Automatique II
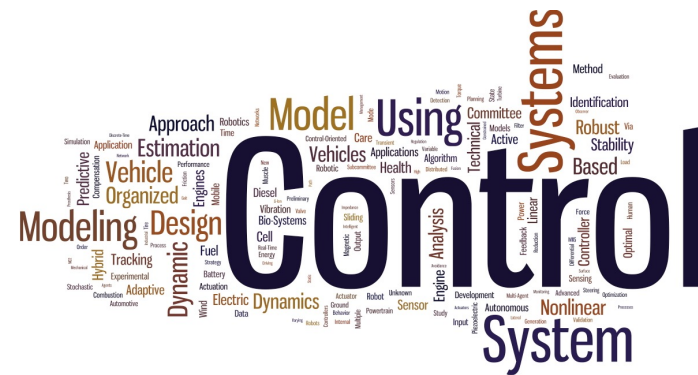

Hugues GARNIER

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Version of January 31, 2025

Timeline in Automatic Control

Prehistoric | **1868** | *Primitive* | **1910** | *Classical* | First computer End of 1940 | **1960** | *Modern*

- **Control**
- **Laplace transform**
- **Transfer function**
- **Feedback loop**
- …

Space Program
- **Digital control**
- **Z- transform**
- **State-space model**
- …

James **Maxwell**
1831-1879

Harold **Black**
1898-1983

John **Ragazzini**
1912-1988
(involved in the Manhattan project)

James **Watt**
1736-1819

Alexandre **Lyapounov**
1857-1918

Harry **Nyquist**
1889-1976

Henrik **Bode**
1905-1982

Gene **Franklin**
1927-2012

Rudolf **Kalman**
1930-2016

Eliahu **Jury**
1923-2020

They all have been PhD student of John **Ragazzini**

Two separate parts for a total of 36 hours

- ***Digital control***
  - 6h of lecture

  - 8 h of tutorials

  - 4h of Labs

  Course materials in English

- ***State-space control***
  - 5h of lecture

  - 6h of tutorials

  - 4h of Labs

- - - - - - - - - - - - -

- Lectures
  - Hugues Garnier

- Tutorials/Labs
  - Hugues Garnier
  - Floriane Collin

- Lectures/tutorials
  - Gilles Millérioux

- Labs
  - Hugues Garnier
  - Floriane Collin

Examination

- Exam 1 (2h00) *– Digital control*
  - In March
- Exam 2 (1h00) *– State-space model & control*

- 1 Lab report
  - In pairs

- Calculation of the final grade for the course

  Final grade = 0,5 Exam 1 + 0.25 Lab report + 0.25 Exam 2
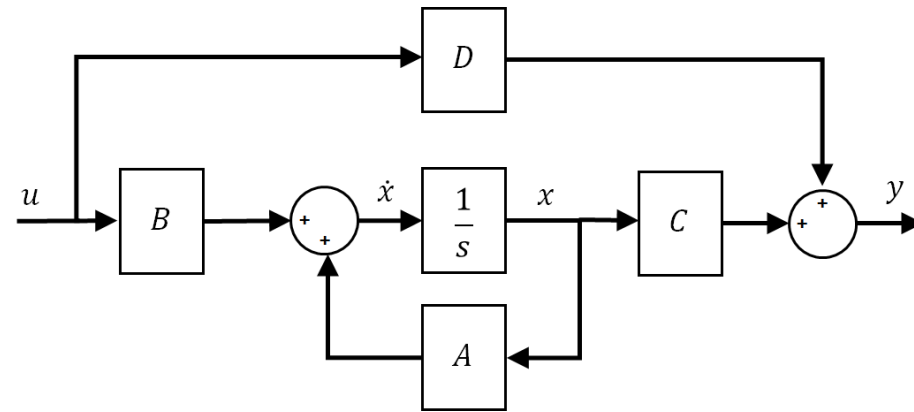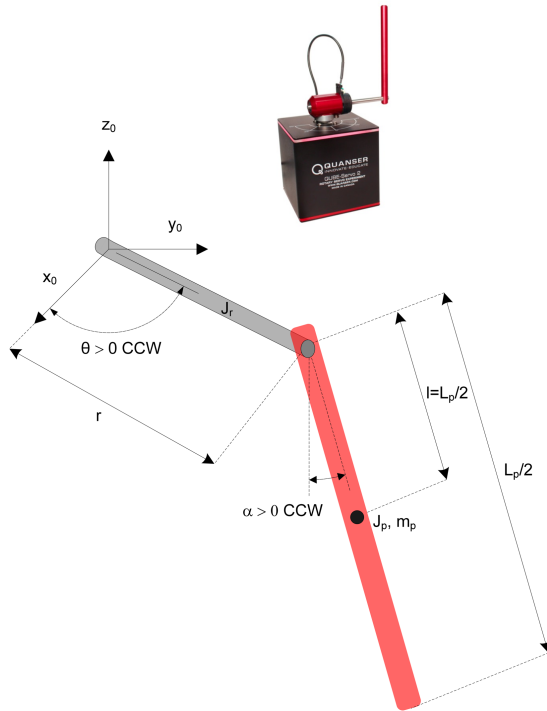
Rule for the lectures

