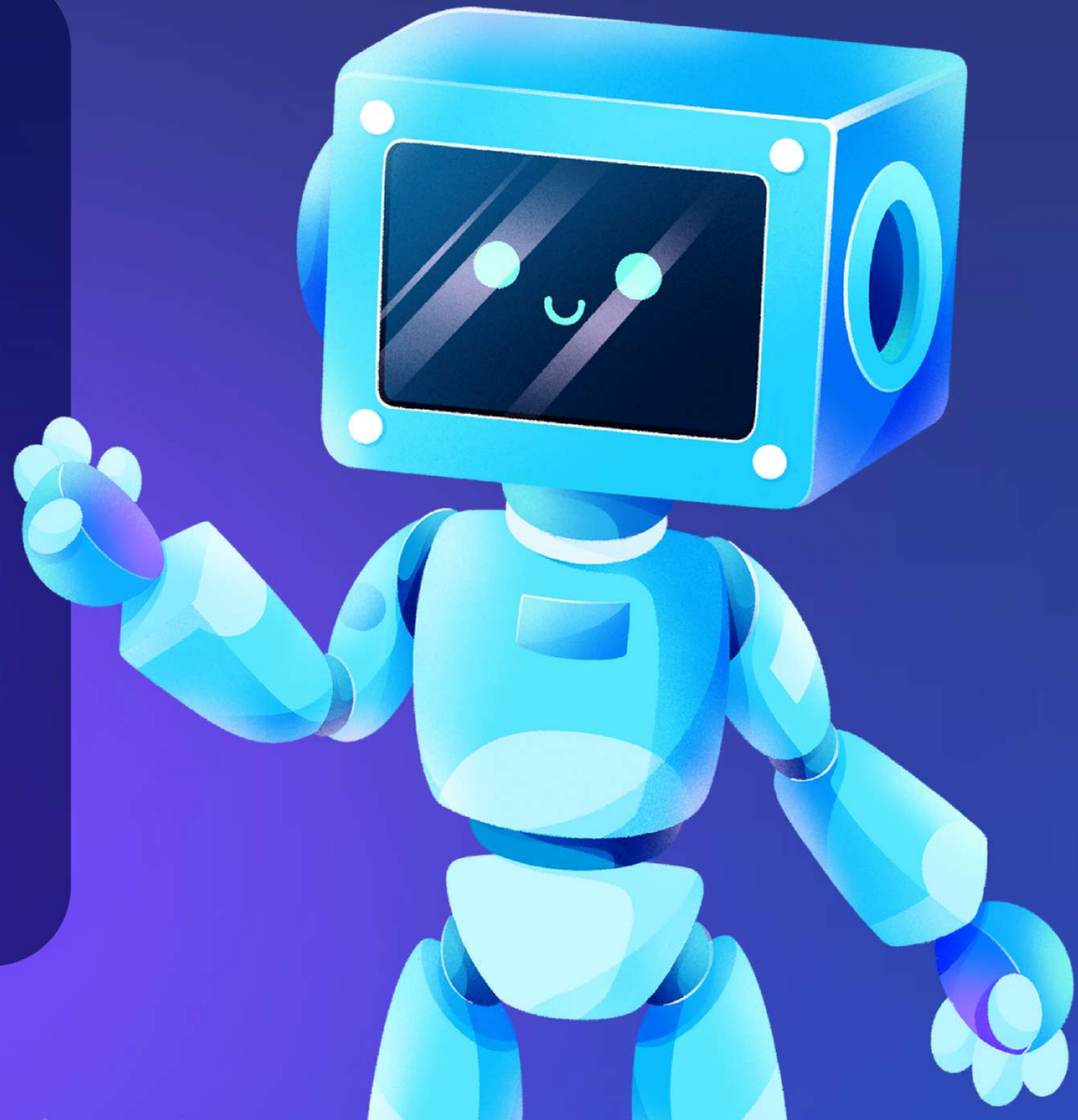
EN4563 - ROBOTICS

MINI PROJECT

GROUP 11



TEAM MEMBERS

