Controlo por Computador

Computer Control

Introduction to design for Cyber-Physical Systems

J. Miranda Lemos

Professor Catedrático do IST

TÉCNICO LISBOA

2015

Documents that support the course

Available at the course web page (Fénix):

- Slides
- Laboratory guide and auxiliary documents
- Problems for self-study
- Other (Solution to selected problems, papers, etc.)

Available at the IST Library (complements):

- Franklin, Powell, Workman, *Digital Control of Dynamic Systems*. 🕮
- Astrom, Wittenmark, *Computer Controlled Systems*
- Other references

Student evaluation and grading

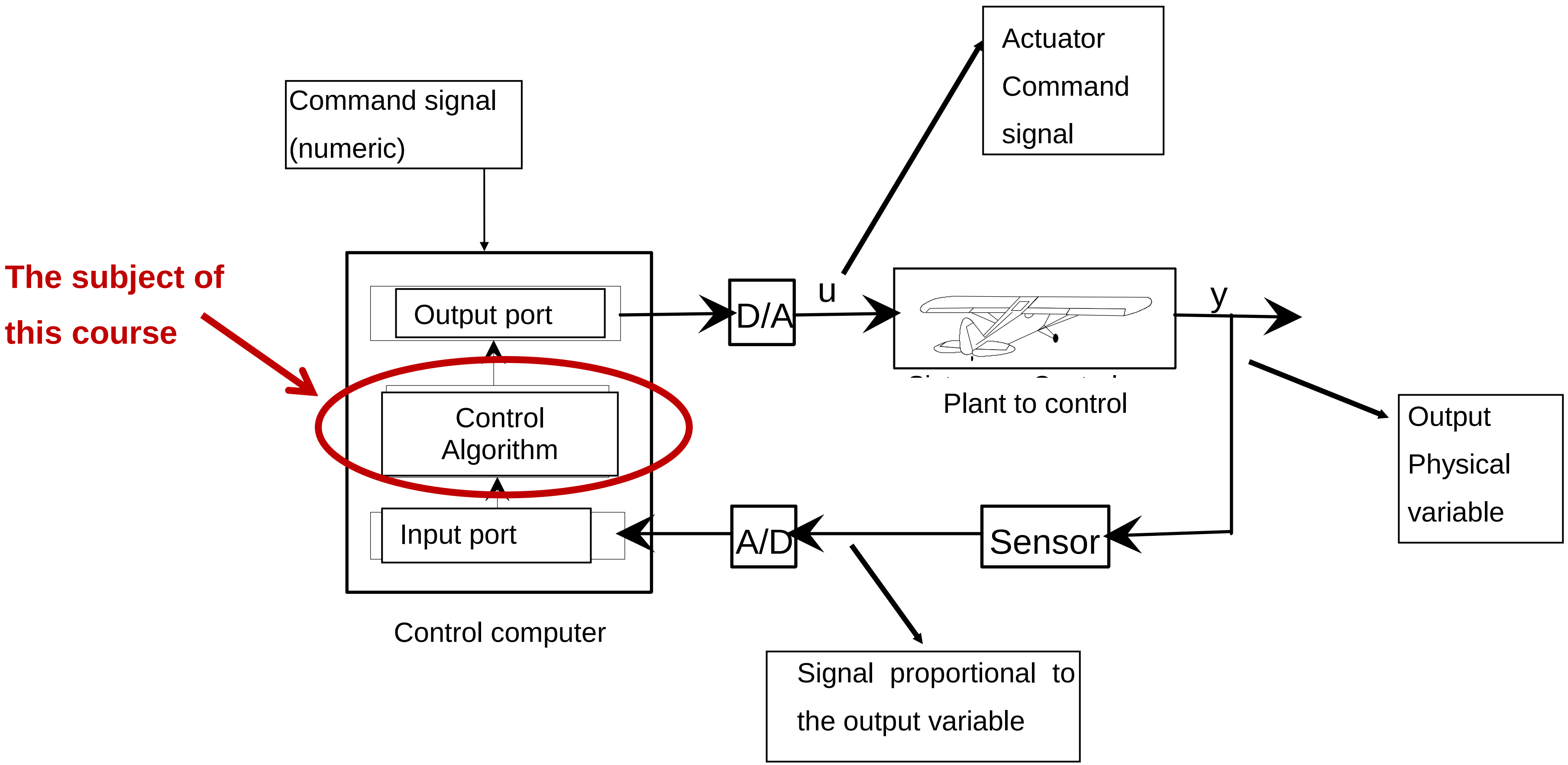
- **Theory**
  - **2 tests** (recommended) or 1 exam; Weight: 50%
  - Minimum 9,3 in the test average or exam;
  - No minimum in each test
  - After succeeding in the tests it is possible to attend the exam. Counts only the best. Not possible to recover individual tests
- **Lab**
  - 2 reports; Weight: 50%; No minimum grade. Accepted: grades from last 2 years
- **Final**
  - F=0,5 T+0.5 min(T+4, L)
  - Approval: round(F) >= 10 and T >= 9,3

