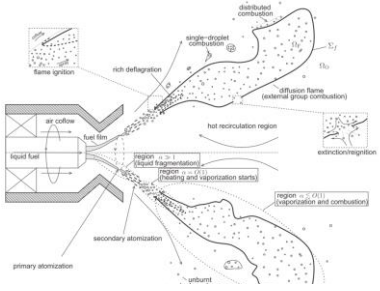


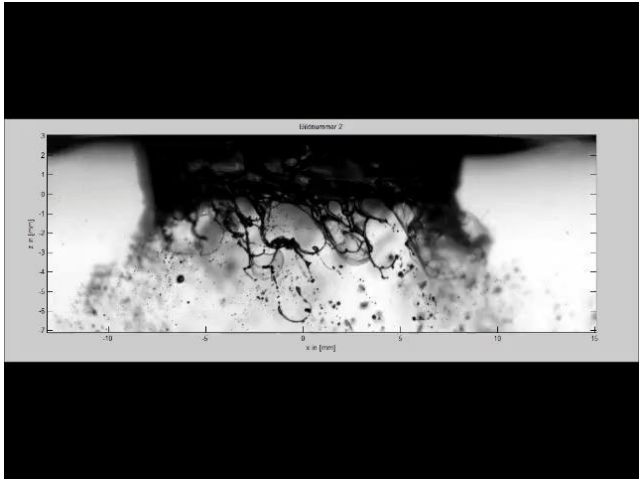


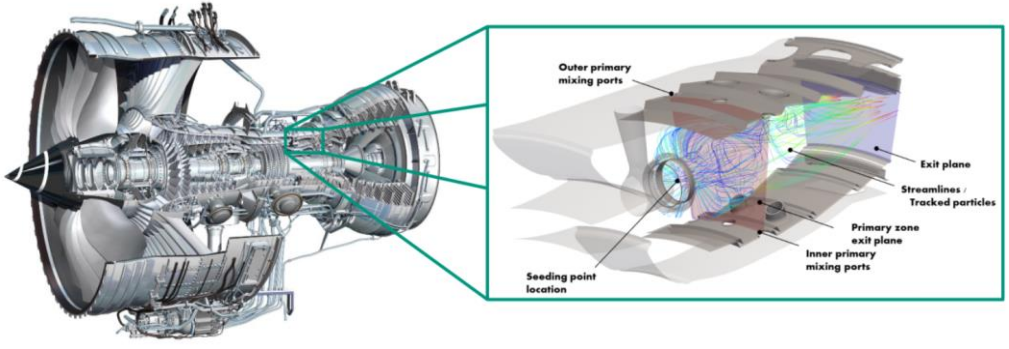
* Basic questions ⇒ All chapters
  - eg. classification vs. regression
  - how a neuron works?
  - when to use dim. reduction
* Intermediate questions ⇒ Tools used in project
* Open-ended question ⇒ Describe a case. ⇩ Make a comment.

MA Options


Trent XWB
AIRBUS


distributed combustion
single-droplet combustion
rich deflagration
flame ignition
diffusion flame (external group combustion)
air coflow
fuel film
liquid fuel
hot recirculation region
extinction/reignition
secondary atomization
primary atomization
unburnt




Outer primary mixing ports
Exit plane
Streamlines / Tracked particles
Primary zone exit plane
Inner primary mixing ports
Seeding point location

DDE: Dynamical Systems

Discovery // Characterization // Simulation

Karlsruhe Institute of Technology

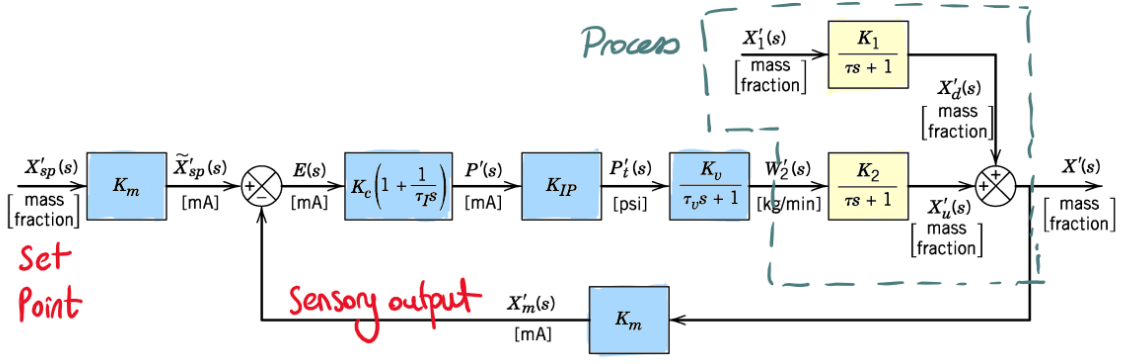
* FACT: Process ⇔ Controller

linked

Tasks:

