ROBOTICS, VISION AND CONTROL

Introduction

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ALTAIR robotics lab

Robotics, Vision and Control – General Info

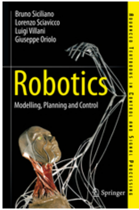
- Master degree: Computer Engineering for Robotics and Smart Industry
- Year | Semester: 1° | II
- ECTS (theory | lab): 6 (4 | 2)
- Prerequisites: Robotics (Master), Advanced Control Systems (Master), Computer Vision (Master)
- Teachers: Umberto Castellani (24h), Nicola Piccinelli (24h)

Robotics, Vision and Control – General Info

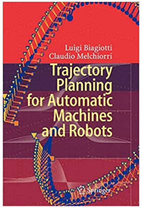
- Classes (2023/2024)
  - Wednesday 14.30–16.30 (room M)
  - Friday 13.30–15.30 (room M)
- Communications via Moodle
- *Robotics, Vision and Control* is a course of the *Robotics systems* path

Robotics, Vision and Control – General Info

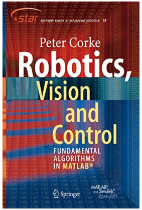
Lectures are based on the textbooks



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



L. Biagiotti, C. Melchiorri, *Trajectory Planning for Automatic Machines and Robots*, Springer, 2008



P. Corke, *Robotics, Vision and Control*, Springer, 2011

All the functions are in Matlab in these toolboxes:

- Robotics Toolbox for MATLAB, Machine Vision Toolbox for MATLAB, Spatial Math Toolbox for MATLAB
- Robotics Toolbox for Python, Machine Vision Toolbox for Python, Spatial Maths Toolbox for Python

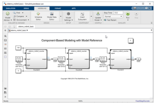
Several pictures from those books have been copied and pasted here

The pdf's of the slides will be uploaded on the course webpage.

Matlab

- Robotics System Toolbox
- Control System Toolbox
- Image Processing Toolbox
- Computer Vision Toolbox

PDF Documentations available on line for both Toolbox



Matlab/Simulink

- simulate the robot dynamics
- implement the control architectures

ROS

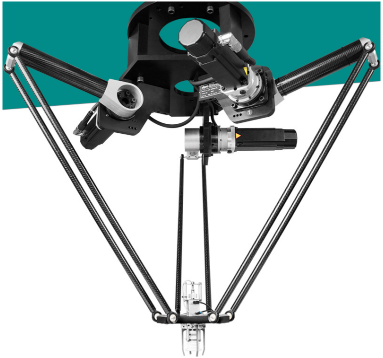
ROS: Robot Operating Systems

- implement the control architectures on real robots

Topics

Why Robotics + Vision + Control?

Video pick–and–place task



The system needs to

- Identify the target on the image
  $\Rightarrow$ *Computer Vision algorithm & Machine learning*
- Estimate the target position (static or dynamic).
  $\Rightarrow$ *Calibration & Registration*
- Plan a feasible trajectory in the operational space
  $\Rightarrow$ *Trajectory planning*
- Control the robot
  $\Rightarrow$ *Motion control*

Topics

1. Trajectory planning:
   - Joint space VS Operational Space
   - Point–to–Point VS Sequence of points
   - Model-based
   - Constraints
2. Computer Vision
   - 3D acquisition systems
   - Image processing for recognition
   - Hand eye calibration
3. Visual servoing
   - Integration of visual feedback and joint measurements
   - Dynamic collision-free trajectory
   - Optimal approaching pose (kind of objects, kind of graspers/grippers)

Exam

The exam consists of a “course-long” project:

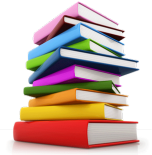
- the dynamics model of the UR5 robot will be given to you

Students have to implement, e.g.,

- algorithms to plan a trajectory
- hand-eye calibration procedures
- recognition algorithms
- dynamics collision free trajectories
- visual-servoing control (in simulation and, hopefully, on the real robot)
- ...

The exam will be only oral and students should prepare a brief technical report and describe their work by explaining the simulations and motivating the design choices.