What is the course about?

What do you expect to learn?

Why are you here?

Computer Controlled Systems



Embedded Control Systems

Embedded control systems consist of an unit that comprise all the hardware and software required to form a control system.

Microcontrollers form a first step towards embedded control systems.

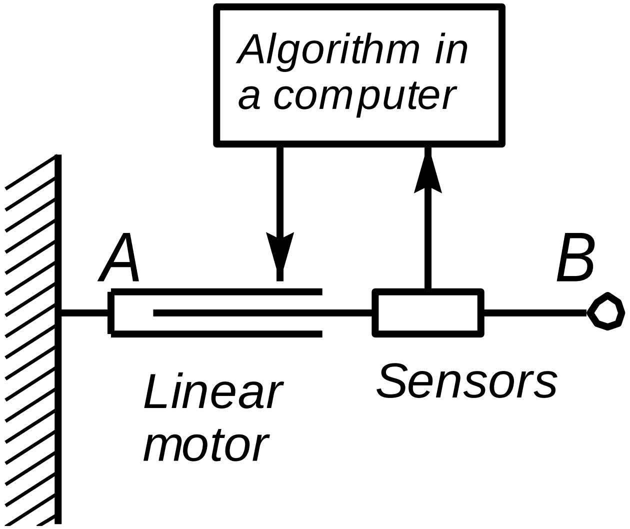
Example of a microcontroller

Modern microelectronic technology provide the possibility of increasing the degree of embedding, with units that can be embedded with the physical systems themselves. Applications: electrical machines, automotive, …

Cyber-Physical Systems

Cyber-physical systems combine physical parts of the system with computational parts.

Example: A cyber physical spring



From the signal read from the sensors (displacement, force) the algorithm in the computer computes the excitation of the linear motor such that from A to B the device behaves as a spring.

An example of application to a medical device

Cyber-physical systems include:

- Control
- Communication
- Fault tolerance and security
- Reconfiguration

IEEE Control Systems Magazine

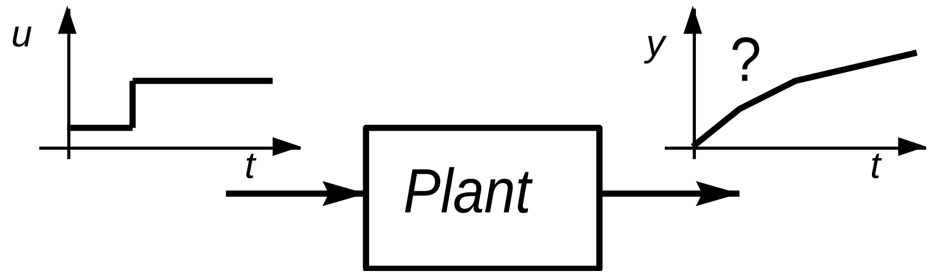
February 2015 (vol 35, nº 1) dedicated to Cyberphysical security

Access through IEEExplore

The ingredients

- Models
- Identification algorithms (from plant data to models)
- Control algorithms (from models to systematic decision of the value of manipulated variables)

Models for Computer Controlled Systems



A model represents the way the system reacts to an input.

