



Robotics 1

Information and Program

Prof. Alessandro De Luca

DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI



SAPIENZA
UNIVERSITÀ DI ROMA



Robotics 1 – 2014/15

- **First semester (12 weeks)**
 - Monday, September 29, 2014 – Friday, December 19, 2014
- **Courses of study**
 - Master in Artificial Intelligence and Robotics (MARR)
 - Master in Control Engineering (MCER)
 - Master in Computer Science (MINR)
 - Laurea Magistrale in Ingegneria Elettronica (MELR*)
- **Credits: 6**
 - 48 hours of classes, 2 of laboratory, 75 of individual study
- **Classes**
 - Monday 15:45-17:15 (room **B2**, Via Ariosto 25)
 - Friday 10:15-11:45, 12:00-13:30 (room **B2**)

* = part of a 12-credit integrated course Robotics 1+2



Contacts

- **Email:** deluca@diag.uniroma1.it
- **Office hours**
 - every Tuesday 12:00-13:30 c/o office **A-210**, left wing, floor 2, **DIAG, Via Ariosto 25**
 - and/or contact me by email (with some advance)
 - check my known travel dates at .../~deluca/Travel.php
- **Course web:** www.diag.uniroma1.it/~deluca/rob1_en.html
- **Course material** (pdf of lecture slides, videos, written exams, ...)
 - [available on the course website](#)
 - lecture slides **all ready**, some updates during the course
- **Registration to exams**
 - www.uniroma1.it/infostud



General information

■ Prerequisites

- self-contained course, without special prerequisites
- elementary knowledge on kinematics and automatic control is useful

■ Aims

- tools for kinematic analysis, trajectory planning, and programming of motion tasks for robot manipulators in industrial and service environments

■ Textbook

- B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo: *Robotics: Modelling, Planning and Control*, 3rd Edition, Springer, 2009

■ Other strictly related courses

- **Robotics 2**: second semester, 6 credits
- **Autonomous and Mobile Robotics**: second semester, 6 credits



Programming robot motion

Teaching Cartesian poses and playing them back

video



KUKA LBR iiwa robot with 7 revolute joints



Programming robot motion

Executing nominal trajectories and “complying” with uncertainties

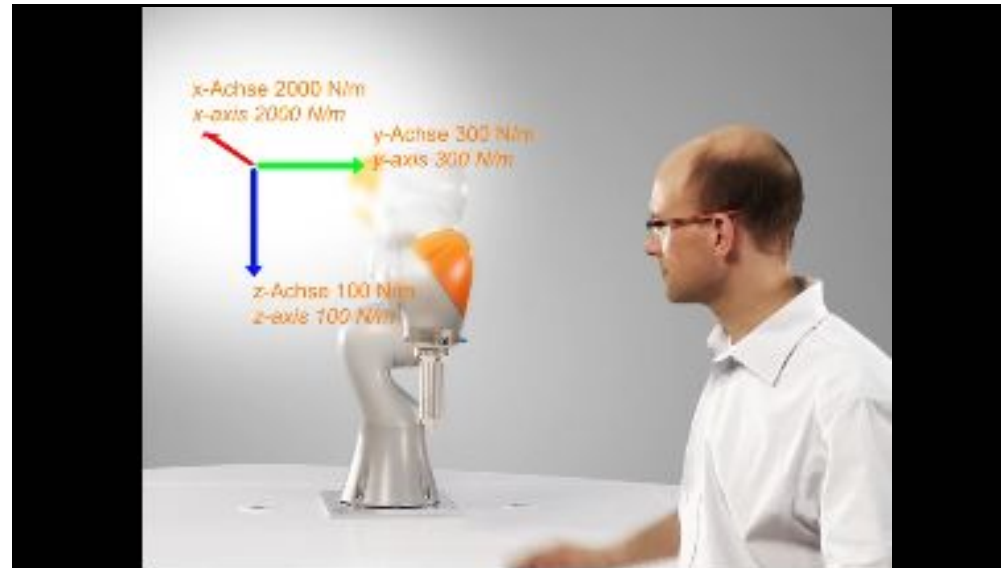
video





Programming robot compliance

Controlled reaction to applied forces/torques at robot end-effector



video



video



Programming robot motion

Teaching tasks by demonstration (kinesthetic learning)



sketch of the original idea
— a first need & use of **Safe physical Human-Robot Interaction (pHRI)**

video

video

the working industrial solution

More videos on the LBR iiwa robot:
[KUKA Laboratories YouTube Channel](#)





