Robotics 2

Course Projects 2022-23

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DIPARTIMENTO DI INGEGNERIA INFORMATICA
AUTOMATICA E GESTIONALE ANTONIO RUBERTI

SAPIENZA
UNIVERSITÀ DI ROMA

Rules on projects

1. Groups of up to 2 students
2. To be completed anytime, but no later than by end of December 2023
   - written report with results (source + pdf), software, videos, ppt/keynote presentation (+ pdf version) ⇒ all on G-drive folder
   - upon delivery, a date is agreed for presentation (20 min + Q&A)
   - final grade takes into account the result of the Midterm Test
   - in case of no show/delay ⇒ complete conventional exam
3. Some topics may develop into Master theses
4. Reference papers available on the following G-drive

   https://drive.google.com/drive/folders/14fmBOz-y_z1IiBecG9O57LM4qOMVWeFH?usp=sharing
   - you have editing access with your Sapienza account
   - when you are done, create your own folder therein with your materials

Complete list of qualifying students

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9	SCANDIUZZI	Elisa	**B**	MARR	scandiuzzi.2069444@studenti.uniroma1.it
10	SCHIAVELLA	Claudio	**B**	MARR	schiavella.1884561@studenti.uniroma1.it
11	CARBONI	Paola	**B-**	MARR	carboni.1811419@studenti.uniroma1.it
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13	SPAGNOLI	Valerio	**B-**	MARR	spagnoli.1887715@studenti.uniroma1.it

1. On-line task scaling at acceleration/torque level

- in the presence of hard bounds on position, velocity, and acceleration/torque
- two cases: robot non-redundant (e.g., joint space trajectory) or redundant (Cartesian trajectory) for the task
- with possible experiments of the KUKA LWR 7R robot
- references
  - C. Guarino Lo Bianco and O. Gerelli, "Online trajectory scaling for manipulators subject to high order kinematic and dynamic constraints," *IEEE Trans. on Robotics,* 27(6), 1144-1152, 2011
  - F. Flacco, A. De Luca, and O. Khatib, "Prioritized multi-task motion control of redundant robots under hard joint constraints," *Proc. IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, 3970-3977, 2012
- students:

2. Neural network control of a UR10 robot

- implement the NN-based controller in [1] for trajectory tracking
  - on a 3R planar arm
  - on the 6R UR10 robot
- compare its performance with the adaptive controller in [2]
- references
  - [1] F. L. Lewis, A. Yesildirek, and K. Liu, "Multilayer neural-net robot controller with guaranteed tracking performance," *IEEE Trans. on Neural Networks*, 7(2), 388-399, 1996
  - [2] J.-J. E. Slotine and W. Li, "On the adaptive control of robot manipulators," *Int. J. of Robotics Research*, 6(3), 49-59, 1987
  - C. Gaz, E. Magrini, and A. De Luca , "A model-based residual approach for human-robot collaboration during manual polishing operations," *Mechatronics*, 55, 234-247, 2018
- students:

3. Vibration reduction via command shaping for a one-link flexible arm

- evaluate the command shaping technique of [1] on a one-link flexible arm with revolute joint
- evaluate the performance of the filter on the linear model used for its design and on a nonlinear model of the arm, see [2]
- references
  - [1] N. C. Singer and W. P. Seering, "Preshaping command inputs to reduce system vibration," *Trans. ASME J. of Dynamic Systems, Measurement, and Control*, 112(1), 76–82, 1990
  - [2] A. De Luca and B. Siciliano, "Trajectory control of a non-linear one-link flexible arm," *Int. J. of Control,* 50(5), 1699-1715, 1989
  - A. De Luca and B. Siciliano, "Flexible links," in C. Canudas de Wit, B. Siciliano, G. Bastin (Eds.), *Theory of Robot Control,* 221-263, Springer, 1996
- students:

4. Joint torque control

- a comparative performance analysis by simulation of joint torque control laws, possibly including in the design
  - transmission elasticity (e.g., Harmonic Drive), friction phenomena
  - observer of unmeasured quantities
- multiple references
  - M. Hashimoto et al., "Experimental study on torque control using harmonic drive built-in torque sensors," *Proc. IEEE Int. Conf. on Robotics and Automation*, 2026-2031, 1992
  - D. Visher and O. Khatib, "Design and development of high-performance torque-controlled joints," *IEEE Trans. on Robotics and Automation*, 11(4), 537-544, 1995
  - L. Le Tien et al., "Friction observer and compensation for control of robots with joint torque measurement," *Proc. IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, 3789-3794, 2008
  - T. Kawakami et al., "High-fidelity joint drive system by torque feedback control using high precision linea encoder," *Proc. IEEE Int. Conf. on Robotics and Automation*, 3904-3903, 2010
  - M. Osada et al., Honda Motor Co., "Control system for power unit," *US Patent 2017*
- students:

5. Dynamic modeling and rest-to-rest motion for a one-link flexible arm with flexible joint

- Euler-Bernoulli modeling of a flexible link with elastic joint, using a finite number of modes and dynamic boundary conditions
- rest-to-rest motion in finite given time
- references
  - D. Li, J.W. Zu, and A.A. Goldenberg, "Dynamic modeling and mode analysis of flexible-link, flexible-joint robots," *Mechanism and Machine Theory*, 33(7), 1031-1044, 1998
  - A. De Luca and G. Di Giovanni, "Rest-to-rest motion of a one-link flexible arm," *Proc. IEEE/ASME Int. Conf. on Advanced Intelligent Mechatronics*, 923-928, 2001
- students:

6. Data-driven identification of a one-link robot with flexible joint

- identify the dynamic model of a one-link robot with flexible joint using the Lagrangian neural network of [1]
- extra: use the identified model to control the robot as in [2]
- references
  - [1] M. Cranmer, S. Greydanus, S. Hoyer, P. Battaglia, D. Spergel, and S. Ho, "Lagrangian neural networks," *Preprint arXiv:2003.04630,* 2020
  - [2] P. Tomei, "A simple PD controller for robots with elastic joints," *IEEE Trans. on Automatic Control*, 36(10), 1208-1213, 1991
- students:

7. Adaptive feedforward + PD control for trajectory tracking

- online adaptation of the feedforward inverse dynamics command for trajectory tracking of rigid robots
- completed by a PD command with suitable gains
- references
  - V. Santibanez and R. Kelly, "Global convergence of the adaptive PD controller with computed feedforward for robot manipulators," *Proc. IEEE Int. Conf. on Robotics and Automation*, 1831-1836, 1999
  - V. Santibanez and R. Kelly, "PD control with feedforward compensation for robot manipulators: analysis and experimentation," *Robotica*, 19, 11-19, 2001
- students:

Assignments to students

Final status on **May XX**

Student	Group	Project
	1	
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Assignment of projects

Final status on **May XX**

#	Project	Student(s)
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