Robotics 1

Information and Program

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DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI

SAPIENZA
UNIVERSITÀ DI ROMA

Robotics 1 – 2019/20

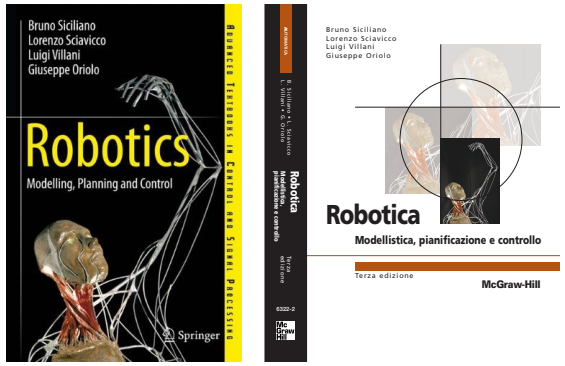
- First semester (12 weeks)
  - Tuesday, September 24, 2019 – Friday, December 20, 2019
- Courses of study (where this course is mandatory or present as optional)
  - Master in Artificial Intelligence and Robotics (MARR)
  - Master in Control Engineering (MCER)
- Credits: 6
  - 54 hours of classes + 6 of tests/laboratory, 90 of individual study
- Classes
  - Tuesday 8:00-10:00 (room B2, DIAG, Via Ariosto 25)
  - Friday 8:00-11:00, with break (room B2)

Contacts and materials

- Course website www.diag.uniroma1.it/deluca/rob1_en
- 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
- 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 classroom, about 41 h, > 52000 independent 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: II semester, 6 credits
  - Autonomous and Mobile Robotics: I semester (of year 2), 6 credits

