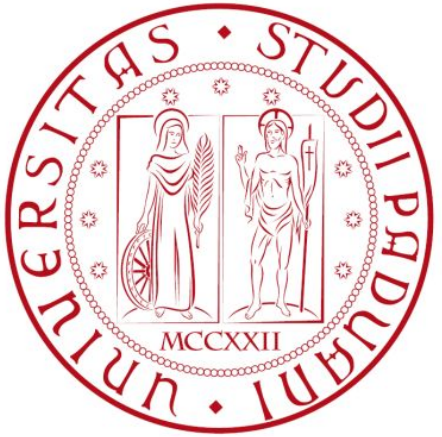
Laurea Magistrale in Control Systems Engineering

Angelo Cenedese



Control Systems Engineering

Main design principle:

Technology is important but changes rapidly, **ideas and methods** much more slowly

We aim for an optimal balance between
current technological tools and
deep understanding of the methods.

Control Systems Engineering

total formative credit units: **120-126 cfu**

offering a **rich spectrum** of courses (with few mandatory exams)

proposing **4 new paths** in the most modern and active areas of control

featuring a final project (internship+thesis) of up to **30 cfu**

entirely taught in **English**

Enrolment Requirements

1) Bachelor Degree with enough credits/courses in:
   - Mathematics and Physics (Calculus, Linear Algebra, Probability, …)
   - Control Engineering (Signals and Systems, Basic Control Courses, …)
   - Electrical Engineering and Computer Science

2) English Knowledge:
   - Certified B2 level

Course Catalogue

Foundation - Common courses and activities (69 cfu):

SYSTEMS THEORY	9 cfu	(Year 1, Semester 1)
MACHINE LEARNING	9 cfu	(Year 1, Semester 1)
DIGITAL CONTROL	6 cfu	(Year 1, Semester 1)
ESTIMATION AND FILTERING	6 cfu	(Year 1, Semester 2)
CONTROL ENGINEERING LABORATORY	9 cfu	(Year 1, Semester 2)

FINAL THESIS + INTERNSHIP/RESEARCH TRAINING 21+9=30 cfu

Course Catalogue: Make Your Own Path

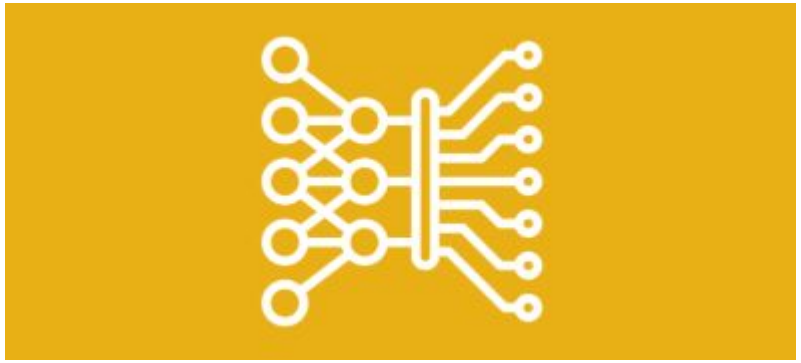
(with limited constraints: 15 cfu core + 15 cfu affine courses)

Robotics and Control 1
Robotics and Control 2
Robotics Laboratory
Reinforcement Learning
Learning Dynamical Systems
Nonlinear Systems and Control
Adaptive and Model Predictive Control
Industrial Automation
Embedded Real-Time Control
Network Dynamical Systems
System Biology
Convex Optimization
Advanced Topics in Optimization
Mathematical Physics
Digital Signal Processing
Quantum Information and Computing
Stochastic Processes

Computer Vision
Intelligent Robotics
Industrial Robotics
Design of Mechanical Drives
Automotive and Domotics
Sensing and Measurement Systems
Neural Networks and Deep Learning
Electric Drives for Automation
Big Data Computing
Learning from Networks
Game Theory
Information Security
Automata, Languages and Computation
Control of Biological Systems
Mathematical Cell Biology
Smart Grids
(+ other Master Programs offering)

