ECE4560 - Homework #10

Due: Nov. 6, 2017

Problem 1. (40 pts) Consider the elbow manipulator depicted in Figure 1. The home position is the straight-out position. This manipulator has a reorientable wrist, hence it has a non-empty dextrous workspace (in the absence of joint limits). Supposing that the link lengths were $l_0 = \frac{1}{2}$, $l_1 = 1$, $l_2 = 1$, $l_3 = \frac{1}{2}$.

(a) What are the inverse kinematics?

(b) Solve the inverse kinematics corresponding to the following two configurations:

$$g_i = \left[\begin{array}{ccc|c} 0.9280 & 0.3536 & 0.1174 & 1.01 \\ -0.3245 & 0.6124 & 0.7209 & 1.7551 \\ 0.1830 & -0.7071 & 0.6830 & 0.5947 \\ \hline & 0 & & 1 \end{array}\right]$$

and

$$g_f = \left[\begin{array}{ccc|c} 0.25 & -0.6424 & -0.7244 & -1.071 \\ -0.4330 & 0.5950 & -0.6771 & 1.5966 \\ 0.8660 & 0.4830 & -0.1294 & 1.6075 \\ \hline & 0 & & 1 \end{array}\right].$$

Just as a reminder, recall that Pieper's approach can be used to break this problem into two separate problems, one for the wrist, then one for the hand. The solution then follows from what we've been discussing in class.

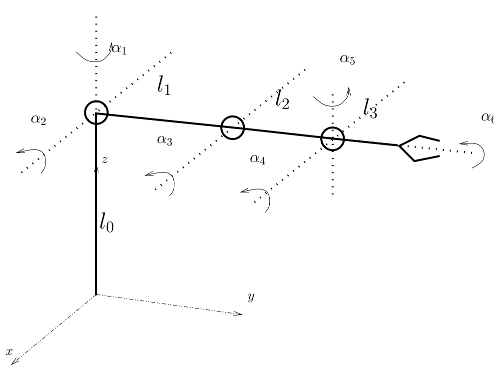

Figure 1: Elbow Manipulator.

Problem 2. (10 pts) Let's consider again the three-link rotational planar manipulator from the previous homeworks, c.f. Figure 2. The link lengths were specified to be $l_1 = 1$, $l_2 = \frac{1}{2}$, and $l_3 = \frac{1}{4}$. The task is to now generate trajectories for the manipulator.

If the initial joint angles are $\alpha(0) = (-\pi/6, \pi/4, -\pi/3)^T$ and the final joint angles are to be $\alpha(5) = (0, -\pi/12, \pi/4)^T$, design a splined trajectory in the joint space that will connect the two joint configurations. Note that the duration of the trajectory should be 5 seconds. In addition to turning in the polynomials, you need to turn in a plot of the manipulator performing the routine. Have it plot about 5-7 points along the trajectory.

Lab Assignments: For the traditional manipulator problems, there are two items to accomplish. Both involve the Lynx 6 manipulators.

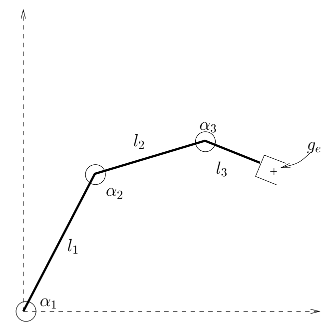

Figure 2: Planar 3R Manipulator.

Problem 3: Manipulator. (25 pts) Consider your Lynxmotion manipulator. It is not fully dextrous since it is missing a revolute joint at the wrist. Nevertheless, if we'd like to pick up things on the "ground," then it is completely feasible to do so. We can consider it to be dextrous when it comes to pick and place operations. What that means is, as long as I am careful about the desired end-effector configuration, an inverse will exist.

(a) Derive the inverse kinematics of the Lynxmotion L6 manipulator. Please use the forward kinematics for the straight-up home configuration.

Hint: The main difference between this problem and the one derived in class (or in the homework) is in the re-orientation of the wrist, the L6 cannot arbitrarily reorient. Still work out the solution like I did in class even though the wrist does not have full $SO(3)$ control. When you compute the rotation matrix of achievable orientations, you will get a special form. Assume that the desired orientation fits that special form so that the inverse kinematics work out. Let me know what test you would perform to verify that the orientation was of the special form.

You should probably code it up into a member function for the `lynx6` class. It takes in an $SE(3)$ object and returns the joint angles. Also, you should make sure to pick the up-then-down configuration in the inverse kinematics solution rather than the down-then-up solution. I refer here to the `acos` solution and selecting a sign that makes the manipulator reach up then down, since down then up may hit the base or do something silly like hit the ground.

(b) Solve the inverse kinematics corresponding to the following two configurations,

$$g_i = \left[\begin{array}{ccc|c} 0.8660 & 0.5000 & -0.0000 & -4.4079 \\ 0.5000 & -0.8660 & -0.0000 & 7.6348 \\ 0.0000 & -0.0000 & -1.0000 & 0.8110 \\ \hline & 0 & & 1 \end{array}\right]$$

and

$$g_f = \left[\begin{array}{ccc|c} 0.7071 & 0.0000 & -0.7071 & -8.7393 \\ 0.7071 & 0.0000 & 0.7071 & 8.7393 \\ 0.0000 & -1.0000 & -0.0000 & 6.0836 \\ \hline & 0 & & 1 \end{array}\right]$$

To make sure we are all on the same page, please use the link lengths that I measured for my manipulator and posted in the solutions. Then in future homeworks, you can adjust it to agree with your manipulator lengths.

Problem 3: Manipulator. (25 pts) Working with the Lynxmotion manipulator, where the link lengths correspond to your manipulator, let's get a splined trajectory going. Given the initial joint configuration $\alpha(0) = (-\pi/6, -\pi/3, \pi/6, -\pi/2, 0)^T$, and the desired final joint configuration $\alpha(8) = (\pi/6, 0, -\pi/12, \pi/3, -\pi/3)^T$, design a splined trajectory in the joint space that will connect the two joint configurations. Note that the duration of the trajectory should be 8 seconds.

Demo your manipulator going through the splined trajectory.

Problem 3: Biped. (40 pts) Work out the next step in the biped project.

Problem 3: Turtlebot. (50 pts). Work out the fourth module within Module Set 1, which is "wandering with the turtlebot."

Problem 3: Custom Lab. (40 pts). If you are working on a group project, then your group contact will review the submissions associated to the prior tasks and provide a new set of tasks. You should work out whatever baby steps this group contact assigns the group as opposed to the lab problem.