Robotics II
April 2, 2014

Exercise 1

The *Justin* upper-body robot by DLR (Fig. 1) is made of a 3-dof torso (with coordinates $\boldsymbol{q}_T \in \mathbb{R}^3$), carrying two identical 7-dof structures as left ($\boldsymbol{q}_L \in \mathbb{R}^7$) and right ($\boldsymbol{q}_R \in \mathbb{R}^7$) arms. Neglecting the anthropomorphic hands, there is a total of 17 joints (all revolute), with $\boldsymbol{q} = \left(\boldsymbol{q}_T^T \ \boldsymbol{q}_L^T \ \boldsymbol{q}_R^T\right)^T \in \mathbb{R}^{17}$. Let the desired Cartesian motion (in position and orientation) of the end-effectors of the left and right robot arms be independently specified as $\boldsymbol{r}_{L,d}(t) \in \mathbb{R}^6$ and $\boldsymbol{r}_{R,d}(t) \in \mathbb{R}^6$, respectively.

Figure 1: *Justin* upper-body robot: A 3-dof torso with two 7-dof arms

- Define a **kinematic control** law for the joint velocity $\dot{\boldsymbol{q}}$ of the robot that is able to accomplish the whole task, recovering also from any possible initial errors at the Cartesian level.

- Is it possible to shape the joint solution so that motion of the torso is reduced (i.e., most of the task is executed by the two arms only)? And by blocking completely the dofs of the torso? Discuss qualitatively the nature of possible singularities that can be encountered with the proposed control strategies, and how to avoid them or milden their effects.

Exercise 2

The 3R robot in Fig. 2 is placed on a horizontal plane. The three links have unitary length, uniform mass distribution, and their masses are m_1, m_2, and m_3. With the robot at rest, a force $\boldsymbol{F}$ is applied to the tip as illustrated.
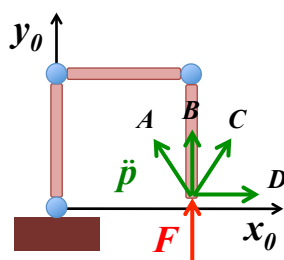

Figure 2: A planar 3R arm with a force applied at the end effector

- Will the robot end effector accelerate like in case A, B, or C? Motivate your answer.

- Determine the symbolic expression of the end-effector acceleration $\ddot{\boldsymbol{p}}$ in terms of the dynamic coefficients of the robot model.

- By considering a special distribution of link masses and inertias, would it be possible to obtain an end-effector acceleration like in case D? Motivate your answer.

[180 minutes; open books]