EN3563 - Robotics

Mini Project

Group 1

Team Members

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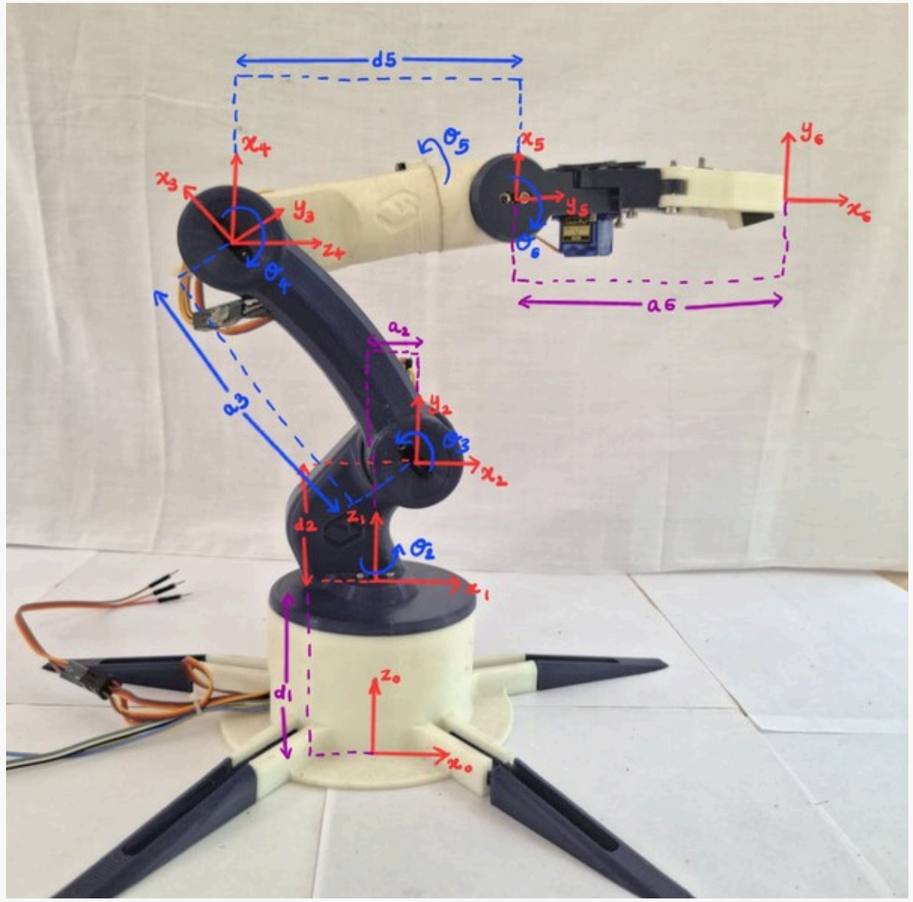
Robot Arm

