FACOLTÀ DI INGEGNERIA DELL'INFORMAZIONE
INFORMATICA E STATISTICA

Master of Science in **Control Engineering**

Laurea Magistrale in **Ingegneria Automatica**

www.diag.uniroma1.it/~automatica

DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI

SAPIENZA
UNIVERSITÀ DI ROMA

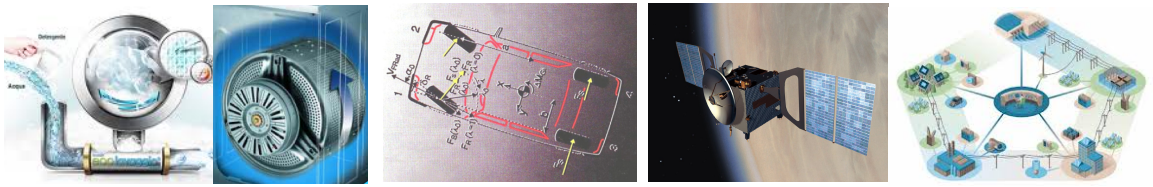
Presentation to the students
September 21, 2016

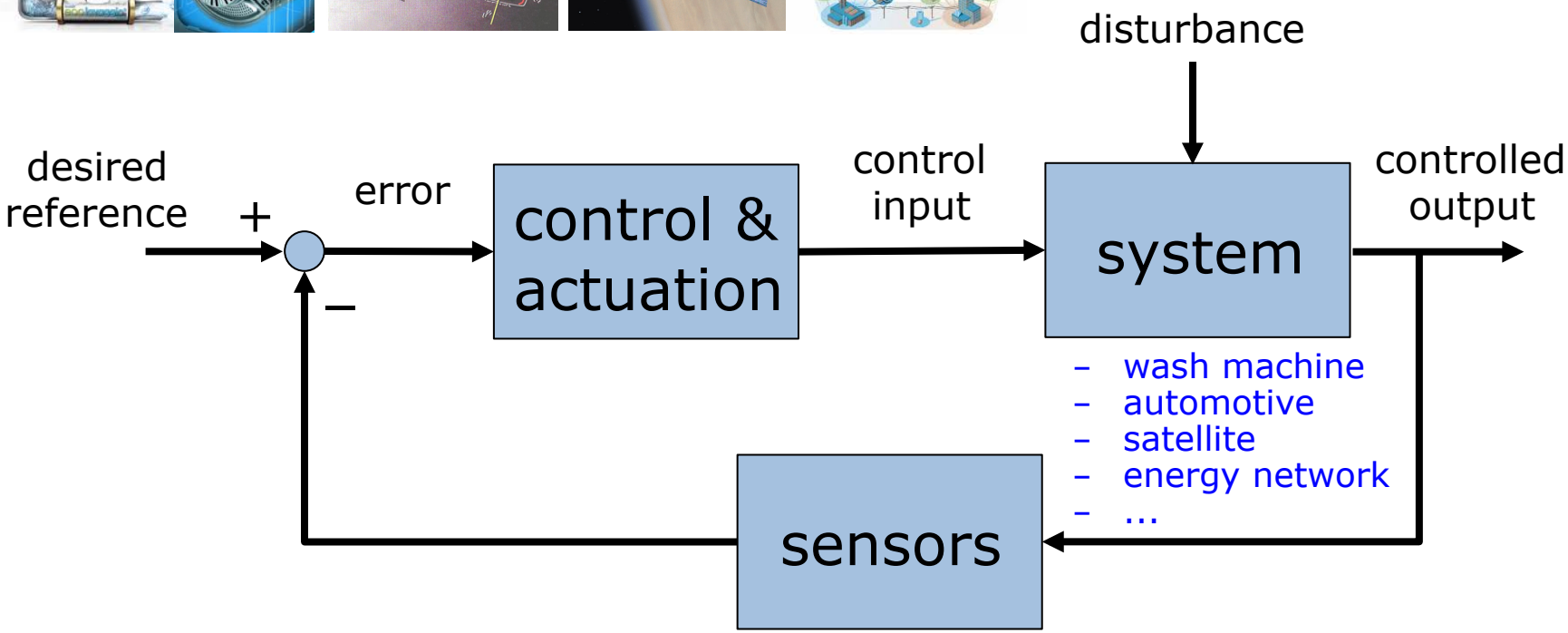
“Automatica”

αυτωσ, ”by itself", ματωσ, ”task”, τικη, "technique/study"

- **Control Engineering** (Ingegneria Automatica) deals with the bulk of engineering methods and technologies for the supervision, automation, and real-time control of dynamical systems
- an automatic control system enables to impose, in autonomous mode and using the robust properties of feedback, a desired behavior to physical devices and processes so as to guarantee
  - high performance (precision, speed, comfort, reliability, quality of service)
  - energy savings (reduction of operating costs, optimal use of primary goods)
  - improved safety, lower impact on the environment
- a **Control Engineer** is responsible for the design, realization, optimization and conduction of automatic control systems for industrial plants and other processes/systems of different nature and functionality
- use of descriptive (mathematical, cognitive) models, measurements and information acquired from sensors, and actuators to execute commands

Feedback control

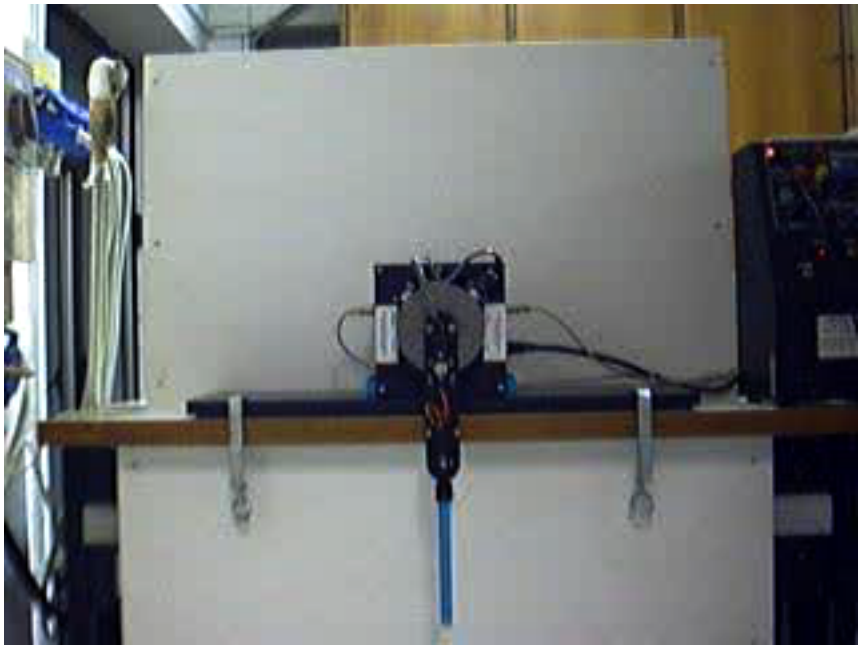




- human example: locomotion based on visual feedback
- automatic example: humanoid robot guided by a camera

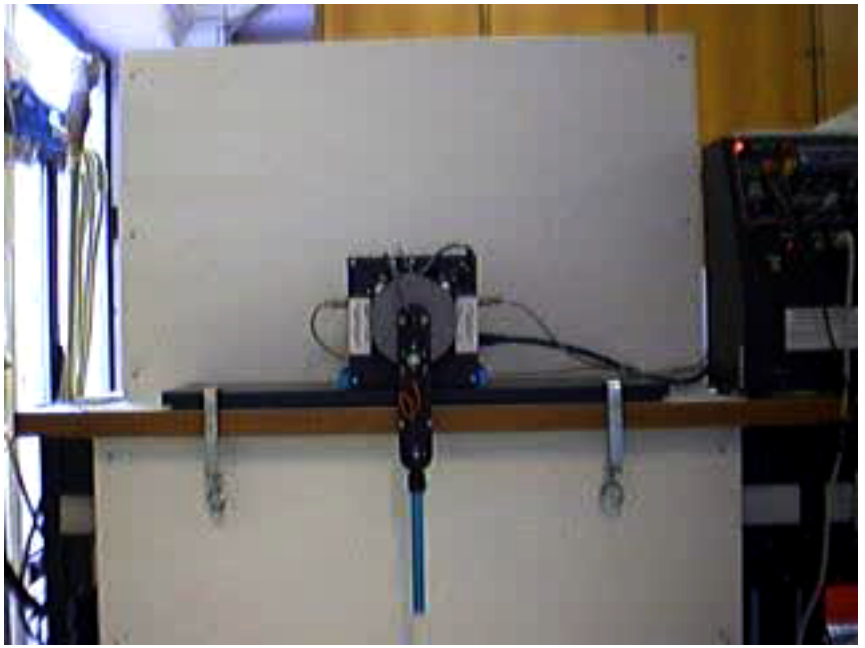
“Swing-up” of a double inverted pendulum

video



specific control strategy
(energy pumping + local PID)

video

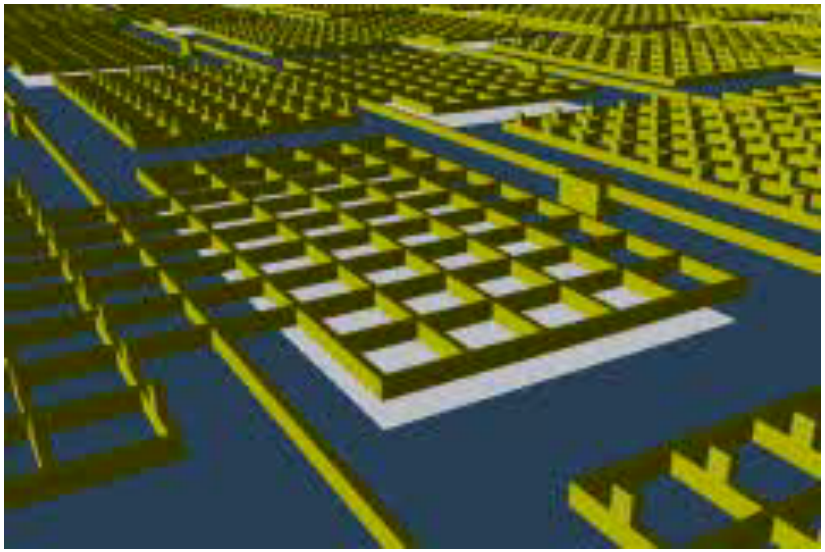


nonlinear control

a similar control technique is used also for the stabilization of walking motion in humanoid robot!