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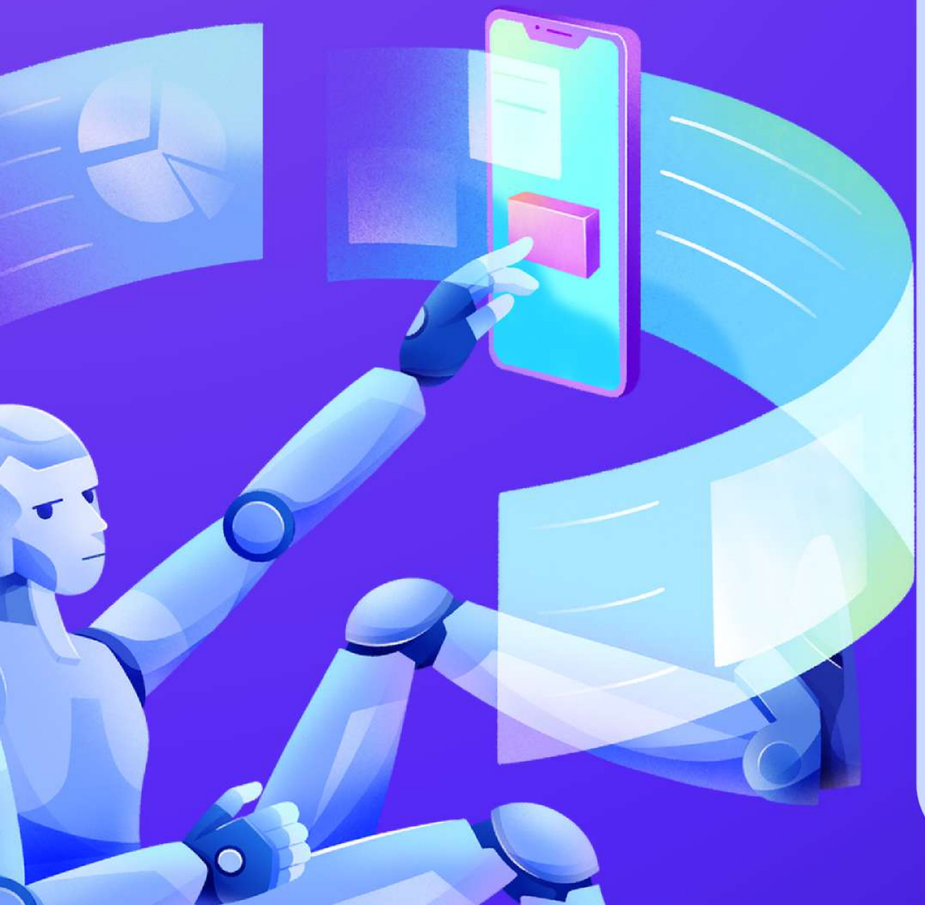
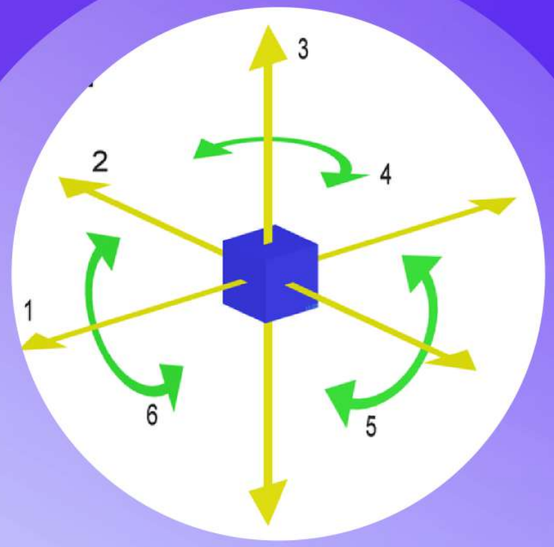
CONTENT



