1. Sketch the dexterous workspace for the robot arm. This diagram does not need to be to scale. Add annotations to point out any important features of your drawing. (Do not consider any self-collisions.)
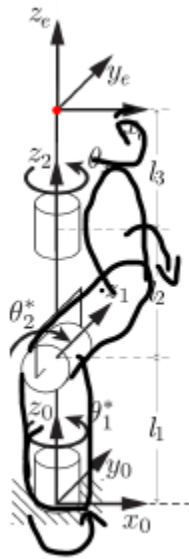
    2. Sketch the reachable workspace for the robot arm.

    3. Using what we learned in class, derive the forward kinematics for the robot arm, which will result in coordinate frames for each joint and a transformation matrix that describes the end effector pose in base frame coordinates. Note that you can use any convention you desire, but we want you to use the base frame 0 and end effector frame e we have specified in Fig. 1.
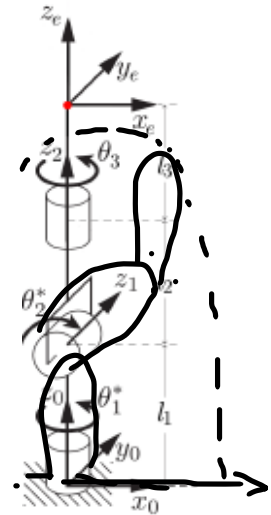

Figure 1

Figure 1

The DH may be used to determine the forward kinematics for the robot arm. This technique offers a methodical way to explain the kinematic connections between a robot arm's joints and links.

Assuming the robot arm has n joints, the frames for each joint will be designated as frame 0, frame 1, frame 2,..., frame n-1, and frame n, where frame 0 represents the base frame and frame n represents the end effector frame.

The changes between each next frame can then be described using the DH convention. Homogeneous matrices T(i-1,i), where I is the index of the current frame and T(i-1,i) specifies the transformation from frame i-1 to frame, can be used to express the transformations. T(i-1,i) = [0, 0, 0, 1]], so T(0,n) = T(0,1) * T(1,2) * T(2,3) * ... * T(n-1,n)

4. Write 3 - 5 sentences about the process you used to get the transformation matrix which can describe the end effector in base frame coordinates.

One popular technique is to employ forward kinematics to create the transformation matrix characterizing the end effector in base frame coordinates. To do this, you must determine how the location and orientation of the end effector relate to the joint angles. A series of matrices that describe this connection can be multiplied to create the transformation matrix. This approach necessitates an understanding of the joint angles and geometry of the robot arm. Combining these details allows for the calculation of the transformation matrix, which provides a thorough explanation of the location and orientation of the end effector with respect to the base frame.

5. Select a few example configurations and using your transformation compute the end effector pose in base frame coordinates. Do your results make sense? Write down one of your configurations and the resulting end effector pose, along with a 1 sentence reason for why this is the right answer. (Hint: Pick configurations that make it easy for you to check, e.g θ = [0, 0, 0].)

When the configuration θ = [0, 0, 0]. In this case, the transformation matrices for each joint would be:

T(0,1) = [[cos(0), -sin(0)*cos(alpha(0)), sin(0)*sin(alpha(0)), a(0)*cos(0)],
[sin(0), cos(0)*cos(alpha(0)), -cos(0)*sin(alpha(0)), a(0)*sin(0)],
[0, sin(alpha(0)), cos(alpha(0)), d(1)],
[0, 0, 0, 1]]

T(1,2) = [[cos(0), -sin(0)*cos(alpha(1)), sin(0)*sin(alpha(1)), a(1)*cos(0)],
[sin(0), cos(0)*cos(alpha(1)), -cos(0)*sin(alpha(1)), a(1)*sin(0)],
[0, sin(alpha(1)), cos(alpha(1)), d(2)],
[0, 0, 0, 1]]

T(2,3) = [[cos(0), -sin(0)*cos(alpha(2)), sin(0)*sin(alpha(2)), a(2)*cos(0)],
[sin(0), cos(0)*cos(alpha(2)), -cos(0)*sin(alpha(2)), a(2)*sin(0)],
[0, sin(alpha(2)), cos(alpha(2)), d(3)],
[0, 0, 0, 1]]

T(0,n) = T(0,1) * T(1,2) * T(2,3)

6. Now think about the Panda Robot arm. Draw out the full schematic of the Panda arm using the joint notation introduced in lecture. Write down 2 differences you observe between the Panda arm and the robot arm shown in Figure 1.

The number of joints: The Panda arm has 7 joints, whereas the robot arm has 3 joints.
The axis of rotation of the joints: The axis of rotation for the joints in the Panda arm is along the X-axis, whereas in the robot arm, the axis of rotation can be along any axis.

7. Read through the instructions for the Code and Lab assignments and develop a preliminary testing plan for your lab. Consider what data (quantitative or qualitative) you want to collect and how you will collect this data. See 3.2 and 3.3 for some ideas to get you started.

Determine the data to be collected: To evaluate the accuracy of the forward kinematics solution, we need to collect data that can be used to compare the results of the solution to the actual robot arm configurations. This data can be in the form of quantitative measurements such as joint angles, end-effector positions, and orientations.