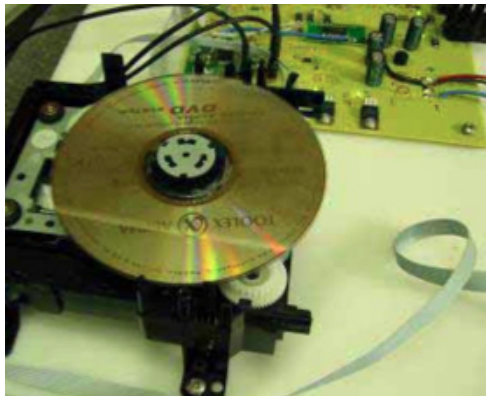
Automatic control and mechatronics

video



micro/nano actuators

periodic oscillations are induced by electro-static forces that are controlled by an AC voltage applied between the silicon substrate and the aluminum electrodes



video

reading head of an HD drive

~10^2 point-to-point moves per second

Applications of control systems

Generation and distribution of energy (smart grids)

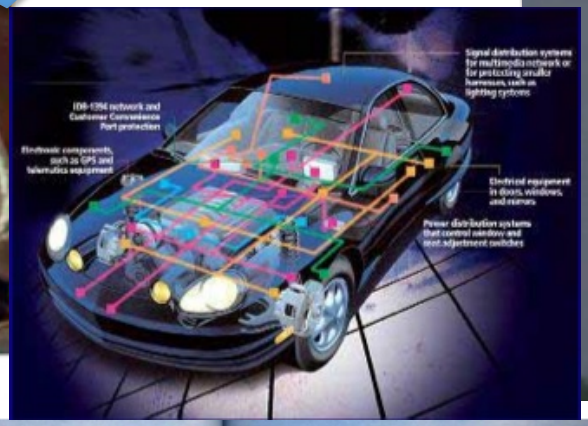
Control of continuous industrial processes (e.g., chemical)

Green energy management

Service robotics and industrial automation

Applications of control systems

Automotive (ABS, ESP, automatic parking)



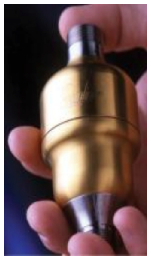
Aeronautics (fly-by-wire)

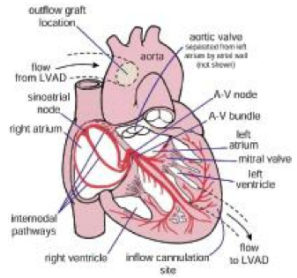
Astronautics (optimal control, satellite attitude, space robotics)

Navigation (auto pilot)

Applications of control systems

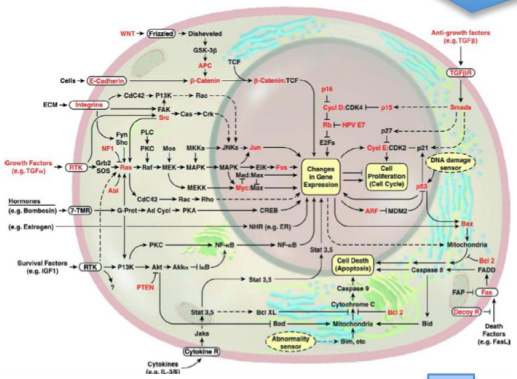
Control of artificial prostheses

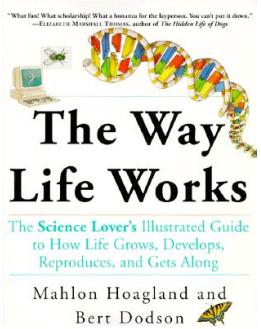




LVAD = Left Ventricular Assist Device

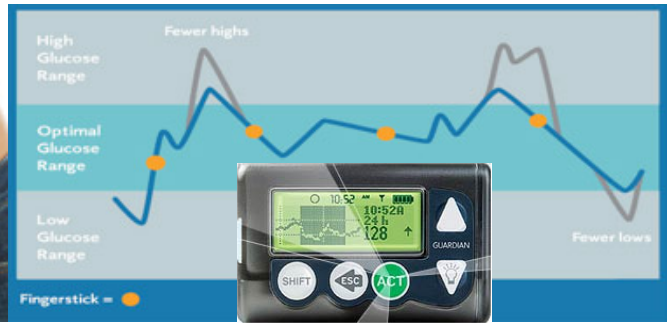
Models of biological systems





Feedback mechanisms for regulation of: body temperature, blood pressure, glucose levels, cellular interactions ...

Robotic surgery (daVinci system)



A “table” with multiple diners

models
- mathematical
- physical, chemical, ...
- economic

components
- sensors and actuators
- PC, DSP, μ-processors
- local/wireless networks

Control systems: an integrated approach

engineering
- user requirements
  - objectives, costs, constraints
- design
- simulation
- programming
- implementation

technologies
- computer science
- electronics
- mechanics
- electrotechnics
- telecommunication

Courses of study at Sapienza

Bachelor in Computer Science and Control Engineering

- italian name: Laurea in Ingegneria Informatica e Automatica
- 3 years, 180 credits, 20 exams
- curriculum in Automatic Control (one out of three)
- final work (3 credits)

Master of Science in Control Engineering

- italian name: Laurea Magistrale in Ingegneria Automatica
- 2 years, 120 credits, **12 exams**
- cooperation of the two Schools of Engineering (I3S + ICI)
- theoretical and lab activities (control of networks, robotics)
- final work (30 credits = internship + master thesis)

PhD in Automatic Control, Bioengineering and Operations Research

- 3 years of research activity
- possibility of spending up to 1 year abroad
- original PhD thesis

Laurea in Ingegneria Informatica e Automatica
Bachelor curriculum in "Automatica"

First year (in common)

- Analisi matematica I (12 cfu)
- Geometria (6 cfu)
- Fondamenti di informatica I (12 cfu)
- Fisica (12 cfu)
- Tecniche di programmazione (6 cfu)
- Calcolo delle probabilità e statistica (6 cfu)
- Ricerca operativa (9 cfu)
- Idoneità lingua straniera (3 cfu)

Second year

- Programmazione orientata agli oggetti (6 cfu)
- Telecomunicazioni (9 cfu)
- **Teoria dei sistemi (6 cfu)**
- Analisi matematica II (6 cfu)
- Sistemi di calcolo (12 cfu)
- **Controlli automatici (9 cfu)**
- Elettrotecnica (6 cfu)
- **Modellistica e simulazione (9 cfu)**

cfu = credits

Third year

- **Automazione (9 cfu)**
- **Controllo e gestione delle reti (6 cfu)**
- Elettronica (6 cfu)
- Economia e organizzazione aziendale (9 cfu)
- **Laboratorio di automatica (6 cfu)**
- Esami a scelta dello studente (12 cfu)
- Prova finale (3 cfu)

access to M.Sc. in Control Engineering is straightforward when coming from this bachelor course

in general, **96 credits are needed** in some coded scientific disciplines (SSD):
- any ING-INF
- many ING-IND
-also MAT, FIS, CHIM

≥ 9 credits in the domain of Automatic Control (ING-INF/04) are *recommended*

Curriculum of the Master

(our two-year course of study is fully active since 2014-15)

- **2** mandatory core courses of 12 cfu [in 1st year] 24 cfu
  - **Nonlinear systems and control**
  - **System identification and optimal control**
  - taught during both semesters
- **6** other core courses to be chosen among 9 (group **B**) 36 cfu
- **3** completing courses to be chosen among 7 (group **C**) 18 cfu
- **1** or **2 free** choices 12 cfu
  - either in groups B/C or from any other course offered at Sapienza
  - typically, in 2nd year
- internship (6 cfu) + master thesis (24 cfu) [in 2nd year] 30 cfu