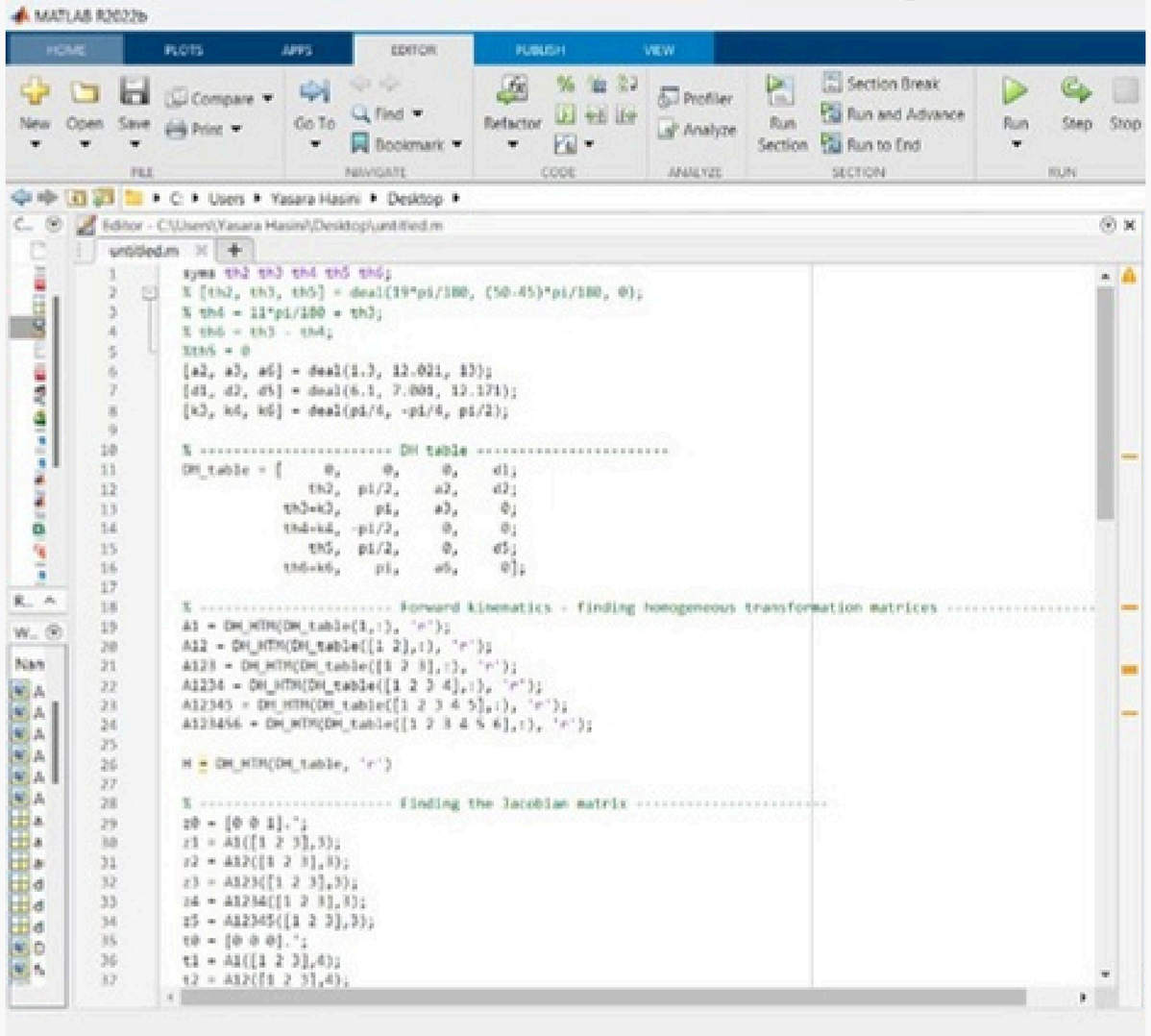
- 5 DOF
- 6 links
- Has RRRRR configuration : all joints are revolute joints