Models:

- Transfer function and linear difference equation (linear)

$$y(k+1) = 0{,}5y(k) + 3u(k)$$

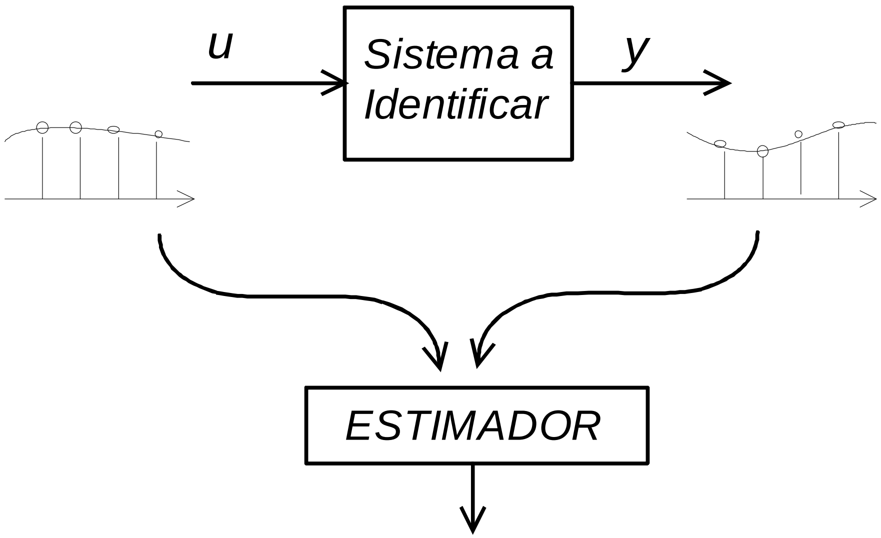
- State-space (linear and non-linear)

In this course we mainly consider linear design, but some techniques can be used to solve nonlinear problems.

Identification: Building models from plant i/o data

Model: $y(t)+a_1 y(t-1)+a_2 y(t-2)=b_0 u(t-1)+b_1 u(t-2)$

Problem: A partir das amostras de u e y, estimar os parâmetros a_i, b_j



Controllers for computer controlled systems

- Linear controllers
  - State-space based
  - Input/output based $u(k) = k_1 y(k) + k_2 y(k-1) + k_3 u(k-1)$
- Optimal control (Dynamic Programming).

  How to go from A to B with a minimum effort?
- Stochastic control

  Counteract stochastic disturbances
- Predictive control (MPC, Receding Horizon Control)

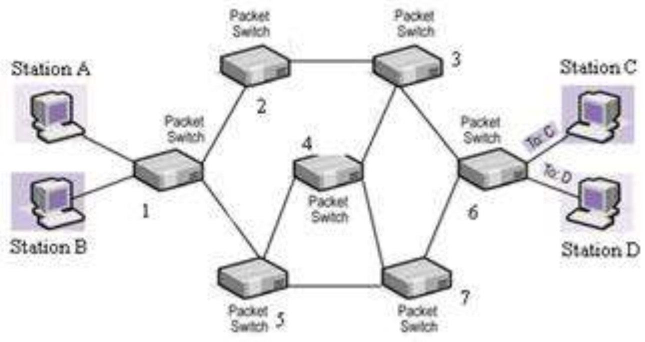
  Make decisions about control moves based on predictions over a sliding horizon and cost optimization

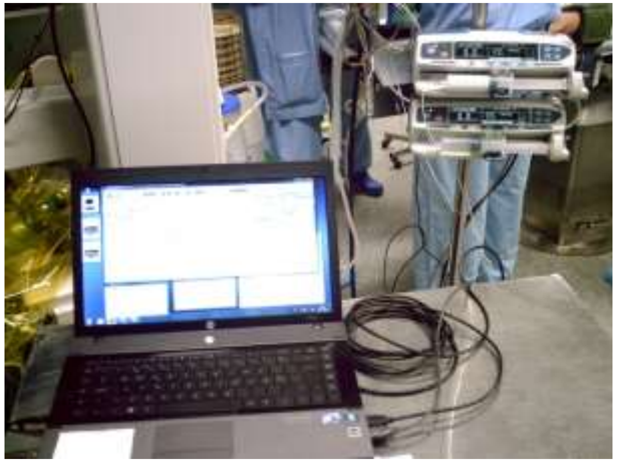
A mosaic of possible application areas

From aerospace to agriculture there is no limit to the areas where you can apply the techniques studied in this course:

- Get data with sensors,
- Identify a model from data,
- Design a controller from the model,
- Connect your controller to the sensors and the actuators to obtain on-line (real time) decisions to manage the process.