- Arm Properties
- Frame Assignment Diagram
- DH Table
- Forward Kinematics
- Inverse Kinematics
- Manipulator Jacobian
- Pick and place Task

ARM PROPERTIES

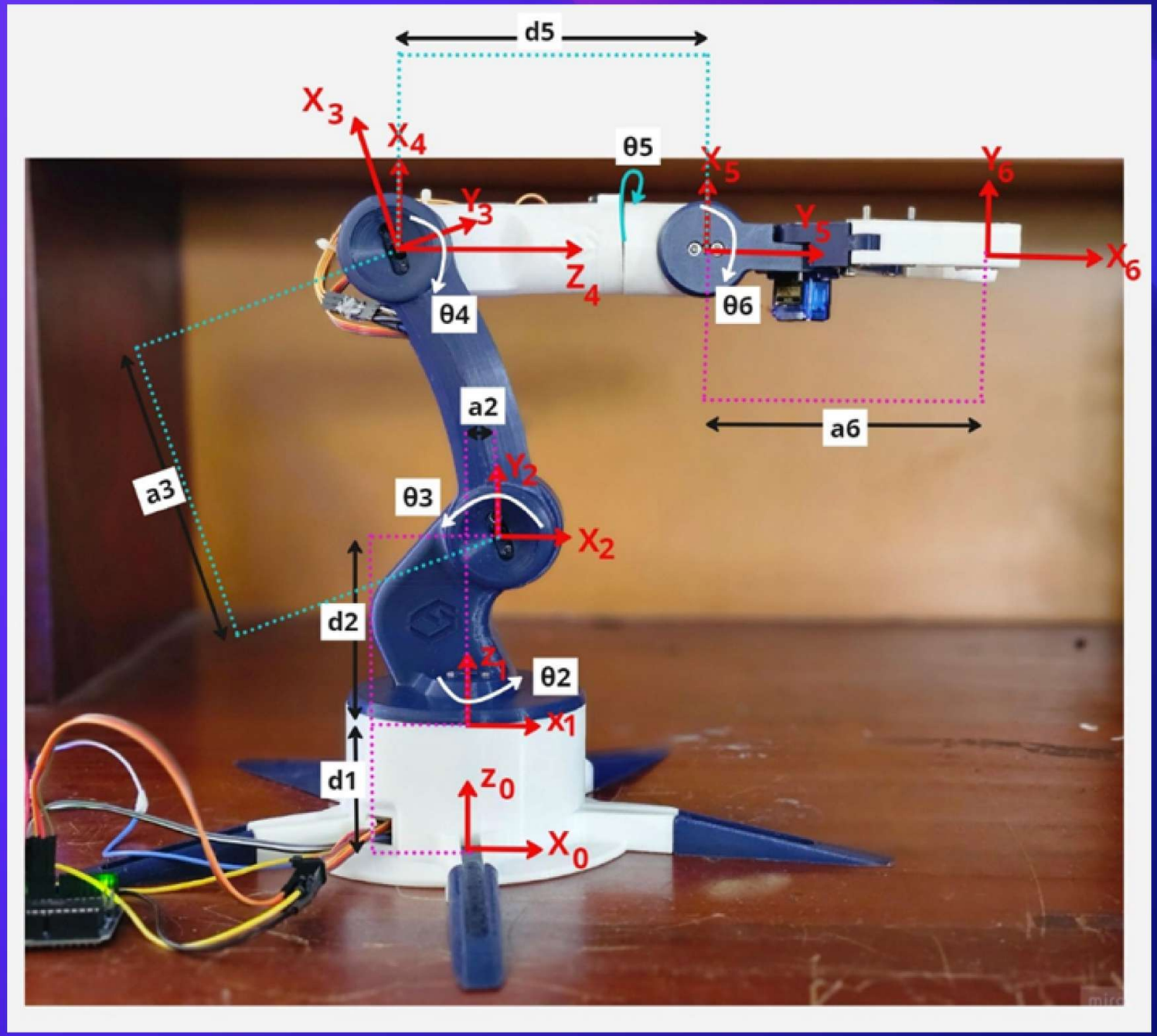


5 - Degree of Freedom (DoF)

