EGR 455: Robotic Systems 1

Exam 1: Kinematics

Name:

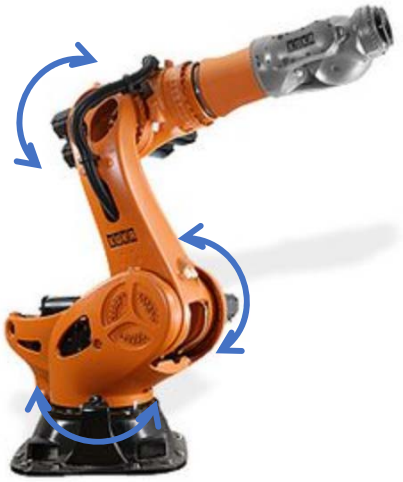
Equations:

$$R_X = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & -sin\theta \\ 0 & sin\theta & cos\theta \end{bmatrix} \quad R_Y = \begin{bmatrix} cos\theta & 0 & sin\theta \\ 0 & 1 & 0 \\ -sin\theta & 0 & cos\theta \end{bmatrix} \quad R_Z = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Equations for Graduate Students:

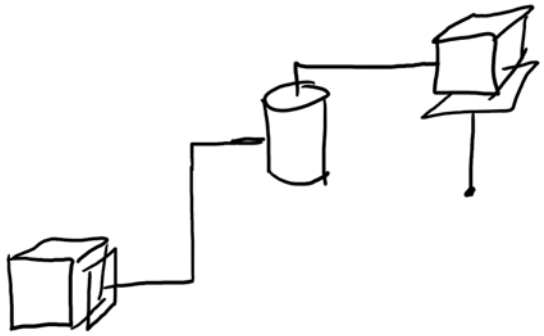
$$H = \begin{bmatrix} C\theta & -S\theta C\alpha & S\theta S\alpha & rC\theta \\ S\theta & C\theta C\alpha & -C\theta S\alpha & rS\theta \\ 0 & S\alpha & C\alpha & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

1. One of the biggest robotics companies in the world today is a company called 'Kuka'. Shown here is one of Kuka's manipulators. Draw a kinematic diagram of this manipulator. Include only the three joints labeled with arrows. You don't have to label the diagram with frames, joint variables, or link lengths.

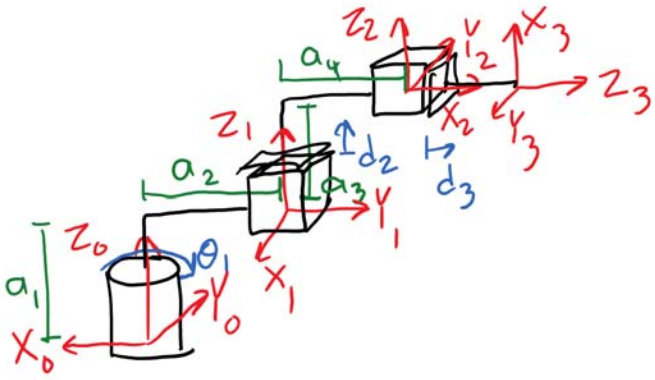


2. Is the manipulator in question 1 a standard type? If so, what type is it?

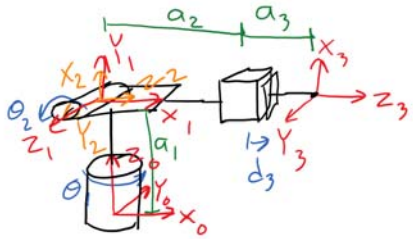
3. Shown here is a kinematic diagram that is unlabeled. Draw frames on this diagram according to the Denavit-Hartenberg rules, and label the joint variables and link lengths.



4. Shown here is a labeled kinematic diagram. There at least five errors in this diagram. Find five errors and write (in words) what is wrong.

