MeEn 537 Homework #3

The problems below mostly require you to build on previous code and understanding. Please make sure you understand what we have been doing before you move on.

1. Download "transforms_hw03.py" and copy the code to the bottom of your "transforms.py" file from HW #2. Now do the following in your transforms.py file:
   (a) Complete the definition of the "se3" function
   (b) Complete the "inv" function for 4x4 numpy arrays that represent the SE(3) group
   (c) Check that you've implemented everything correctly using: "hw03_test_homogenous_transform_notebook.ipynb" Start by copying it into the same folder with your "transforms.py" file and then see if your answers match the correct answers for the first few cells.
   (d) For the last cell, calculate T_1^0 and T_2^1 using a DH parameterization (as described in the comments of the last cell in "hw03_test_homogenous_transform_notebook.ipynb"), and then plot both frames relative to a fixed, base, or global frame using the "add_frame" and "update" functions.

2. Work the following problems from the Spong Robotics Textbook which are included on the following pages. For any problem where distances are not included, please use a, d, and theta appropriately to define the DH parameters.
   (a) 2-37 (hints: (1) make sure you find T_3^2 for the solution and not T_2^3,and (2) only the base frame of the robot shown is part of the problem, the rest of the robot is just a visual representation of why we might care about the other frames for a robot manipulation task
   (b) Using your implementation of SE(3) from problem 1 and the "add_frame" and "update" functions, plot each coordinate frame relative to the base of the robot to see if they match the picture.
   (c) 2-38
   (d) 3-4 (make sure to include a sketch and assigned coordinate frames) - you need to define A_1, A_2 using DH paramters and multiply them together.
      i. for two different joint configurations, pick actual values for the link lengths, etc. and plot the coordinate frames for A_1, A_2 using the "add_frame" function again. Do they make sense based on how you expect the robot to move? It may help to sketch the two configurations of the robot before (or while) plotting the corresponding coordinate frames.
   (e) 3-6 (make sure to include a sketch and assigned coordinate frames) - you only need to define A_1, A_2, A_3 using DH parameters. However, in order to compare with problem (f), you may need to multiply them together.

(f) For problem 3-6 pick a different convention (i.e. different intermediate frame orientations and locations) that still makes the first coordinate frame and last coordinate frame agree with the DH convention, and calculate the forward kinematics. Are these representations different? If so, how?

(g) 3-8 (make sure to include a sketch and assigned coordinate frames) - you only need to define the DH parameters, no need to form the A matrices or multiply them together.

For all of these problems you can use software to help you find the solutions. However, please make sure you know how to do each part by hand (for simple calculations).

Homework Problems from “Robot Modeling and Control” by Mark Spong et al. – Fair Use

2-37

Consider the diagram of Figure 1. A robot is set up 1 meter from a table. The table top is 1 meter high and 1 meter square. A frame o_1 is fixed to the edge of the table as shown. A cube measuring 20 cm on a side is placed in the center of the table with frame o_2 established at the center of the cube as shown. A camera is situated directly above the center of the block 2 m above the table top with frame o_3 attached as shown. Find the homogeneous transformations relating each of these frames to the base frame o_0. Find the homogeneous transformation relating the frame o_2 to the camera frame o_3.

2-38

In Problem 2-37, suppose that, after the camera is calibrated, it is rotated 90 degrees about z_3. Recompute transformations for o_0 to o_3 and o_2 to o_3.