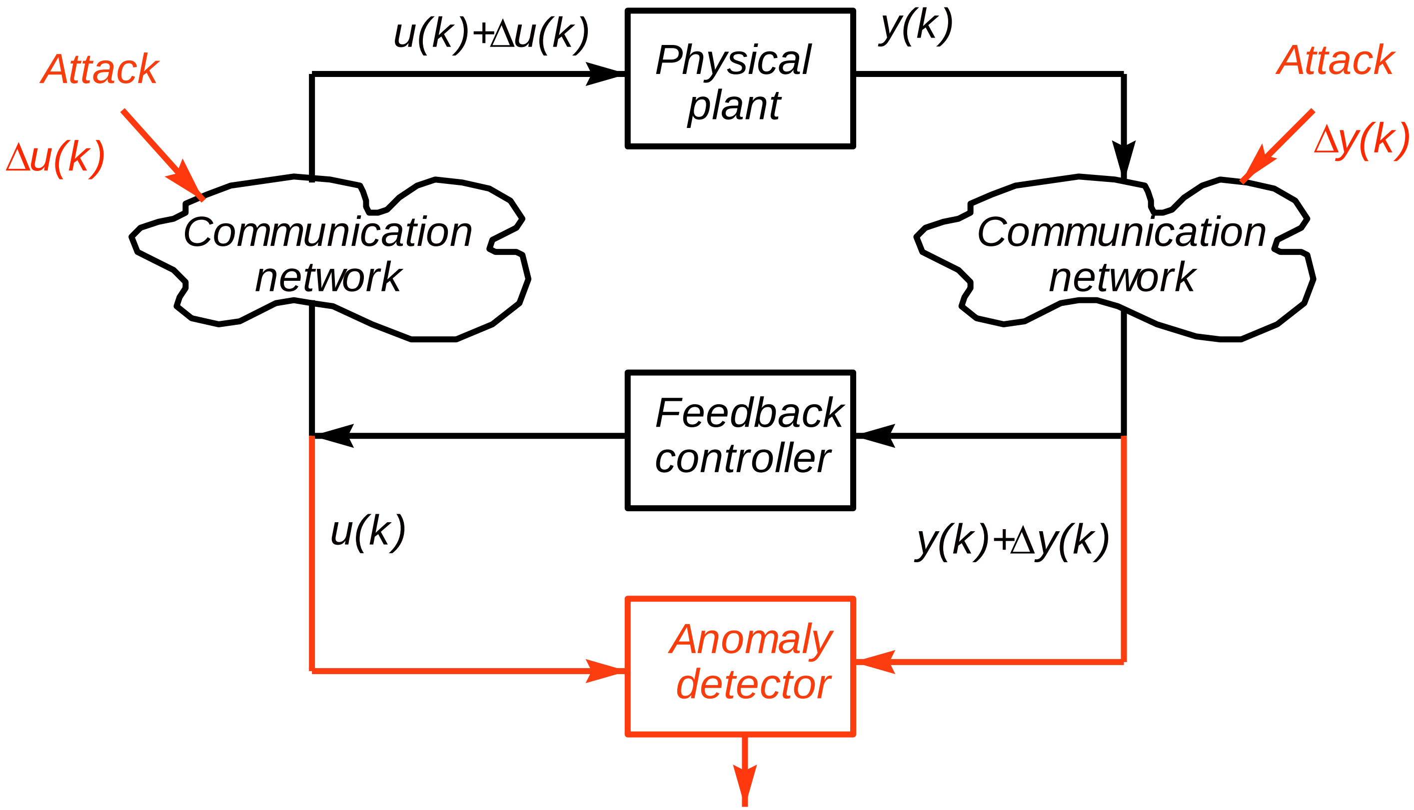
More (unconventional) application areas





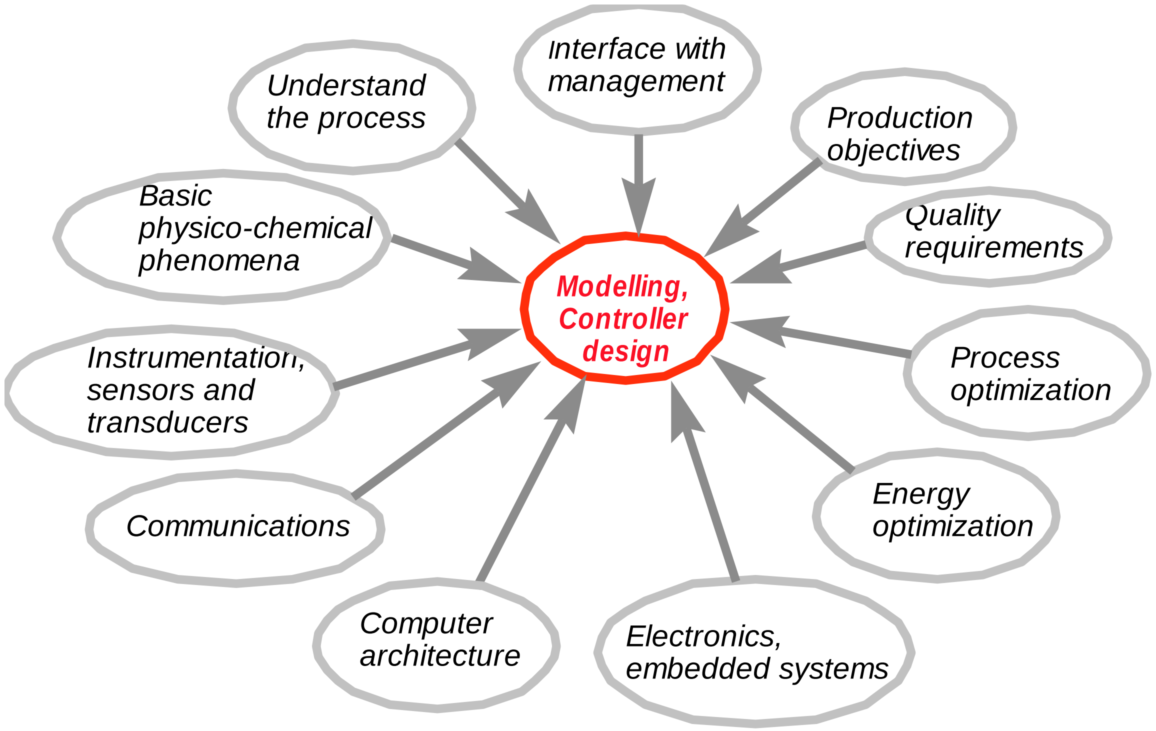
- Traffic control in communication networks
- Computers and computing systems
- Medical systems (figure refers to control of anesthesia)
- Security of networked control systems
  - Mars path finder
  - Large power systems
  - Integrated circuits