- total (approx 60 cfu/year) = **120 cfu**
- **12** exams as a whole
  - courses of free choice count always as 1 exam

cfu (= credito formativo universitario) ⇒ 1 credit = 8h of lectures

Tailoring your curriculum

Group B: choose 6 out of 9 (36 cfu in total)	year	sem
Process automation	1	I
Robotics I	1	I
Robust control	1	I
Multivariable feedback control	1	II
Robotics II	1	II
Control of communication and energy networks	2	I
Digital control systems	2	I
Dynamics of electrical machines and drives	2	I
Vehicle system dynamics	2	II

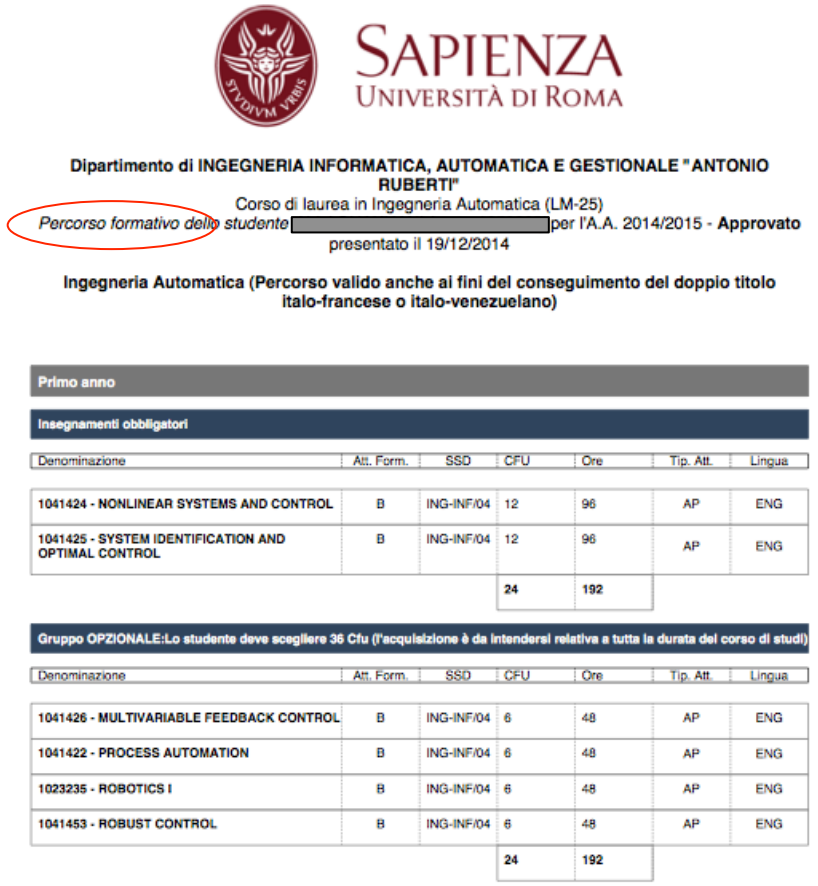
Group C: choose 3 out of 7 (18 cfu in total)	year	sem
Autonomous and mobile robotics	1	II
Robotics II	1	II
Computer and network security	2	I
Control of communication and energy networks	2	I
Digital control systems	2	I
Machine Learning	2	I
Control of autonomous multi-agent systems	2	II

three courses appear in both groups B and C

Study plan

your personal choice of a curriculum of exams = "percorso formativo"

- study plan is prepared and submitted on-line via Infostud
- it includes
  - *i. which courses you actually choose from the two optional groups in the "Manifesto"*
  - *ii. which courses you select of free choice (any offered at Sapienza)*
  - *iii. pay attention in which year you place a course (few options)*
- plan must be submitted before registering to the single exams (October 15, 2016 - March 30, 2017)



SAPIENZA
UNIVERSITÀ DI ROMA

Dipartimento di INGEGNERIA INFORMATICA, AUTOMATICA E GESTIONALE "ANTONIO RUBERTI"

Corso di laurea in Ingegneria Automatica (LM-25)

Percorso formativo dello studente [redacted] per l'A.A. 2014/2015 - **Approvato**

presentato il 19/12/2014

Ingegneria Automatica (Percorso valido anche ai fini del conseguimento del doppio titolo italo-francese o italo-venezuelano)

Primo anno

Insegnamenti obbligatori

Denominazione	Att. Form.	SSD	CFU	Ore	Tip. Att.	Lingua
1041424 - NONLINEAR SYSTEMS AND CONTROL	B	ING-INF/04	12	96	AP	ENG
1041425 - SYSTEM IDENTIFICATION AND OPTIMAL CONTROL	B	ING-INF/04	12	96	AP	ENG
			24	192		

Gruppo OPZIONALE:Lo studente deve scegliere 36 Cfu (l'acquisizione è da intendersi relativa a tutta la durata del corso di studi)

Denominazione	Att. Form.	SSD	CFU	Ore	Tip. Att.	Lingua
1041426 - MULTIVARIABLE FEEDBACK CONTROL	B	ING-INF/04	6	48	AP	ENG
1041422 - PROCESS AUTOMATION	B	ING-INF/04	6	48	AP	ENG
1023235 - ROBOTICS I	B	ING-INF/04	6	48	AP	ENG
1041453 - ROBUST CONTROL	B	ING-INF/04	6	48	AP	ENG
			24	192		

www.uniroma1.it/studenti/infostud

Refresh syllabus

Basics in Systems Analysis and Automatic Control

Mathematical modeling of systems. Examples from different physical domains. Differential equations. Linearization. Use of the Laplace transform. Input-output and state-space representations. Transfer functions. Poles and zeros. Interconnected systems and block diagrams. Difference equations. Sampling of continuous time systems. Use of the Z-transform.

Dynamic systems and their description in Simulink (for simulation purposes), taking some simple electro-mechanical systems and their controls as reference.

Linear systems analysis in the time domain. Free and forced evolution. Stability. Steady-state and transient responses. Impulse response. Step response.

Linear systems analysis in the frequency/Laplace domain. Frequency response. Bode and Nyquist diagrams. Routh criterion. Transient response and relation with the closed-loop frequency response.

Refresh syllabus

Basics in Systems Analysis and Automatic Control

Feedback control systems. Feedforward, feedback, and mixed schemes. Precision. Steady-state error. Disturbance rejection and attenuation. Sensitivity analysis. The cost of feedback. Performance indices.

Design based on the frequency response. Nyquist criterion. Stability margins. Bandwidth and resonant frequency. Open- vs. closed-loop frequency characteristics (Nichols chart). Lead and lag compensation. PID control.

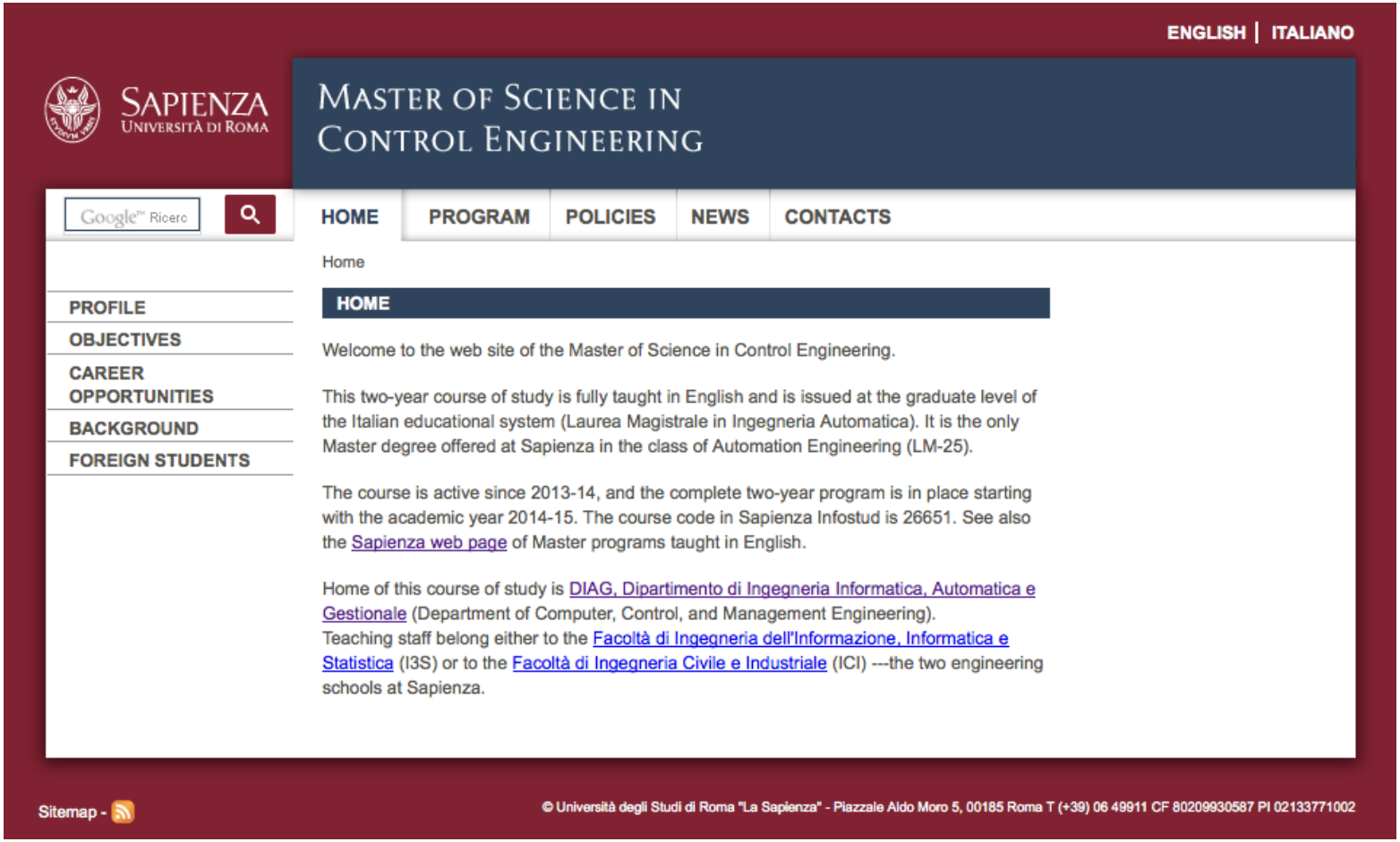
Design in the Laplace domain. Root locus method. Stabilization of minimum and non-minimum phase systems. Direct design. Pole placement techniques.