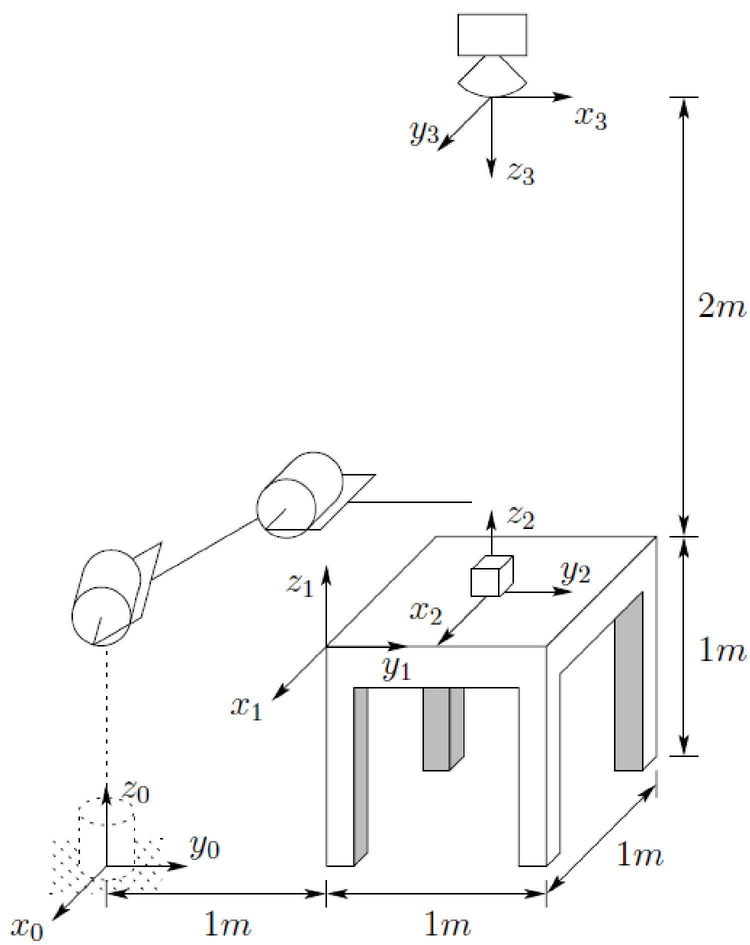

Figure 1

3-4

Consider the two-link manipulator of Figure 2 which has joint 1 revolute and joint 2 prismatic. Derive the forward kinematic equations using the DH-convention.

3-6

Consider the three-link articulated robot of Figure 3. Derive the forward kinematic equations using the DH-convention.

3-8

If we attach a spherical wrist to the three-link articulated manipulator of Problem 3-6. as shown in Figure 4. Derive the forward kinematic equations for this manipulator using the DH-convention.

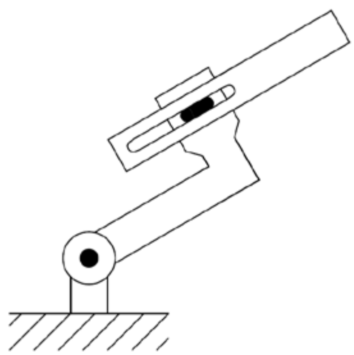

Figure 2

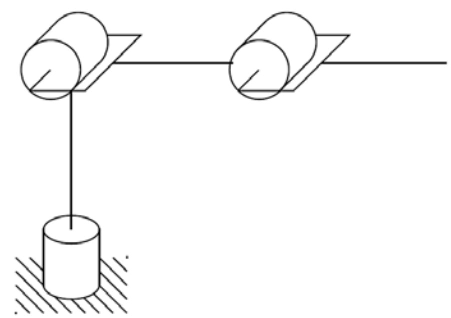

Figure 3

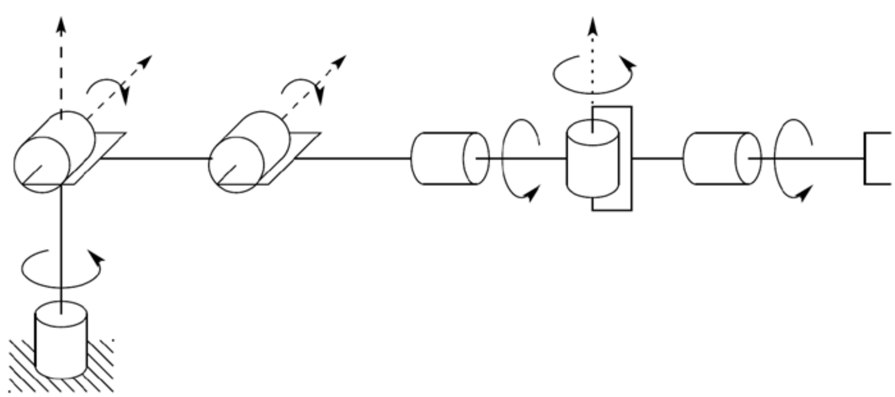

Figure 4