Course Catalogue: Specialized Automatic Paths

Robotics



Machine Learning

Industrial Automation

Complex Systems

Robotics

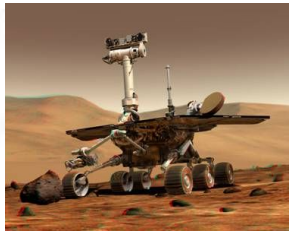
Robots **today** are making a *considerable impact* from industrial manufacturing to healthcare, transportation, and exploration of the deep space and sea...

...**tomorrow**, robots will become *pervasive* and touch upon many aspects of modern life

Goal : to provide the main competencies in the field of robotics

Main topics :

- basic concepts of robotics, kinematic and dynamic models
- advanced control schemes for industrial and mobile robots



Robotics Path

Core Courses

Robotics and Control 1

Robotics and Control 2

Convex Optimization

Computer Vision

CFU:

30 path cfu to be completed with…

+ **6 control cfu**

+ **15 elective cfu**

"Advanced Control"

Nonlinear Systems & Control

Network Dynamical Systems

Adaptive and Model Predictive Control

"Applied"

Industrial Robotics

Intelligent Robotics

Robotics Laboratory

Design of Mechanical Drives

"Industrial"

Electric Drives for Automation

Embedded Real-Time Control

Sensing and Measurement Systems

"Learning"

Learning Dynamical Systems

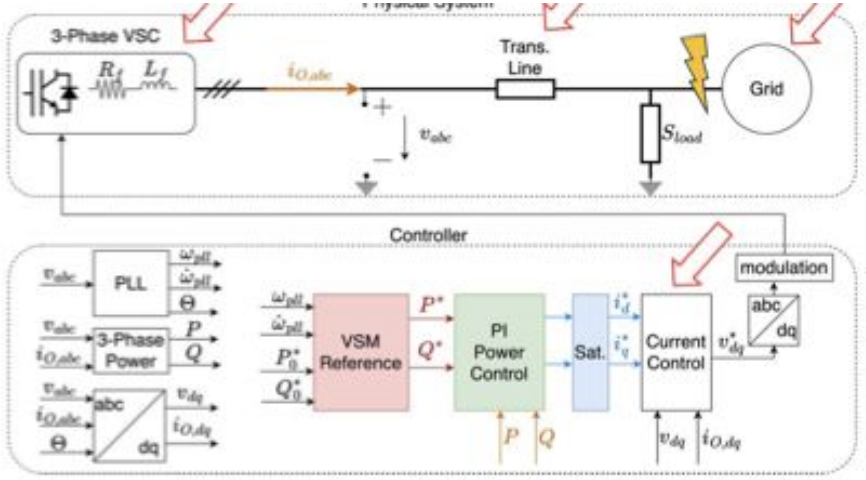
Reinforcement Learning

Machine Learning

Modern Control System must:

(1) exploit an unprecedented **quantity and/or quality** of **data**

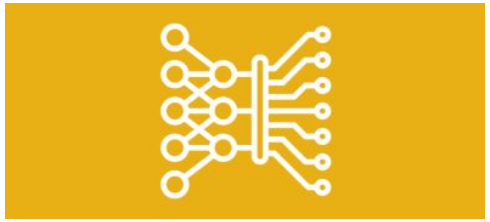
(2) be **flexibile, adaptable and robust**



Control meets *Machine Learning*

- merge physical ***modeling***/insight with ***data*** driven methods
- exploit ***data*** to design ***control*** architectures/algorithms

Machine Learning Path



Core Courses

Convex Optimization

Learning Dynamical Systems

Reinforcement Learning

Computer Vision

CFU:

30 path cfu to be completed with…

+ **6 control cfu**

+ **15 elective cfu**

"Advanced Control"

Nonlinear Systems & Control

Robotics and Control 1

Robotics and Control 2

Adaptive & ModelPredictiveControl

"Methods and Models"