– It is forbidden to use your PC, tablet or cell phone during the course

First part of the course: digital control is more appropriate to the current controller implementation
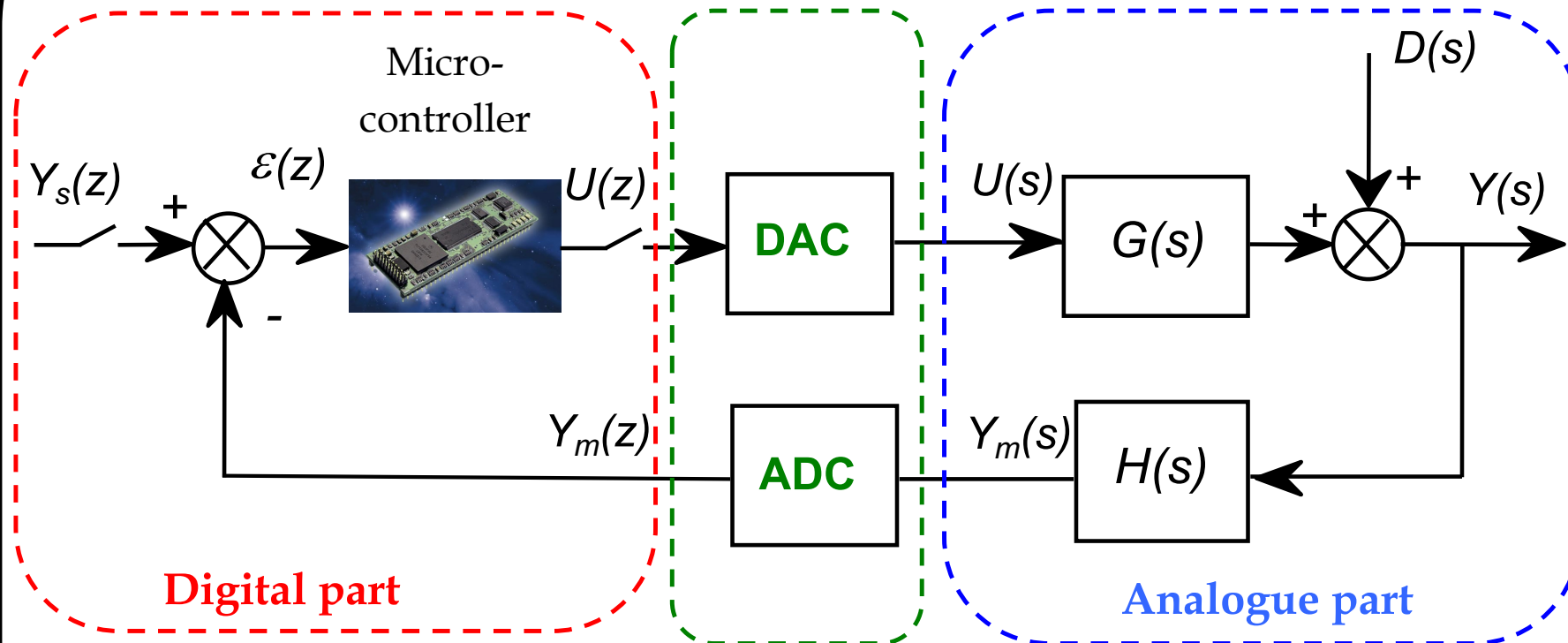
- Need for blocks to enable analogue and digital parts to interact : Digital to Analogue Converter (**DAC**) and **ADC**

- New mathematical tool to ease the analysis: the Z-transform

- PID controllers implemented digitally: discretization methods

Second part: State-space models and control is more appropriate for the control of complex systems

$$\ddot{\theta} = \frac{1}{J_t}\left(m_p^2 l^2 rg\alpha - J_p b_r \dot{\theta} + m_p lr b_p \dot{\alpha} + J_p \tau\right)$$

$$\ddot{\alpha} = \frac{1}{J_t}\left(-m_p gl J_r \alpha + m_p lr b_r \dot{\theta} - J_p b_p \dot{\alpha} - m_p rl\tau\right).$$

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) + Du(t) \end{cases}$$

The state vector $\quad x = \begin{bmatrix} \theta & \alpha & \dot{\theta} & \dot{\alpha} \end{bmatrix}^T$

The two outputs to be controlled $\quad y = \begin{bmatrix} \theta & \alpha \end{bmatrix}^T$