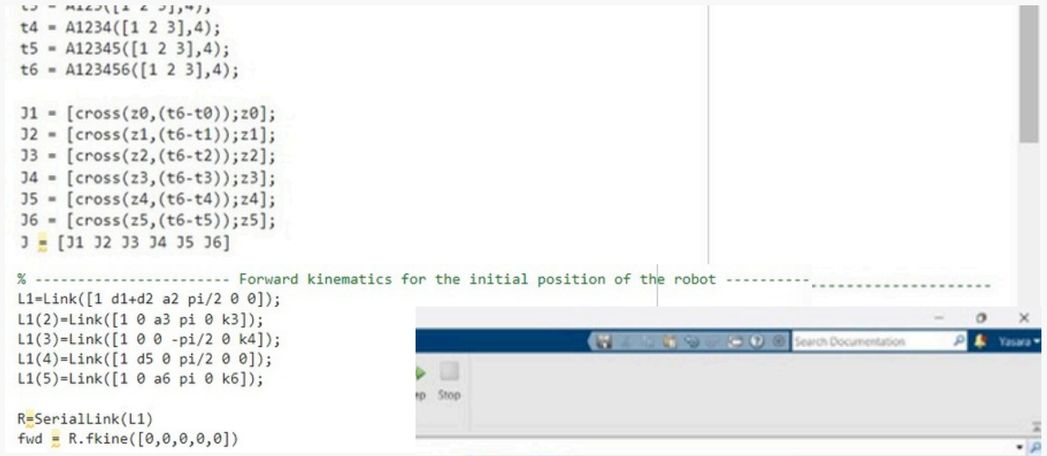
DH Table for the Robot Arm

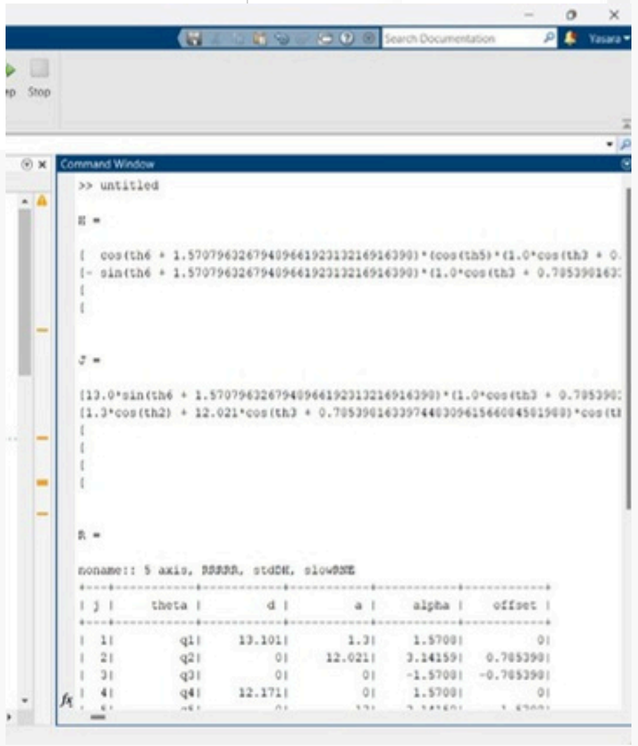


Link	α_i	α_i	d_i	θ_i
1	0	0	6.1	0
2	1.3	π/2	7	θ_2^*
3	12	π	0	$\theta_3^* + \pi/4$
4	0	-π/2	0	$\theta_4^* - \pi/4$
5	0	π/2	12.2	θ_5^*
6	13	π	0	$\theta_6^* + \pi/2$

Forward Kinematics Equations







Forward Kinematics Equations

$$\mathrm{R} = \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}$$

$$\mathbf{t} = \begin{bmatrix} t_{11} \\ t_{21} \\ t_{31} \end{bmatrix}$$

$$\mathrm{H} = \begin{bmatrix} R_{3\times3} & t_{3\times1} \\ O_{1\times3} & 1_{1\times1} \end{bmatrix}$$

R_{11} = cos(th6+1.57)*(cos(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*cos(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*cos(th2))+1.0*sin(th2)*sin(th5))-sin(th6+1.57)*(1.0*cos(th3+0.79)*sin(th4-0.79)*cos(th2)-1.0*cos(th4-0.79)*sin(th3+0.79)*cos(th2))

R_{12} = 1.0*cos(th6+1.57)*(1.0*cos(th3+0.79)*sin(th4-0.79)*cos(th2)-1.0*cos(th4-0.79)*sin(th3+0.79)*cos(th2))+sin(th6+1.57)*(cos(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*cos(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*cos(th2))+1.0*sin(th2)*sin(th5))

R_{13} = 1.0*cos(th5)*sin(th2)-1.0*sin(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*cos(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*cos(th2))

Forward Kinematics Equations

R_{21} = -sin(th6+1.57)*(1.0*cos(th3+0.79)*sin(th4-0.79)*sin(th2)-1.0*cos(th4-0.79)*sin(th3+0.79)*sin(th2))-cos(th6+1.57)*(1.0*cos(th2)*sin(th5)-cos(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*sin(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*sin(th2)))