Schematic view of a networked control system under attack



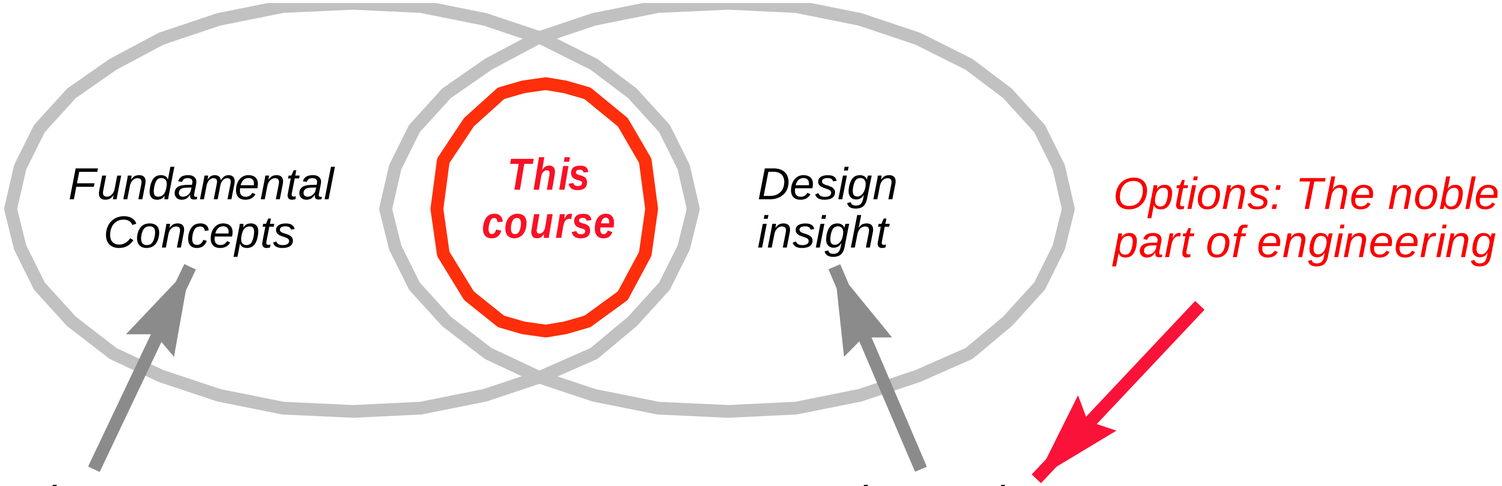
Teixeira et al., Secure Control Systems, IEEE Control Systems Magazine, Feb 2015, 36(1):24-45

A global view of engineering



The course on Computer Control provides an integration tool to the different components of engineering design.

What type of course is this?



Basic concepts
Mathematical manipulations
Algorithm deduction
Algorithm properties
Analysis tools
(stability, convergence)

Design options
Model structure choice
Specifications
Controller structure choice

Boltzman: *Nothing is more practical than a good theory.*

Conclusion

The course on Computer control provides

- A top view on design that combines
  - Physical systems
  - Information technology
- The basic tools from Systems, Decision and Control

A wide range of applications, with strong socio-economic impact can be addressed by mastering the course.

The course follows a structure and content that is common to all the reference engineering schools in the world.

Syllabus

1. Structure of computer controlled systems
2. Models for computer controlled systems
3. Model Identification

1^{st} Test

---

4. Controller design

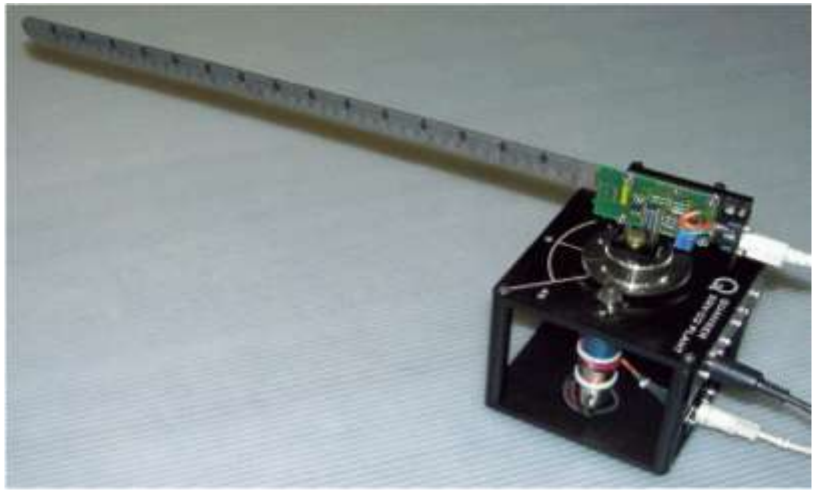
a) Linear state variables feedback
b) Output feedback with polynomial methods
c) Stochastic control and Model Predictive Control (MPC)
d) Dynamic Programming

