Robotics 1

Information and Program

Prof. Alessandro De Luca

DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI

SAPIENZA
UNIVERSITÀ DI ROMA

Robotics 1 – 2015/16

- First semester (12 weeks)
  - Monday, October 5, 2015 – Monday, December 21, 2015
- Courses of study (with this course mandatory or explicitly in optional group)
  - Master in Artificial Intelligence and Robotics (MARR)
  - Master in Control Engineering (MCER)
- Credits: 6
  - 48 hours of classes, 2 of laboratory, 75 of individual study
- Classes
  - Monday ~~15:45-17:15~~ 8:30-10:00 (room B2, Via Ariosto 25)
    - starting from Monday, October 12
  - Friday 10:15-11:45, 12:00-13:30 (room B2)

Contacts

- Email deluca@diag.uniroma1.it
- Office hours
  - Tuesday 12:00-13:30 c/o 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 website www.diag.uniroma1.it/~deluca/rob1_en.html
- Extra material (pdf of lecture slides, videos, written exams, …)
  - available on the course website
    - lecture slides ready, but with updates during the course
- Video DIAG Channel playlist Robotics 1 full course 2014/15 videos
  - 30 (+1) videos in the classroom, about 41 h, > 8300 views
- YouTube Channel with more videos of research performed in the Lab
  - www.youtube.com/user/RoboticsLabSapienza

