The Practical Guy

It works!
But I don’t know why.
The Theoretical Guy

I know everything,
But I can’t make it work.
Theory and Practice

Practice is when everything works but no one knows why

Theory is when you know everything but nothing works

After this course you should make things work and know why they work
Course Prerequisites

- Linear Algebra
  - Matrices, linear operators, vector spaces
- Newton Mechanics
  - Motion equations, linear and rotational
- Classic (Linear) Control Theory (Continuous systems)
  - Laplace transform, Bode diagrams
- Matlab
- Basic programming skills (c)
- Object oriented programming (c++)
Course Material

• Slides and Notes provided by the teacher.
  • http://metropolis.scienze.univr.it/altair/events/laboratorio-ciberfisico/
  • Shared folder

• Lessons hand notes

• Suggested Books
  • “Fondamenti di controlli automatici” di Scattolini, Bolzern.
  • “Robotica. Modellistica, pianificazione e controllo” di Siciliano, Sciavicco, Villani, Oriolo
  • “Robotica industriale. Modellistica e controllo di manipolatori” di Lorenzo Sciavicco e Bruno Siciliano
• Module A – Embedded programming and Control

• Module B – Robot Programming with ROS
Course Info

Orario Lezioni
- Martedì 8:30 – 10:30 in Lab. Ciberfisico
- Mercoledì 8:30 – 10:30 in Lab. Ciberfisico

Docenti
- Andrea Calanca, Domenico Bloisi

Ricevimento
- Dopo lezione o concordando per mail

Esame
- Esercitazioni (make) + Orale (know)
  - Obbligatorio - Voto max 24
- Progetto
  - Facoltativo - Voto max 30L
Embedded programming and Control

- Embedded Programming
- Sensors
- Actuators
- Control theory in practice
  - BLDC voltage control
  - Current control
  - Position control
  - Force Control
  - Impedance Control
- System Identification
About Myself

• Mail: andrea.calanca@univr.it
• Affiliation: Altair Robotics Lab, University of Verona
• Assistant Professor @ University of Verona
• Contract Professor @ University of Brescia

• Previous Experience
  • Academic Researcher (Univ. Verona)
  • Software Engineer (Replay, Sole24)
  • Automation engineer (Tetrapack Group)
  • Audio DSP engineer (Overloud)
  • Control Engineer (Electrolux Group)
What is Robotics?

A very multidisciplinary subject

- Mechanic engineering
- Electronic engineering
- Control engineering
- Computer Science
- Artificial Intelligence
What is Robotics?

Mechanics

- Rigid body kinematics
- Rigid body dynamics
- Lagrangian Mechanics
- Hamiltonian Mechanics
- Deformable body kinematics and dynamics
What is Robotics?

Electronics & Electrotechnics

• Digital electronics (e.g. encoders, hall sensors, stepper motors, inverters)
• Analog electronics (e.g. potentiometers, resolvers, filters, linear amplifiers)
• Sensors & sensor conditioning
• Actuators & power units
• Processors & interfaces
• Communication
What is Robotics?

Control Theory

• Classical Control
  • Linear controllers, loop shaping, root locus, Nyquist and Bode stability criterions, robustness indexes

• Non-Linear Control
  • Feedback linearization, passivity based control, sliding-mode control, adaptive control, back-stepping control and more!

• Modern Control
  • Control as an optimization problem. Not so many examples for the moment due to computational burden (model predictive control)

• System Identification & Optimal Filtering
  • Parametric identification, state observers
What is Robotics?

Computer Science/Engineering

• Operating systems, distributed and networked systems, real-time scheduling and resource allocations
• Software architectures & design patterns
• Modern programming paradigms: object oriented, component oriented.
• Computer Vision: classification, recognition, 3D reconstruction etc.
• Machine learning: learning by demonstration, reinforcement learning, etc.
What is Robotics?

Artificial Intelligence


- Uncertain reasoning: Probabilistic Reasoning (Bayes, e.g. Bayesian networks), Statistical Inference, Data Fusion, Decision Support Systems, Fuzzy Logic.
The Importance of Mechanics
The Importance of Control

Triple Pendulum on a Cart
Swing-up and Swing-down

Two-degrees-of-freedom design:
Constrained feedforward & optimal feedback control

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The Importance of Control

Triple Pendulum on a Cart

Side-stepping

Two-degrees-of-freedom design:

Constrained feedforward control based on the nonlinear model vs. Flatness-based feedforward control based on the linearized model with optimal feedback control

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Unsafety in Position Control
Virtual Stiffness by Force Control

The Future is Force-Controlled
Virtual Stiffness by Force Control
Transparency by Force Control
Gravity Compensation by Force Control
What is a Robot?

**Atlas**

Sensors and cameras construct high-resolution 3-D maps for navigation.

Port for power and communication tether which will eventually be replaced by an on-board power source.

**TASKS THE ROBOT MUST COMPLETE**

- Drive utility vehicle
- Travel dismounted through various terrains
- Remove debris blocking doorway
- Open doors, enter building
- Climb ship's ladder/stairs
- Break through wall
- Locate and close valve
- Connect firehose

**HEIGHT COMPARISON**

- Calhoun, Kelly Olyk: 6'0''
- ATLAS: 6'2''
- Average American male: 5'10''

Shoulder, one of 26 hydraulically actuated joints.

Wrist designed to operate with hands made by another manufacturer.

Two legs — instead of four or six, or caterpillar tracks — to better navigate uneven terrain.
What is a Robot?
What is a Robot?
What is a Robot?
What is a Robot?

Hi, I'm Jibo
What is a Robot?
What is a Robot?
What is a Robot?

This is not a Robot!