CSE4421/5324: Assignment 2

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Due: End of class on Mon Feb 25, 2013

1. Consider the RR arm shown in Figure 1.

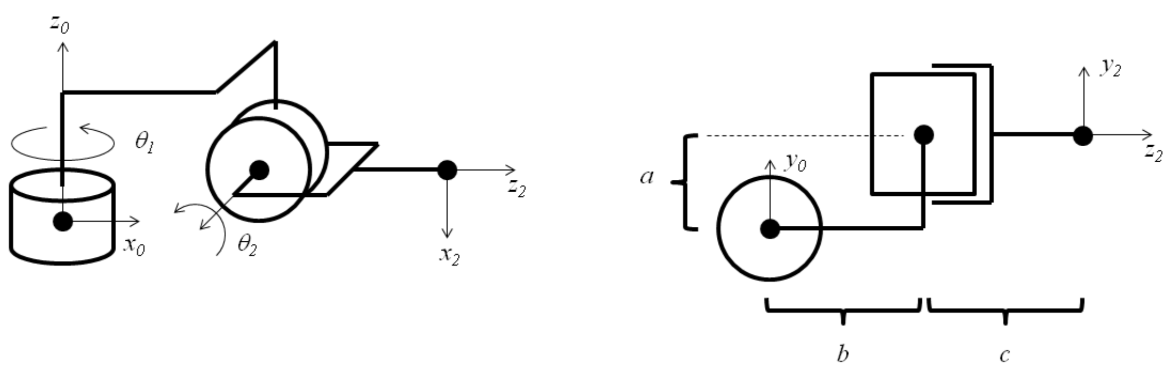

Figure 1: Left: Front view of arm. Right: Top-down view of arm. In this figure, all joint angles are shown at $0°$.

Joints 1 and 2 are connected by a link with a $90°$ bend; the bend allows both joints to rotate through $360°$ without colliding with each other. The axis of joint 2 is always in the plane $z_0 = 0$. You may assume that the link dimensions a, b, and c are always greater than zero, and that $b > c$.

(a) Given the location of frame $\{2\}$ expressed in frame $\{0\}$, $o_2^0 = (x,\ y,\ z)^T$, find the values of θ_1 and θ_2.

(b) A high quality solution to part (a) would check that the point $o_2^0 = (x,\ y,\ z)^T$ is actually reachable by the robot; how would you check if o_2^0 is reachable? Provide a mathematical expression if possible, although a well written description could also receive full marks.

2. Consider the RR arm shown in Figure 2; this arm is similar to the arm from Question 1 except that the link has a bend of $-45°$.

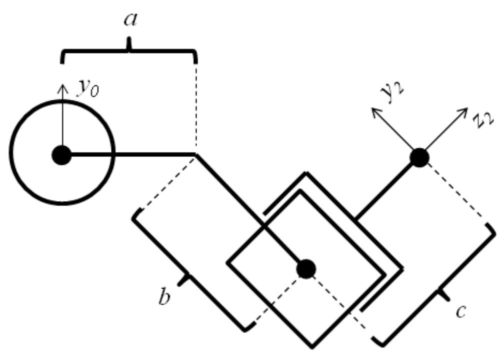

Figure 2: Top-down view of arm.

The axis of joint 2 is always in the plane $z_0 = 0$. You may assume that the link dimensions a, b, and c are always greater than zero.

Solve for the forward kinematics of the arm; that is, given joint angles θ_1 and θ_2, find the orientation and position of frame $\{2\}$ as a 4×4 homogeneous matrix. If your solution involves a sequence of matrix multiplications then show the sequence of matrices in addition to the overall 4×4 homogeneous matrix. Use of the Denavit-Hartenberg convention is acceptable, but not required.

3. *This question assumes that you have completed Lab 3.* In the Matlab simulator for the A150 robot implement the method with signature `move(obj, p)` that takes as input a goal location `p` (expressed in the base frame of the robot); the function should then move the origin of frame 5 to the input location, or output a message indicating that the position is not reachable. You should assume that

$$R_5^0 = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

i.e., the gripper is pointing straight down. The path of the end effector should be a straight line. If a straight line path is not possible then the robot should complete as much of the straight line path as is possible; i.e., it should move from its current position towards the goal in a straight line until it can go no further and then stop. Consider adding a method that solves the inverse kinematics problem for the arm, rather than putting all of the inverse kinematics code inside of `move`; see the final part of this assignment.

Hand in paper copies of Parts 1–2. Submit `sim150.m` using the command

```
submit 4421 a2 sim150.m
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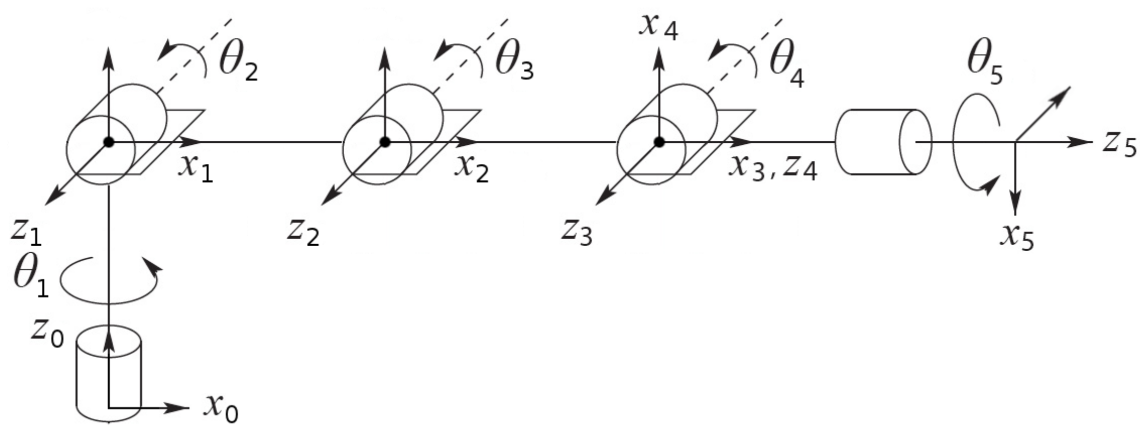

Figure 3: The wrist of the A150 and A255 robots. z_3 points out of the page and y_5 points into the page.

Joint variable	Range
θ_1	$-175°$ to $175°$
θ_2	$0°$ to $110°$
θ_3	$-130°$ to $0°$
θ_4	$-110°$ to $110°$
θ_5	$-180°$ to $180°$

Table 1: The joint variable ranges in the Denavit-Hartenberg convention.