From knowledge to Competence



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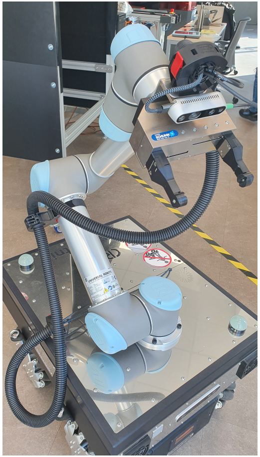
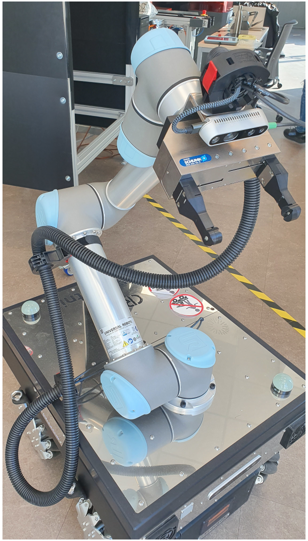
UR5 Robot

Universal Robots UR5



Universal Robots UR5

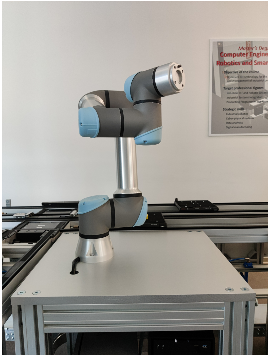


The UR5 is mounted on the RB Kairos mobile robot by Robotnik

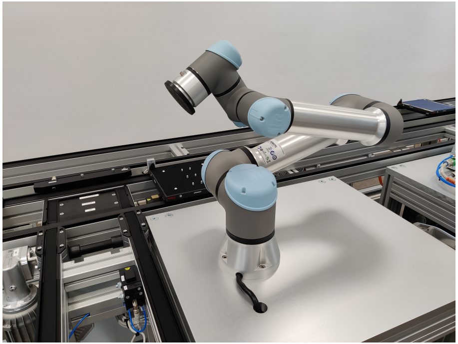
At the end effector there are

- a Schunk gripper
- a Realsense RGBD camera

Universal Robots UR5e



Universal Robots UR5e



At the end effector there *will* be

- a *home-made* vacuum gripper like

but with strain-gauges to measure interaction forces and torques.

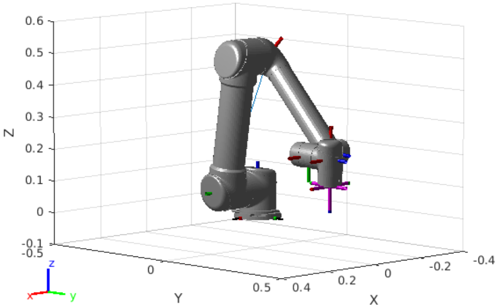
Both robots **cannot** be naively controlled using torque control!

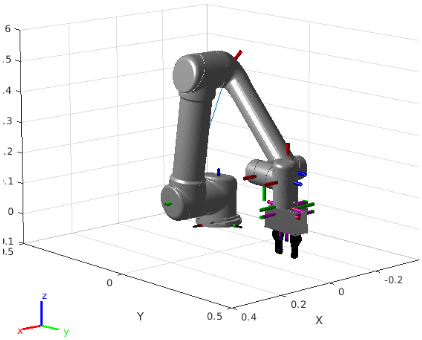
We cannot by-pass

- a velocity controller with gravity compensation, or
- a position controller with gravity compensation.

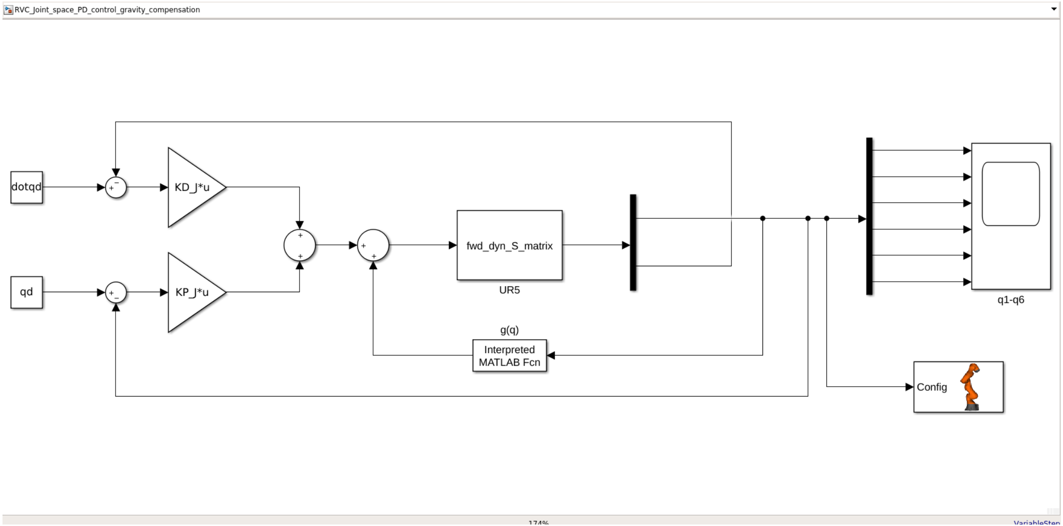
Simulated Robot (Matlab/Simulink)