R_{22} = 1.0*cos(th6+1.57)*(1.0*cos(th3+0.79)*sin(th4-0.79)*sin(th2)-1.0*cos(th4-0.79)*sin(th3+0.79)*sin(th2))-sin(th6+1.57)*(1.0*cos(th2)*sin(th5)-cos(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*sin(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*sin(th2)))

R_{23} = -1.0*cos(th2)*cos(th5)-1.0*sin(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*sin(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*sin(th2))

R_{31} = cos(th6+1.57)*sin(th3-1.0*th4+1.57)*cos(th5)-1.0*sin(th6+1.57)*cos(th3-1.0*th4+1.57)

R_{32} = cos(th6+1.57)*cos(th3-1.0*th4+1.57)+sin(th6+1.57)*sin(th3-1.0*th4+1.57)*cos(th5)

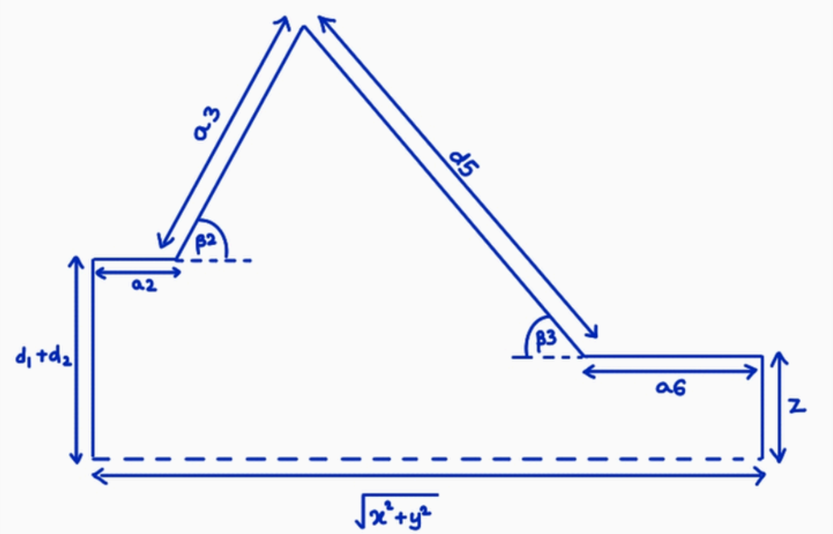
R_{33} = -1.0*sin(th3-th4+1.57)*sin(th5)

t_{11} = 1.3*cos(th2)+12.021*cos(th3+0.79)*cos(th2)+13.0*cos(th6+1.57)*(cos(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*cos(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*cos(th2))+1.0*sin(th2)*sin(th5))-13.0*sin(th6+1.57)*(1.0*cos(th3+0.79)*sin(th4-0.79)*cos(th2)-1.0*cos(th4-0.79)*sin(th3+0.79)*cos(th2))-12.171*cos(th3+0.79)*sin(th4-0.79)*cos(th2)+12.171*cos(th4-0.79)*sin(th3+0.79)*cos(th2)

t_{21} = 1.3*sin(th2)-13.0*sin(th6+1.57)*(1.0*cos(th3+0.79)*sin(th4-0.79)*sin(th2)-1.0*cos(th4-0.79)*sin(th3+0.79)*sin(th2))+12.021*cos(th3+0.79)*sin(th2)-13.0*cos(th6+1.57)*(1.0*cos(th2)*sin(th5)-cos(th5)*(1.0*cos(th3+0.79)*cos(th4-0.79)*sin(th2)+1.0*sin(th3+0.79)*sin(th4-0.79)*sin(th2)))-12.171*cos(th3+0.79)*sin(th4-0.79)*sin(th2)+12.171*cos(th4-0.79)*sin(th3+0.79)*sin(th2)

t_{31} = 12.021*sin(th3+0.79)-12.171*cos(th3-th4+1.57)+6.5*cos(th6-th5+1.57)*sin(th3-th4+1.57)-13.0*cos(th3-th4+1.57)*sin(th6+1.57)+6.5*cos(th5+th6+1.57)*sin(th3-th4+1.57)+13.101

