Control of industrial robots

(Prof. Rocco)

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Name: .....

University ID number:.....

Signature:.....

Warnings:

- This file consists of **8** pages (including cover). All the pages should be signed.
- 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.

Use this page ONLY in case of corrections or if the space reserved for some answers turned out to be insufficient

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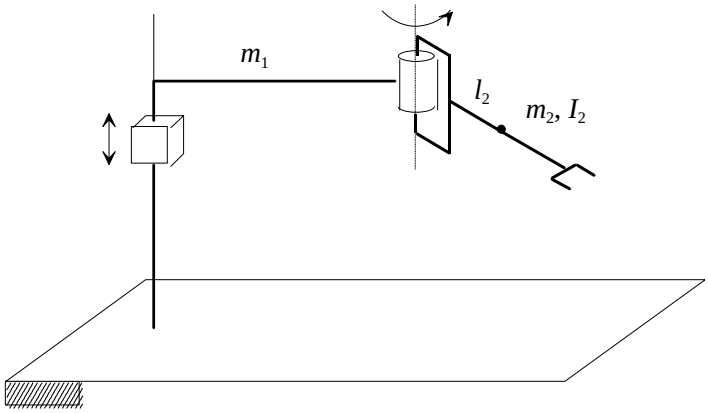
Exercise 1

Consider the manipulator sketched in the picture:



1.1 Find the expression of the inertia matrix of the manipulator.

1.2 Compute the gravitational terms for this manipulator.

1.3 Write the complete dynamic model of the manipulator.

1.4 Write the expression of an inverse dynamics controller for this manipulator. What would be the difference in this case with a PD + gravity compensation controller?

Exercise 2

2.1 Write the parametric expression of a segment in space, used for planning a linear path.

2.1 Write the parametric expression of a circumference in space, used for planning a circular path.

2.3 Define the problem of path planning with obstacle avoidance, making reference to the concept of configuration space of the robot.

2.4 Explain what are probabilistic methods, how they work in general and what are the most popular ones.

Exercise 3

3.1 Draw the scheme of a current controller used in a servomechanism.

3.2 Explain what is the role of a current controller within the control of a servomechanism.

3.3 Consider now a P/PI position/speed control system for a rigid servomechanism.

Assume the following values for the physical parameters:

$J_m = 0.01\ Kg\ m^2$

$D_m \cong 0$

$\rho = 4$ (inertia ratio)

Design a speed PI controller in such a way to obtain a crossover frequency $\omega_{cv} \cong 100$ rad/s

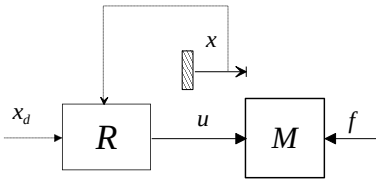
3.4 Design a P position controller in such a way to obtain a crossover frequency $\omega_{cp} \cong 20$ rad/s.

Exercise 4

4.1 Explain what is the mechanical impedance and for what reason it is interesting to assign a prescribed impedance to a mechanical system.

4.2 With reference to the one degree of freedom system sketched in the picture, suppose that you want to design an implicit impedance controller, which makes use of the measurement of the force at the end-effector.

Draw the block diagram of the controller.



4.3 Explain what result can be obtained with the control scheme previously described.

4.4 Explain how an impedance controller can be used to manually guide an industrial robot.