Program

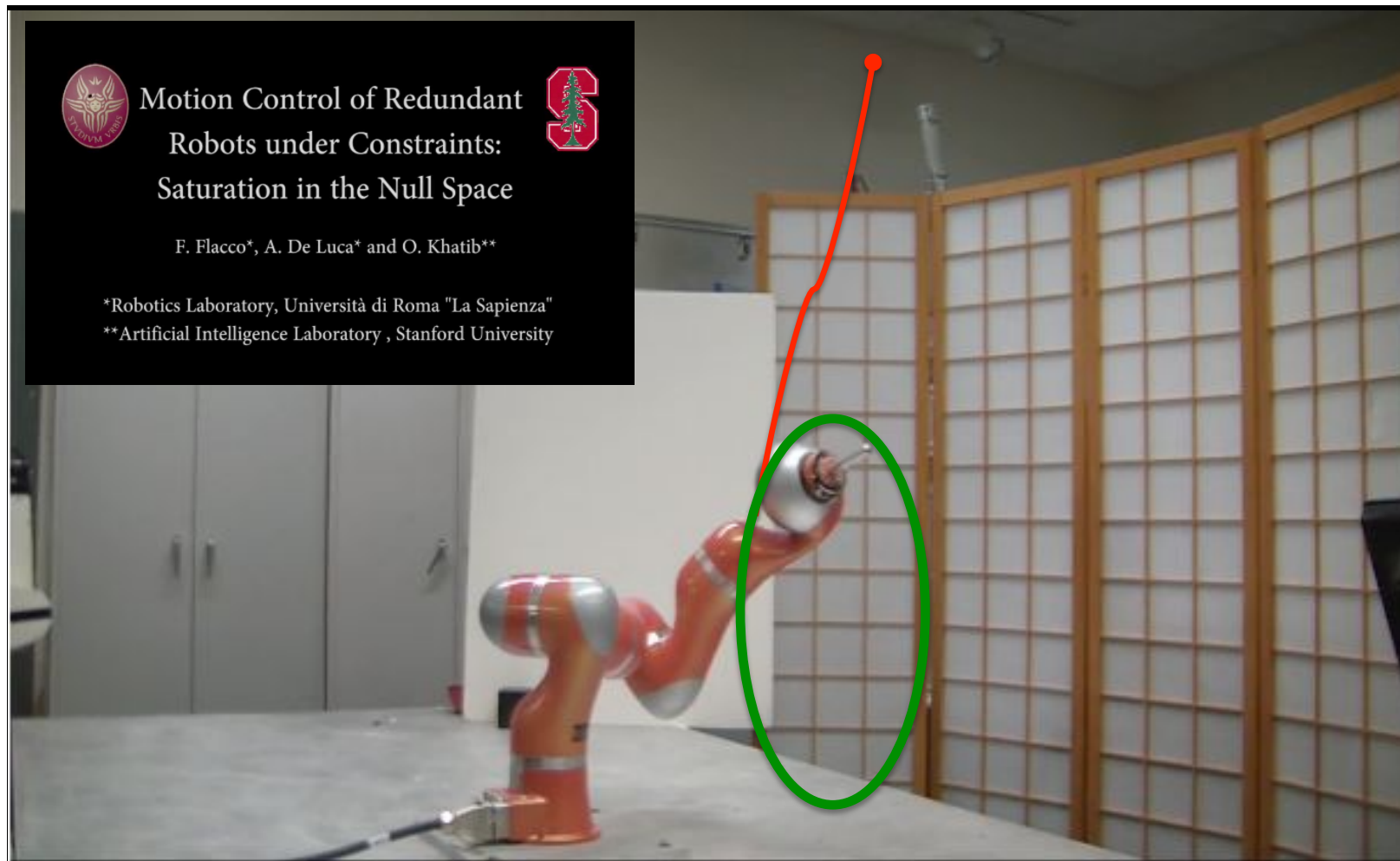
- **Introduction**
 - Manipulator arms (and some mobile robots)
 - Industrial and service applications
- **Components**
 - Mechanical structures
 - Actuators
 - Sensors
 - proprioceptive (encoder, tacho)
 - exteroceptive (force/torque, tactile, ultrasound, infrared, laser, vision)
- **Kinematic models**
 - Minimal representations of orientation
 - Direct and inverse kinematics of robot manipulators
 - Differential kinematics: analytic and geometric Jacobians
 - Statics: Transformations of forces
 - Robot singularities