Design based on state-space techniques. Structural properties and Kalman decomposition. Controllability and stabilizability. Observability and detectability. Stabilization via state feedback. Eigenvalue assignment. Observer design. Separation principle. Stabilization via output feedback. Stability theory.

see doc on web site
http://www.diag.uniroma1.it/~automatica/?p=procedure/ammissione&l=en

Browsing the web site

to find most of the information you need



www.diag.uniroma1.it/~automatica

More information

- rapidly growing course of study (since rebirth in 2013-14), with relatively large involvement of national and international students
  - 2013-14: 13 new students (0 with foreign degree)
  - 2014-15: 23 new students (7 with foreign degree)
  - 2015-16: 42 new students (16 with foreign degree, 7 from other italian universities)
  - 2016-17:...
- personalized tutoring system (since 2015-16: 5 students/instructor)
- student honors program (percorso di eccellenza): 4 positions in 2016-17
- mobility Erasmus+ (also, various partners in European research projects)
- possible italian-french double degree
- contacts with local SMEs & industrial groups for internship and thesis

Laboratories

ENGLISH | ITALIANO

SAPIENZA UNIVERSITÀ DI ROMA

MASTER OF SCIENCE IN CONTROL ENGINEERING

Google™ Ricerca

HOME | PROGRAM | POLICIES | NEWS | CONTACTS

Program › Laboratories

- MANIFESTO
- CURRICULUM
- COURSES
- INSTRUCTORS
- LABORATORIES
- COURSE SCHEDULE
- SCHEDULE OF EXAMS AND GRADUATIONS

LABORATORIES

Students of the Master of Science in Control Engineering can develop their thesis (or perform their internship) in the following DIAG laboratories. They may also collaborate to research activities on systems, networks, and robot control that are being carried out there by professors, researchers, and PhD students.

	WEB PAGE	AREA	RESPONSIBLE
Laboratorio di Controllo delle Reti Dipartimento di Ingegneria Informatica, Automatica e Gestionale "Antonio Ruberti"	Network Control Laboratory	DIAG Via Ariosto 25 A-215 (second floor) 06 77274 037	Prof. Francesco Delli Priscoli dellipriscoli [at] diag.uniroma1.it
	Robotics Laboratory	DIAG Via Ariosto 25 S-218 (basement) 06 77274 158	Prof. Giuseppe Oriolo oriolo [at] diag.uniroma1.it
	Systems and Control Laboratory	DIAG Via Ariosto 25 S-217 (basement) 06 77274 159	Prof. Paolo Di Giamberardino digiamberardino [at] diag.uniroma1.it

task planning and control of robotic systems

- **DIAG Robotics Lab**
- established in 1987
- **www.diag.uniroma1.it/labrob**
- **www.youtube.com/user/RoboticsLabSapienza**
- located in S-218 (basement)
- several EU research projects (Framework VI-VII, Horizon 2020)

PHRIENDS

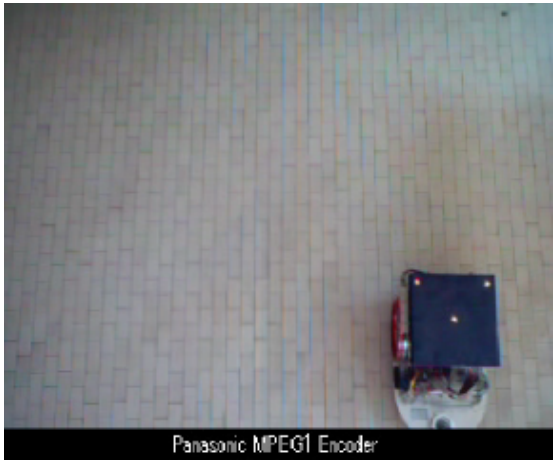
SAPHARI
Safe and Autonomous Physical Human-Aware Robot Interaction

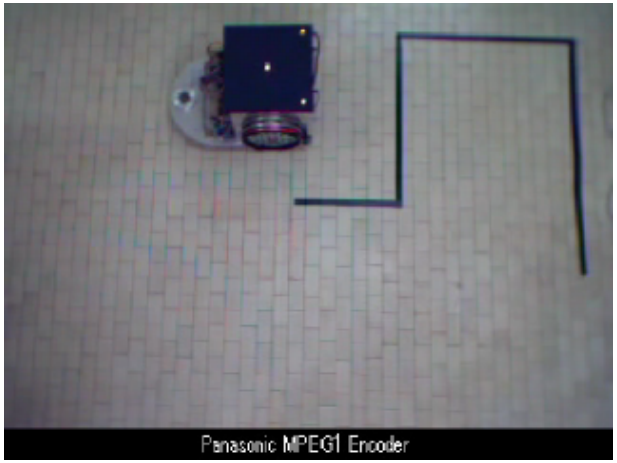
SYMPLEXITY
Symbiotic Human-Robot Solutions for Complex Surface Finishing Operations

COMANOID
Multi-Contact Collaborative Humanoids in Aircraft Manufacturing

oldies, but goldies (1994-2004)

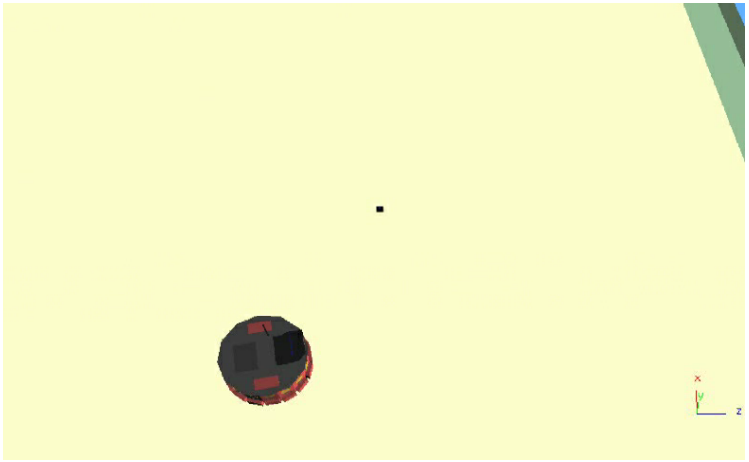
automatic parking
of wheeled mobile robots





3 video

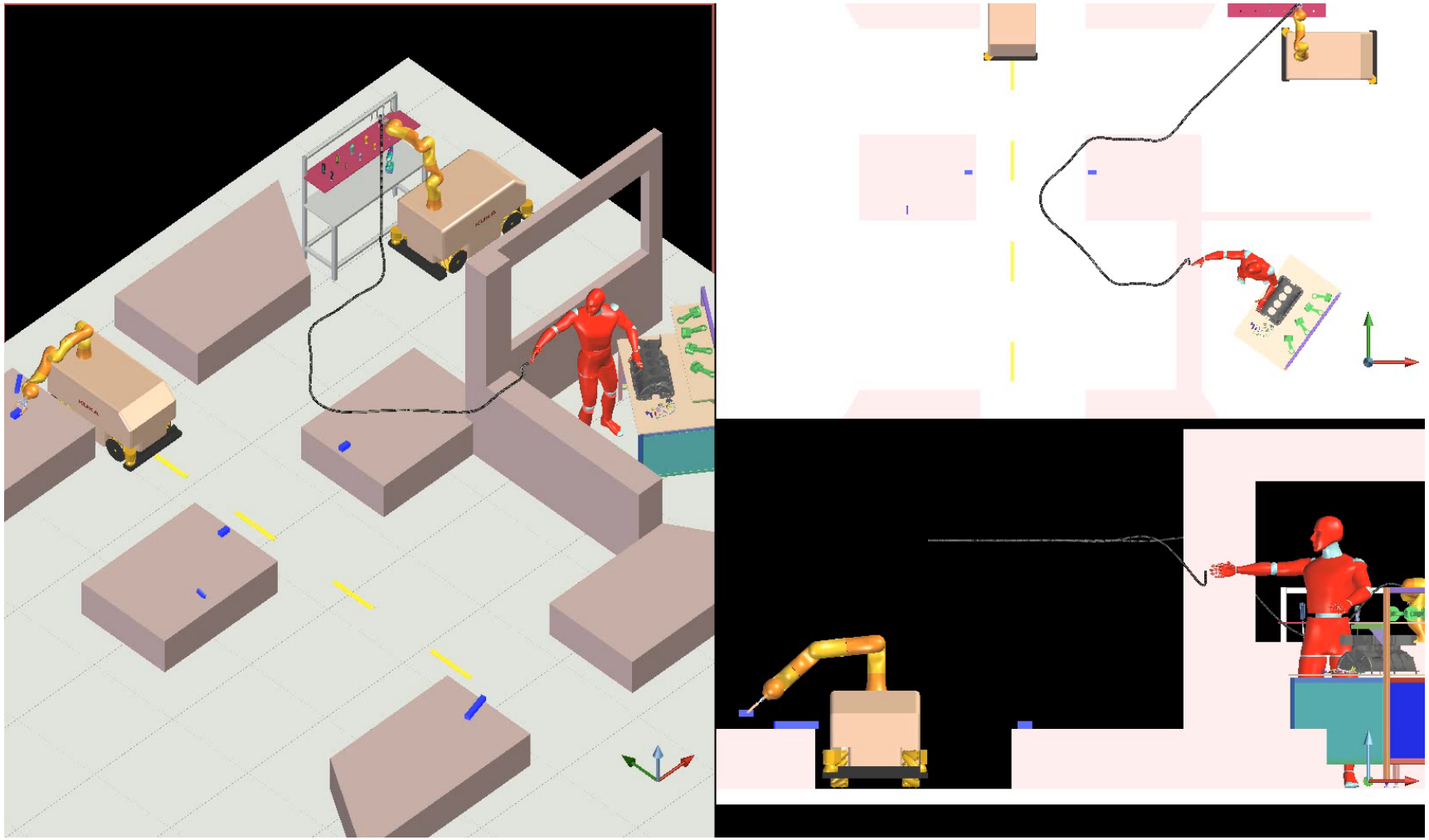
accurate execution
of arbitrary trajectories