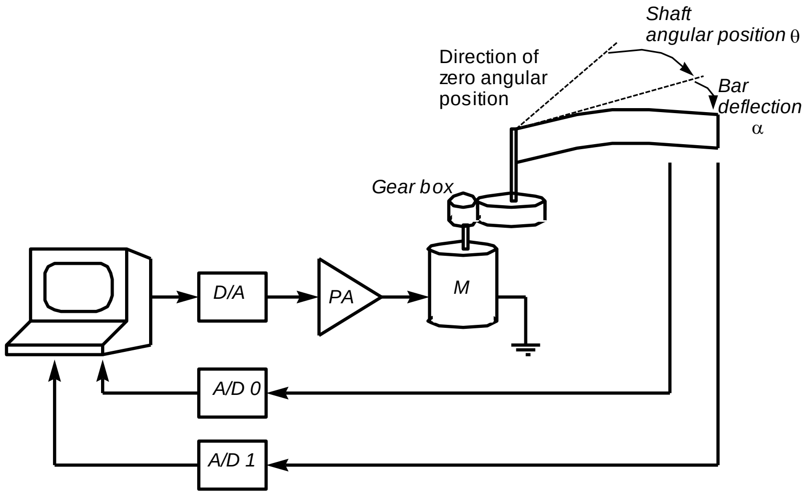
2^{nd} Test

Previous knowledge required

- Basic knowledge about signals and systems, including
  - Time and frequency representation of signals
  - Laplace transform
  - Transfer function, Bode diagrams and frequency response
- Basic knowledge about calculus and differential equations
- Basic course on Control as given in the first cycle of MEEC
- Strong interest on the topic

Laboratory project: Computer control of a flexible robot joint

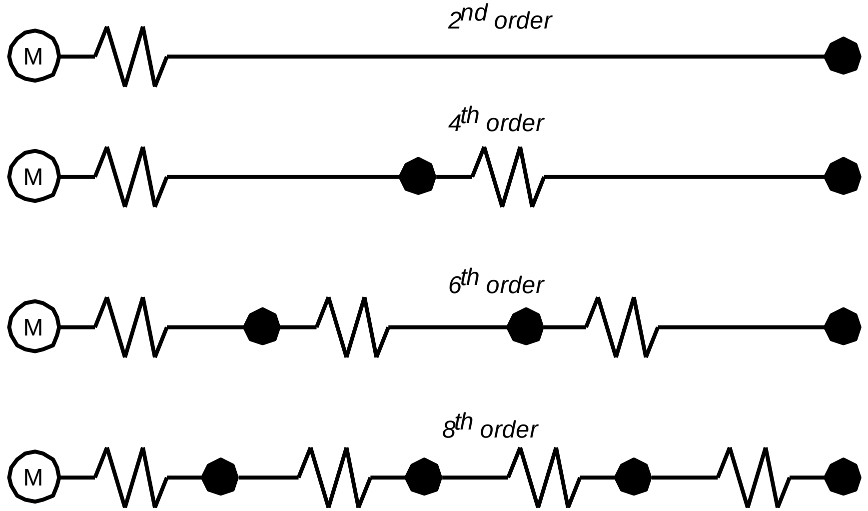




Objective: Drive the motor such that the tip of the flexible bar tracks a reference.

- Part 1: System identification to obtain a model suitable to controller design
- Part 2: Controller design and testing