Universal Robots UR5

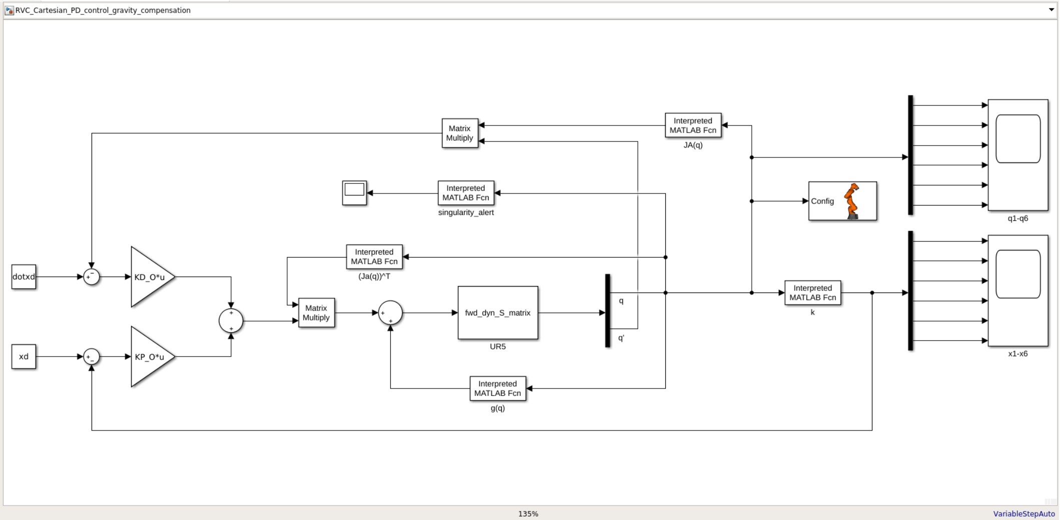




Joint PD Control with Gravity Compensation

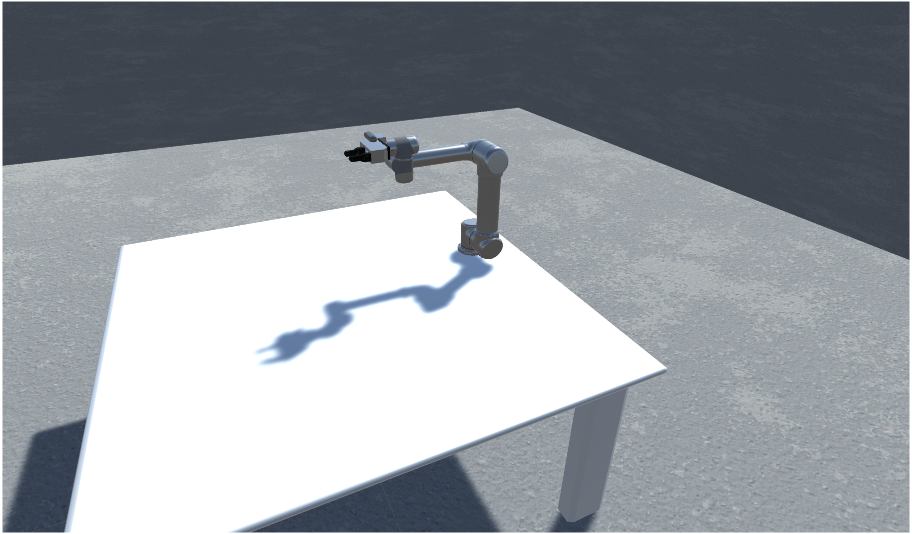


Operational PD Control with Gravity Compensation



Simulated Robot (ROS/Unity)

Universal Robots UR5



Universal Robots UR5