Program *(continued)*

- **Planning of motion trajectories**
 - Trajectory planning in the joint space for robot manipulators
 - Trajectory planning in the task/Cartesian space
- **Control**
 - Control system architectures
 - Kinematic control laws (in joint or in task/Cartesian space)
 - Independent joint axis control laws (P, PD, PID)
- **Programming and Simulation**
 - Programming languages for industrial robots (**KRL**)
 - Use of Matlab/Simulink and VREP
 - Demos in the lab with the **KUKA** robots (**6-dof KR5** and **7-dof LWR4+**)

Tracking a Cartesian trajectory with hard position/velocity bounds on robot motion



video Sapienza/Stanford, IEEE ICRA 2012

Robot control by visual servoing with limited joint motion range



Avoiding joint limits with a low-level fusion scheme

Olivier Kermorgant and François Chaumette

Lagadic team
INRIA Rennes-Bretagne Atlantique

video INRIA Rennes, IEEE/RSJ IROS 2011

Sensor-based robot control in dynamic environment (coexistence with human)



A Depth Space Approach to Human-Robot Collision Avoidance

F. Flacco*, T. Kröger**, A. De Luca* and O. Khatib**

*Robotics Laboratory, Università di Roma "La Sapienza"
**Artificial Intelligence Laboratory, Stanford University

video Sapienza/Stanford, IEEE ICRA 2012

Safe physical human-robot interaction (sensorless and on a conventional industrial robot!)



DIAG Sapienza, IEEE ICRA 2013



Exams and beyond

- **Type:** homework + written test + oral examination
- **Schedule** (ALL sessions of 2014/15 are already open in INFOSTUD)
 - 2 sessions at the end of this semester
 - January 9, 2015 + February 6, 2015
 - 2 sessions at the end of next semester
 - June 5, 2015 + July 10, 2015
 - 1 session after the summer break
 - September 11, 2015
 - 2 extra sessions only for students of previous years, part-time, etc.
 - April 1, 2015 + October 27, 2015
- **Master theses**
 - available at DIAG Robotics Lab: www.diag.uniroma1.it/labrob
- **YouTube Channel** with more videos of research performed in the Lab
 - www.youtube.com/user/RoboticsLabSapienza



Preview of Robotics 2 (next semester)

- **Advanced kinematics / Robot dynamics**
 - Calibration
 - Redundant robots
 - Dynamic modeling: Lagrange and (recursive) Newton-Euler methods
 - Identification of dynamic parameters
- **Control techniques**
 - **Free motion:** linear and nonlinear feedback control, iterative learning, robust control, adaptive control
 - **Constrained motion:** impedance and hybrid force-velocity control
 - **Visual servoing** (kinematic approach)
- **Special topics**
 - Diagnosis and isolation of robot actuator faults
 - Human-robot collision avoidance & detection, with safe robot reaction



Other courses about Robotics...

- **Autonomous and Mobile Robotics (6 credits), next semester**
 - kinematics, planning, control of wheeled mobile robots
 - motion planning with obstacles, navigation, and exploration
 - Prof. Oriolo <http://www.diag.uniroma1.it/~oriolo/amr>
- **Medical Robotics (6 credits), next semester**
 - robot surgical systems and more
 - Dr. Vendittelli <http://www.diag.uniroma1.it/~vendittelli>
- **Elective in Robotics (12 credits), starting this semester**
 - four modules of 3 credits
 - research-related subjects and seminars
 - multiple teachers <http://www.diag.uniroma1.it/~vendittelli/eir>
- **Robot Programming (module: 3 credits in Elective in AI), in this semester**
 - robot programming using C++, ROS, NAO SDK as development frameworks
 - Prof. Nardi <http://www.diag.uniroma1.it/~nardi/Didattica/CAI/robpro.html>