From Brian Douglas
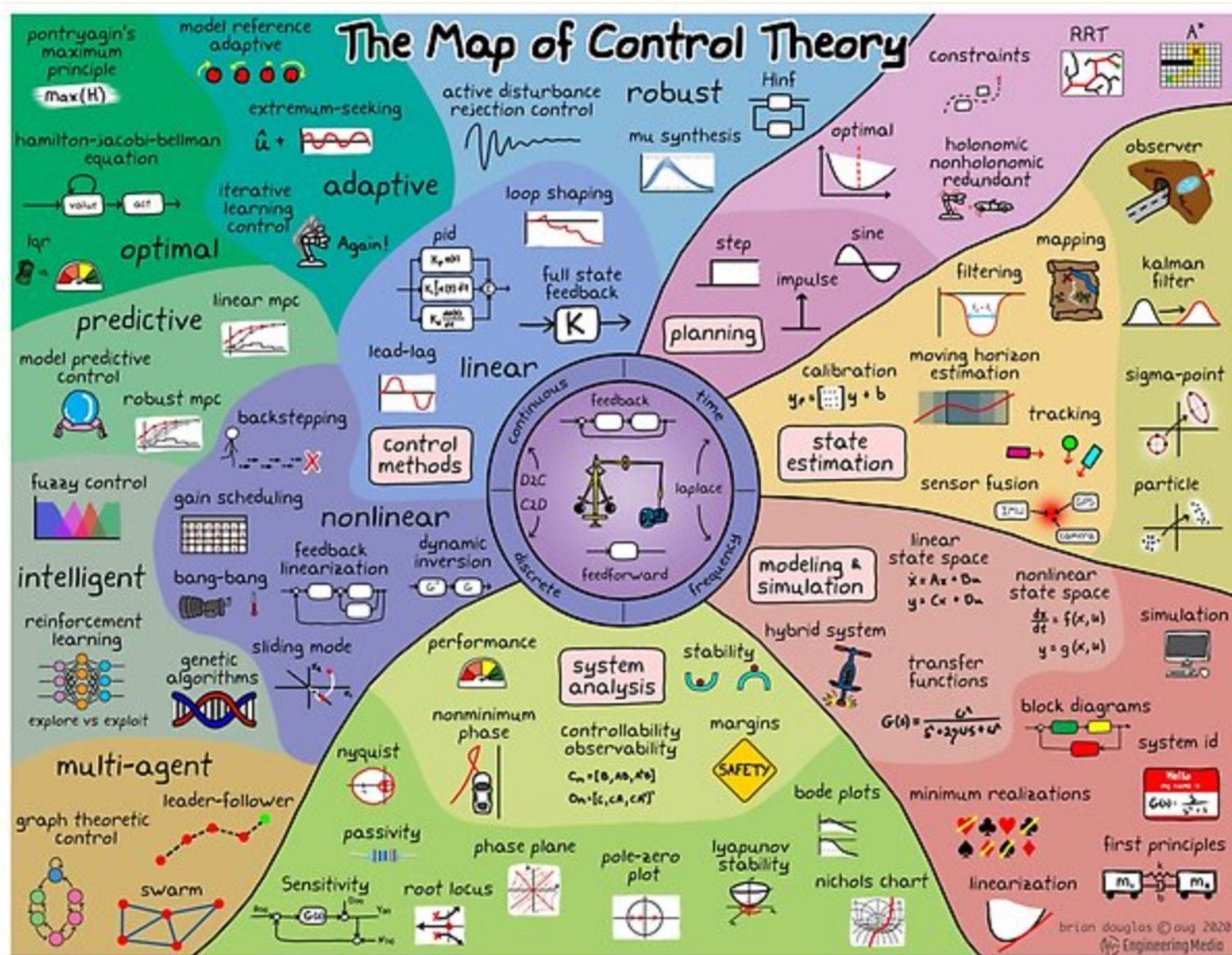
Website for the course

- **w3.cran.univ-lorraine.fr/hugues.garnier/?q=content/teaching**

Teaching

Basic page *Teaching* has been updated. ×

View   Edit

Teaching activities

Since 2018, I have been head of the 3-year engineering programme (see pdf) in *Computer Science, Control Engineering, Robotics, IT Networks (IA2R)* at Polytech Nancy.

where I teach the following courses:

Digital control S6 (3A IA2R FISE)

- Slides for the course
  - Digital control - Intro
  - The z-trransform
    - Table of z-transforms
  - Converters & Holds
  - Sampled data systems
  - Discrete-time systems
  - Synthesis of digital controllers
  - Digital PID controllers
- Tutorials
- Labs
  - Files for Lab 1
  - Files for Lab 2
- Exams

Search

Hugues Garnier

Navigation

Add content

Add file

3 3 2 3 2

Recommended books

Feedback Systems

An Introduction for Scientists and Engineers, *K.J. Åstrom & R. Murray 2021*
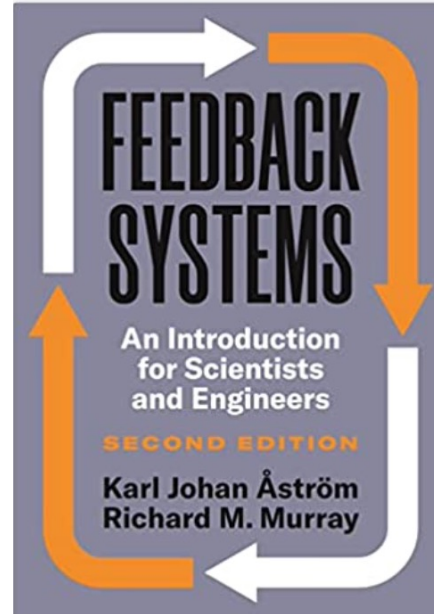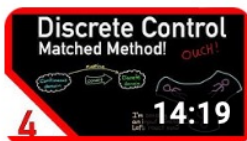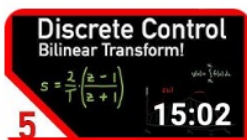

➡ pdf version of the book available

www.cds.caltech.edu/~murray/books/AM08/pdf/fbs-public_24Jul2020.pdf

See also

– K.J. Åström, B. Wittenmark, *Computer-controlled systems: theory and design* (3rd Ed.), Dover Publications, 2011

Videos available on Youtube
Discrete control by *Brian Douglas*

Discrete control #1: Introduction and overview — Brian Douglas — 22:22

Discrete control #2: Discretize! Going from continuous to — Brian Douglas — 24:35

Discrete control #3: Designing for the zero-order hold — Brian Douglas — 13:07

Discrete control #4: Discretize with the matched method — Brian Douglas — 14:19

Discrete control #5: The bilinear transform — Brian Douglas — 15:02

Discrete control #6: z-plane warping and the bilinear
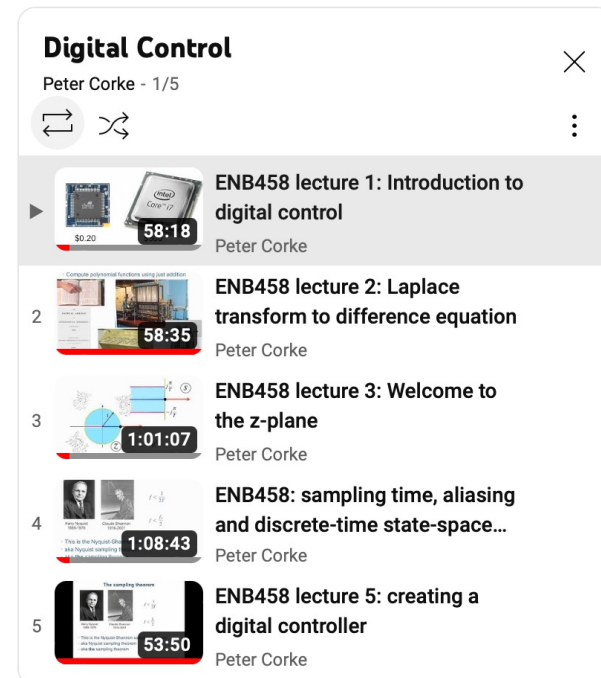
Some other resommended videos on Youtube
Digital control by *Peter Corke*