1. Create a phy. model | DDE-I
2. Create a controller model
3. Coupled optimization | DDE-II

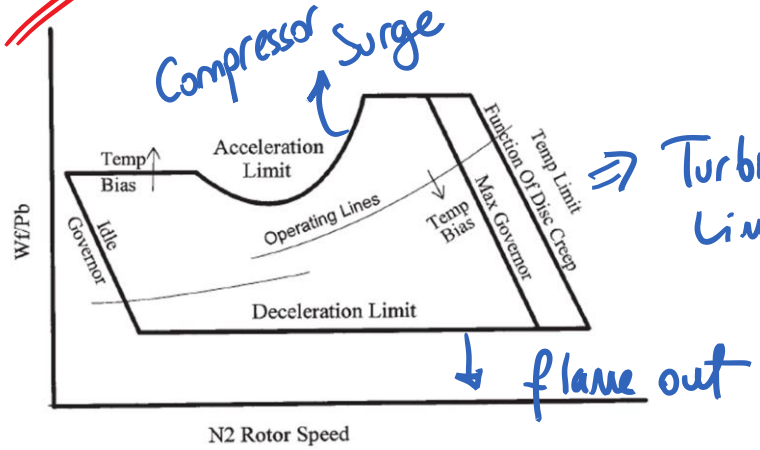
Closed-loop Control System:



Process Control :

* Transient operations
  - start-up / shutdown
  - unusual process disturbances
  - planned transitions in op. map.
  - Batch processes ⇒ Transient

Eg



⇒ Turbine Limit

↓ flame out

* Comp. Surge < 50 ms
* $T_{turbine} > T_{safe}$ < 0.25 sec.
* Overspeed < 2 sec.

Keywords

* Controlled variable (CV) ⇨ process var. that is controlled.
  ↳ set point (SP) ⇒ Desired value of CV.

* Manupulated variable (MV) ⇨ variables we can adjust to keep CV near SP.

* Disturbance variables (DV) ⇨ Affects CV but cannot be manupulated.

Keywords

* **Feedback control**

  (i) CV is measured.

  (ii) Measurement is used to adjust MV.

  (iii) DV is not measured.

  } corrective action takes place regardless of the source (DV...)

* **Feedforward control**

  (i) DV is measured.

  (ii) MV changed before CV deviates from SP.

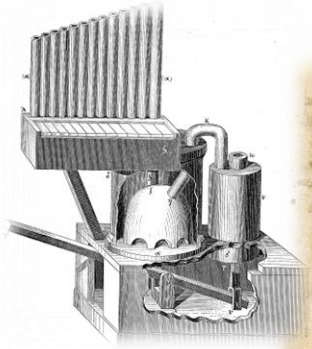
  - Need a process model.
  - MV ~~←~~ for unknown DV
  - All DV should be measured.

Early days of process control

* Feedback control ⇨ [BCE ~300 ; CE 1200]

⇨ | Ktsebios, Philon, Heron, Banu Musa brothers, Al-Jazari, ... |

- ✓ Water clocks
- ✓ Oil regulators for lamps
- ✓ Automatic wine dispenser
- ? On-off control



Early days of process control

* 17th Century : Cornelius Drebbel
  Thermometer ⇒ Valve in a furnace
* 18th Century : James Watt : Governor to control the speed of revolution
* 19th Century : J.C. Maxwell : Th. stability analysis

1930s
1940s : Classical Control theory ⇒ Frequency Domain via Laplace Tr.

