Robotics I

June 6, 2016

Exercise 1

Figure 1 shows a drawing and two pictures of the Universal Robot UR5, a 6R lightweight manipulator with 5 kg of payload. The six joints are labeled as base, shoulder, elbow, wrist1, wrist2, and wrist3. The relevant kinematic lengths are reported in the figure.

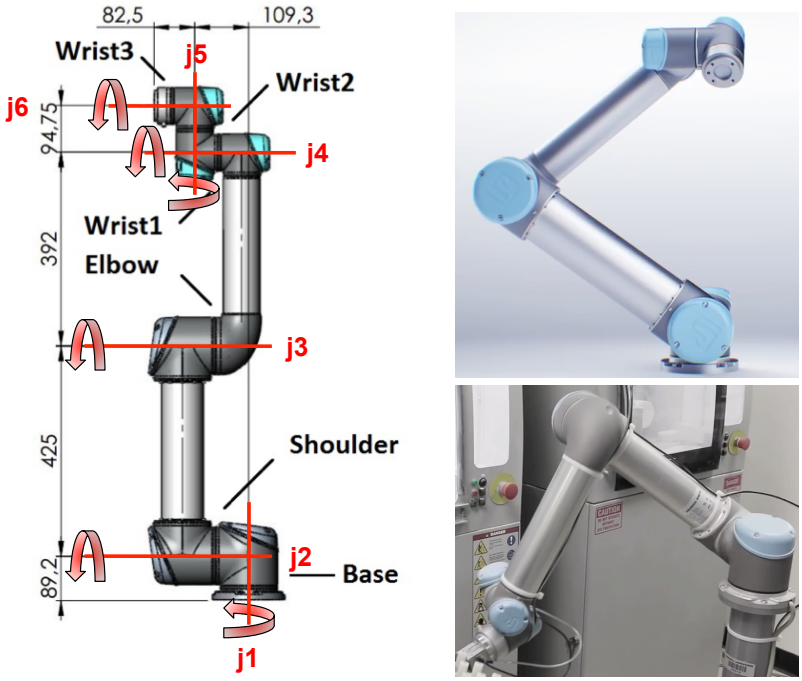

Figure 1: A drawing of the Universal Robot UR5 with the six joint axes indicated, and two views of the manipulator in action.

Assign the link frames according to the classical Denavit-Hartenberg convention and derive the associated table, providing the numerical values of the constant DH parameters. Place the origin of the reference frame (frame 0) at the robot base, and choose the last frame (frame 6) with the origin at the center of the end-effector flange and the $\boldsymbol{z}_6$ axis along the approach direction. Moreover, provide the values of the joint angles θ_i, $i = 1, \ldots, 6$, associated to the robot configuration shown in the drawing of Fig. 1.

Exercise 2

Given a planar 3R robot with equal link lengths, write a program (in pseudo-code or any preferred language) that solves the inverse kinematics in a numerical way, taking as input the desired position $\boldsymbol{p} = (p_x, p_y)$ and providing as output a solution $\boldsymbol{q}$, if one exists. Use appropriate termination/exit conditions for your algorithm. Provide also the robot kinematic functions needed by the program.

[180 minutes; open books]

Solution

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Exercise 1

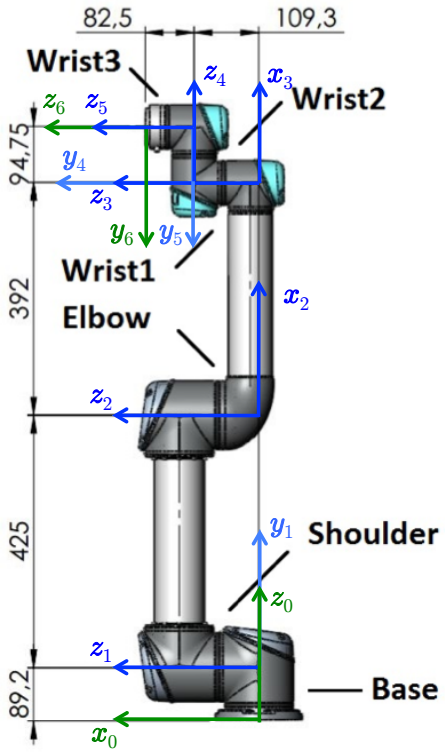

Figure 2: A possible assignment of DH frames for the UR5 robot

i	α_i	a_i	d_i	θ_i
1	$\pi/2$	0	$d_1 = 89.2$	$\theta_1 = \pi/2$
2	0	$a_2 = 425$	0	$\theta_2 = \pi/2$
3	0	$a_3 = 392$	0	$\theta_3 = 0$
4	$\pi/2$	0	$d_4 = 109.3$	$\theta_4 = \pi/2$
5	$-\pi/2$	0	$d_5 = 94.75$	$\theta_5 = 0$
6	0	0	$d_6 = 82.5$	$\theta_6 = 0$

Table 1: DH parameters (units in mm or rad)

A video of this robot in action can be found on YouTube (e.g., `https://youtu.be/ajCLa3YXDc0`).

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