Youtube videos recommended for the course on State-space models and control

Matlab Tech Talks with *Brian Douglas*
State Space Models

Others resources in automatic control
Mobile textbook available from *Quanser*
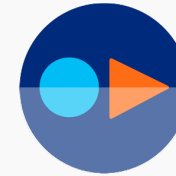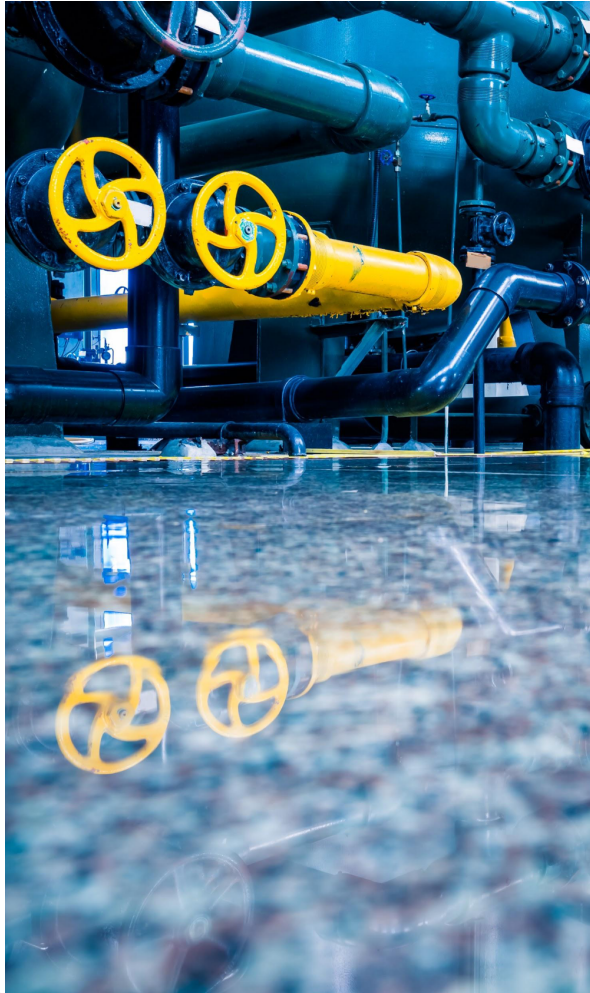
Experience Controls by Quanser

Experience Controls is a free mobile textbook designed to give you real design intuition and relevant skills in a hands-on way in the control systems engineering space.
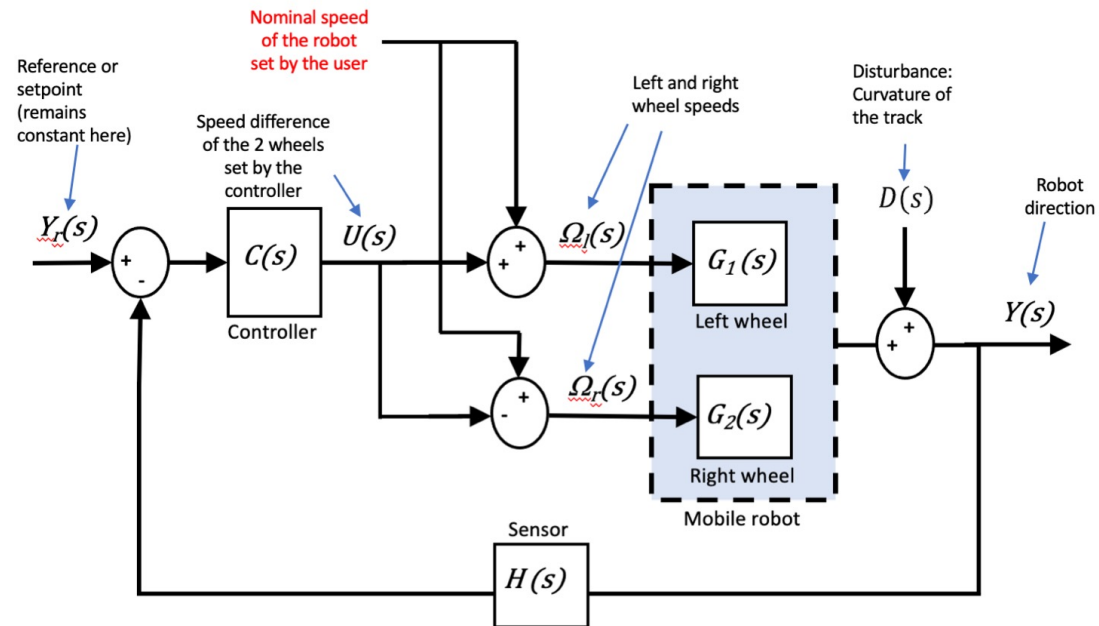
The textbook app includes:
- 50+ lesson modules covering introductory to advanced concepts
- Interactive simulations of industrial-level controls problems
- Mini-lecture podcasts that summarize key takeaways for each chapter, available in-app or in your preferred podcast player
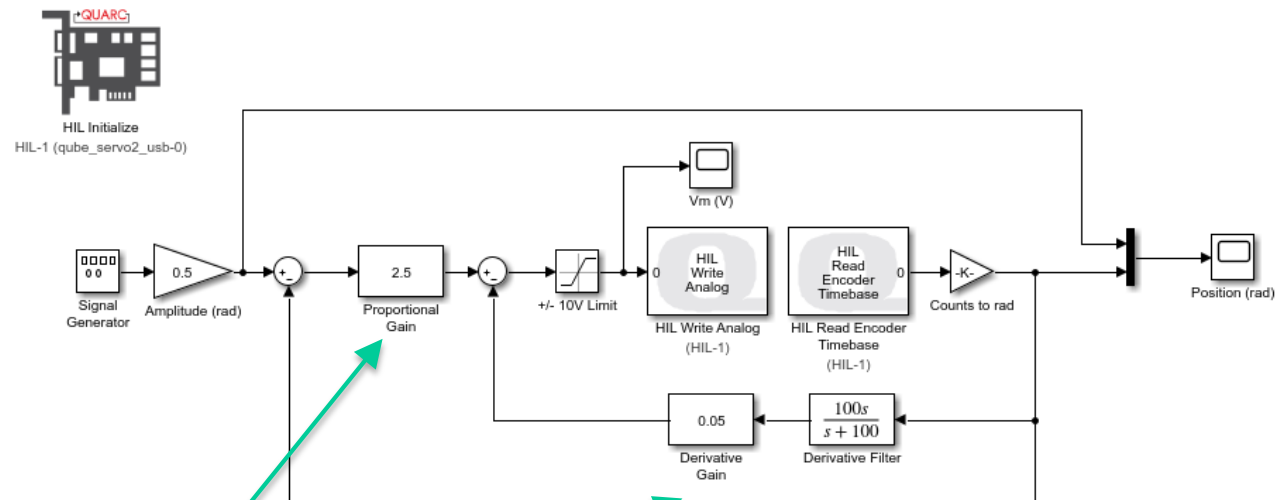- End-of-chapter review questions to check your understanding