RRRRR Configuration

FRAME ASSIGNMENT DIAGRAM

Parameter	Length
a2	1.3 cm
a3	12.021 cm
a6	13 cm
d1	6.1 cm
d2	7.001 cm
d5	12.171 cm



DH TABLE

```
noname:: 5 axis, RRRRR, stdDH, slowRNE
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|     13.101|        1.3|     1.5708|          0|
|  2|         q2|          0|     12.021|    3.14159|   0.785398|
|  3|         q3|          0|          0|    -1.5708|  -0.785398|
|  4|         q4|      12.17|          0|     1.5708|          0|
|  5|         q5|          0|         13|    3.14159|     1.5708|
+---+-----------+-----------+-----------+-----------+-----------+
```

Link	a_i	α_i	d_i	θ_i
1	0	0	d1	0
2	a2	$\frac{\pi}{2}$	d2	θ_2^*
3	a3	π	0	$\theta_3^* + k_3$
4	0	$-\frac{\pi}{2}$	0	$\theta_4^* + k_4$
5	0	$\frac{\pi}{2}$	d5	θ_5^*
6	a6	π	0	$\theta_6^* + k_6$

k - Offset angle

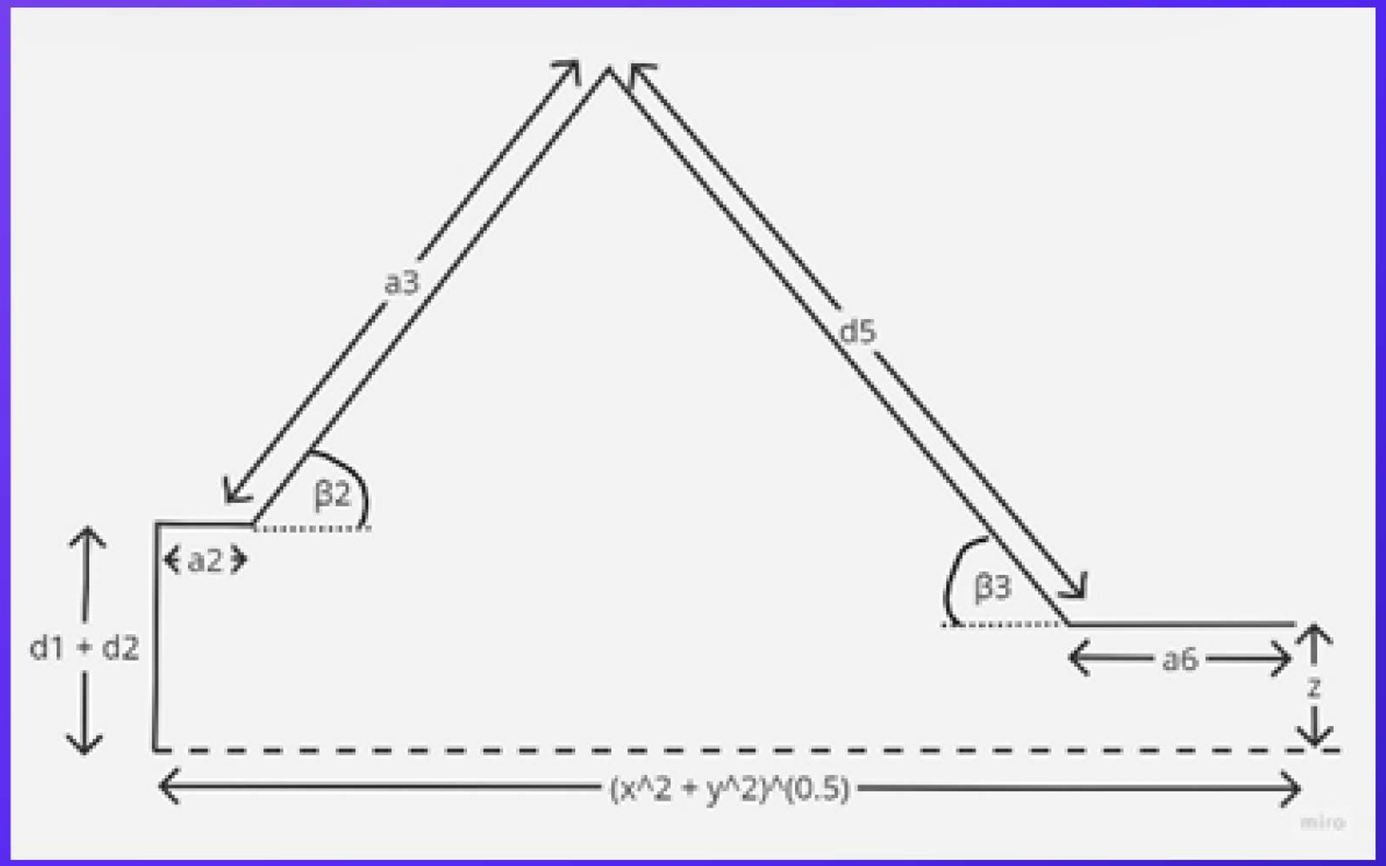
FORWARD KINEMATICS

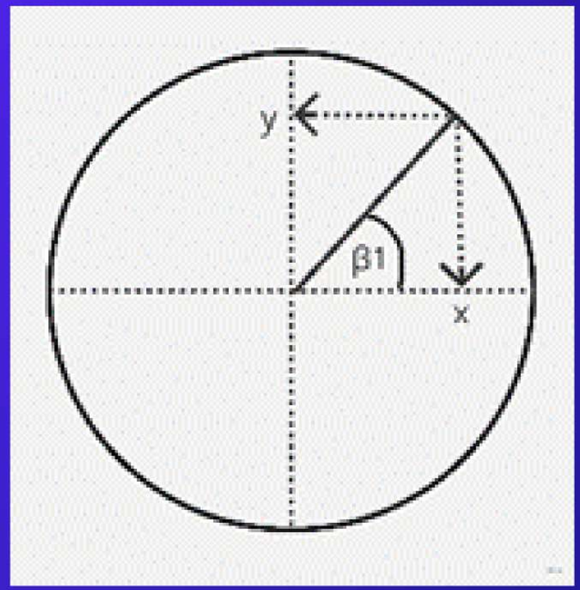
