Control of Industrial Robots

Prof. Rocco

January 29, 2019

NAME:
UNIVERSITY ID NUMBER:

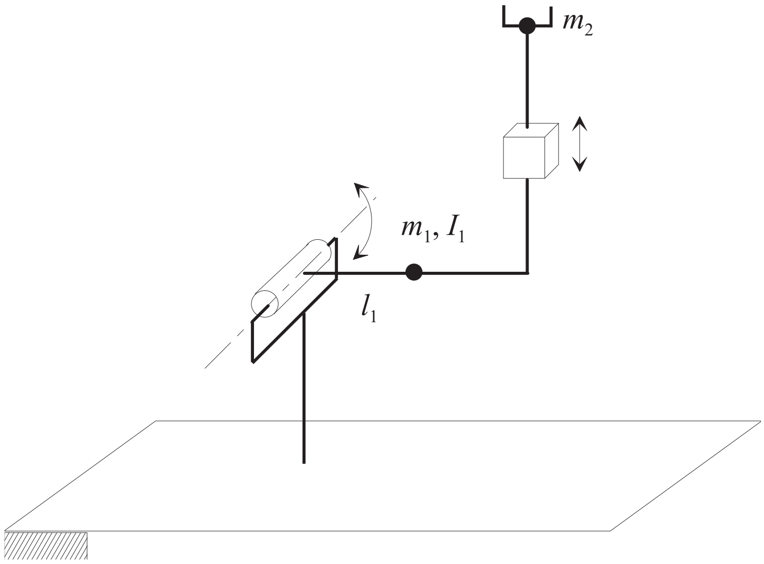
SIGNATURE: ______________________________

Warnings

- This file consists of **8** pages (including cover).
- During the exam you are not allowed to exit the room for any other reason than handing your work or withdrawing from the exam.
- You are not allowed to withdraw from the exam during the first 30 minutes.
- During the exam you are not allowed to consult books or any kind of notes.
- You are not allowed to use calculators with graphic display.
- Solutions and answers can be given **either in English or in Italian**.
- Solutions and answers must be given **exclusively in the reserved space**. Only in the case of corrections, or if the space is not sufficient, use the back of the front cover.
- The clarity and the order of the answers will be considered in the evaluation.
- At the end of the test you have to **hand this file only**. Every other sheet you may hand will not be taken into consideration.

EXERCISE 1

1. Consider the manipulator sketched in the picture, where the mass of the second link is assumed to be concentrated at the end-effector:



Find the expression of the inertia matrix $\mathbf{B}(\mathbf{q})$ of the manipulator.

2. Compute the matrix $\mathbf{C}(\mathbf{q}, \dot{\mathbf{q}})$ of the Coriolis and centrifugal terms[38] for this manipulator.

3. Check that the expression $\dot{\mathbf{q}}^T \mathbf{N}(\mathbf{q}, \dot{\mathbf{q}})\dot{\mathbf{q}} = 0$, where $\mathbf{N}(\mathbf{q}, \dot{\mathbf{q}}) = \dot{\mathbf{B}}(\mathbf{q}) - 2\mathbf{C}(\mathbf{q}, \dot{\mathbf{q}})$, is true in this case.

4. Write the complete expression of the kinetic energy for this specific manipulator.

[38]The general expression of the Christoffel symbols is $c_{ijk} = \frac{1}{2}\left(\frac{\partial b_{ij}}{\partial q_k} + \frac{\partial b_{ik}}{\partial q_j} - \frac{\partial b_{jk}}{\partial q_i}\right)$

EXERCISE 2

1. Consider a kinematically redundant manipulator. Explain what the "null-space motions" are, and write an expression for the null-space motions, explaining the meaning of each symbol used.

2. Define what is a repeatable, or cyclic, method for kinematic redundancy resolution. Explain what are the advantages in using a repeatable method.

3. Write the expression of the extended Jacobian method for redundancy resolution and explain why it is repeatable.

4. Consider now motion planning of the end-effector position. Select as an initial point $\mathbf{p}_i = [0, 0, 1]$ and as a final point $\mathbf{p}_f = [2, 2, 2]$. Write the expression of a segment connecting the initial and the final points, parameterized with the natural coordinate.

   If the end-effector task is expressed in terms of position only, what is the minimum number of joints for the manipulator to be redundant with respect to this task?

EXERCISE 3

1. Sketch the scheme of a current control loop used in a servomechanism.

2. Explain what is the role of a current controller within the control of a servomechanism. Suppose that the servomechanism lacks a current controller: what would be the control variable for speed control in this case?

3. Draw the scheme of a speed control loop for a servomechanism, and explain where the current control closed loop would enter in this speed control loop if we took it into account.

4. Assume now the following values for the physical parameters of the servomechanism.

$$\begin{aligned} J_m &= 0.01 \ kgm^2 \\ D_m &\approx 0 \\ \rho &= 3 \end{aligned}$$

where ρ is the inertia ratio. Design a speed PI controller in such a way to obtain a crossover frequency $\omega_{cv} = 100$ rad/s.