Download on the App Store   GET IT ON Google Play

Reminder - Control Lab 1 S5
Line tracking control for the 3pi+ mobile robot

PD controller

Overview of the control problem

Lab 1 S6 – Digital control of the yaw for the Tello mini-drone
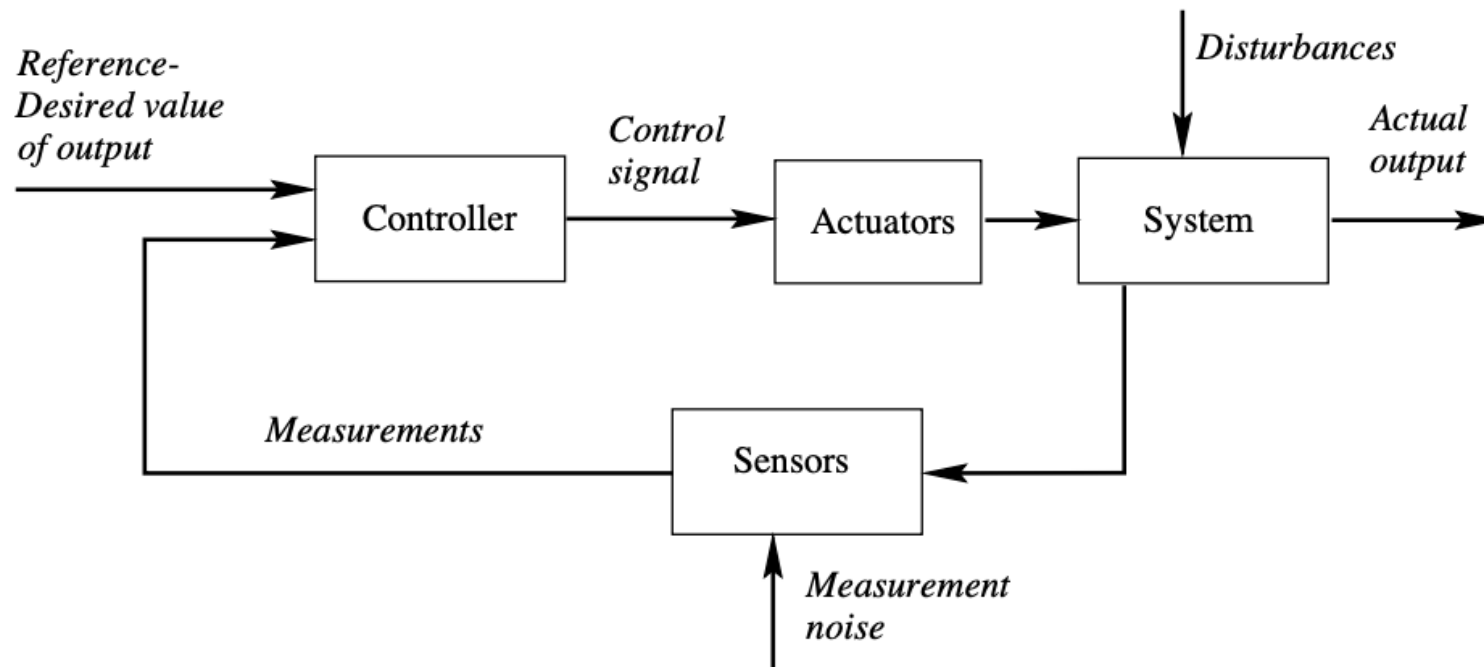
# Lab 2 S6 – State feedback control of the rotary inverted pendulum
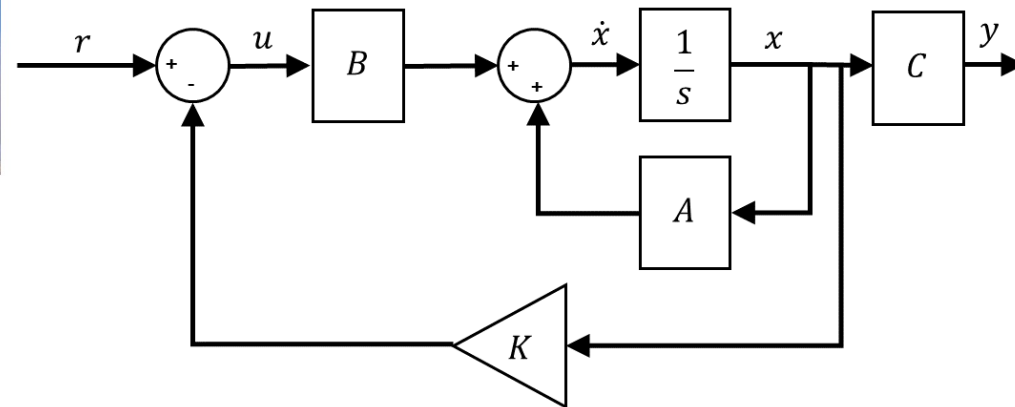
Synthesis of the controller gain by the pole placement method

