CSE4421: Lab 4

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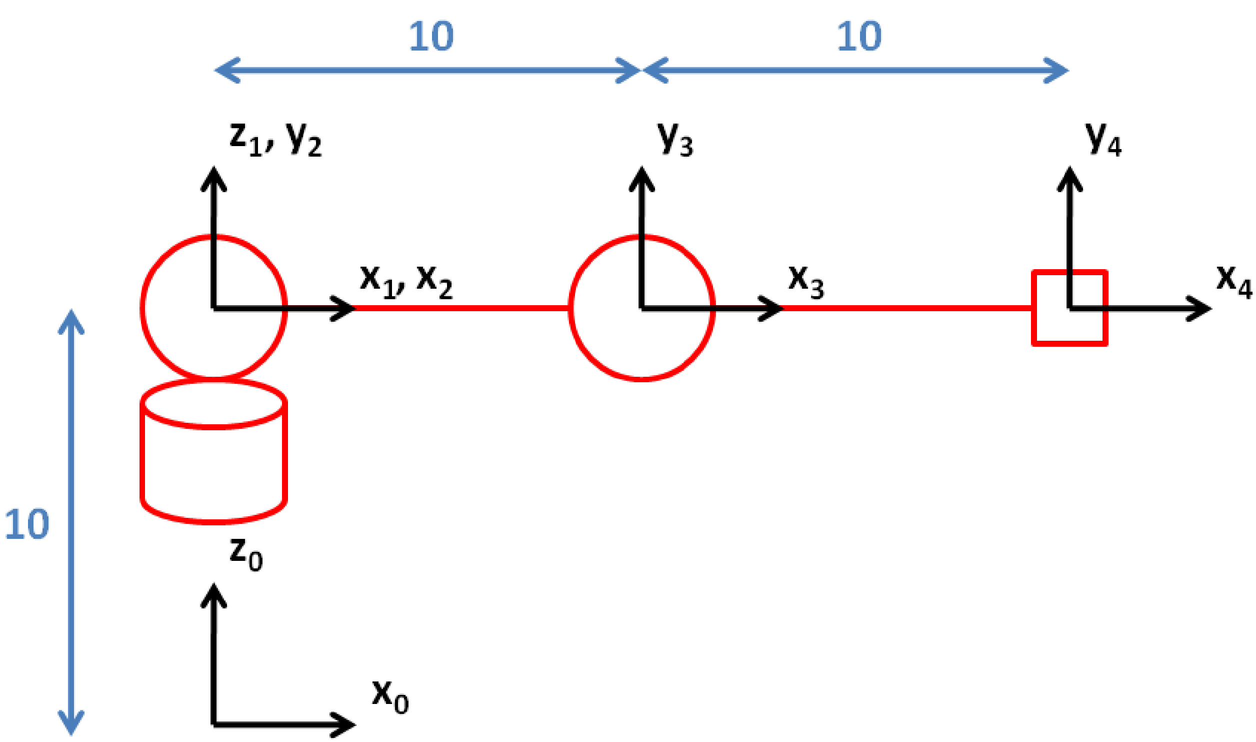
1 Preliminaries

This lab works through the (partial) forward and inverse kinematics of the A150 arm.

2 Denavit-Hartenberg (DH) Parameters



IMPORTANT: The A150 (and A255?) report joint angles for joints 2, 3, and 4 relative to the horizon, which is different from the DH convention. When you ask the robot for the values of its joint parameters (using `w0`, for example), you must convert the values for joints 3 and 4 into their corresponding DH values. Similarly, when you compute the inverse kinematics using the DH parameters, you must convert the computed angles for joints 3 and 4 into angles measured relative to the horizon. In the picture above, joints 2–4 have joint angles of 0 degrees measured relative to the horizon, and joint angles of 0 degrees in DH values. If the arm were pointing straight up, joints 2–4 would have joint angles of +90 degrees relative to the horizon, and joint angles of +90, 0, and 0 degrees in DH values.

The diagram on the previous page shows the partial schematic of the A150 arm where joints 1–3 are revolute, and frame 4 is located on the joint axis of joint 4; we assume that joint 4 is fixed with a DH value of 0 degrees. The diagram shows the robot in the configuration where $\theta_1 = \theta_2 = \theta_3 = 0$ degrees. Notice that there is a small departure from the DH convention in that frame 0 is not coincident with frame 1; this is because the robot defines its base frame as being located on the table surface. The DH parameters are:

i	a_{i-1}	α_{i-1}	d_i	θ_{i-1}
1	0	0	10	θ_1
2	0	90	0	θ_2
3	10	0	0	θ_3
4	10 (or 12)	0	0	0

a_3 is nominally 10, but if you make it 12 (and make sure frame 4 has the same orientation as frame 3) you can compute the same position of the end-effector that is returned when you use the `w0` command.

Before you proceed, answer the following questions:

1. Suppose you issue the `w0` command and you get back the vector of joint angles measured relative to the horizon $[h_1, h_2, h_3]$; what are the corresponding DH values for the joint angles $[\theta_1, \theta_2, \theta_3]$? (Note: you need the θ_i to compute the forward kinematics.)

2. Suppose you compute the inverse kinematics to get the DH values for the joint angles $[\theta_1, \theta_2, \theta_3]$; what are the corresponding joint angles measured relative to the horizon $[h_1, h_2, h_3]$? (Note: you need the h_i to issue the `madeg` command.)

3. Suppose you've answered Question 2. What joint angle h_4 measured relative to the horizon is required to keep frame 4 in the same orientation as frame 3?

3 Matlab

Log on to a workstation and create a directory for this lab somewhere under your account. Change to the created directory and copy all of the lab files into your directory:

```
cp /cs/dept/www/course_archive/2009-10/W/4421/src/matlab/* .
```

Start Matlab by typing `matlab &` in the console.

3.1 Forward Kinematics

Open the files `rx.m`, `rz.m`, `dx.m`, `dz.m`, and `forwardA150.m`. The first four files define Matlab functions that return canonical transformations. The file `forwardA150.m` computes the forward kinematics (up to frame 4) for the A150 and returns a homogeneous matrix encoding the pose of frame 4 relative to the base frame; take the time to study the forward kinematics and convince yourself that the functions are correct.

3.2 Inverse Kinematics

This is the hard part. Open the file `inverseA150.m`; notice that there is nothing but a function declaration and comments. You need to work out the inverse kinematics (up to frame 4). Fear not; the solution is mostly in your notes, but you need to translate your notes into Matlab. Use the comments as a guide, and ask questions if you get stuck. You need to take care that the angles you compute lie inside the range of values that each joint can take; if a joint angle falls outside the valid range for that joint then your function should return the empty matrix (ie. `J = []`).

Once you have the inverse kinematics worked out, you can test your solution with the following steps (assuming my implementation of the forward kinematics is correct):

1. Define a vector of joint angles `J` (measured relative to the horizon). In the ready position `J = [0 90 0 0 0]`.
2. Compute the forward kinematics `T = forwardA150(J)`.
3. Compute the inverse kinematics `myJ = inverseA150(T)`. Your solution is correct if `J` and `myJ` are identical.