Programming robot motion

Teaching Cartesian poses and playing them back

video

KUKA LBR iiwa robot with 7 revolute joints

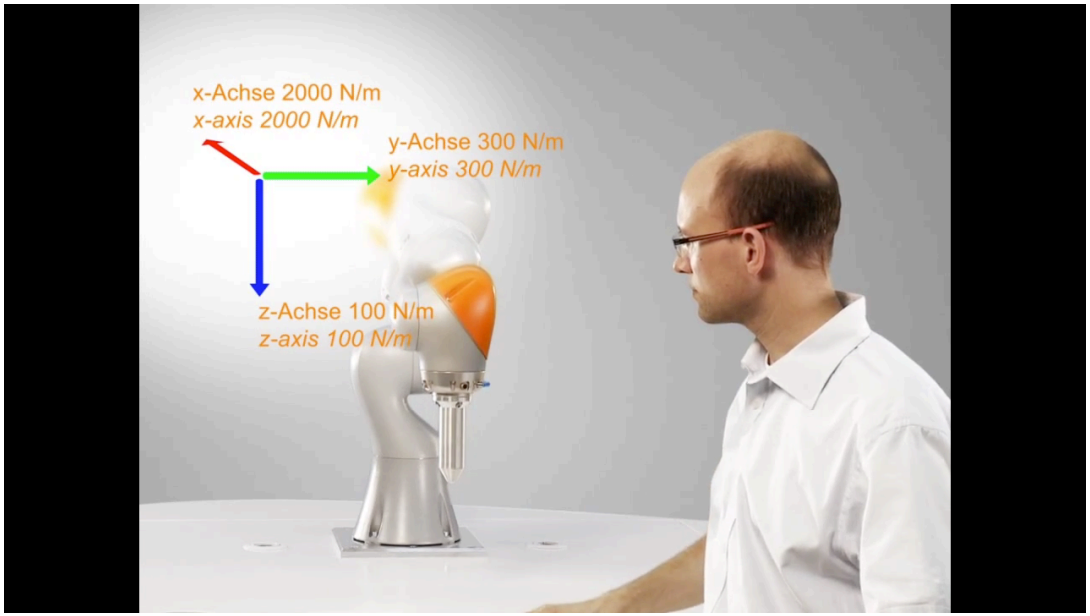
Programming robot motion

Executing nominal trajectories and "complying" with uncertainties

video

Programming robot compliance

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

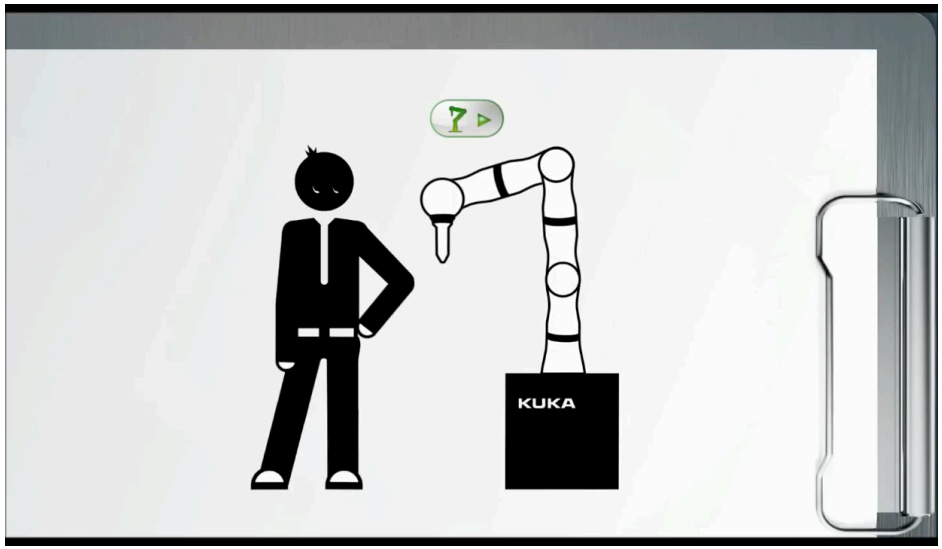


video

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 Robotics 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
    - Denavit-Hartenberg formalism for frame assignment
  - 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 with the KUKA robots (6-dof KR5; 7-dof LWR4+) and the Universal Robots (6-dof UR-10, with non-spherical wrist)

Robot manipulators
available in the DIAG Robotics Lab (S-218)

video

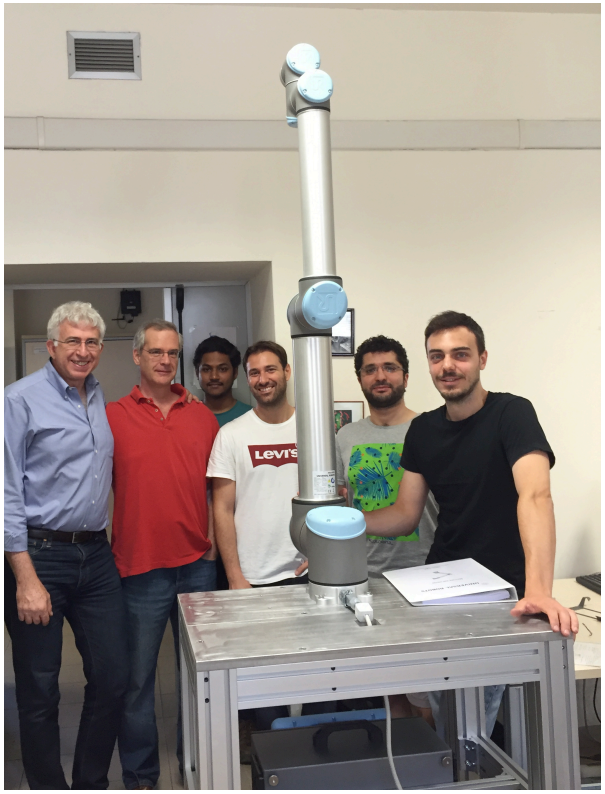
KUKA KR-5

video

KUKA LWR4+ (lightweight, about 14 kg)

Robot manipulators
available in the DIAG Robotics Lab (S-218)