Game Theory

Neural Networks and DL

Learning from Networks

Network Dynamical Systems

"Computation and measurements"

Big Data Computing

Sensing and Measurement Systems

Industrial Automation

Modern Industrial Engineering is a powerful blend of
Automation – Computer Science – Telecommunication

Challenges and **stars** of the Industrial Revolution 4.0:

- *Cyber Physical Systems*: physical quantities are translated into data and information…
- *Human is in the loop*: the barrier between man and machine dissolves…
- *Resilience and autonomicity*: systems gain ability to recover from or adjust easily to misfortune or change…
- *Hyperautomation:* automating everything that can be automated…

Industrial Automation Path

Core Courses

Convex Optimization

Embedded Real-Time Control

Industrial Automation

Electric Drives for Automation

CFU:

30 path cfu to be completed with…

+ **6 control cfu**

+ **15 elective cfu**

"Applied"

Industrial Robotics

Computer Vision

Design of Mechanical Drives

Sensing & Measurement Systems

"Disruptive"

Reinforcement Learning

Information Security

Adaptive & Model Predictive Control

"Methodological"

Learning Dynamical Systems

Robotics and Control 1

Robotics and Control 2

Complex Systems

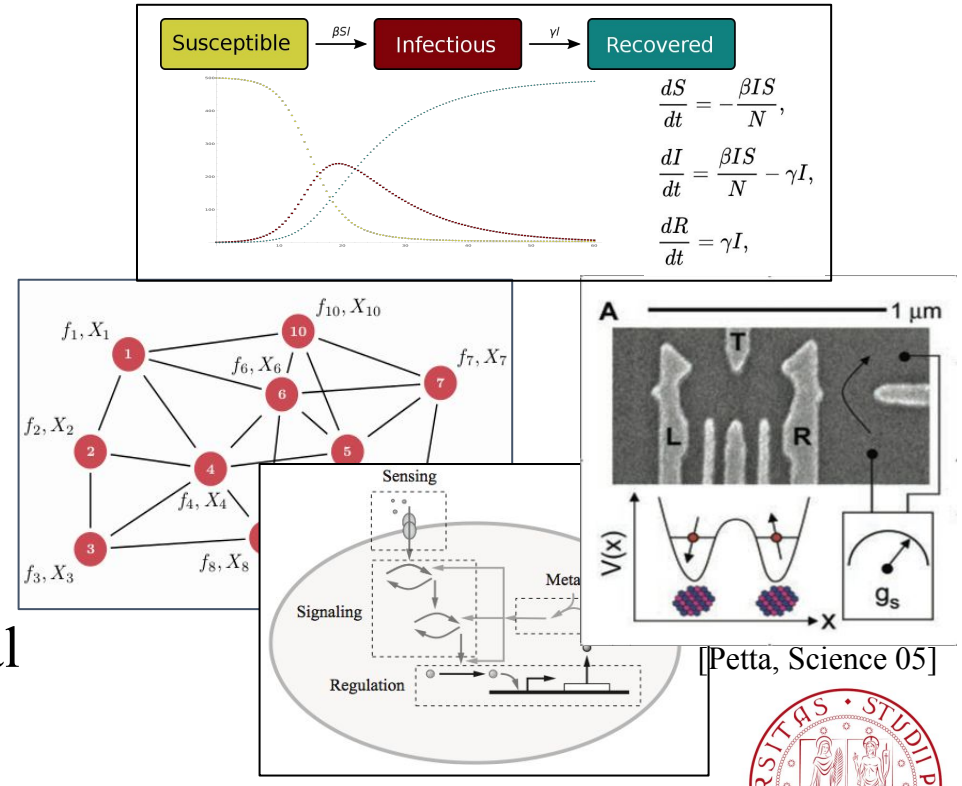
Raw data are the starting point, ***models*** *are needed to* ***interpret*** *them, effectively* ***predict*** *evolution and optimize* ***intervention strategies****!*

Focus on tools to understand, model and control real-world systems of interest for emerging technologies: **Nonlinear, Networked, Biological and Quantum Systems.**

How to build models from *data* and *first principles*.