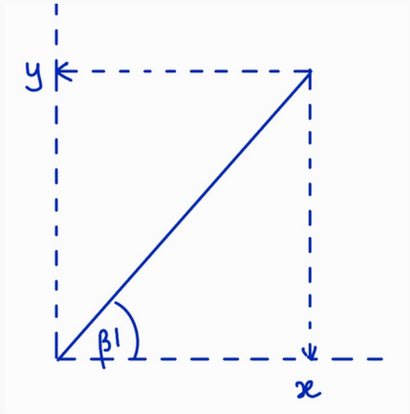
Inverse Kinematics Equations



$$y = x \tan \beta_1$$

$$\sqrt{x^2 + y^2} = 1.3 + 12.0 \cos \beta_2 + 12.171 \cos \beta_3 + 13$$

$$Z = 6.1 + 7.0 + 12.0 \sin \beta_2 - 12.1 \sin \beta_3$$



$$\theta_2 = \beta_1$$

$$\theta_3 = \beta_2$$

$$\theta_4 = \beta_2 + \beta_3 - \frac{\pi}{2}$$

$$\theta_5 = 0$$

$$\theta_6 = \frac{\pi}{2} - \beta_3$$

Manipulator Jacobian

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

J_{11} = -(sin(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000

J_{12} = -0.001*sin(th2)*(13000.0*cos(th3-th4-th6+)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0)

J_{13} = 1.0*cos(th2)*(12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79))

J_{14} = -cos(th2)*(12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79)+12.021*sin(th3+0.79))

J_{15} = 1.0*cos(th3-th4+1.57)*((sin(th2)*(12021.0*cos(th3+0.79)+1300.0))/1000-(sin(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)-sin(th3-th4+1.57)*sin(th2)*(12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79)+12.021*sin(th3+0.79))

J_{16} = -cos(th2)*(12.171*cos(th3-th4+1.57)-12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79)+12.021*sin(th3+0.79))

J_{21} = (cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000

Manipulator Jacobian

J_{22} = 0.001*cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.5)+12021.0*cos(th3+0.79)+1300.0)

J_{23} = sin(th2)*(12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79))

J_{24} = -1.0*sin(th2)*(12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79)+12.021*sin(th3+0.79))

J_{25} = 1.0*cos(th3-th4+1.57)*((cos(th2)*(12021.0*cos(th3+0.79)+1300.0))/1000-(cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)+sin(th3-th4+1.57)*cos(th2)*(12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79)+12.021*sin(th3+0.79))

J_{26} = -1.0*sin(th2)*(12.171*cos(th3-th4+1.57)-12.171*cos(th3-th4+1.57)+13.0*sin(th4-th3+th6)-12.021*cos(th3-0.79)+12.021*sin(th3+0.79))