- Transformation methods
- Math. model of a system

Early days of process control

1950s
1960s : State space models ⇨ "Time Domain"

$$\frac{dx}{dt} = Ax + Bu \; ; \quad dy/dt = Cx + Du$$

~1960s : Adaptive control methods

* "Intelligent Control Systems" := ill-defined / nonlinear / stochastic
  - ☐ little prior knowledge about env.
  - ☐ flexible, adaptive, robust

eg NN, Fuzzy logic, EA

How control works:

* Old days → Process Design
  → Control system

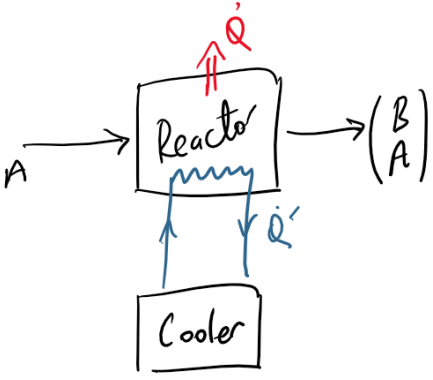
(1) Define objective

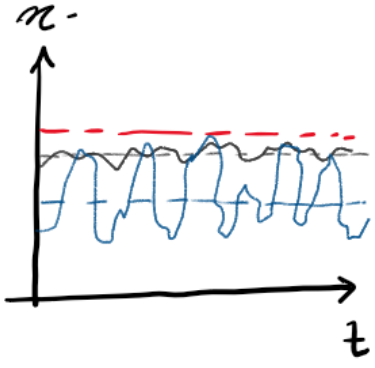
(2) Create process model

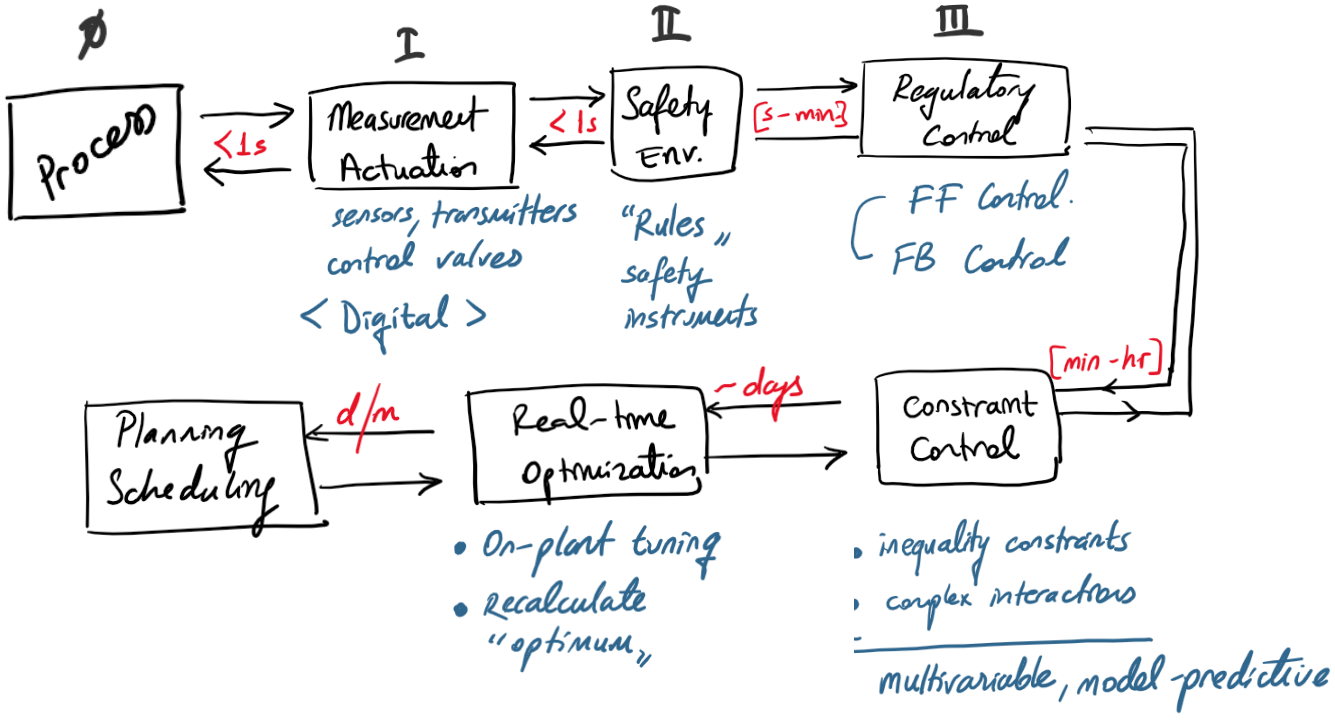
(3) Use the model to create a control strategy.

(4) Tune the system on-site.