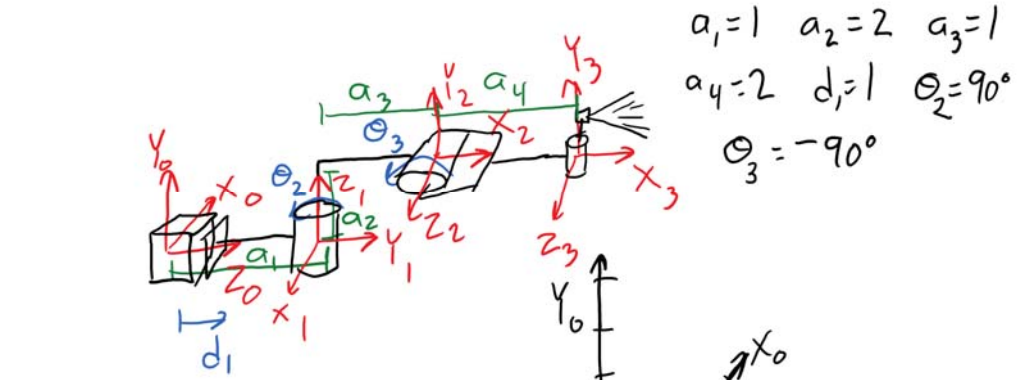


5. Shown here is a labeled kinematic diagram. Find the complete homogeneous transformation matrix (HTM) from the base-frame to the end-effector frame by first finding the rotation matrices and the displacement vectors, then assembling into the HTM.

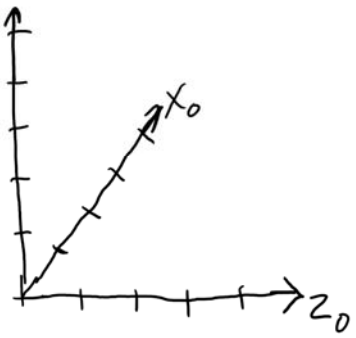


6. (Graduates Only): Create a Denavit-Hartenberg parameter table for question 5.

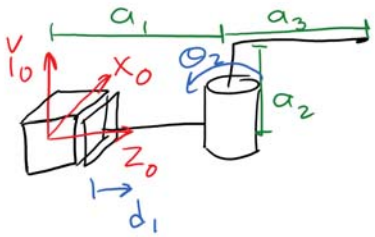
7. Shown here is a kinematic diagram along with its homogeneous transformation matrix. There is a spray-paint can attached to the end-effector as shown in the diagram. When the link lengths and joint variables are set as shown, where is the spray-paint can located, and in what direction is it pointing? Answer by drawing the spray-paint can on the provided 0 frame.



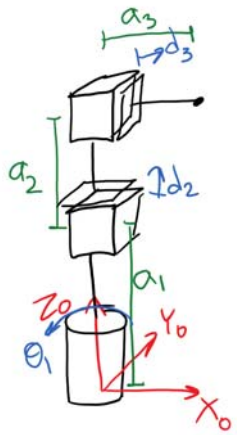
$$H^0_3 = \begin{bmatrix} s\theta_2 c\theta_3 & -s\theta_2 s\theta_3 & -c\theta_2 & a_4 c\theta_3 s\theta_2 + a_3 s\theta_2 \\ s\theta_3 & c\theta_3 & 0 & a_4 s\theta_3 + a_2 \\ c\theta_2 c\theta_3 & -c\theta_2 s\theta_3 & s\theta_2 & a_4 c\theta_2 s\theta_3 + a_3 c\theta_2 + a_1 + d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



8. (Undergraduates Only): Shown here is the kinematic diagram of a 2-degree-of-freedom manipulator. Find the inverse kinematics equations.



8. (Graduates Only): Shown here is the kinematic diagram of a 3-degree-of-freedom manipulator. Find the inverse kinematics equations.



9. Shown here is a rotation matrix. Is this a valid rotation matrix? Why do you think so/how can you tell?

$$R = \begin{bmatrix} 0.8 & 0 & 0 \\ 0.8 & 1 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$