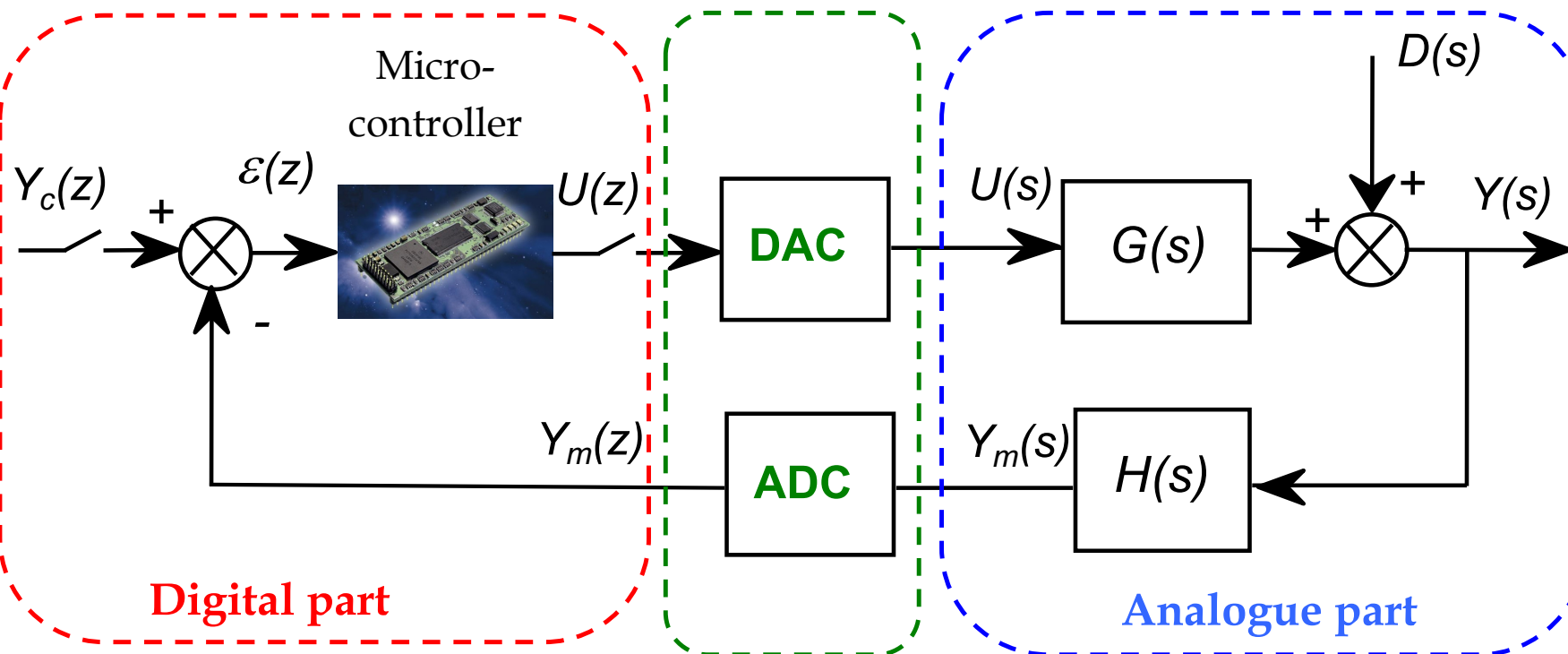# Reminder - Principle of feedback control

- Designing a control system means inserting:
  - a feedback loop
  - a control element: the controller or regulator