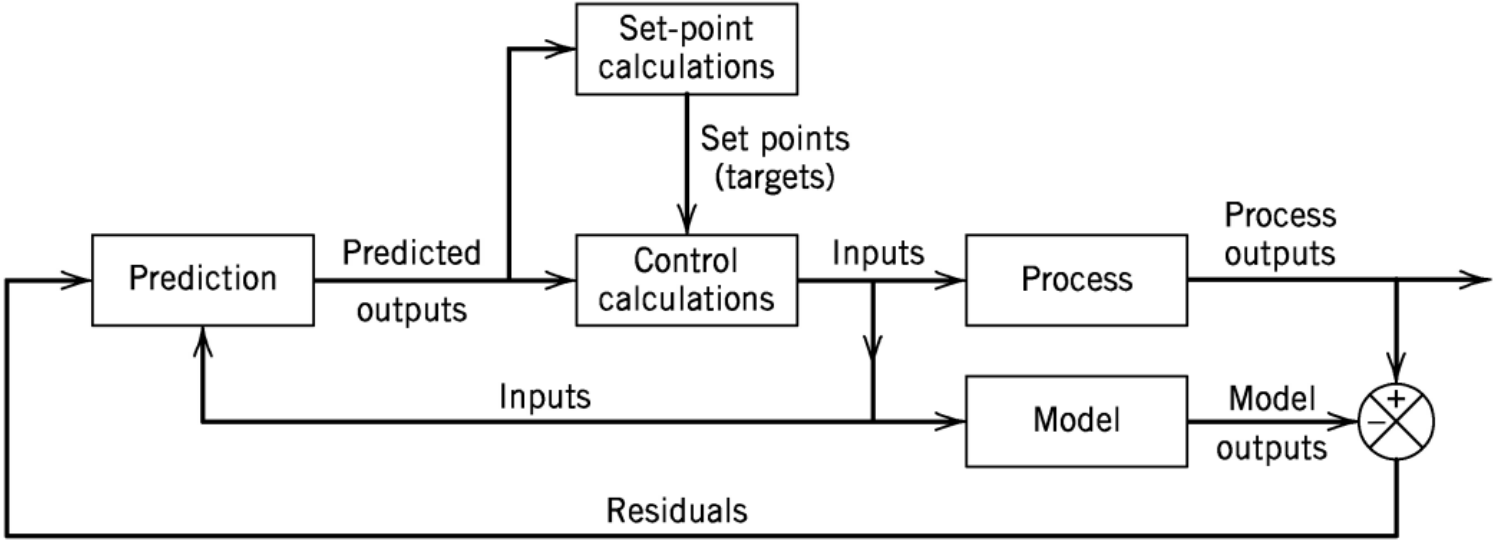
How control works:





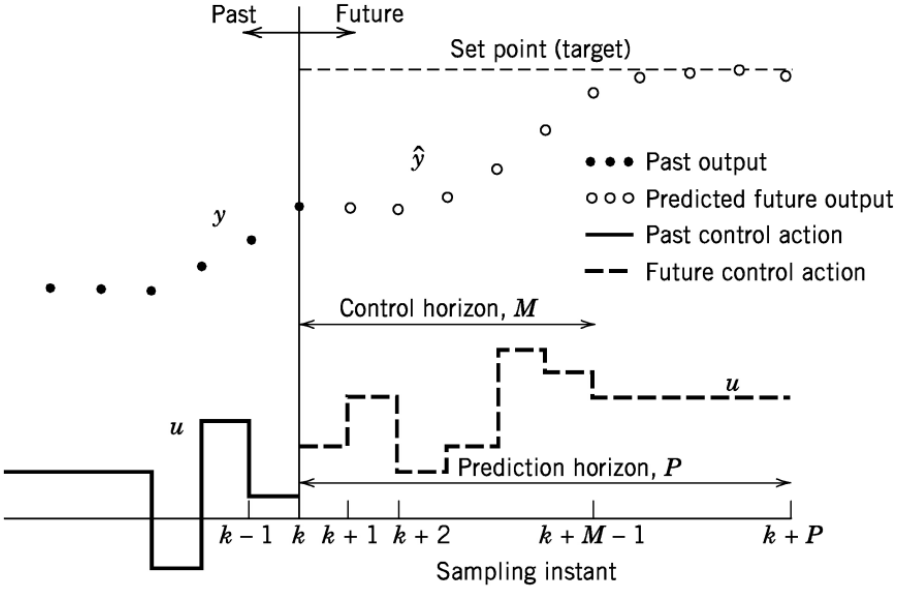


Model Predictive Control



– Seborg, Process Dynamics & Control, Ch. 20 –

Model Predictive Control



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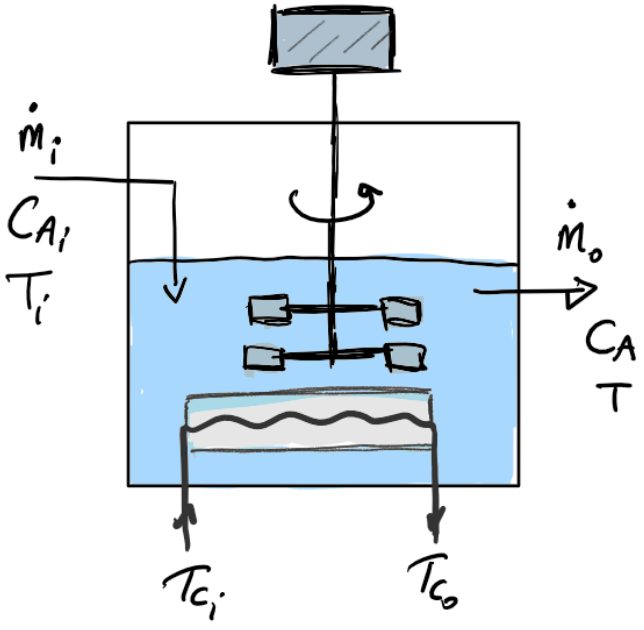
Data Driven Control



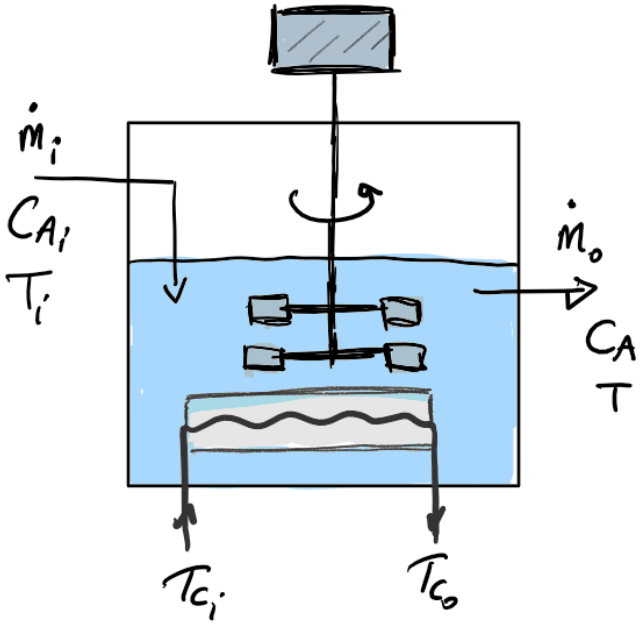
(1) $\dot{m}_i = \rho_i \dot{q}_i$

(2) $\dot{m}_o = \rho_o \dot{q}_o$

(3) $\frac{d}{dt}(\rho V) = \dot{m}_i - \dot{m}_o = \emptyset$

$V \Rightarrow$ Constant

Data Driven Control



(4)

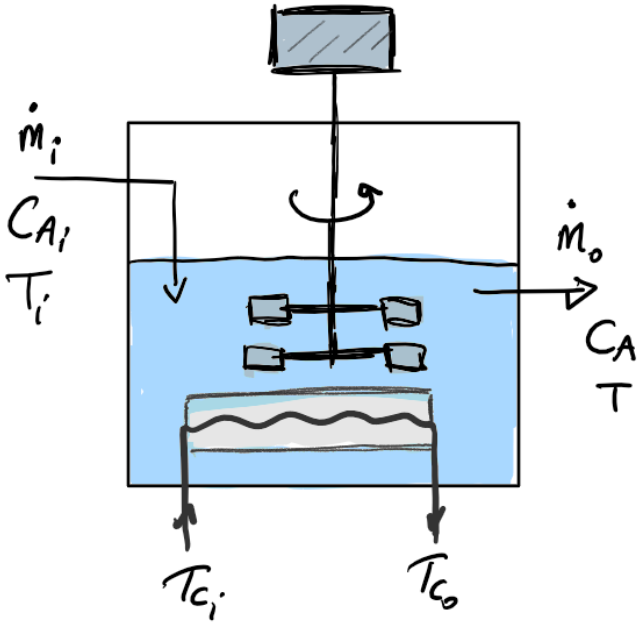
$$r = k \cdot C_A = k_0 \exp\left(\frac{-E_a}{RT}\right)$$

$$V \frac{dC_A}{dt} = q(C_{A_i} - C_A) - V(k \cdot C_A)$$

(5)

$$V \rho c_p \frac{dT}{dt} = \dot{m} c_p (T_i - T) + (-\Delta H_{rxn}) V k(T) C_A + UA(T_c - T)$$

Data Driven Control



* Well mixed $\Rightarrow$ No "inertia" in the phy. system

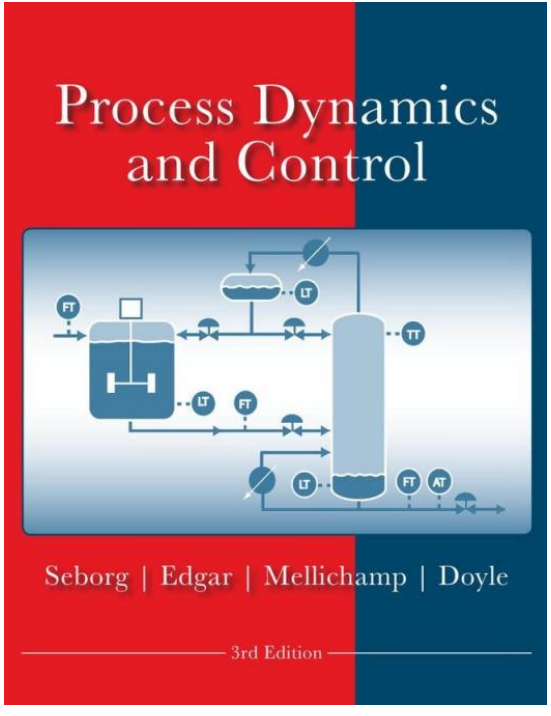
$\Rightarrow MV := T_c$

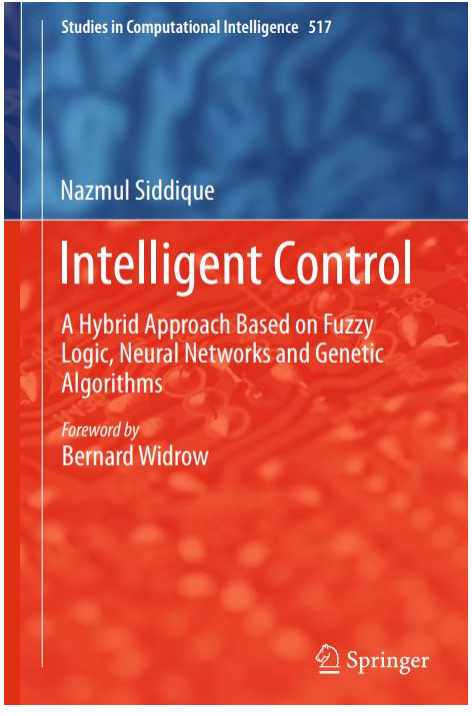
+

Difficult to control if system is unstable

Ateliers & Saveurs in Montreal

colab


Process Dynamics and Control
Seborg | Edgar | Mellichamp | Doyle
3rd Edition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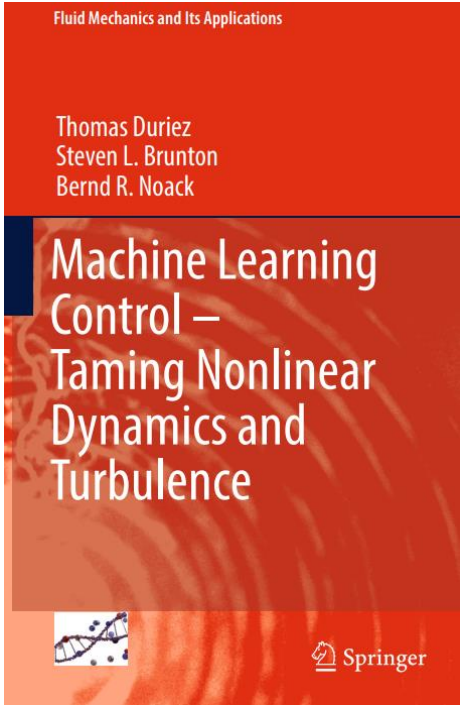
Foreword by
Bernard Widrow
Springer


Fluid Mechanics and Its Applications
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Machine Learning Control – Taming Nonlinear Dynamics and Turbulence
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