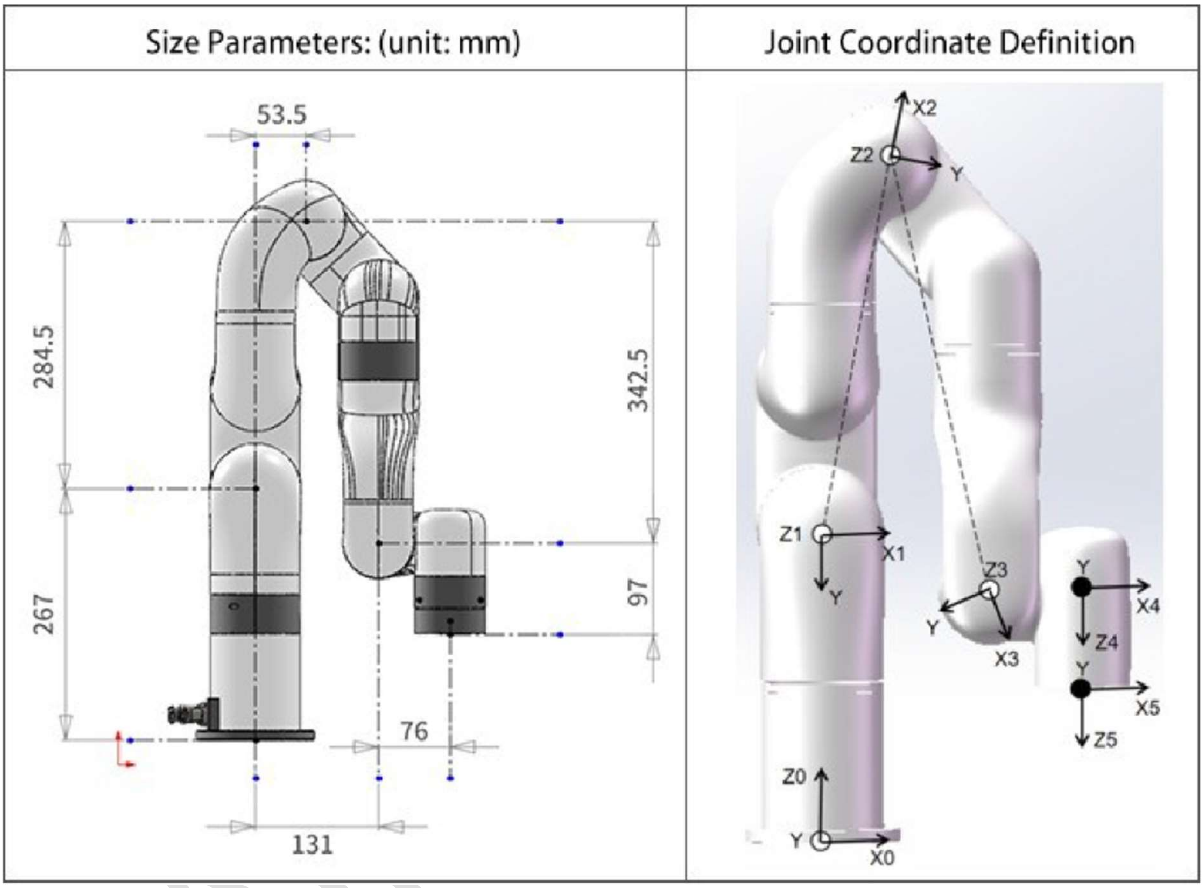
Experiment No: 1&2

Experiment Name: Obtain the DH parameters of X-arm 5 lite and forward kinemtics

Objective:

Obtain the DH parameters of X-arm 5 lite and forward kinematics.

Theory:



Kinematics	theta (rad)	d (mm)	alpha (rad)	a (mm)	offset (rad)
Joint1	0	267	-pi/2	0	0
Joint2	0	0	0	a2	T2_offset
Joint3	0	0	0	a3	T3_offset
Joint4	0	0	-pi/2	76	T4_offset
Joint5	0	97	0	0	0

Note:

'**Tx_offset**' is the offset joint angle from the mathematical zero position to the mechanical zero position shown in the picture.

T2_offset = -atan(284.5/53.5) = -1.3849179 (-79.34995°);

T3_offset = atan(284.5/53.5)+atan(0.3425/0.0775) = 2.7331843 (156.599924°);

a2 = sqrt(284.5^2+53.5^2) = 289.48866;

T4_offset = -atan(342.5/77.5) = -1.3482664 (-77.249974°);

a3 = sqrt(77.5^2+342.5^2) = 351.158796;

Based on the DH convention, the transformation matrix **from joint i to joint i+1** is given by:

$$i + 1iT = A_{n+1}$$

$$= Rot(z, \theta_{n+1}) Trans(z, d_{n+1}) Trans(x, a_{n+1}) Rot(x, \alpha_{n+1})$$

$$= [C\theta_i \ - S\theta_i C\alpha_i \ S\theta_i S\alpha_i \ a_i C\theta_i \ S\theta_i \ C\theta_i C\alpha_i \ - C\theta_i S\alpha_i \ a_i S\theta_i \ 0 \ S\alpha_i \ C\alpha_i \ d_i \ 0\,0\,0\,1] \qquad (1)$$