Typical feedback loop in analogue control

Analogue PID controller

$Y_c(s)$ + $\varepsilon(s)$ $U(s)$ $G(s)$ $D(s)$ $Y(s)$
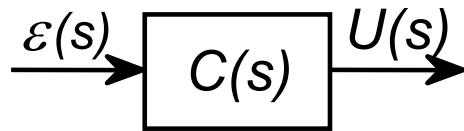
$Y_m(s)$ $H(s)$
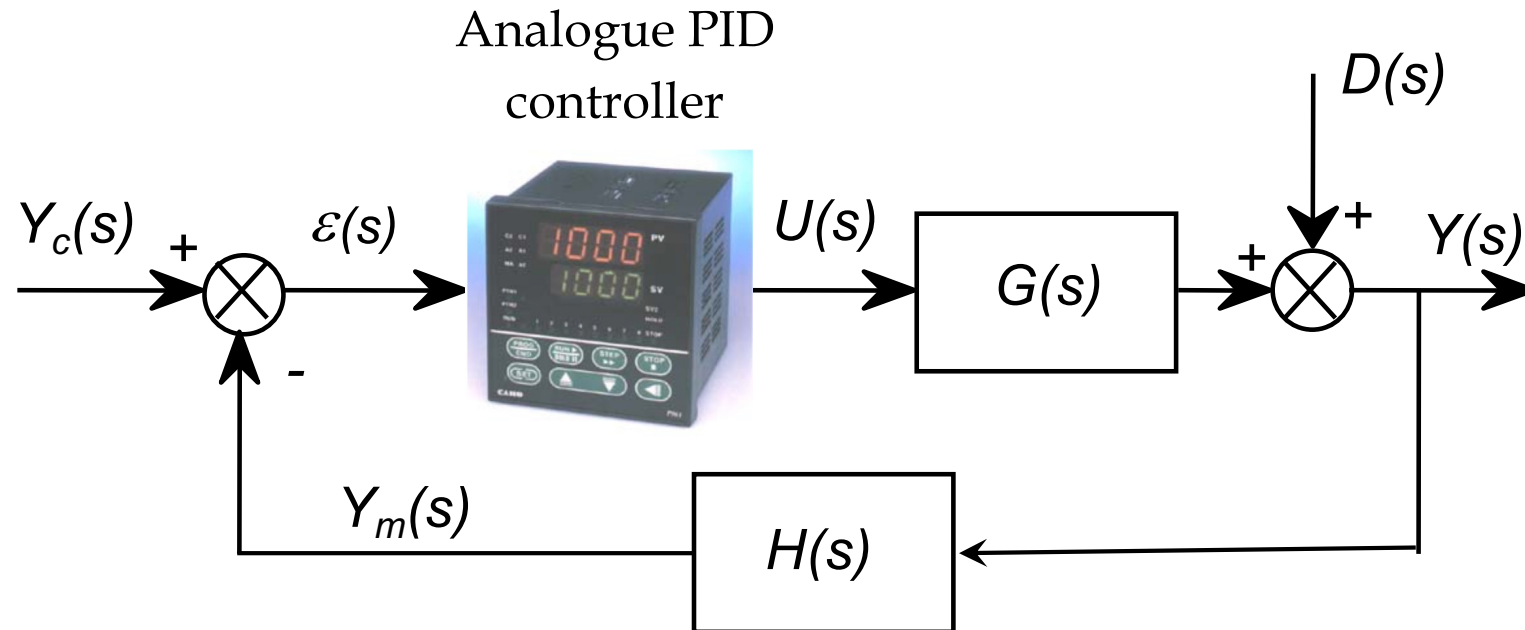
Typical feedback loop in digital control

- Advantages: low cost, speed, high accuracy, insensitivity to noise, ease of implementation and flexibility with regard to modifications
- Need for blocks to enable analogue and digital parts to interact: **DAC** and **ADC**
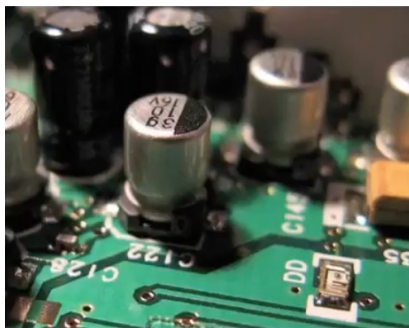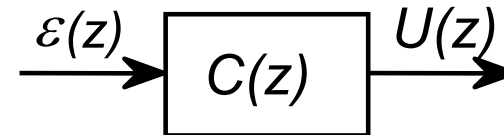
Technology of analogue/digital controllers

$\varepsilon(s) \rightarrow \boxed{C(s)} \rightarrow U(s)$

Tool: Laplace transform

$$u(t) = k_p\, \varepsilon(t) + k_i \int_0^t \varepsilon(\tau)d\tau + k_d\, \frac{\varepsilon(t)}{dt}$$

Differential equation

Electronic board

$\varepsilon(z) \rightarrow \boxed{C(z)} \rightarrow U(z)$

Tool: *z* transform

$$u(k) = K_p \varepsilon(k) + u_i(k) + u_d(k)$$

Difference equation

```
program CruiseControl

repeat
  r = getReferenceMeasurement
  y = getSpeedMeasurement
  u = K*(r-y);
  sendCommandToEngine(u)
end
```