$$\mathrm{R} = \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}, \ \mathrm{t} = \begin{bmatrix} t_{11} \\ t_{21} \\ t_{31} \end{bmatrix}, \mathrm{H} = \begin{bmatrix} R_{3\times3} & t_{3\times1} \\ O_{1\times3} & 1_{1\times1} \end{bmatrix}$$

Forward kinematics for θ2 = θ3 = θ4 = θ5 = θ6 = 0

```
fwd =
          1          0          0      33.97
          0          0         -1          0
          0          1          0       21.6
          0          0          0          1
```

INVERSE KINEMATICS





INVERSE KINEMATICS

$$\sqrt{x^2 + y^2} = a_2 + a_3 \cos\beta_2 + d_5 \cos\beta_3 + a_6$$
$$y = x \tan\beta_1$$
$$Z = d_1 + d_2 + a_3 \sin\beta_2 - d_5 \sin\beta_3$$

$$0^0 < \beta_1 < 165^0$$
$$0^0 < \beta_2 < 120^0$$
$$-80^0 < \beta_3 < 85^0$$

$$\theta_2 = \beta_1$$
$$\theta_3 = \beta_2 - \frac{\pi}{4}$$

$$\theta_4 = \beta_3 - \beta_2 + \frac{\pi}{4}$$
$$\theta_6 = \theta_3 - \theta_4$$