How to design controls tailored to the application.

Oriented to concepts and methods, naturally leads to theoretical and multidisciplinary research.



[Petta, Science 05]

Complex Systems Path

Core Courses

Learning Dynamical Systems

Convex Optimization

Mathematical Physics

Nonlinear Systems & Control

CFU:

30 path cfu to be completed with…

+ **6 control cfu**

+ **15 elective cfu**

"NL Dynamics"

Network Dynamical Systems

Reinforcement Learning

Robotics and Control 1

Robotics and Control 2

"Algorithms and Information"

Learning from Networks

Automata, Languages & Computation

Quantum Information & Computing

Game Theory

"System Biology"

System Biology

Control of Biological Systems

Mathematical Cell Biology

Research Laboratories

Industrial Applications Laboratory:

Kuka robotic arm: industrial robot for man-machine collaborative action

Duckietown: cooperative mobility in a miniature smart-city

VI-Grade Driving simulator: motion cueing & control

SPARCS Laboratory:

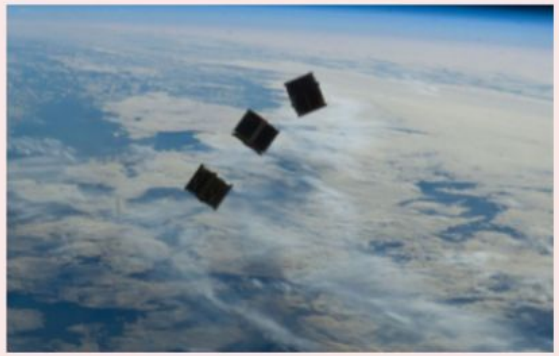
Mobile robotics laboratory

Multirotor platforms: design, simulation, estimation/perception, control, experiments

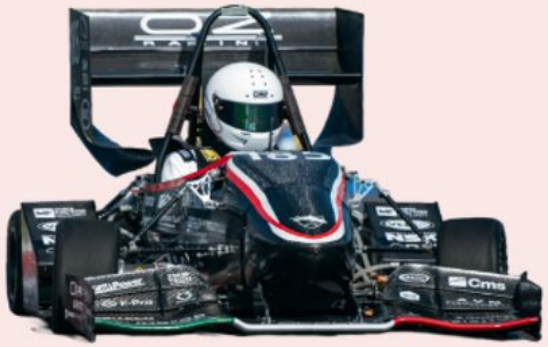
Students' Projects

Student projects are activities where groups of students, coordinated by professors, work on the design and construction of engineering systems. These projects often participate in competitions at both national and international levels. Some examples…

Alba CubeSat Unipd: the project aims to launch a CubeSat into orbit to study the space debris environment and the satellite micro-vibrations.



Race Up Team: with Formula SAE the conception, design, and production of a Formula-style car is carried out, to compete in a static and dynamic events.



BOSCH Future Mobility Challenge: Autonomous driving on 1:10 scale vehicles to navigate (and compete) in a miniature smart city.