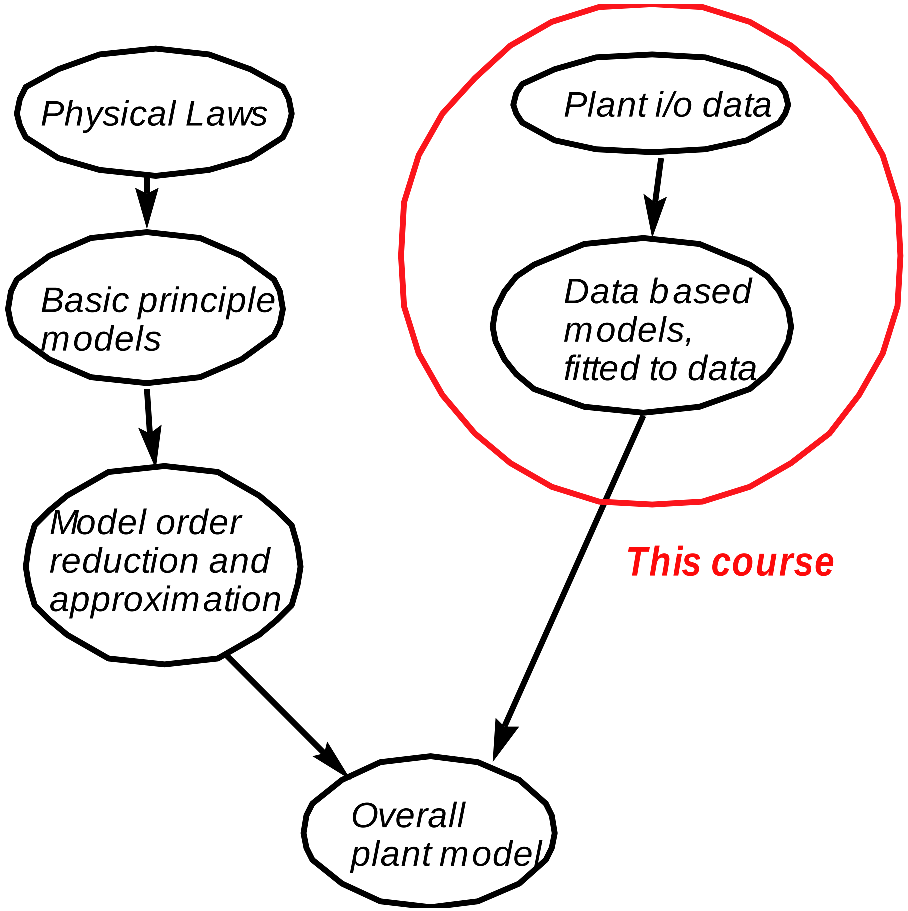
Main difficulty: What is the order of the system?

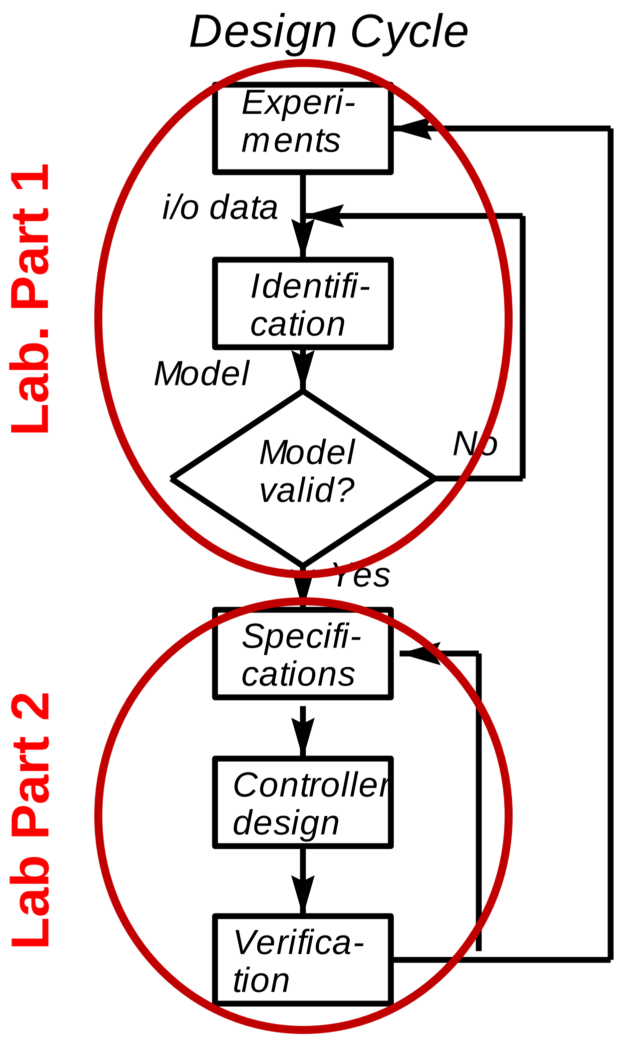


A continuum of metal yields an infinite dimensional model.

We need a finite dimensional model for controller design!

Approaches to model building






Reprodução de uma gravura de Francisco Goya (1746-1828)

Até à próxima aula