Micro-controller

Lab platform example:
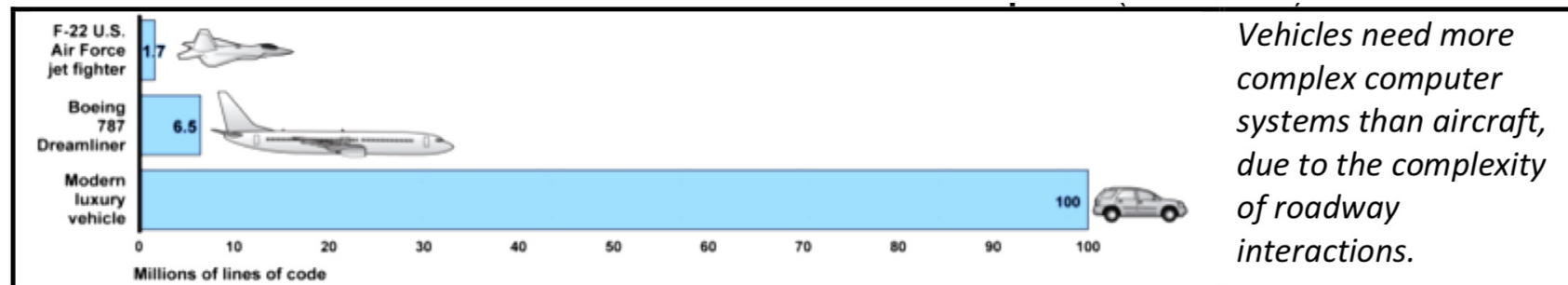## analogue versus digital PID controller for magnetic levitation
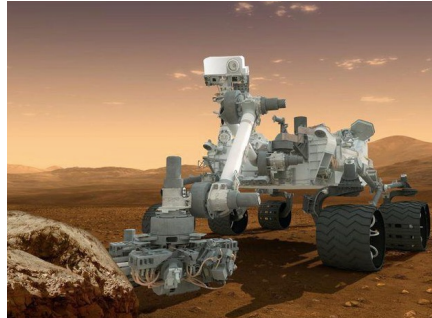

Implementation of the
analogue PID controller
Via electronic amplifiers

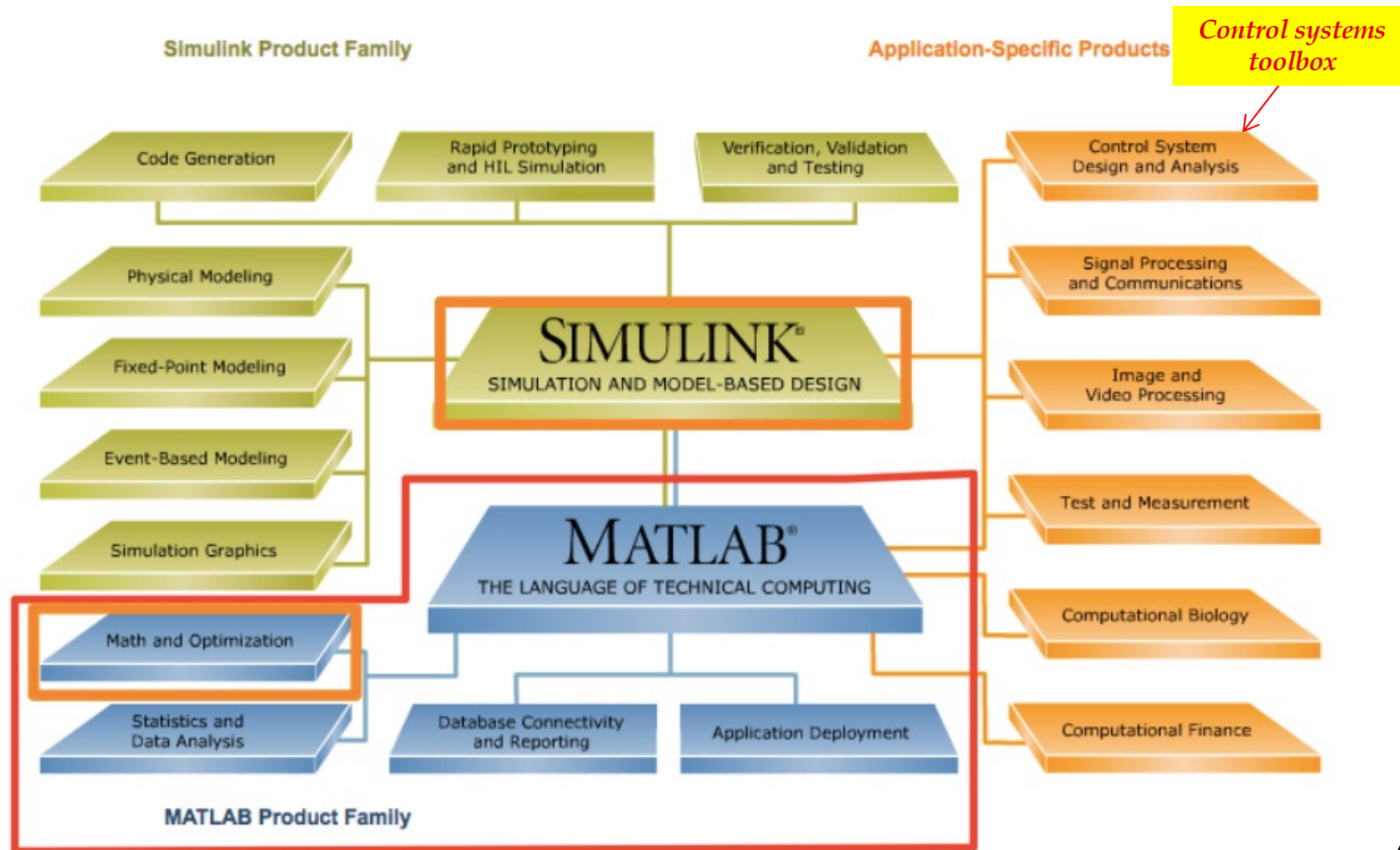Implementation of the digital
PID controller
via code

Digital control is everywhere

Vehicles need more complex computer systems than aircraft, due to the complexity of roadway interactions.

Use of Matlab/Simulink in the tutorial and lab sessions

Objectives of the digital control course

- To provide tools and methods for:

    – analyzing digital control, i.e. the problem of using digital computers or micro-controllers in real time to control physical processes

    – modelling and studying the various interactions between analogue and digital components (ADC/DAC)

    – designing and implementing digital PID controllers

Outline of the digital control course

I.   The z-transform

II.   Analogue to digital converter

III. Sampled systems

IV.   Discrete-time systems

V.   Design and implementation of digital PID controllers