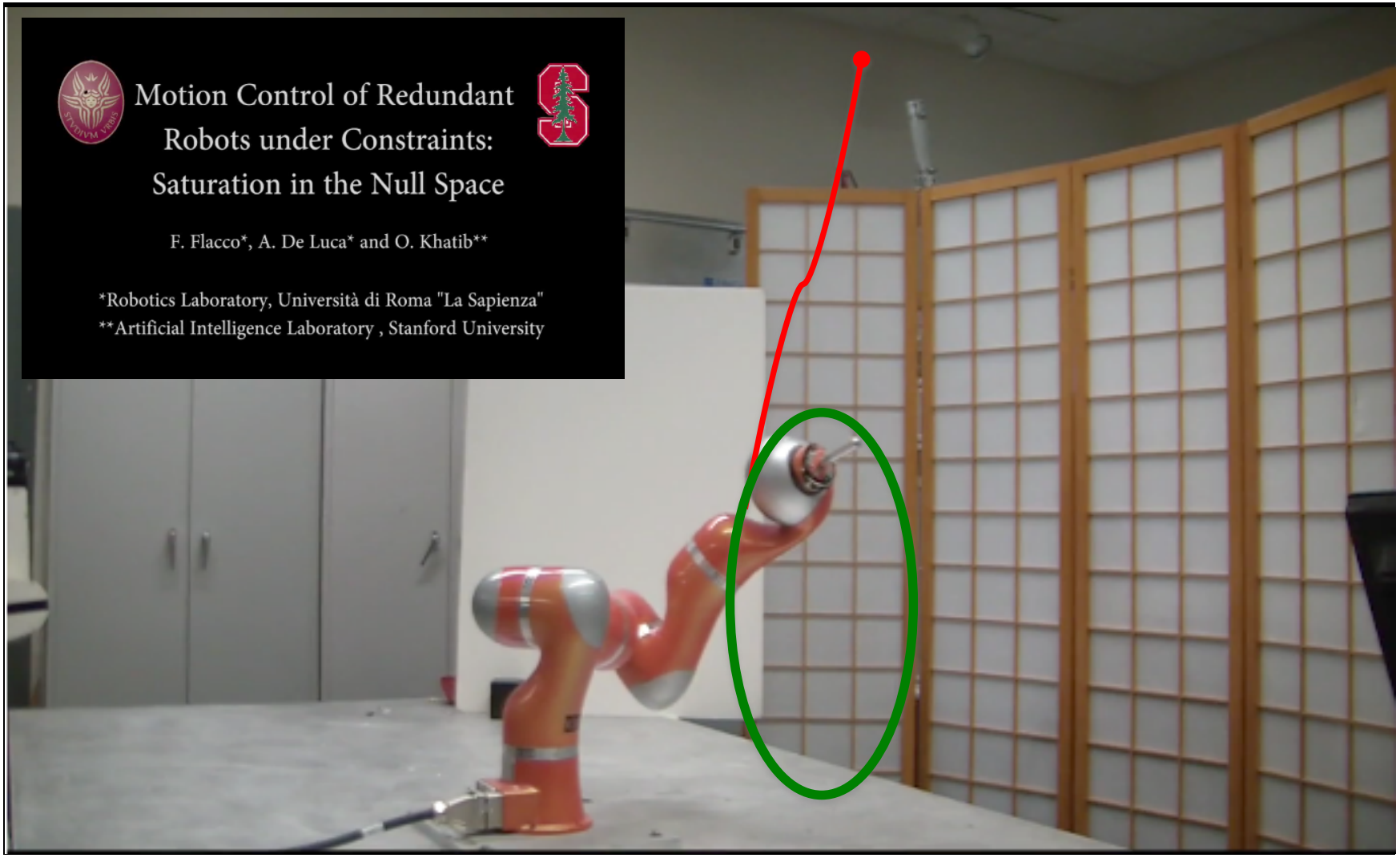
commercial video



upon arrival (July 2016)

Universal Robots UR-10 (= 10 kg of payload)

