

Homework – Forward Kinematics

Recall that for a 2-link planar manipulator the end-effector (EE) p has the position (x_{p0}, y_{p0}) :

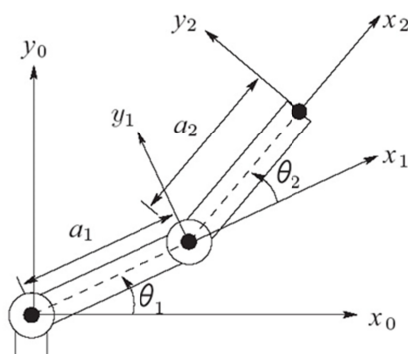
$$\begin{aligned} x_{p0} &= l_1 \cos \theta_1 + l_2 \cos(\theta_1 + \theta_2) \\ y_{p0} &= l_1 \sin \theta_1 + l_2 \sin(\theta_1 + \theta_2) \end{aligned} \tag{1}$$

For both 1 and 2 provide the following

- a. All files (e.g. NXC and Headers). Comment and make readable (e.g. good use of white space)
 - b. URL to your YouTube video demonstrating this program
1. Show hand calculations given (1) and the values in Columns 1 and 2 to complete Column 3. Execute program with those values to complete Column 4 below (20-points).

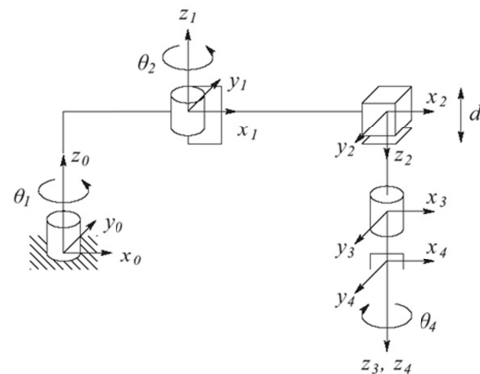
θ_1 [deg]	θ_2 [deg]	Equation (1) [studs]	Observed value [studs]
0	+90	(7, 5)	(7, 5)
0	-90		
+90	-90		
-90	-90		
+45	+45		

2. Unscrew and reverse the beams such that Link 1 is a Beam 7 and Link 2 is a Beam 9. Repeat Question 1 to complete a new table (20-points).
3. The DH parameters for the two-link planar arm are given below (above left). Confirm by hand calculations and derivations the given T_2^0 (15-points).
4. The DH parameters for the SCARA arm are given below (above right). Confirm by hand calculations and derivations the given T_4^0 (15-points).



Link	a_i	α_i	d_i	θ_i
1	a_1	α_1	d_1	θ_1
2	a_2	α_2	d_2	θ_2

$$T_2^0 = \begin{bmatrix} c_{12} & -s_{12} & 0 & a_1 c_1 + a_2 c_{12} \\ s_{12} & c_{12} & 0 & a_1 s_1 + a_2 s_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



Link	a_i	α_i	d_i	θ_i
1	a_1	180	0	θ_1^*
2	a_2	0	0	θ_2^*
3	0	0	d_3^*	0
4	0	0	d_4^*	θ_4^*

* denotes variable

$$T_4^0 = \begin{bmatrix} c_{12}c_4 + s_{12}s_4 & -c_{12}s_4 + s_{12}c_4 & 0 & a_1 c_1 + a_2 c_{12} \\ s_{12}c_4 - c_{12}s_4 & -s_{12}s_4 - c_{12}c_4 & 0 & a_1 s_1 + a_2 s_{12} \\ 0 & 0 & -1 & -d_3 - d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$