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

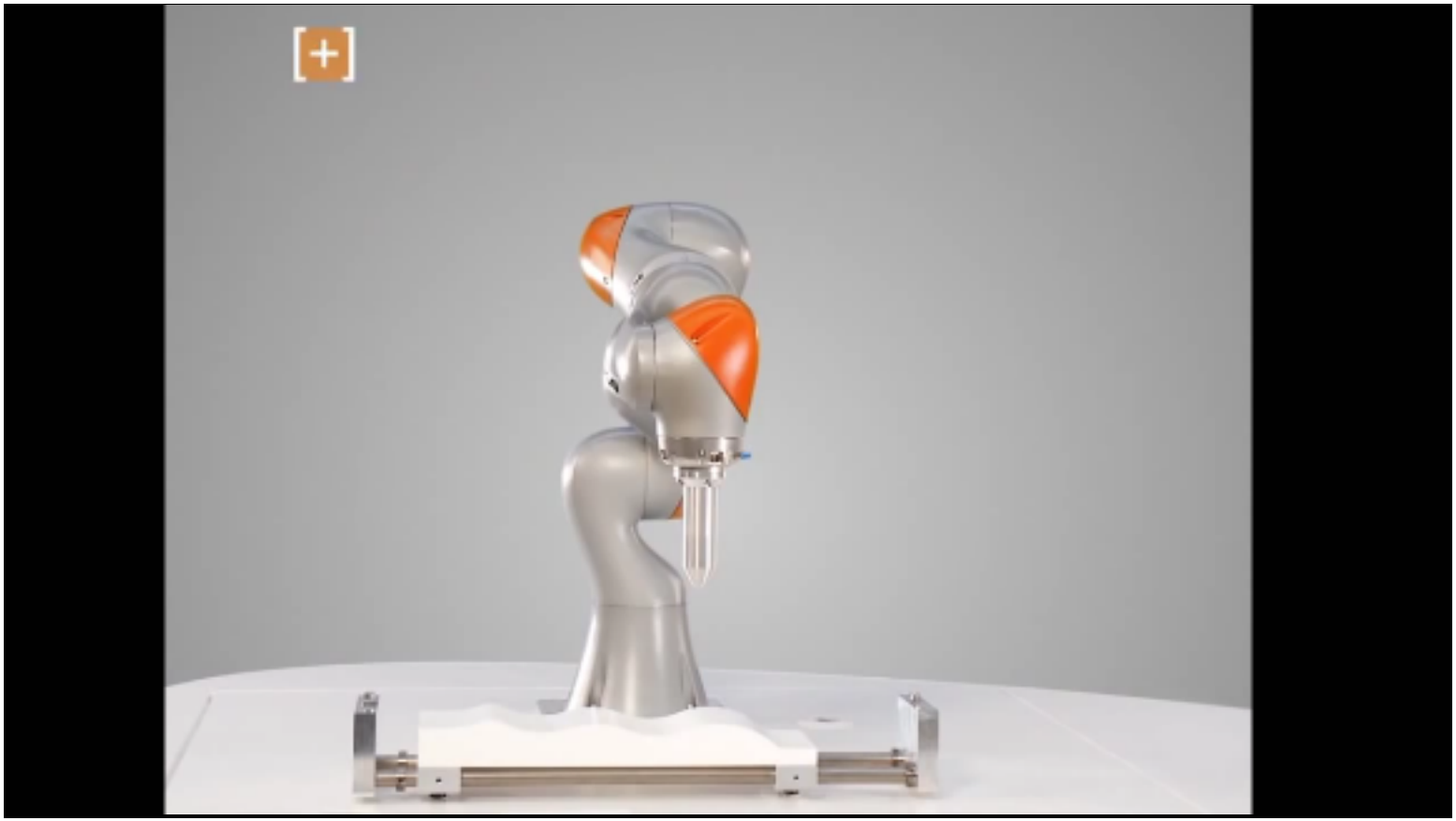
video

KUKA LBR iiwa robot with 7 revolute joints

Programming robot motion

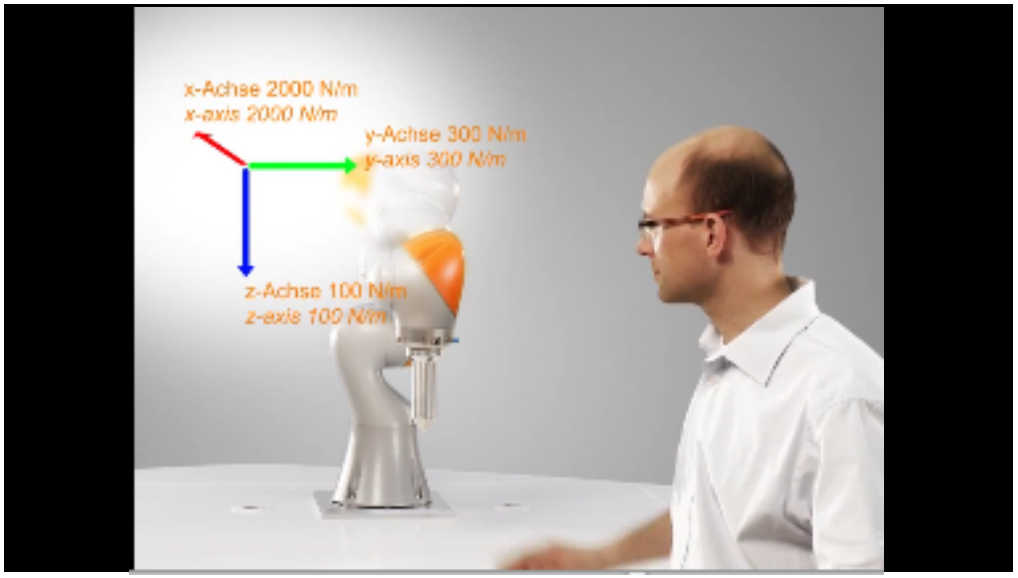
Executing nominal trajectories and "complying" with uncertainties

