CMP755 - Robotics - 2021

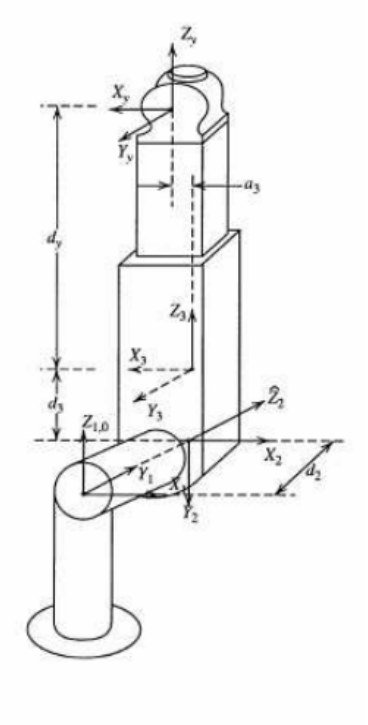
Homework #2

Due: 26.10.2021

For Questions 1-4; you can submit your files as softcopy (scans, readable proper images, etc.) or bring as hardcopies to the class. For Question 5, you can submit your functions as files.

1. (20 pts) (Question from book, 3.2., the requested figure with changes is given for ease of your computations.)

   3.2 [37] Imagine an arm like the PUMA 560, except that joint 3 is replaced with a prismatic joint. Assume the prismatic joint slides along the direction of $\hat{X}_1$ in Fig. 3.18; however, there is still an offset equivalent to d_3 to be accounted for. Make any additional assumptions needed. Derive the kinematic equations.



2. (20 pts) (Question from book, 4.9.)
3. (20 pts) (Question from book, 4.11.)

4.9 [26] Figure 4.13 shows a two-link planar arm with rotary joints. For this arm, the second link is half as long as the first—that is, $l_1 = 2l_2$. The joint range limits in

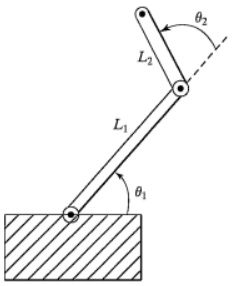


FIGURE 4.13: Two-link planar manipulator.

degrees are

$$0 < \theta_1 < 180,$$
$$-90 < \theta_2 < 180.$$

Sketch the approximate reachable workspace (an area) of the tip of link 2.

4.11 [24] Â 2-DOF positioning table is used to orient parts for arc-welding. The forward kinematics that locate the bed of the table (link 2) with respect to the base (link 0) are

$${}^0_2T = \begin{bmatrix} c_1c_2 & -c_1s_2 & s_1 & l_2s_1 + l_1 \\ s_2 & c_2 & 0 & 0 \\ -s_1c_2 & s_1s_2 & c_1 & l_2c_1 + h_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

Given any unit direction fixed in the frame of the bed (link 2), ${}^2\hat{V}$, give the inverse-kinematic solution for θ_1, θ_2 such that this vector is aligned with ${}^0\hat{Z}$ (i.e., upward). Are there multiple solutions? Is there a singular condition for which a unique solution cannot be obtained?

4. (20 pts) (Question from book, 4.24.)

4.24 [20] Given the description of link frame $\{i\}$ in terms of link frame $\{i-1\}$, find the four Denavit–Hartenberg parameters as functions of the elements of ${}^{i-1}_{i}T$.

5. (20 pts) For the following questions, use Robotic Toolbox (https://github.com/petercorke/robotics-toolbox-python, for documentation: https://petercorke.github.io/robotics-toolbox-python/).

   (a) Compute a Transformation with your own functions for translation of $[x, y, z] = [0.2, 0.3, 0.5]$ and for fixed XYZ angles $[X, Y, Z] = [30, 45, 30]$ and by using spatialmath.

   (b) Specify a kinematic model using DH notation for Q.1 (Q3.2 from text

book). (symbolic manipulation)