online tracking
of a mobile target
from visual feedback
(many other applications!)

video

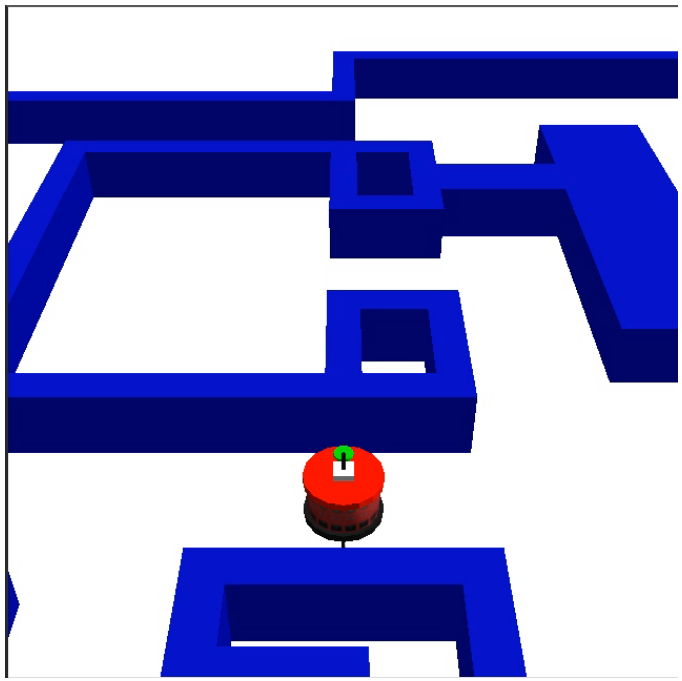
Motion planning in cluttered environments



video

Exploration and mapping of unknown environments

video



single robot
with laser sensor

video

team of Khepera robots
(decentralized control with limited communication range)

Control of UAV (drones)

Hummingbird
quadrotor

video

- heigth control using ultrasonic sensor
- tracking of ground vehicle with on-board vision system

Visual hovering
su target mobile

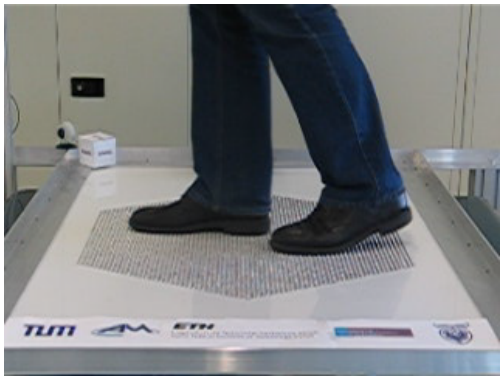
Lorenzo Rosa
Pietro Peliti
Giuseppe Oriolo

UAV = Unmanned Aerial Vehicle

Motion control of a locomotion platform for the physical exploration of VR worlds

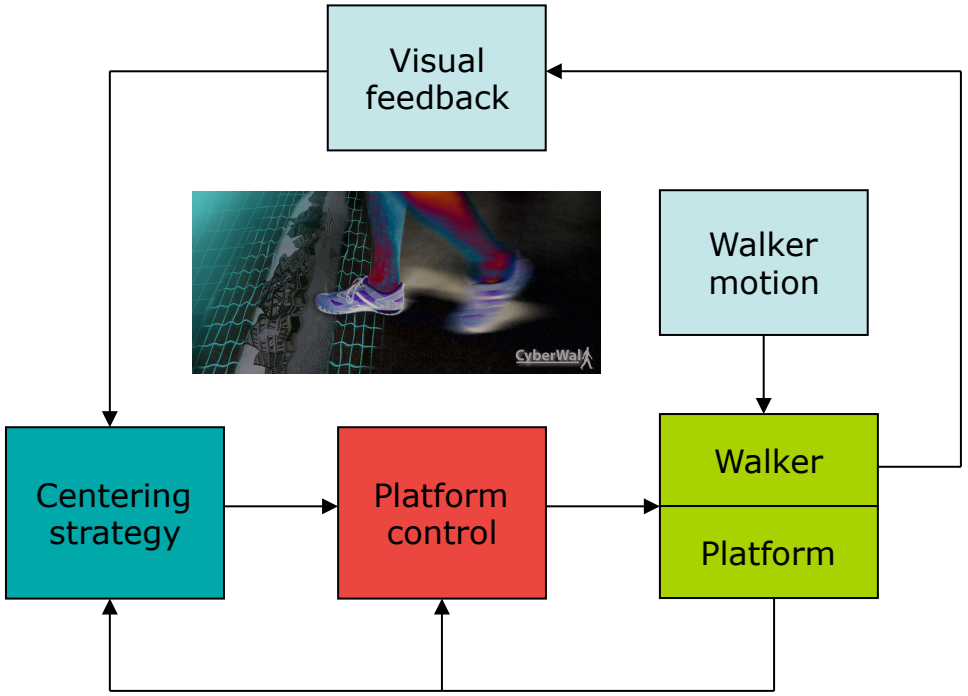
CyberWalk platforms for natural and unconstrained locomotion in VR

video



small-scale ball array CyberCarpet

full-scale 2D omnidirectional treadmill

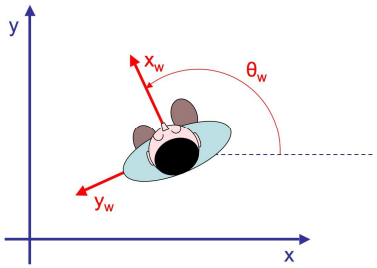


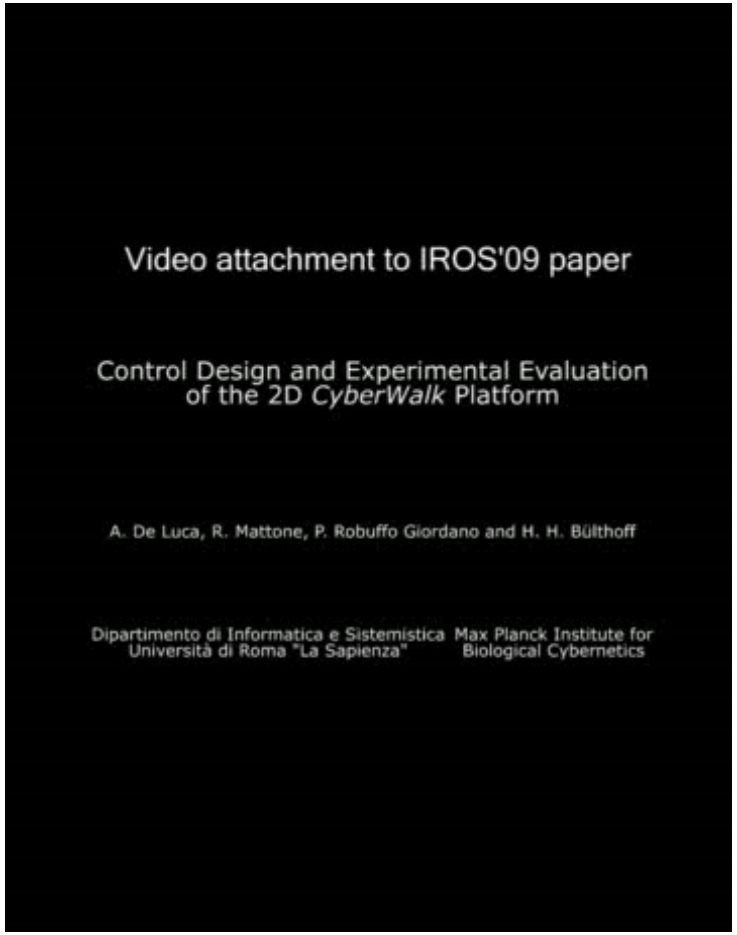
control law: feedback using also a dynamic observer + feedforward