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

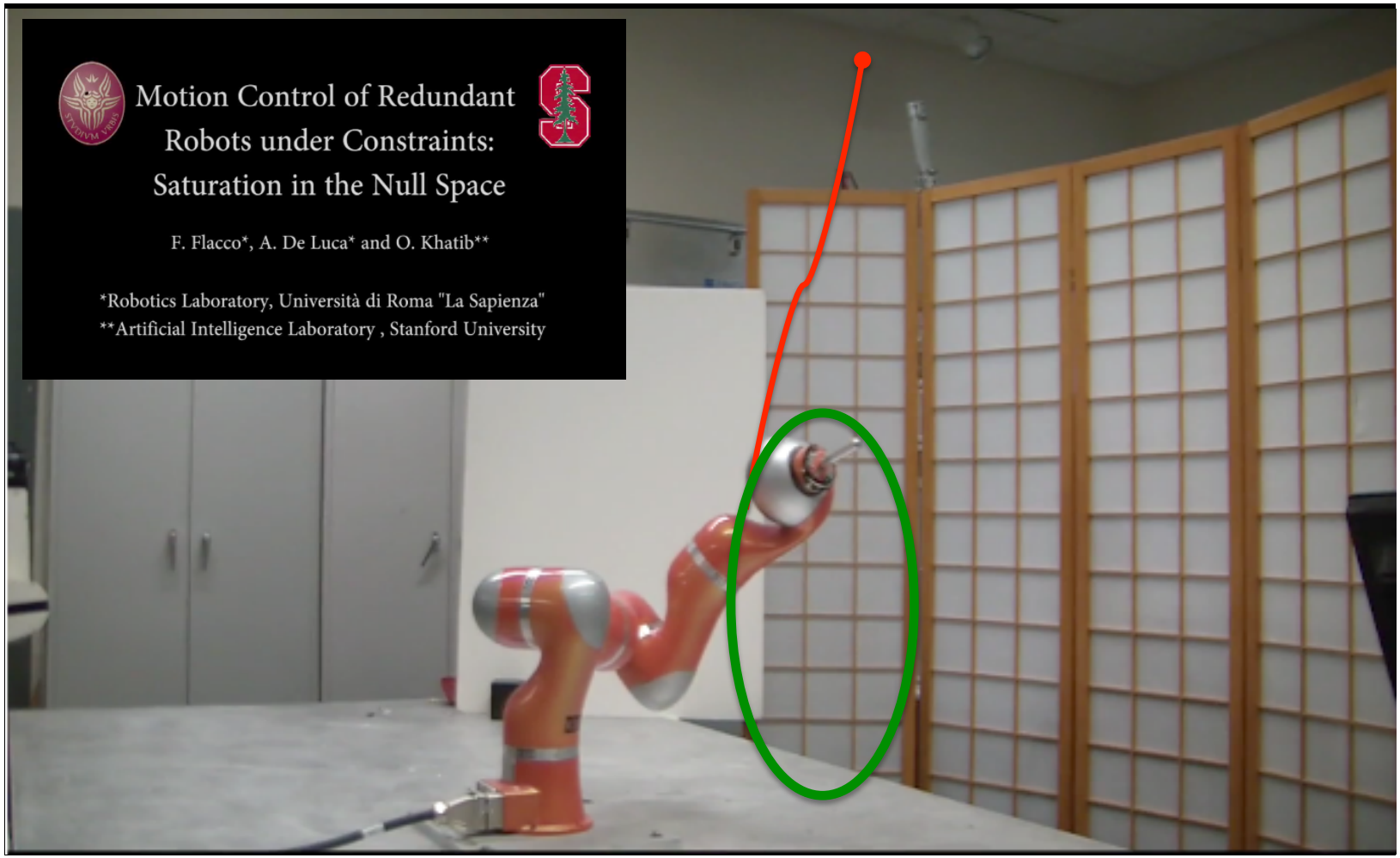
Program

- 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)*

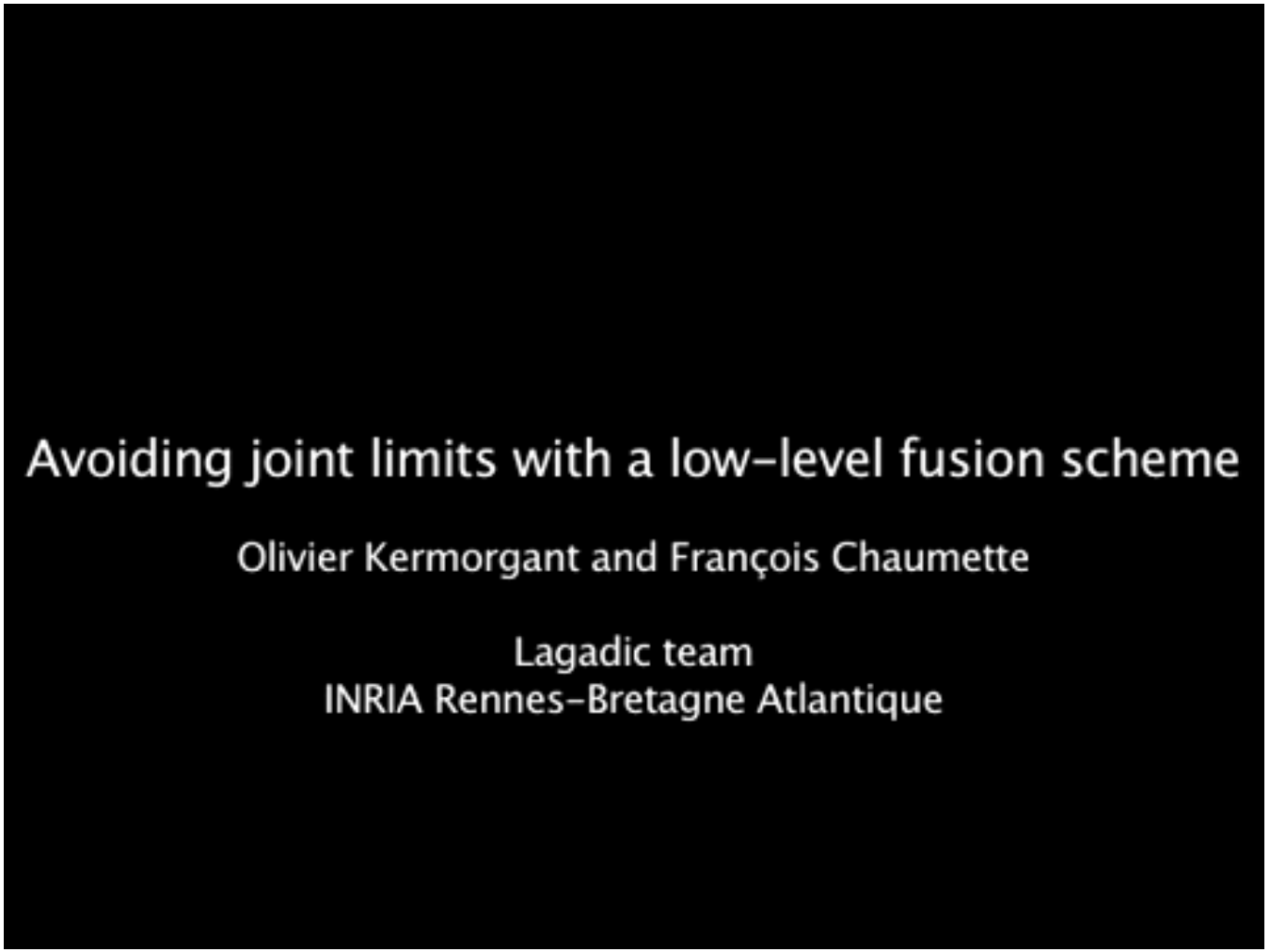
- Planning of motion trajectories
  - Trajectory planning in the joint space for robot manipulators
  - Trajectory planning in the task/Cartesian space
- Control
  - Control system architectures
  - Kinematic control laws (in joint or in task/Cartesian space)
  - Independent joint axis control laws (P, 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 DIAG-Sapienza/Stanford, IEEE ICRA 2012

Robot control by visual servoing with limited joint motion range



video INRIA Rennes, IEEE/RSJ IROS 2011

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

video DIAG-Sapienza/Stanford, IEEE ICRA 2012

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

video DIAG-Sapienza, IEEE ICRA 2013

Exams and beyond

- Type homework + written test + oral examination
- Schedule (written sessions of 2015/16, open soon in INFOSTUD)
  - 2 sessions at the end of this semester
    - January 11 and February 5, 2016
  - 2 sessions at the end of next semester
    - June 6 and July 11, 2016
  - 1 session after the summer break
    - September 11, 2016
  - *2 extra sessions only for students of previous years, part-time, etc.*
    - April 1, 2016 and in Fall (tbd in the period 19/10-11/11/2016)
- Registration to exams
  - www.uniroma1.it/infostud
- Master theses
  - available at DIAG Robotics Lab: www.diag.uniroma1.it/labrob

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 and Control...

- 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