MANIPULATOR JACOBIAN

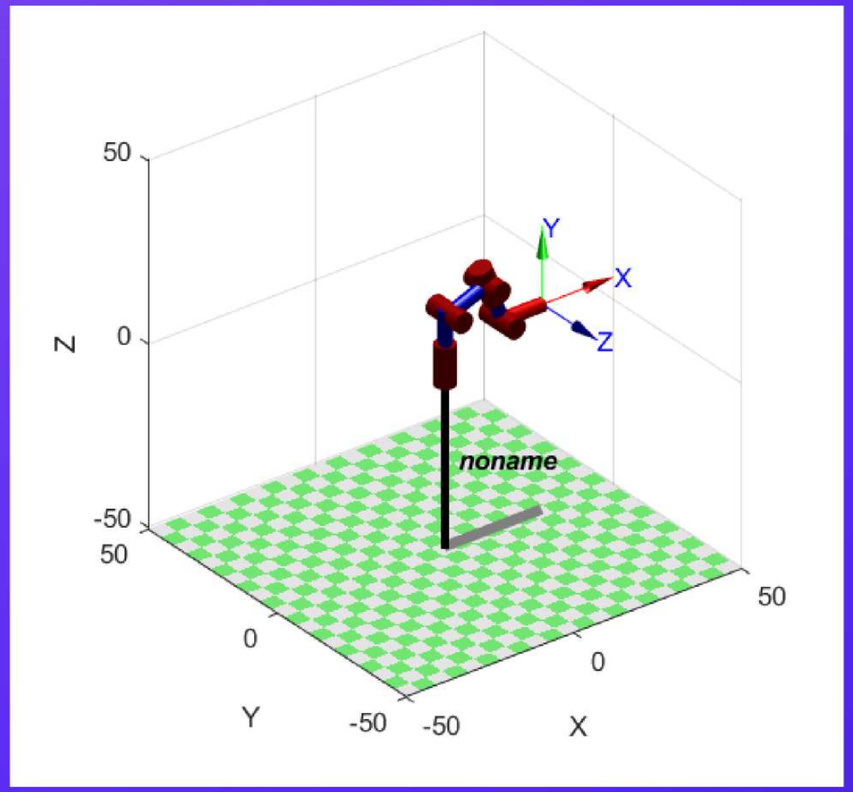
$$
\mathrm{J} = \begin{bmatrix}
J_{11} & J_{12} & J_{13} & J_{14} & J_{15} & J_{16} \\
J_{21} & J_{22} & J_{23} & J_{24} & J_{25} & J_{26} \\
0 & 0 & J_{33} & J_{34} & J_{35} & J_{36} \\
0 & 0 & \sin(th2) & -\sin(th2) & \sin(th3 - th4 + 1.57) \cdot \cos(th2) & -\sin(th2) \\
0 & 0 & -\cos(th2) & \cos(th2) & \sin(th3 - th4 + 1.57) \cdot \sin(th2) & \cos(th2) \\
1 & 1 & 0 & 0 & -\cos(th3 - th4 + 1.57) & 0
\end{bmatrix}
$$