FP6 CyberWalk (2005-08)

Control of the CyberWalk locomotion platform

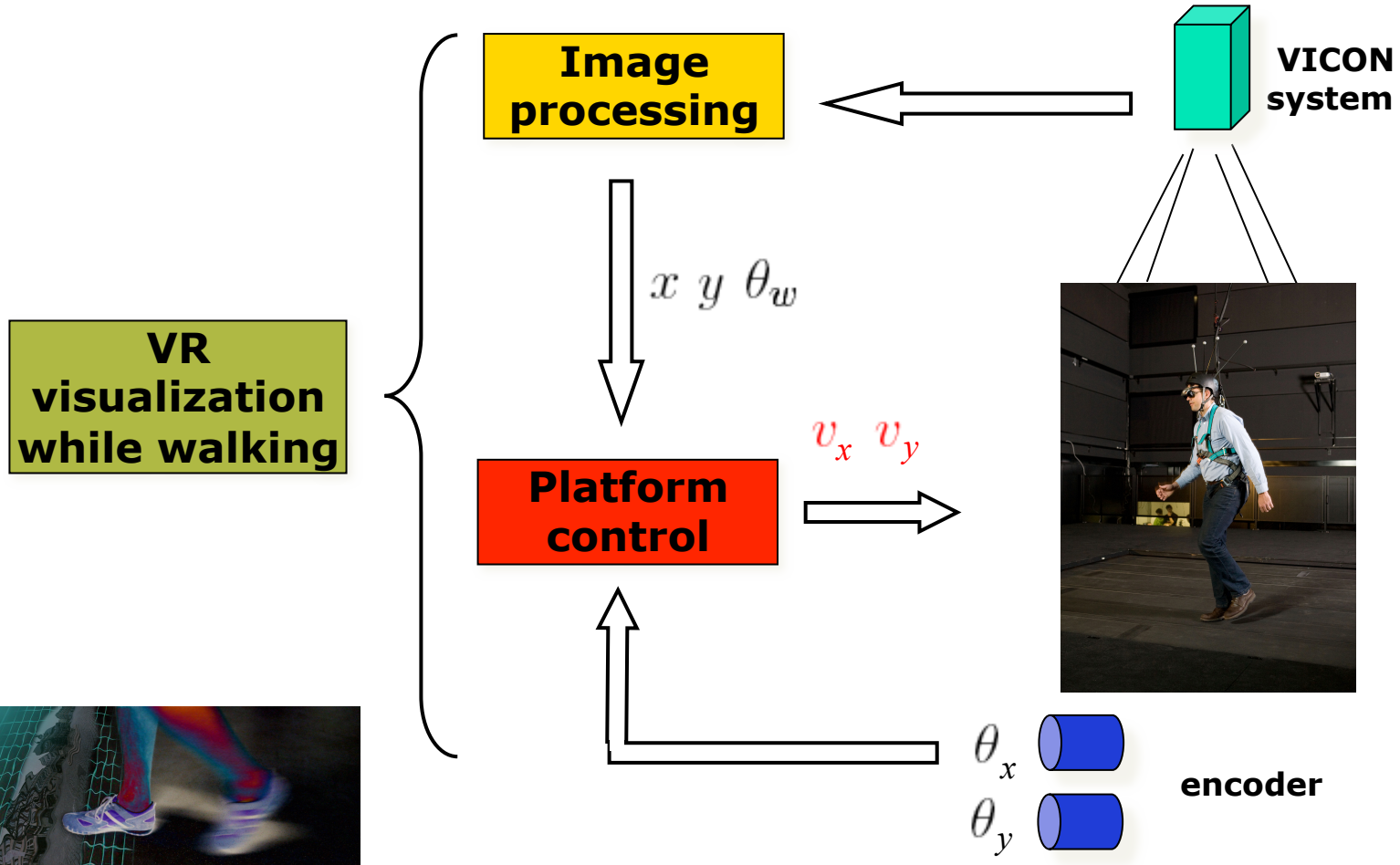
video





video

Control system "architecture" of the 2D CyberWalk platform



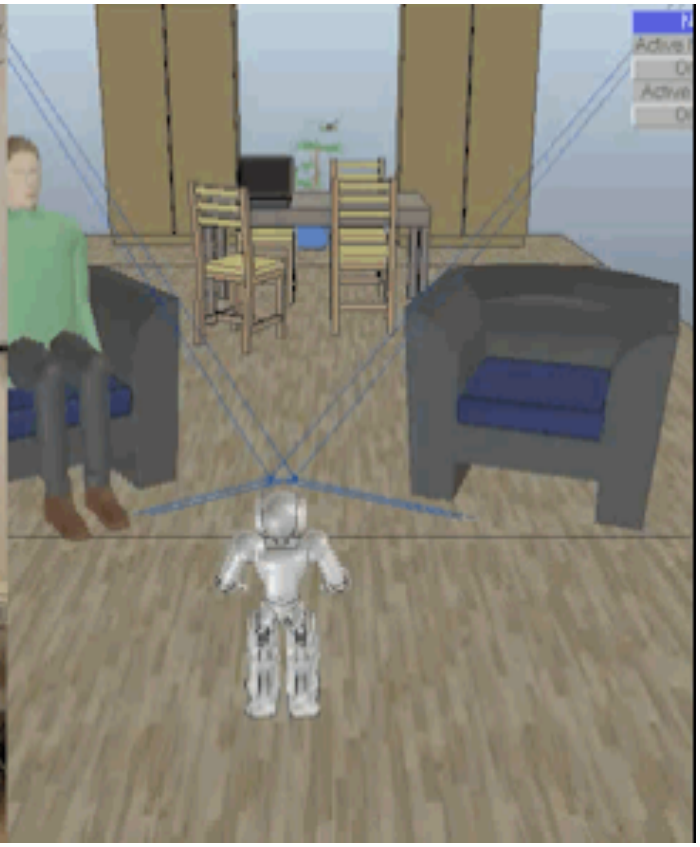
Cyberith platform and remote control (telepresence)

video

passive but sensorized!

Oculus Rift HMD

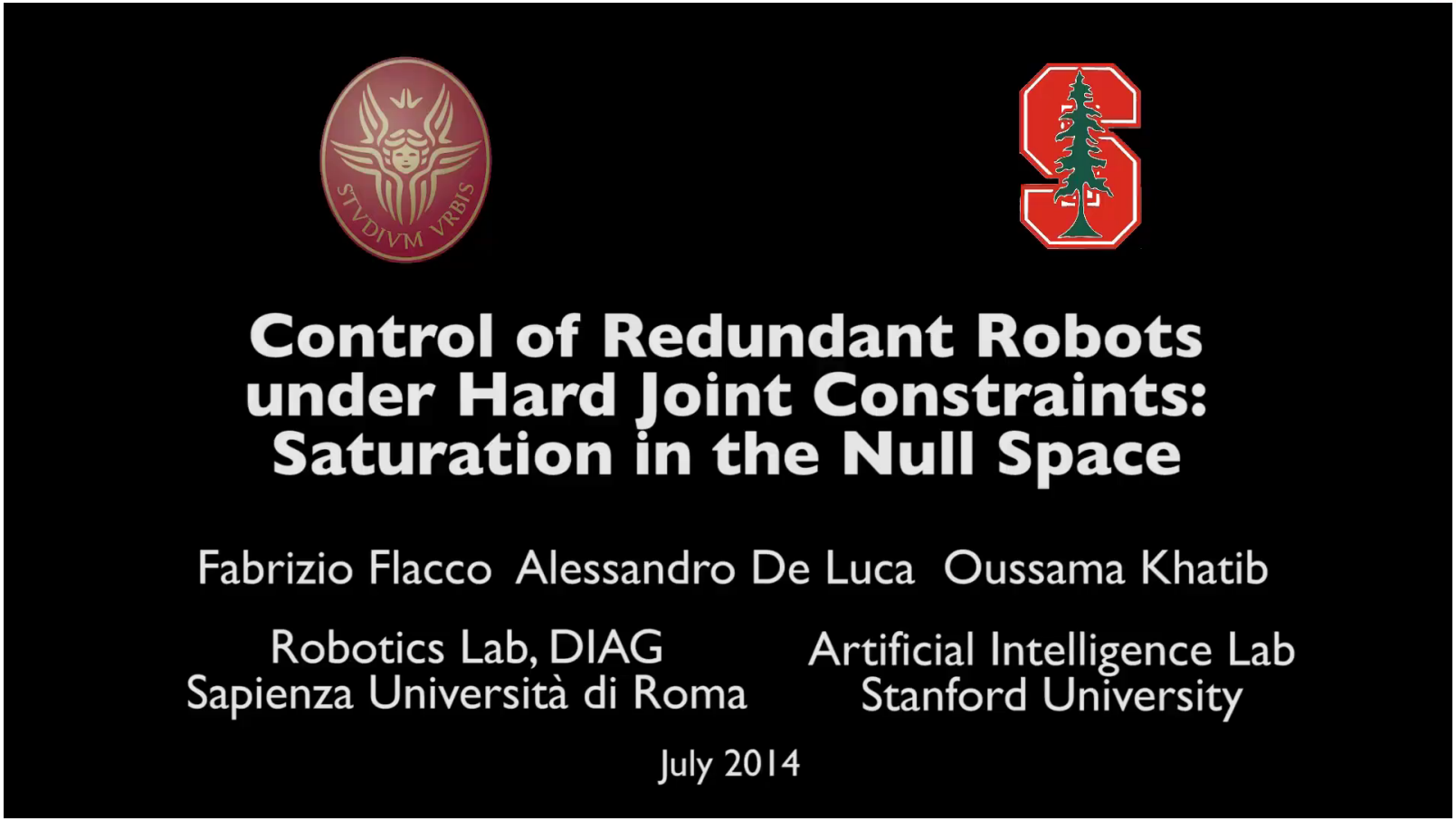
video



NAO humanoid (virtual in VREP, real in the lab)