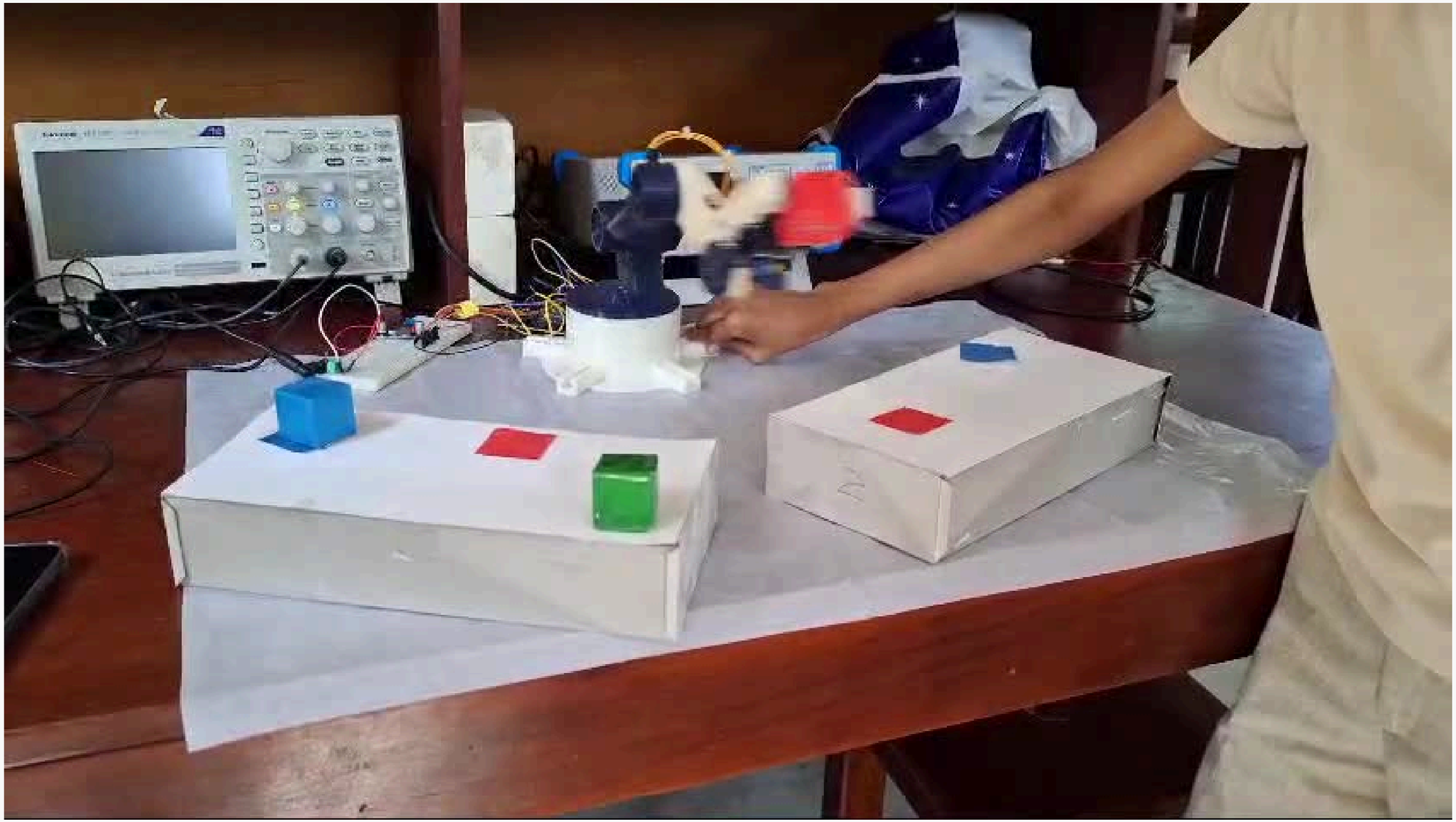
J_{33} = -1.0*cos(th2)*(1.3*cos(th2)-(cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)-sin(th2)*(1.3*sin(th2)-(sin(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)