PICK & PLACE TASK

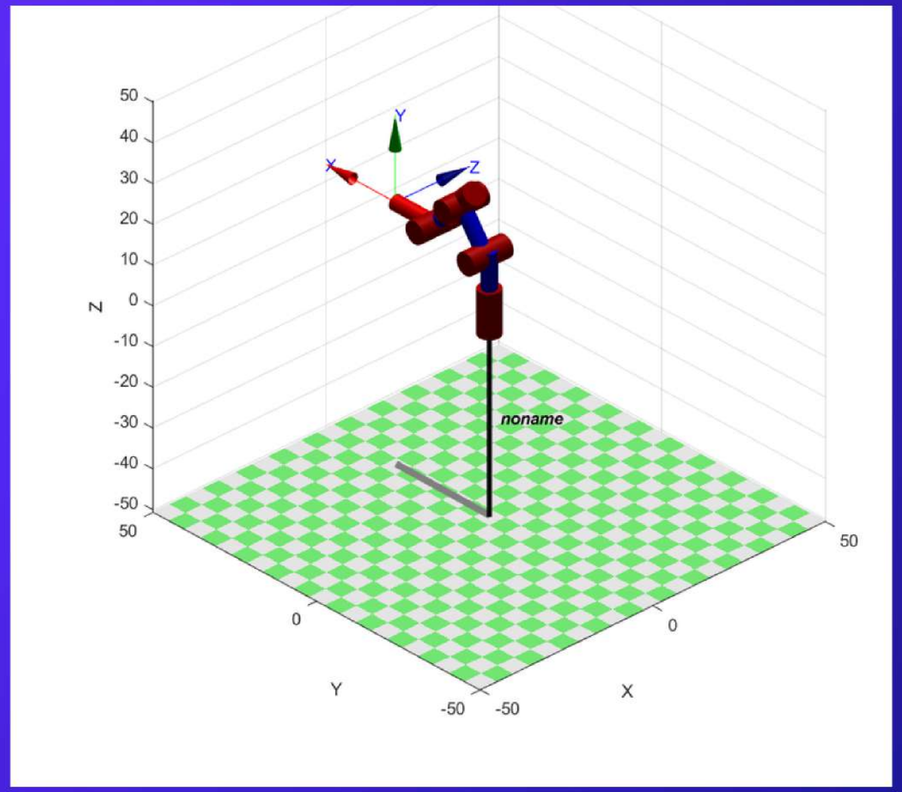
Starting Point		X	30		Y	0		Z	6		
Ending Point		X	0.2		Y	30		Z	14		
Joint Angles	Starting Point	θ_2	0^0	θ_3	-24^0	θ_4	69^0	θ_5	0^0	θ_6	-69^0
	Ending Point	θ_2	90^0	θ_3	8^0	θ_4	46^0	θ_5	0^0	θ_6	-46^0
Homogeneous Matrix	Starting Point	fwd =									
		1	0	0	29						
		0	0	-1	0						
		0	1	0	6.001						
		0	0	0	1						
	Ending Point	fwd =									
		0.0067	0	1.0000	0.1933						
		1.0000	0	-0.0067	29						
		0	1	0	14						
		0	0	0	1						

PICK & PLACE TASK

PICK & PLACE TASK



Starting Point - Pick



Ending Point - Place

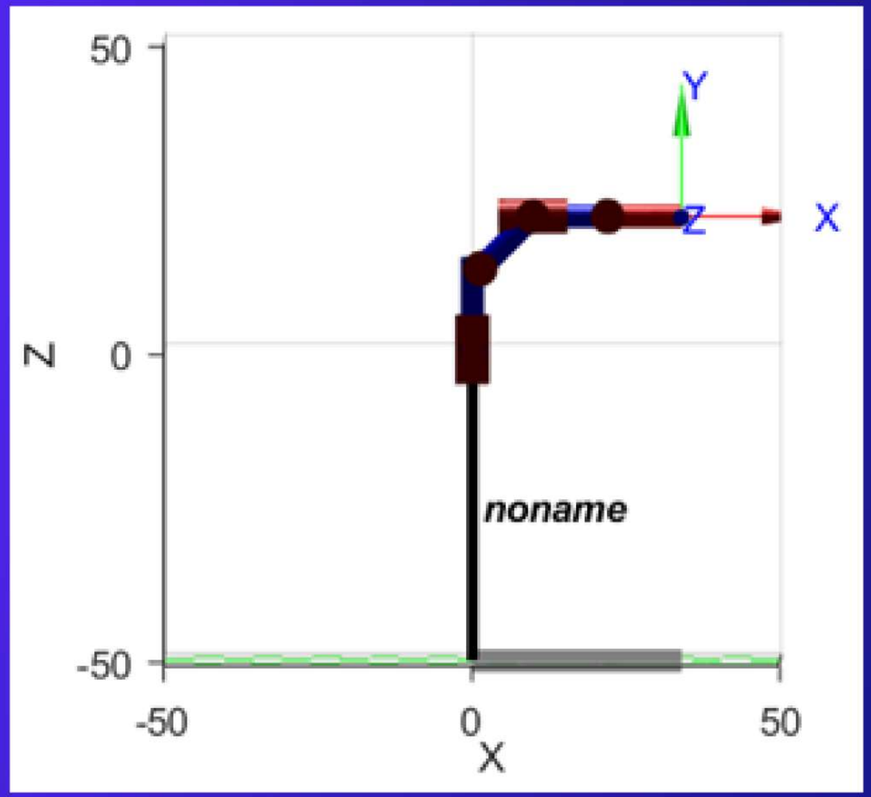
FORWARD KINEMATICS VERIFICATION

```
fwd =
         1         0         0    33.97
         0         0        -1        0
         0         1         0    21.6
         0         0         0        1
```