Accurate and feasible motion control using redundancy

video



satisfying robot actuation constraints:
joint range limits; max joint velocity, acceleration, and torque

Safe control of physical human-robot interaction

video

video

PHRIENDS

sensorless (!)
collision detection
and reaction

SAPHARI
Safe and Autonomous Physical Human-Aware Robot Interaction

Safe control of physical human-robot interaction

video

collision avoidance
for coexistence

video

human-robot
collaboration

SAPHARI
Safe and Autonomous Physical Human-Aware Robot Interaction

Sensor-based control of NAO humanoid robot

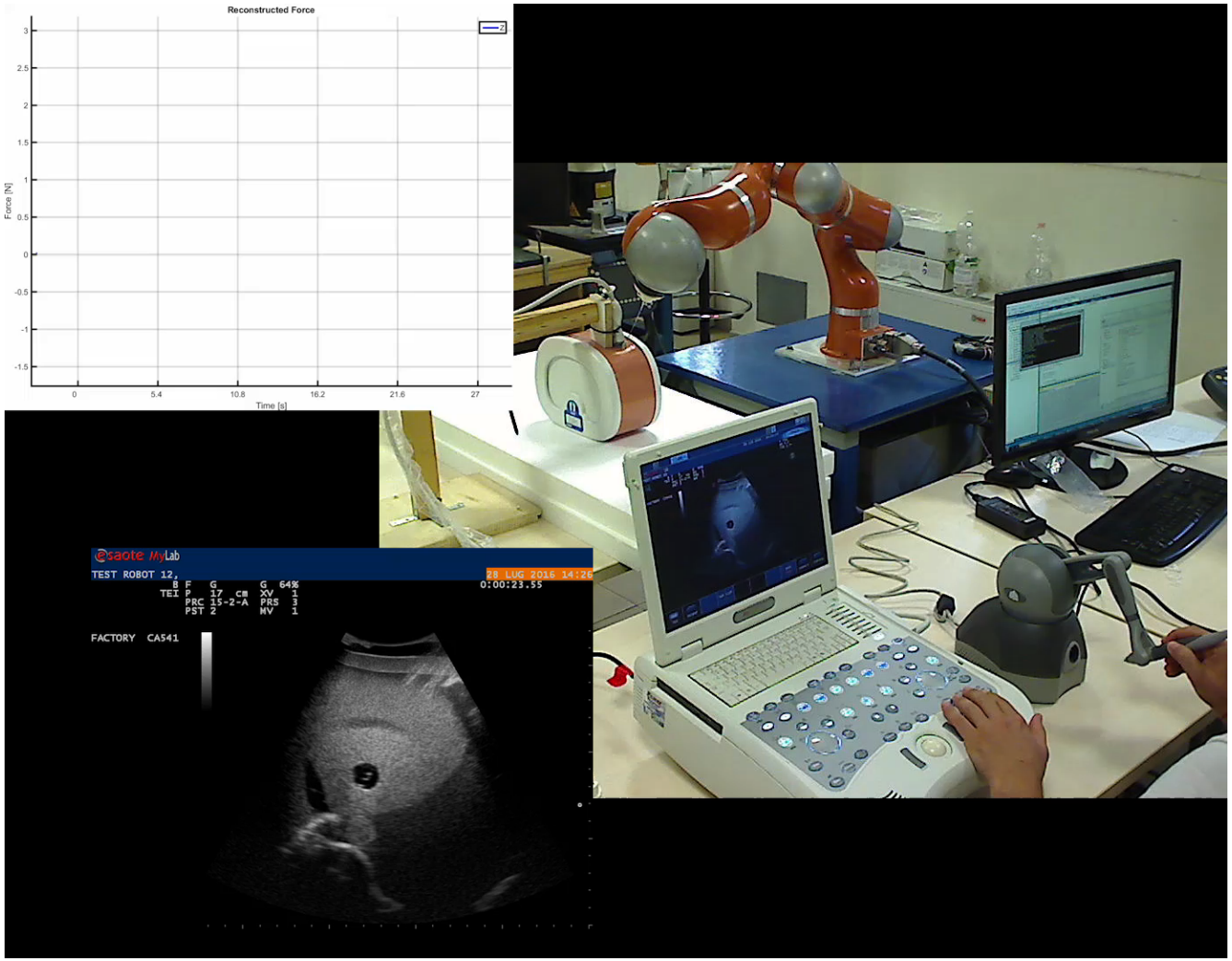
video

vision-driven...

video

guided (also, hand-guided) through the exchanged forces...

Haptic control in medical applications (needle steering)



KUKA LWR holding the needle

Omni Geomagic haptic device

video

smart grids, e-vehicle routing, car sharing/pooling,
mobile and fixed networks, critical infrastructures,
QoS/QoE in heterogeneous networks & Future Internet, ...

- **DIAG Network Control Lab**
- **labreti.ing.uniroma1.it,** located in A-215 (second floor)

Future Internet and ICT domain

Energy, Smart Grids and Intelligent Transportation Systems

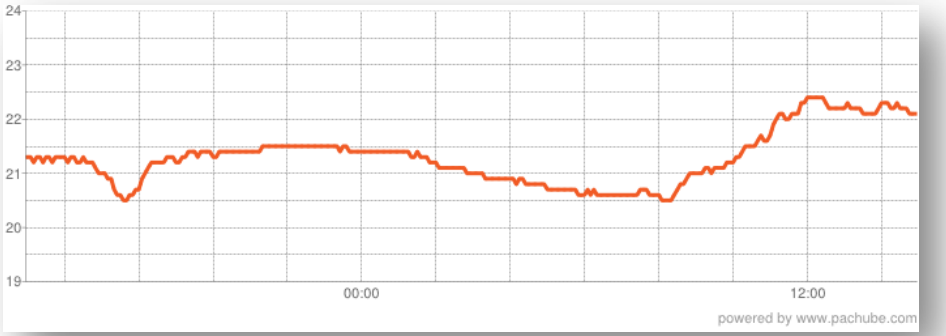
Security and Complex Systems

SMART CITY

- a "hidden" but ubiquitous role of automatic control systems in all these complex systems

SMART HOME Automation

- integration of sensor networks for energy management
- connection of domestic/local networks with regional/national smart grids so as to optimize energy demand/offer
- display of information to users allows informed management of own energy consumption
- tele-control and video-surveillance (electricity, heating, safety,...)



SMART HOME e-Health

tele-medicine

- simple installment of sensors and their automatic reconfiguration
- remote monitoring of the health status of patients and/or old people
- decision support systems for medical diagnostics and alarm control