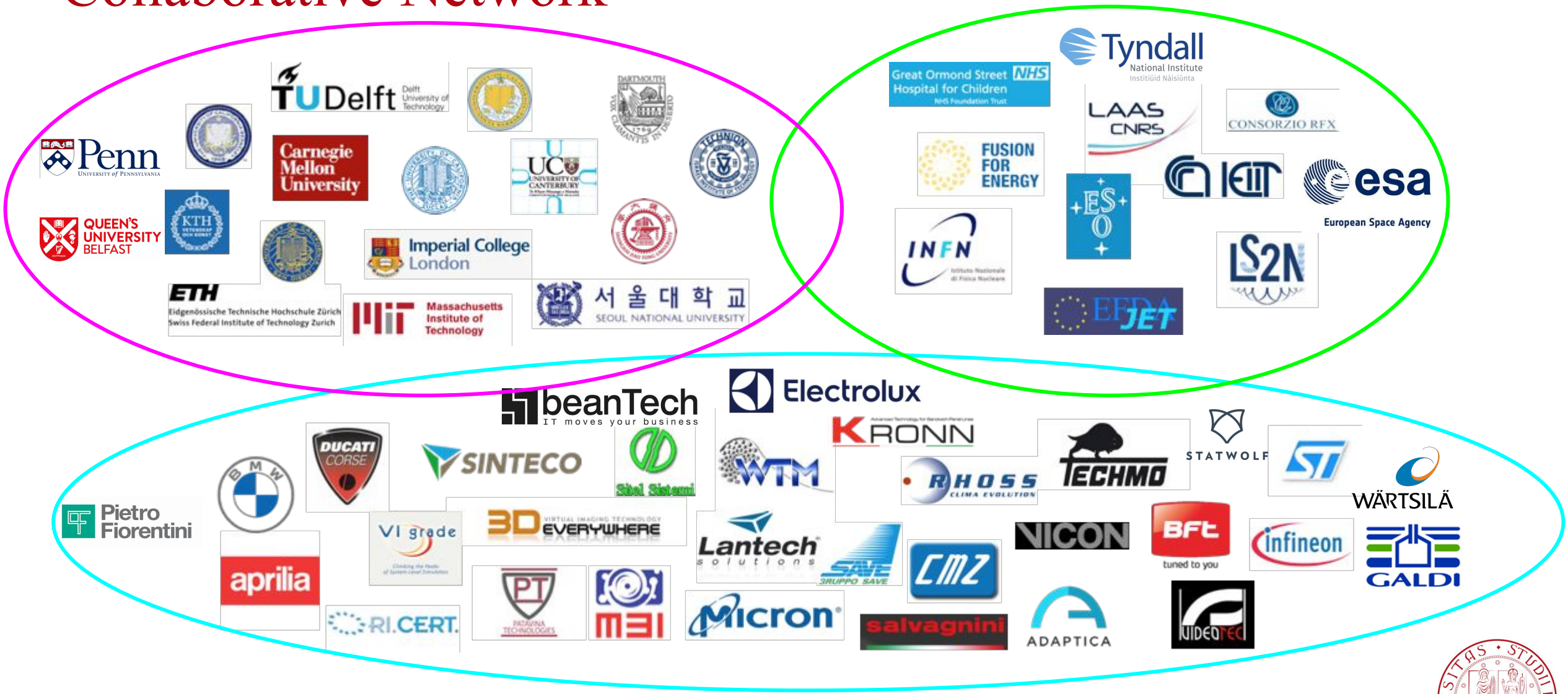
UniZEB: multidisciplinary and permanent Living Lab on Zero Energy Buildings, with cutting-edge technologies from construction to management.

Career Opportunities

- Our students found rewarding and important technical and research positions both in local and international companies in heterogeneous sectors, such as:
  - Automotive;
  - Automation and Robotics;
  - Home Appliances;
  - Power and Energy;
  - ...

- Several of our fellow students are faculties/hold positions at prestigious universities around the world.

Collaborative Network



The Control and Systems Group: Faculty and Affiliates

G. Baggio

A. Beghi

M. Bruschetta

R. Carli

A. Cenedese

A. Chiuso

A. Dalla Libera

P. Falco

A. Ferrante

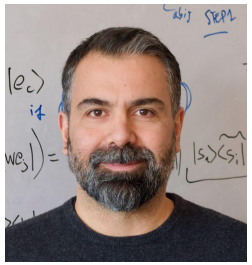
M. Pezzutto

G. Pillonetto

M. Rampazzo

L. Schenato

G.A. Susto



F. Ticozzi

M.E. Valcher

D. Varagnolo

S. Vitturi

S. Zampieri

M. Zorzi