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



video DIAG-Sapienza/Stanford, IEEE ICRA 2012

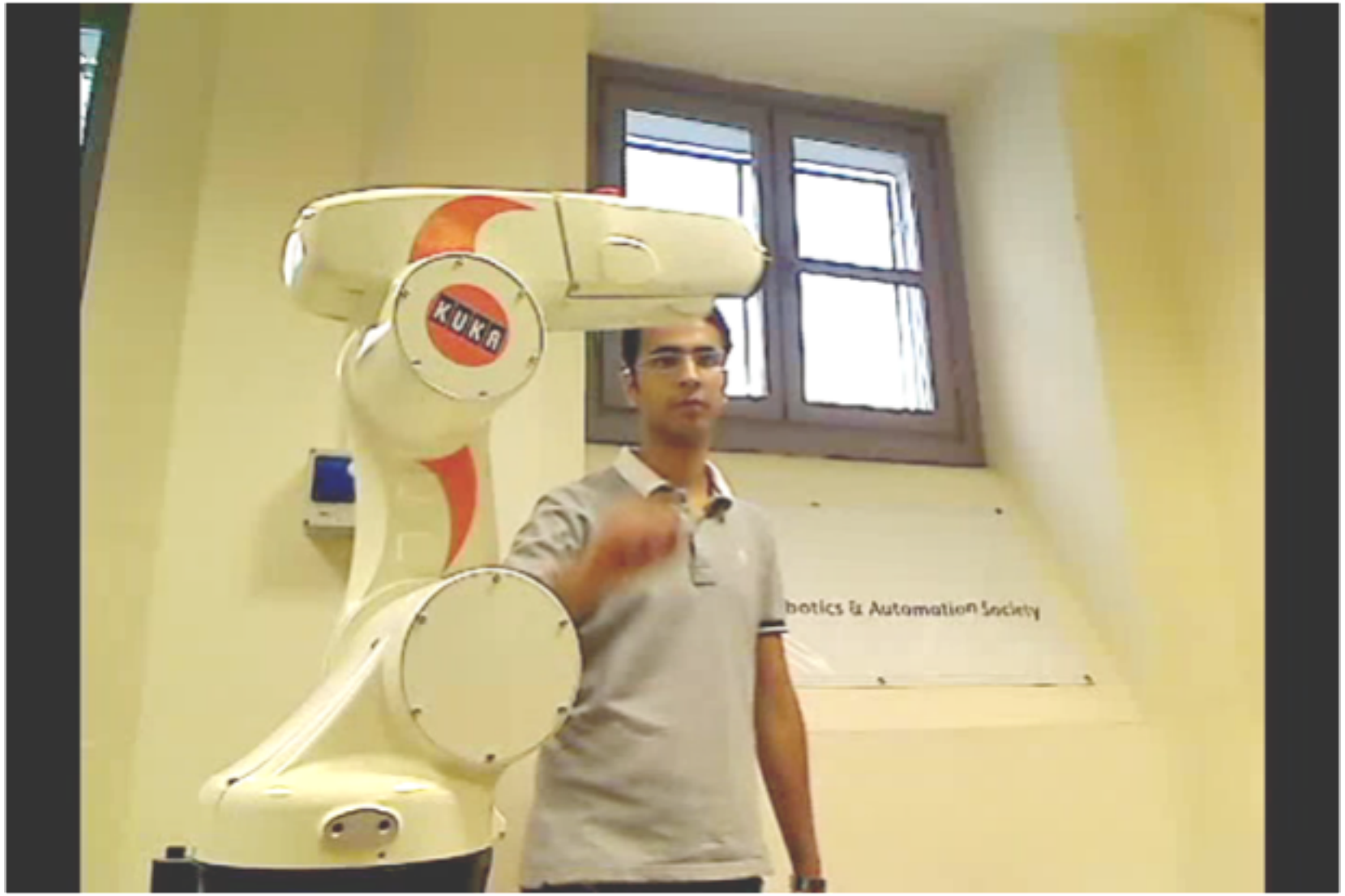
Robot control by visual servoing
with limited joint motion range