Where $S\theta_i = sin\, sin\, \theta_i$, $C\theta_i = cos\, cos\, \theta_i$, $S\alpha_i = sin\, sin\, \alpha_i$, $C\alpha_i = cos\, cos\, \alpha_i$, $S_{ijk} = sin\, sin\, (\theta_i + \theta_j + \theta_k)$ and $C_{ijk} = cos\, cos\, (\theta_i + \theta_j + \theta_k)$

For 5 DoF robot, $HoT = [n_x \ o_x \ a_x \ p_x \ n_y \ o_y \ a_y \ p_y \ n_z \ o_z \ a_z \ p_z \ 0\,0\,0\,1] = A_1 A_2 A_3 A_4 A_5$

The above equation will give expressions for the end effector position and orientation.

NB: Joint variable θ will be updated according to the table below after considering offset. Use the new value with offset for Arm matrix calculation.

Joint variables(degree)	Joint variable (radian)	Offset (radian)	Joint variable + offset (radian)
$J_1 = \theta_1$	$\theta_1(rad)$		$\theta_1(rad)$
$J_2 = \theta_2$	$\theta_2(rad)$	-1.38	$\theta_2(rad) - 1.38$
$J_3 = \theta_3$	$\theta_3(rad)$	2.73	$\theta_3(rad) + 2.73$
$J_4 = \theta_4$	$\theta_4(rad)$	$-1 \cdot 35$	$\theta_4(rad) - 1.35$
$J_5 = \theta_5$	$\theta_5(rad)$		$\theta_5(rad)$

Find $[p_x \ p_y \ p_z\ ]^T$ using the above table and DH table by substituting in (1).

Procedure:

1. Find DH parameters.
2. Open MATLAB and prepare code for forward kinematics calculation.
3. Input all DH values and calculate each transformation matrix.
4. Calculate the Arm equation from above calculated matrices.
5. Display the result.
6. Turn On the X-arm and open the X-arm studio.
7. Adjust the slider to set joint parameters as in the table.
8. Run the robot.
9. Observe the end effector position of the real robot, with input joint parameters as in the calculation table.
10. Compare the calculated value with the observed value with the real robot.

Calculation:

Joint variables(degree)	Joint variable (radian)	Offset (radian)	Joint variable + offset (radian)
$J_1 =$			
$J_2 =$		-1.38	
$J_3 =$		2.73	
$J_4 =$		$-1 \cdot 35$	
$J_5 =$			

$A_1 =$	$A_2 =$	$A_3 =$
$A_4 =$	$A_5 =$	
$EBT =$		

Find $[p_x \; p_y \; p_z \,]^T$ using above table and DH table by substituting in (1) .

Observation:

Calculated value =

Observed value =

Code:

MATLAB code

```
d1=267;
d2=0;
d3=0;
d4=0;
d5=97;

Theta1=0;
Theta2=-0.7749262;
Theta3=-0.577704;
Theta4=1.35263;
Theta5=0;

a1=0;
a2=289.48866;
a3=351.158796;
a4=76;
a5=0;

alpha1=-pi/2;
alpha2=0;
alpha3=0;
alpha4=-pi/2;
alpha5=0;

M1=[cos(Theta1) -cos(alpha1)*sin(Theta1) sin(alpha1)*sin(Theta1)
a1*cos(Theta1); sin(Theta1) cos(alpha1)*cos(Theta1) -
sin(alpha1)*cos(Theta1) a1*sin(Theta1);0 sin(alpha1) cos(alpha1)
d1;0 0 0 1];
M2=[cos(Theta2) -cos(alpha2)*sin(Theta2) sin(alpha2)*sin(Theta2)
a2*cos(Theta2); sin(Theta2) cos(alpha2)*cos(Theta2) -
```

```
sin(alpha2)*cos(Theta2) a2*sin(Theta2);0 sin(alpha2) cos(alpha2)
d2;0 0 0 1];
M3=[cos(Theta3) -cos(alpha3)*sin(Theta3) sin(alpha3)*sin(Theta3)
a3*cos(Theta3); sin(Theta3) cos(alpha3)*cos(Theta3) -
sin(alpha3)*cos(Theta3) a3*sin(Theta3);0 sin(alpha3) cos(alpha3)
d3;0 0 0 1];
M4=[cos(Theta4) -cos(alpha4)*sin(Theta4) sin(alpha4)*sin(Theta4)
a4*cos(Theta4); sin(Theta4) cos(alpha4)*cos(Theta4) -
sin(alpha4)*cos(Theta4) a4*sin(Theta4);0 sin(alpha4) cos(alpha4)
d4;0 0 0 1];
M5=[cos(Theta5) -cos(alpha5)*sin(Theta5) sin(alpha5)*sin(Theta5)
a5*cos(Theta5); sin(Theta5) cos(alpha5)*cos(Theta5) -
sin(alpha5)*cos(Theta5) a5*sin(Theta5);0 sin(alpha5) cos(alpha5)
d5;0 0 0 1];
M=M1*M2*M3*M4*M5;
P=[0;0;0;1];
PM=M*P;
```

Result: