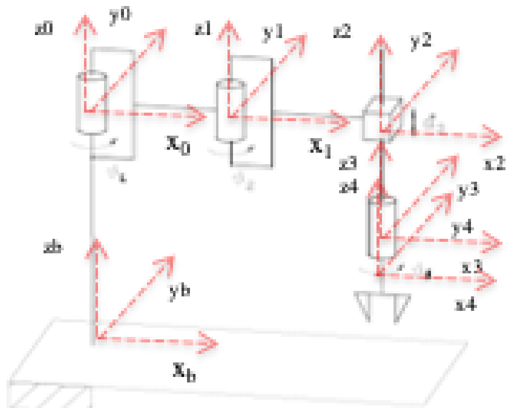
ROB-6003 Foudations of Robotics | **Project 3**
New York University, Fall 2022 | updated November 17, 2022
Due on December 6, 11:59 PM

1 Direct and Inverse Kinematics

Consider the SCARA manipulator depicted below. For this project only the kinematic parameters are needed. You have received a trajectory for the the manipulator end effector. The trajectory is provided in a file named kinematic_traj.mat and can be read using init.m.



The manipulator parameters are

$$d_0 = 1\ m,\ a_1 = a_2 = 0.5\ m,\ l_1 = l_2 = 0.25\ m$$

$$\theta_{1_{min}} = -\pi/2\ rad,\ \theta_{1_{max}} = \pi/2\ rad,\ \theta_{2_{min}} = -\pi/2\ rad,\ \theta_{2_{max}} = \pi/4\ rad$$

$$m_{l1} = m_{l2} = 25\ kg,\ m_{l3} = 10\ kg, Il1 = I_{l2} = 5\ kgm^2,\ I_{l4} = 1\ kgm^2$$

$$k_{r1} = k_{r2} = 1,\ k_{r3} = 50\ rad/m,\ k_{r4} = 20,$$

$$I_{m1} = I_{m2} = 0.0001\ kgm^2,\ I_{m3} = 0.01\ kgm^2, I_{m4} = 0.005\ kgm^2$$

$$F_{m1} = F_{m2} = 0.0001\ N \cdot m \cdot s/rad, F_{m3} = 0.01\ N \cdot m \cdot s/rad, F_{m4} =\ 0.005\ N \cdot m \cdot s/rad$$

$$d_{3_{min}} = 0.25\ m,\ d_{3_{max}} = 1\ m,\ \theta_{4_{min}} = -2\pi\ rad,\ \theta_{4_{max}} = 2\pi\ rad$$

As done for projects 1 and 2, the frames are depicted into the figure and the DH parameters are

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

Table 1: Table with DH parameters.

Please not that the 0 frame is not coincident with the b frame. There is a translation from the ground plane denoted with $d_0 = 1$. The frame 4 is coincident with the frame 3 at the starting. Be careful on the d_3 component. The range of values is always positive. When the arm is fully extended (down towards the floor) the value is $1m$ whereas 0.25 when retracted (away from the floor). However, when you build your matrix note that d_3 moves along $-z_2$ axis and for this reason you translation in A_3^2 should be negative as $-d_3$.

Questions:

1. Generate a trajectory in the robot operational space of 4 s with trapezoidal velocity profile for each segment passing trough the following waypoints $p_0 = \begin{bmatrix} 0 & -0.80 & 0 \end{bmatrix}$ at time $t_0 = 0.0$, $p_1 = \begin{bmatrix} 0 & -0.80 & 0.5 \end{bmatrix}$ at time $t_1 = 0.6$, $p_2 = \begin{bmatrix} 0.5 & -0.6 & 0.5 \end{bmatrix}$ at time $t_2 = 2.0$, $p_3 = \begin{bmatrix} 0.8 & 0.0 & 0.5 \end{bmatrix}$ at time $t_3 = 3.4$, $p_4 = \begin{bmatrix} 0.8 & 0.0 & 0.0 \end{bmatrix}$ at time $t_4 = 4.0$. The trajectory should be generated such that the robot should not stop at each waypoint so that the waypoints are via points. The anticipation time for each segment should be 0.2 s. You need show the position, velocity and acceleration of your path. The sampling time will be $T_s = 0.001$ s.

2. Consider a 5 kg load placed at the end effector. Generate an inverse dynamic control approach. The setpoints for each joint have to be generated starting from the trajectory generated in the operational space considering a second order inversion kinematic algorithm developed during project 2.

Instructions:

- Make your code as a combination of matlab and simulink. The structure is already provided in the folders. For part 1, you can create all functions you need, but your program should run by playing the init_traj.m function available in the folder. Once your trajectory has been generated save it in a mat file generated_traj.mat.

- For part 2 as usual, you should call your initialization in a function named init.m. This will load your saved trajectory as well from part 1. For the second order inverse kinematic algorithm same rules of project 2 apply, so you will find the same files. You will have as well another couple of .m files related to control. You will notice in the simulink file that there is a specific subsystem where you should put your second order inverse kinematic algorithm and will give you as output the desired joint values. The trajectory you generated is loaded in the init.m file as generated_traj.mat. Copy it from the previous part in the part 2 folder once you finished part 1. You will have to show your position and velocity errors in the joint space as well as the joint trajectories. You can use the same function for projects 1 and 2 as reference.

2 Report

You need to summarize your results in a report submitted in pdf format and generated with latex or word. Please add on top of your manuscript your name and NYU ID. The report should not be more than 8 pages including plots. In addition to the results, please include your models and any explanation you think is appropriate. Do not just write equation, but try to add your logic process and explain why and how you used the equations or models you have in your code.

3 Grade Policy and Submission

The overall score will be 100 and will be subdivided in the following way, part 1 (30 points), part 2 (60 points), and report quality and readability (10 points). Do not modify any part of the code as specified above. Any other type of modification will result in 0 points. All the files, including code and report, should be submitted in an unique zip file.