video INRIA Rennes, IEEE/RSJ IROS 2011

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

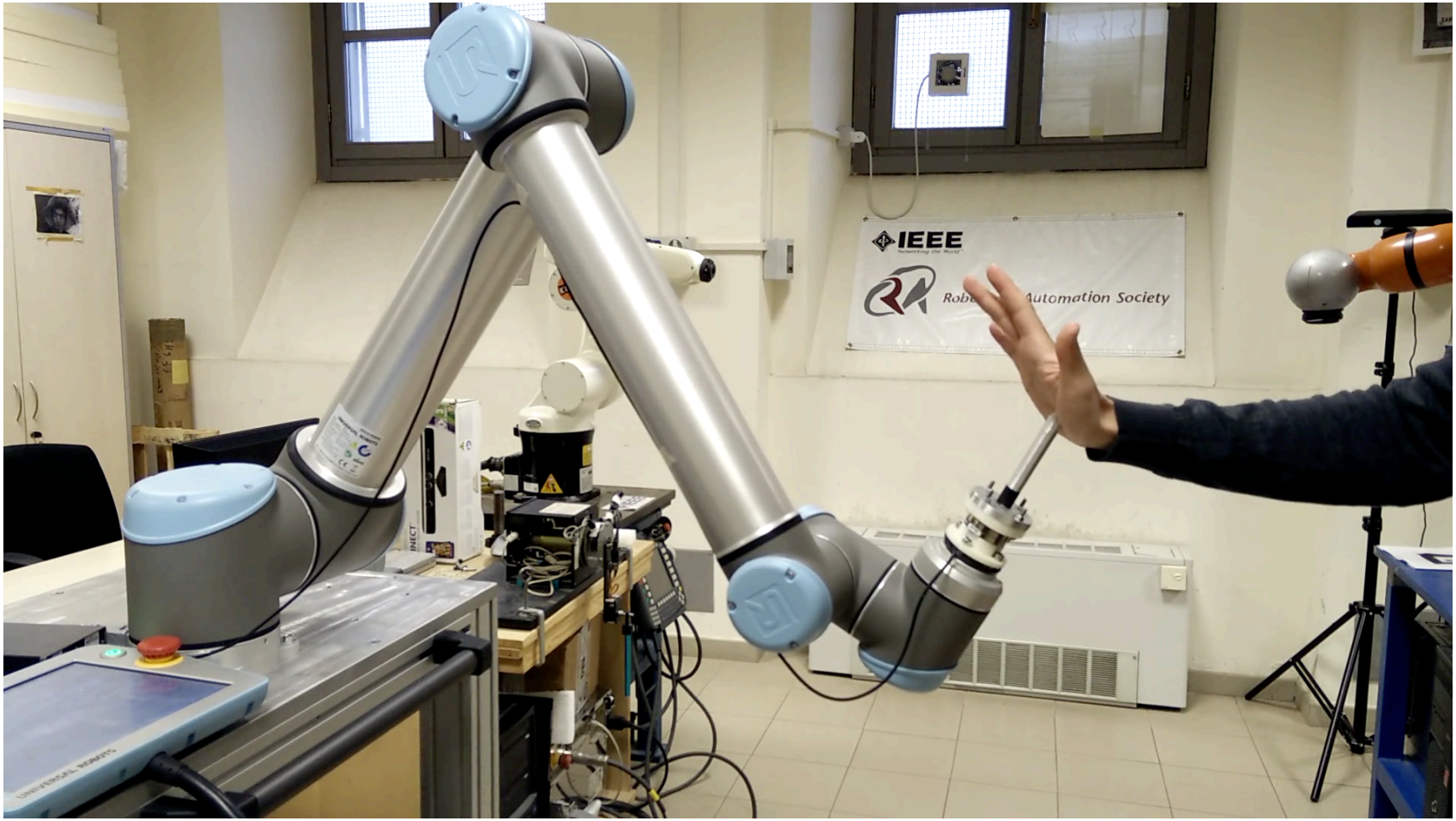
video DIAG-Sapienza/Stanford, IEEE ICRA 2012

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



video DIAG-Sapienza, IEEE ICRA 2013

Human-robot collaboration
(with a real F/T and a "virtual" sensor to distinguish contacts)



video DIAG-Sapienza, J. of Mechatronics, 2018

Exams and beyond

- Type homework/classroom test + written test + oral exam if needed
- Schedule (sessions of 2019/20: will open soon on Infostud)
  - 2 sessions at the end of this semester
    - between January 7 and February 20, 2020
  - 2 sessions at the end of next semester
    - between June 1 and July 24, 2020
  - 1 session after the summer break
    - between September 1 and 17, 2020
  - *2 extra sessions* **ONLY** *for students of previous years, part-time, ...*
    - March 16–April 16 and October 5–November 5, 2020

check the course website!

- Registration to exams
  - on Infostud
- Master theses
  - available at DIAG Robotics Lab: www.diag.uniroma1.it/labrob

Preview of Robotics 2 (next semester)