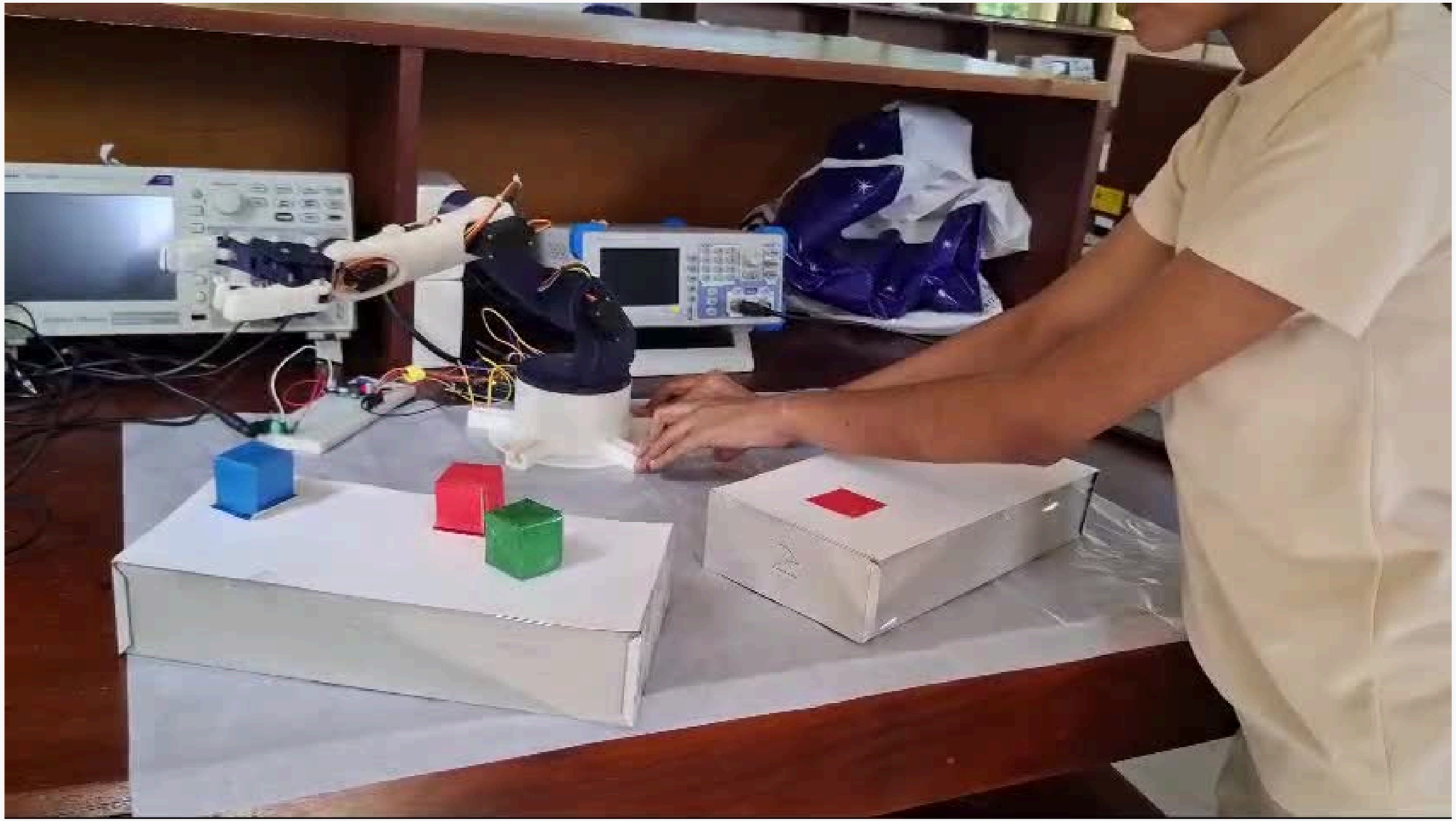
J_{34} = cos(th2)*((cos(th2)*(12021.0*cos(th3+0.79)+1300.0))/1000-(cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)+1.0*sin(th2)*((sin(th2)*(12021.0*cos(th3+0.79)+1300.0))/1000-(sin(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)

J_{35} = sin(th3-th4+1.57)*sin(th2)*((cos(th2)*(12021.0*cos(th3+0.79)+1300.0))/1000-(cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)-sin(th3-th4+1.57)*cos(th2)*((sin(th2)*(12021.0*cos(th3+0.79)+1300.0))/1000-(sin(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))/1000)

Manipulator Jacobian

J_{36} = -cos(th2)*((cos(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+ 1300.0))/1000-0.001*cos(th2)*(12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+ 0.79)+1300.0))- 1.0*sin(th2)*((sin(th2)*(13000.0*cos(th3-th4-th6)+12171.0*sin(th3-th4+ 1.57)+12021.0*cos(th3+ 0.79)+1300.0))/1000-0.001*sin(th2)*(12171.0*sin(th3-th4+1.57)+12021.0*cos(th3+0.79)+1300.0))





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