X out = 34 cm

Y out = 0 cm

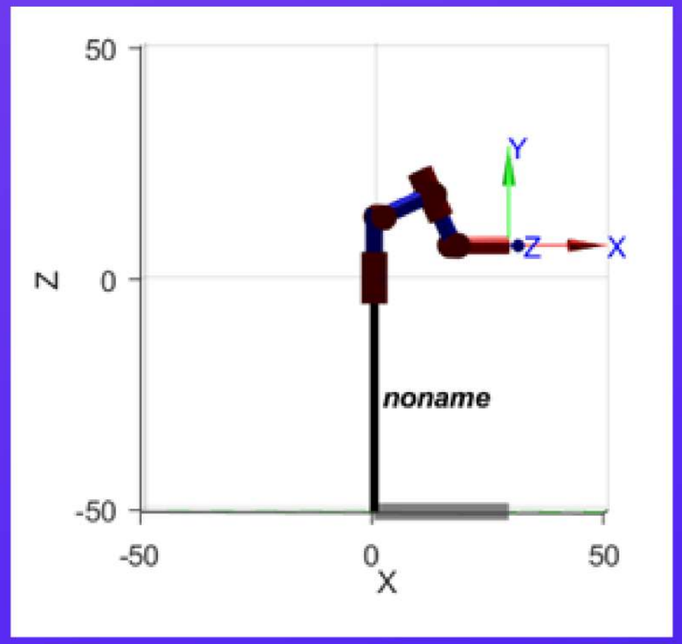
Z out = 22 cm

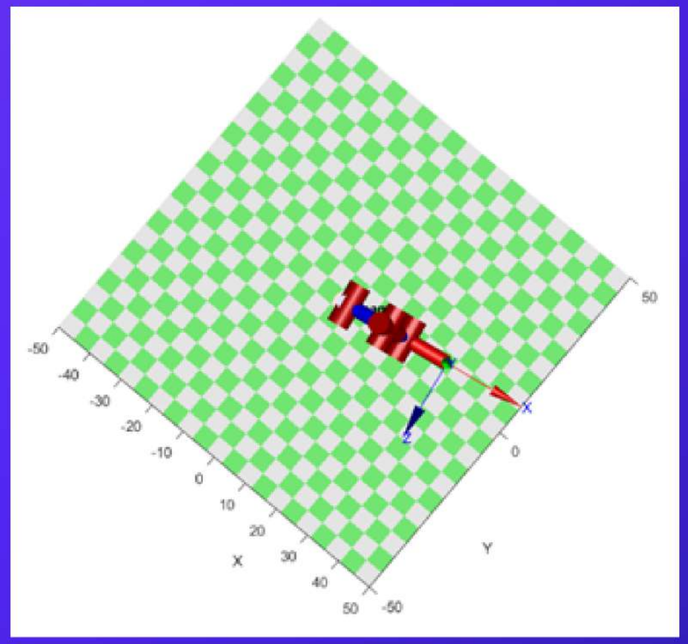


INVERSE KINEMATICS VERIFICATION

```
fwd =
    0.9864         0    0.1644   29.01
    0.1644         0   -0.9864    4.836
         0         1         0    7.001
         0         0         0        1
```

X = 30 cm Y = 5 cm Z = 7 cm





THANK YOU!