Control and Robotics in Medicine
2017-2018

Deliverable D3

October 17, 2017

Deadline: November 10th, 2017 - 9:00
Total mark contribution: 40 %
Modality: Workgroup

This deliverable is based on the robot of Figure 1.

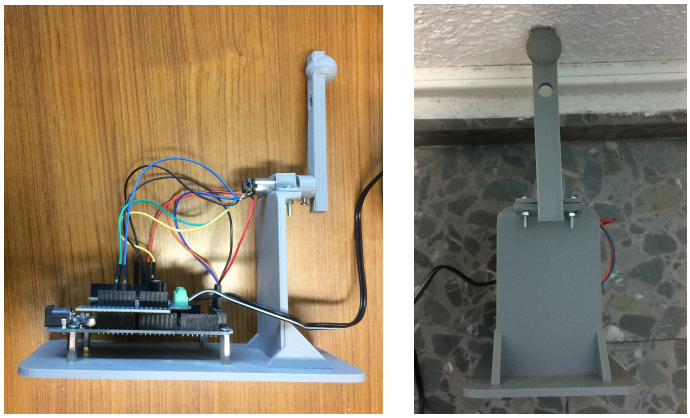

Figure 1: Laboratory robot.

Figure 2 shows the inertial reference axis to be used in the deliverable. The robot consists of a DC motor with an encoder and a reduction gearbox at which a vertical bar has been attached. Dimensions and characteristics are shown in Table 1.

Parameter	**Description**	**Value**
v_{max}	Motor maximum voltage	12 V
r	Gearbox reduction ratio	1:9.68
η	Gearbox efficiency	1.0
R_m	Motor resistance	16 Ohm
k_m	Motor torque constant	23.5 mNm/A
m	Vertical bar mass	37 g
l_c	Distance from the motor axis to the center of mass	5.5 cm

Table 1: Dimensions and characteristics of the laboratory robot.

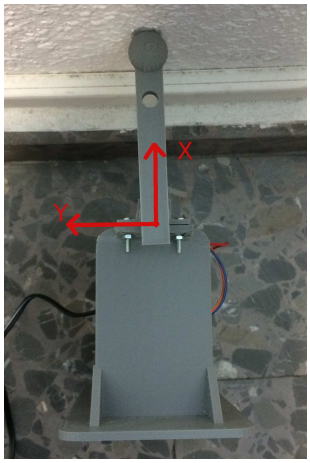

Figure 2: Inertial reference axis.

Deliverable will be evaluated by a written document, the code of the laboratory and the functioning of the robot. The document must include all items requested in the problem definition, all of them referred to the laboratory robot. All questions must be developed in the robot and should present data of the functioning of the robot and the explanations considered to demonstrate the haptic perceptions. Explanations will be evaluated related to the haptic behavior and perceptions of the robot.

In all items, robot must start with the bar in a vertical position (as shown in Figure 2). θ is defined as the angular displacement of the vertical bar with respect to the inertial axis x, therefore $\theta(t=0)=0$. For all experiments, the working space is defined as $\theta \in (-\infty, \infty)$. Hence, for the virtual environment $\theta(t_1) = 0 \neq \theta_2(t_2) = 2\pi$ or $\theta(t_1) = -\pi/2 \neq \theta(t_2) = 3\pi/2$.

Problem definition

1. **Gravity torque compensation (30%)**. Taking into account the values of Table 1.
   (a) **Design a controller without including the linear control of speed (40%)**
   (b) **Design a controller including the linear control of speed (40%)**
   (c) **Design a controller including the linear control of speed and with errors in the mass calculation (20%)**. In this last item, remove the extra weight of the screw and bolts. Explain which is the behavior of the robot.

2. **Haptic system (60%)**. In this item, the existence of a wall will be emulated as a torsion spring with viscous friction. The wall will be implemented with different values of rigidity (elasticity constant) which will provide different haptic perceptions.

   (a) **Design a haptic system with a torsion spring (50%)** Locate the virtual wall at position $\theta \leq -\pi/2$, where θ is the angular position. Obtain different values of the torsion constant that allow to perceive the wall as a "soft", "hard" and "very hard" element.
      i. **Design the system without including the viscous friction (40%)**
      ii. **Design the system including the viscous friction (40%)**
      iii. **Design the system including the viscous friction and with errors in the mass calculation (20%)**. In this last item, remove the extra weight of the screw and bolts. Explain which are the differences in perception.

   (b) **Design a haptic system that attaches to a virtual object (50%)** The wall will be substituted by an object modelled as a torsion spring located at position $\theta = -\pi/2$, where θ is the angular

position. Once the object has been touched, the system should emulate that it has been grasped. Observe and explain the differences with the previous item when the vertical bar is released in different positions of the working space.

3. **Conclusion (10%)**.
4. **References**.

Submission. A compressed file (preferably a .tar.gz file) will be submitted before the deadline through the Moodle platform.

Files should have the following nomenclature:

- The **compressed file** which includes the manuscript and the code should have the following name: "**GRXX-D3.tar.gz**", where XX represents the group number.
- The **manuscript file** should have the following name: "**GRXX-D3.pdf**", where XX represents the group number.
- The **code file or files** for the laboratory should have the following name: "**GRXX-D3Y.ino**", where XX represents the number of the group and Y a letter from "a" to "z" depending on the number of files provided.