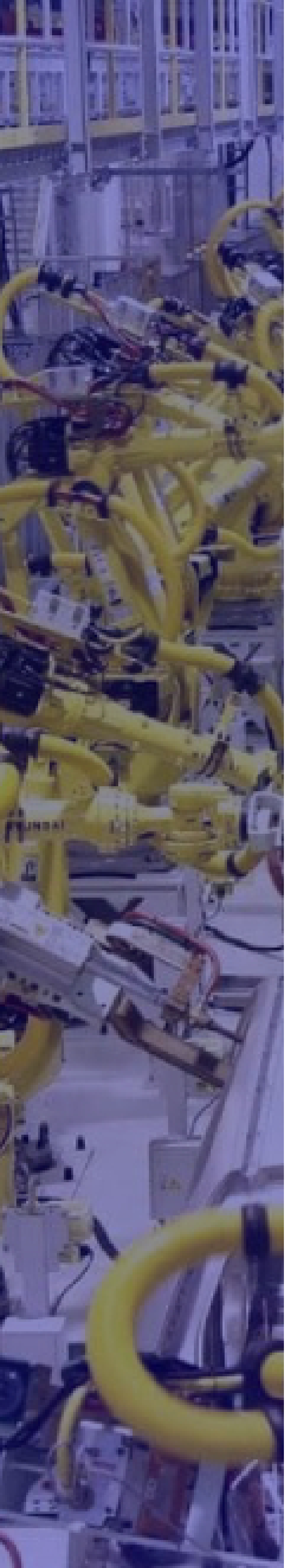

Dep. of Mechanical Eng.

Robotics

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Homework 2

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November 3, 2023

Robotics

Homework 2

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Questions

Construct a model for the RPP robot in Simulink/Simmechanis. Show your reference frames on the following figure and submit them along with your Simulink model.

Question 1

Use the IC block to set the values of the joint variables according to the following table and find the position of the tip of the last link (end-effector):

$\theta(deg)$	-90	30	150	-18	56	280
$d_1(mm)$	150	120	30	100	30	220
$d_2(mm)$	100	80	0	0	170	110

$$L_1 = 45mm, L_2 = 22.5mm, L_3 = 30mm$$

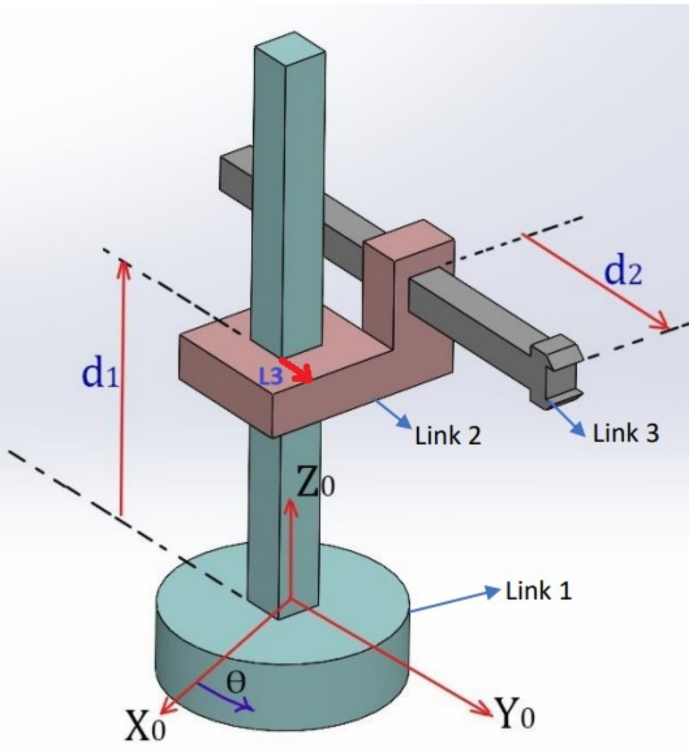

Figure 1: Isometric view of the robot.

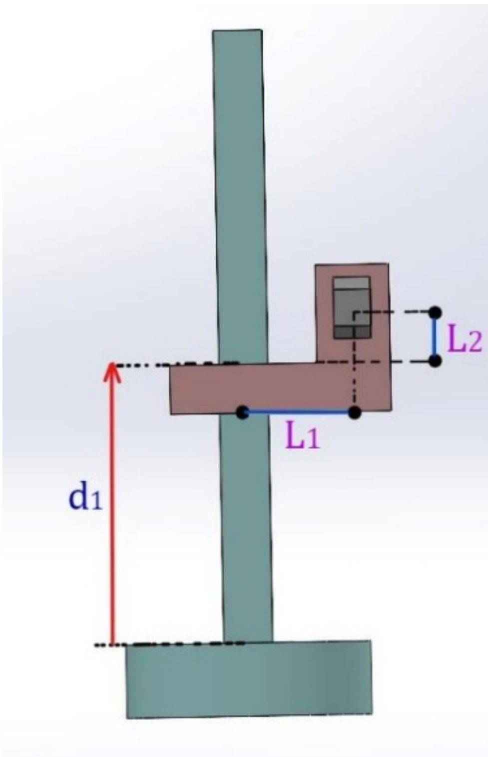

Figure 2: Front view of the robot.