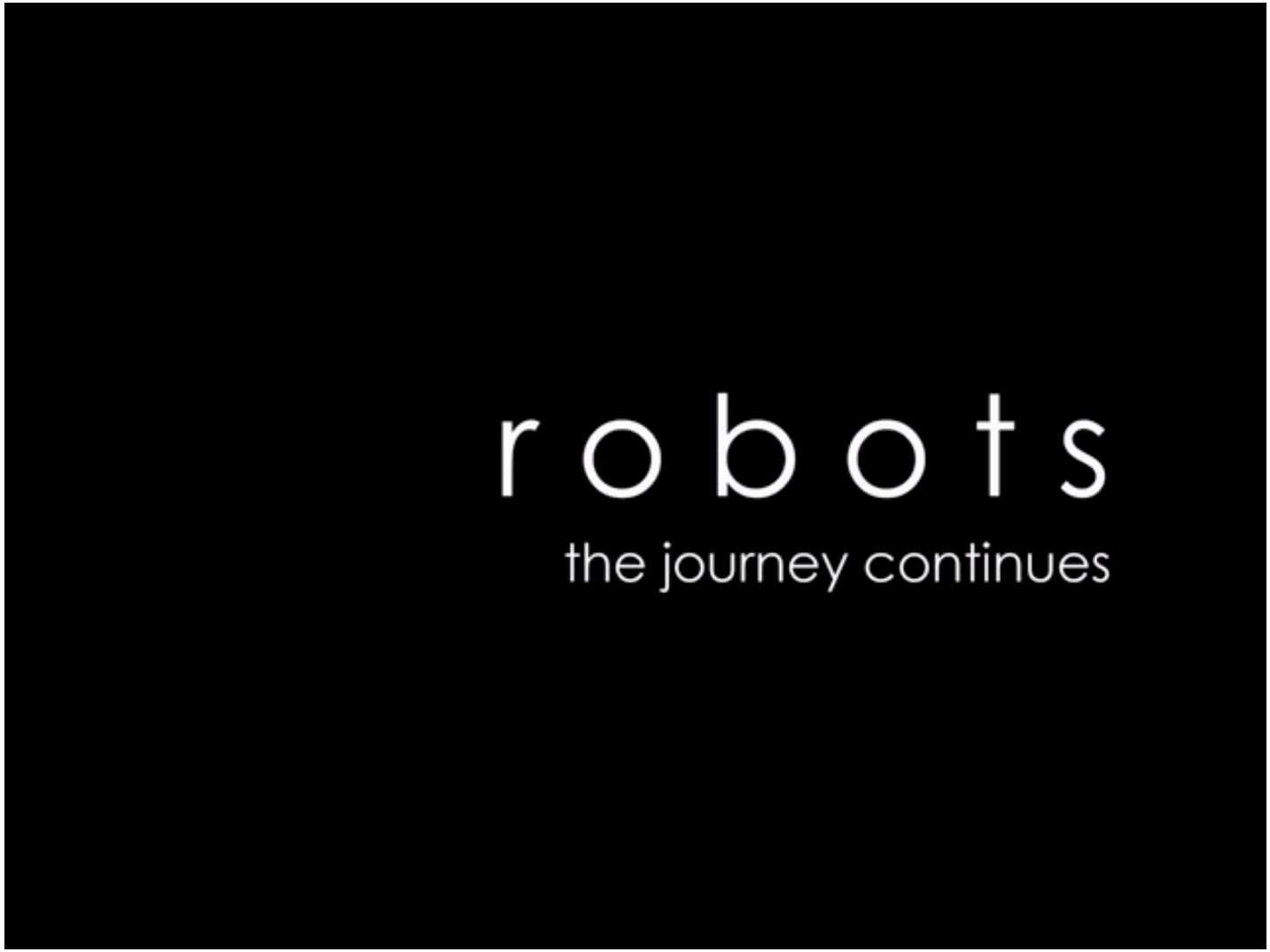
- Advanced kinematics / Robot dynamics
  - Calibration
  - Redundant robots
  - Dynamic modeling: Lagrange and (recursive) Newton-Euler methods
  - Identification of dynamic parameters
- Control techniques
  - Free motion linear and nonlinear feedback control, iterative learning, robust control, adaptive 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), I semester, year 2
  - kinematics, planning, control of wheeled and legged mobile robots
  - motion planning with obstacles, navigation, and exploration
  - Prof. Oriolo www.diag.uniroma1.it/oriolo/amr
- Medical Robotics (6 credits), II semester
  - robot surgical systems, haptics, and more ...
  - Prof. Vendittelli www.diag.uniroma1.it/vendittelli/didattica/mr
- Elective in Robotics (12 credits) or Control Problems in Robotics (6 credits)
  - I-II semesters, starting this semester
  - 4 modules of 3 credits (for CPR, MCER students take 2 modules out of the 4 in EiR)
  - research-related subjects and seminars
  - multiple teachers www.diag.uniroma1.it/lanari/EIR
- Robot Programming (lectures, not for credits!)
  - robot programming using C++, ROS, NAO SDK as development frameworks
  - see Prof. Nardi www.diag.uniroma1.it/nardi/Didattica/CAI/robpro-free

Robotics around the world...

Springer Handbook of Robotics (2nd Edition, July 2016)



https://vimeo.com/173394878