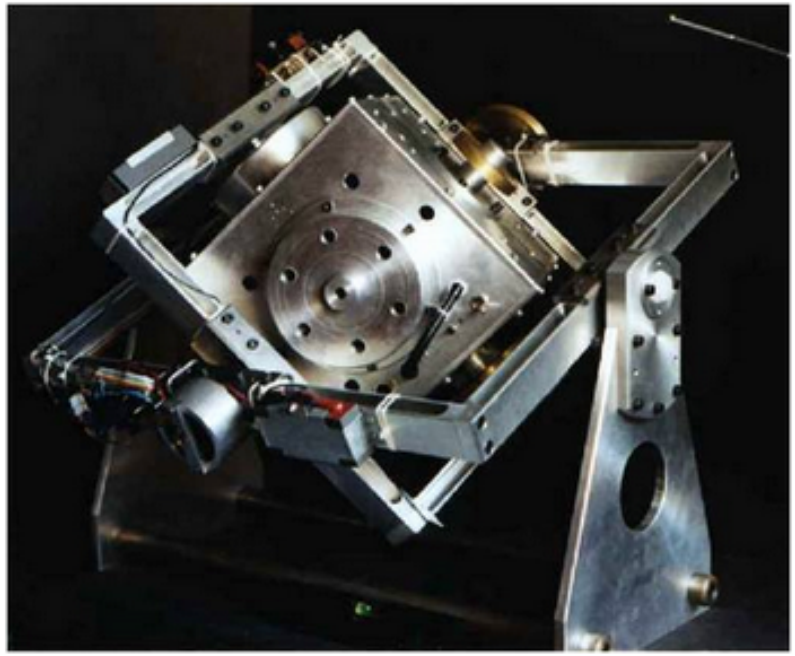
SMART MOBILITY

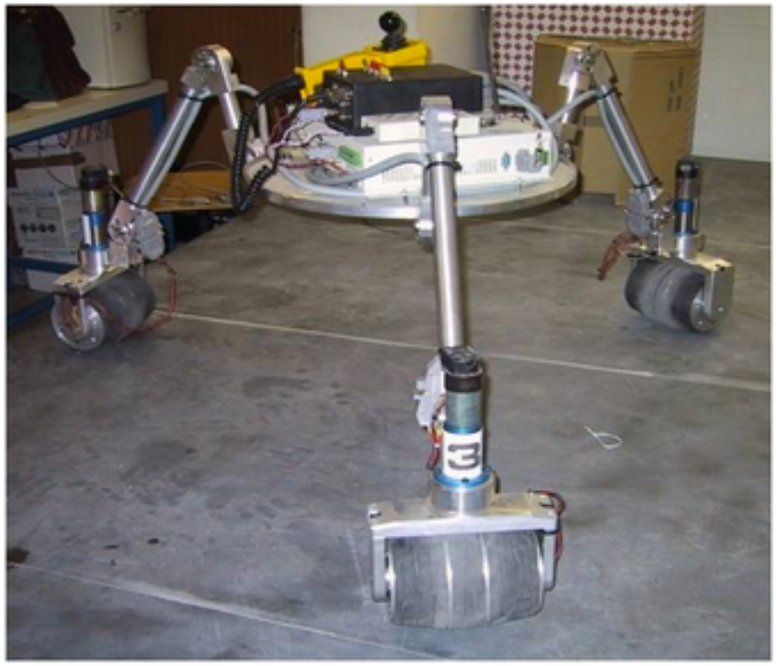
Trip PLANNING and optimal ROUTING for e-MOBILITY

Control strategies for RECHARGING for e-MOBILITY

Control for aerospace and space exploration

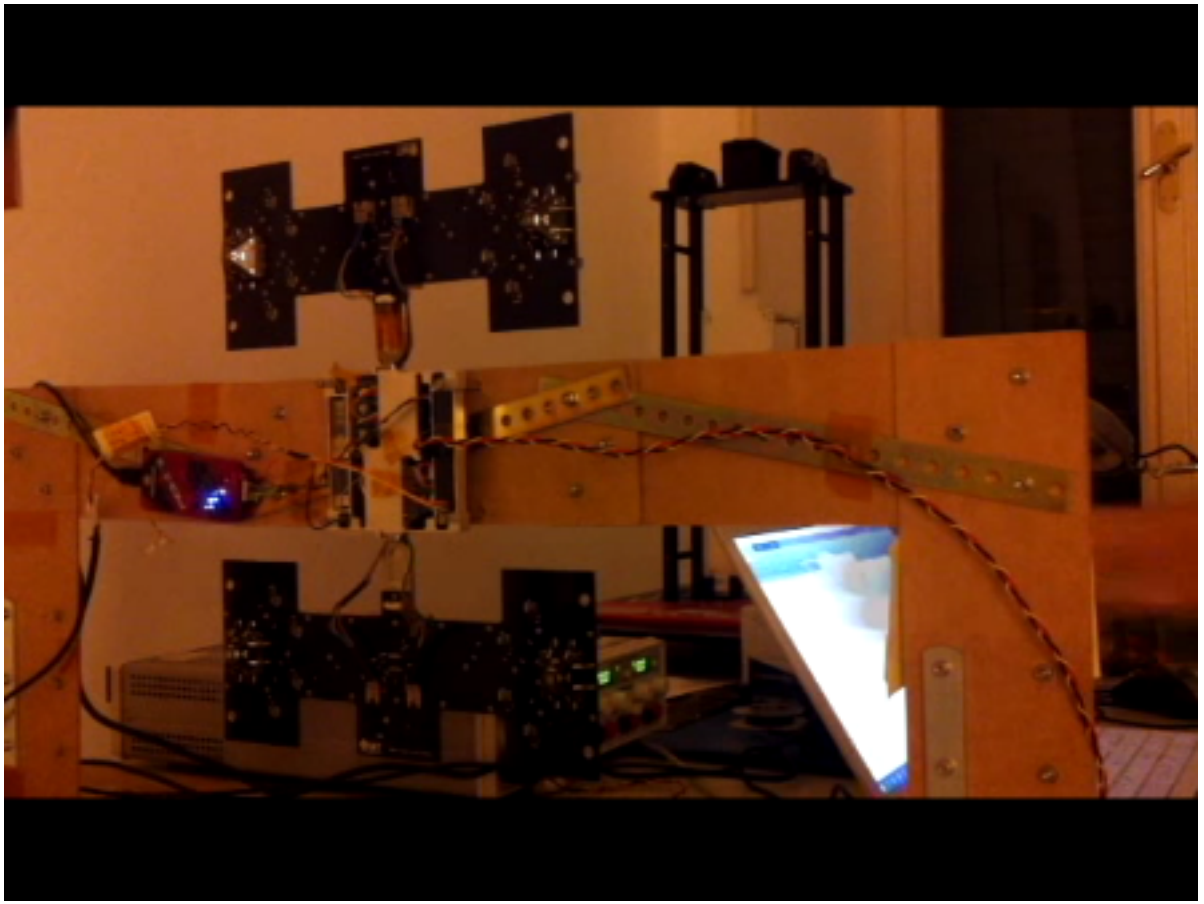
www.diag.uniroma1.it/~syscon





DIAG Systems and Control Lab
(basement S-217)

A sample master thesis in Control Engineering



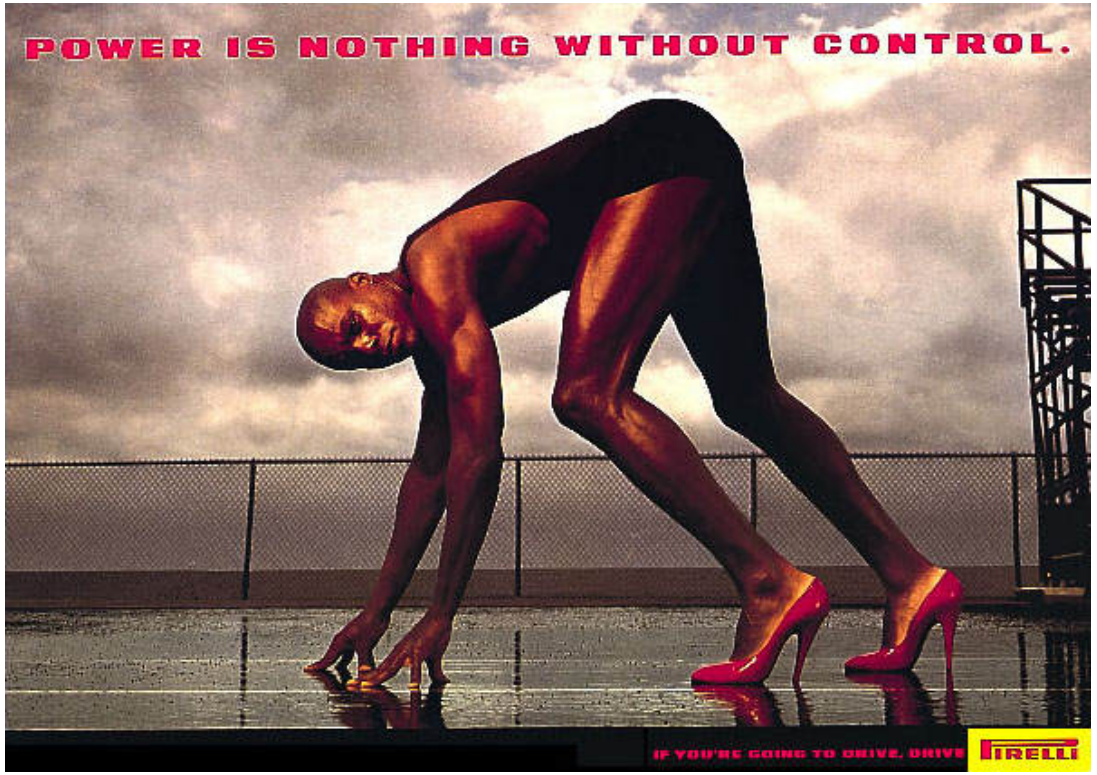
video

Raffaele Palamides. *SADA (Solar Array Drive Assembly): A Solar Tracking Control System for the Movement of a Nano-Satellite Solar Array*,
Master thesis in Control Engineering, DIAG, Sapienza Università di Roma, May 2016

Contacts

- Director of the course: Alessandro De Luca (deluca@diag.uniroma1.it)
  ⇒ office hours for students: Tuesday 12:00-13:30 (or by email)
- Student office: Giuseppina Melita (melita@...), c/o DIAG, room B-001 (ground floor)
- Foreign students help desk: Ester Latini (ecs-int@...), room SORT (next to A7)
- Student representative: Antonio Rabezzano (new elections soon for 2 representatives)
- Web site (bilingual): www.diag.uniroma1.it/~automatica
- News: http://www.diag.uniroma1.it/~automatica/?p=news&l=en

“Power is nothing without control”



Carl Lewis in a commercial for Pirelli tyres in the early ‘90