Solution

I begin by placing the coordinates in the specified locations on the every link of the robot as the figure beside. By linking $Frame_0$ with World Frame via revolute joint, the rotation of the robot with respect to World Frame is available. Hence $Frame_1$ is defined in a manner that there is a prismatic joint along the z-axis and this joint performs the altitude of robot's end-effector. Afterwards $Frame_2$ is defined such that there is a prismatic joint between $Link_2$ and $Link_3$ along the z-axis and this joint performs length of robot's end-effector hand.

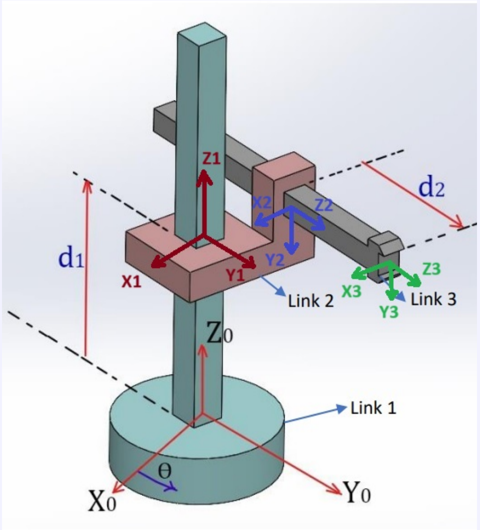

Figure 3: Frame Placement

Now the robot is modeled as below in Simulink:

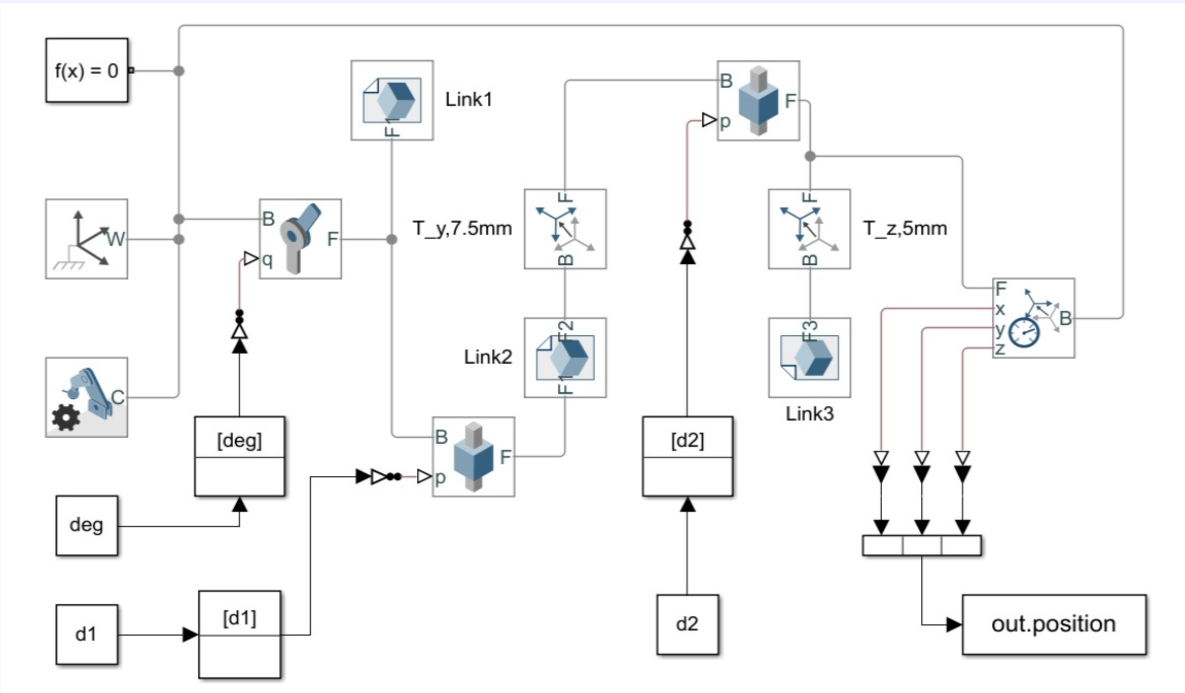

Figure 4: Simulink Model

At the start of every simulation, a pop-up window asks for the values of the robot's parameters,θ,d_1, and d_2, to configure the robot according to the parameters. Using the transformation sensor, the end-effector's position is calculated and is concatenated in a vector called "pos" in the Base Workspace for every 6 simulation. The position of the robot's end-effector for every configuration is shown in the table below:

Config.	$\theta(deg)$	-90	30	150	-18	56	280
	$d_1(mm)$	150	120	30	100	30	220
	$d_2(mm)$	100	80	0	0	170	110
End-Eff.	$x(mm)$	130.00	-93.9711	23.9711	-33.5270	-190.9712	130.0589
	$y(mm)$	45.00	72.7628	-48.4808	42.4375	74.5319	68.6271
	$z(mm)$	172.50	142.50	52.50	122.50	52.50	242.50

Question 2

Follow the DH convention, fill up the table, and use your last assignment to solve the forward Kinematics and find the end-effector position for the last table's joint values. Report your DH table and the results and compare with those of part 1.

Solution

Following the DH convention, $Frame_0$ or respectively our World Frame is contacted with $Frame_1$ through revolute joint along z-axis. Next, $Frame_2$ is placed in between $Link_1$ and $Link_2$ along the z-axis performing as prismatic joint. The other prismatic joint between $Link_2$ and $Link3$ is represented with $Frame_3$ which its z-axis is along the prismatic joint path and $Link_3$ and also its x-axis is placed on the common perpendicular of z_2 and z_3. Note that following the DH convention forced us to place $Frame_3$ $L_3 = 30mm$ behind the start point of prismatic joint and d_2, thus the end-effector frame, $Frame_4$, is placed in a way that its z-axis is along the z-axis of $Frame_3$ and its x-axis is parallel with the x-axis of $Frame_3$, which apparently represents the displacement of end-effector via prismatic joint. As said before, this displacement is actually $d_2 + 30$ due to frames' placement based on DH convention.

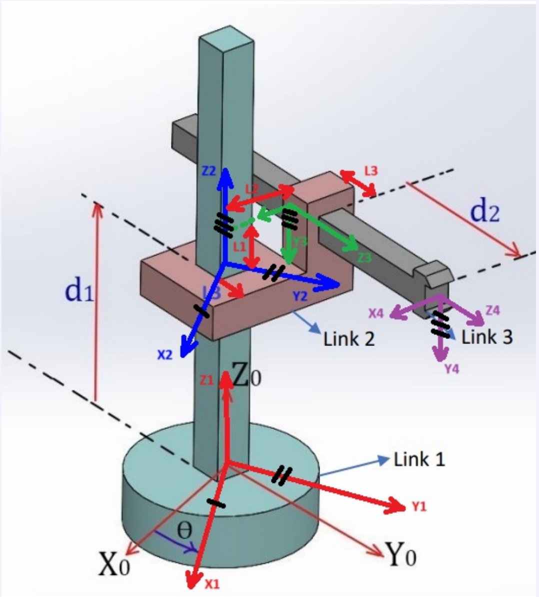

Figure 5: Frame Placement

DH Table is formed as below:

	θ	d	l	α
1	$\underline{\theta}$	$\underline{d_1}$	0	0
2	0	L_3	L_3	$-90°$
3	0	$\underline{d_2}$	0	0

According to the DH table, H_4^0 is found as below:

$$H_4^0 = \prod_{i=0}^{3} H_{i+1}^i = H_1^0 H_2^1 H_3^2 H_4^3 = R_{z,\theta} T_{z,d_1} T_{x,-L_1} T_{z,L_2} R_{x,-90^\circ} T_{z,d_2+L_3}$$

Using the homogeneous transformation above, the position of the robot's end-effector is found as below:

$$\begin{bmatrix} \vec{O}_4^0 \\ 1 \end{bmatrix} = H_4^0 \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}^T$$

The steps above are implemented in the MATLAB code below:

```
function [position] = RPP_Pos(theta,d1,d2)
position=[];
L1=45;L2=22.5;L3=30;
for i=1:length(theta)
    H=Rot('z',theta(i))*Trans('z',d1(i))*Trans('x',-L1)*Trans(
       'z',L2)*Rot('x',-90)*Trans('z',d2(i)+L3)*[0;0;0;1];
    position=[position H(1:3)]; % Concatenating the results
       for different configuration along each other
end
end
```

The position of the robot's end-effector according to the DH convention is shown in the table below:

Config.	$\theta(deg)$	-90	30	150	-18	56	280
	$d_1(mm)$	150	120	30	100	30	220
	$d_2(mm)$	100	80	0	0	170	110
End-Eff.	$x(mm)$	130.00	-93.9711	23.9711	-33.5270	-190.9712	130.0589
	$y(mm)$	45.00	72.7628	-48.4808	42.4375	74.5319	68.6271
	$z(mm)$	172.50	142.50	52.50	122.50	52.50	242.50

Conclusion

It's apparent that the Simulink model and DH convention have the same results for the position of the robot's end-effector.