MCE4101
Robotic Engineering

Assignment 5 SOLUTION

Due: 27 Sept 2021

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Assignment 5: Q1

Q1. With RRR with 3 DOF wrist.

Given DH table and Transformation matrices. Find 2 possible posture solutions for end point location P(2.75,4.763,-2.33).

Given

a2 = 3

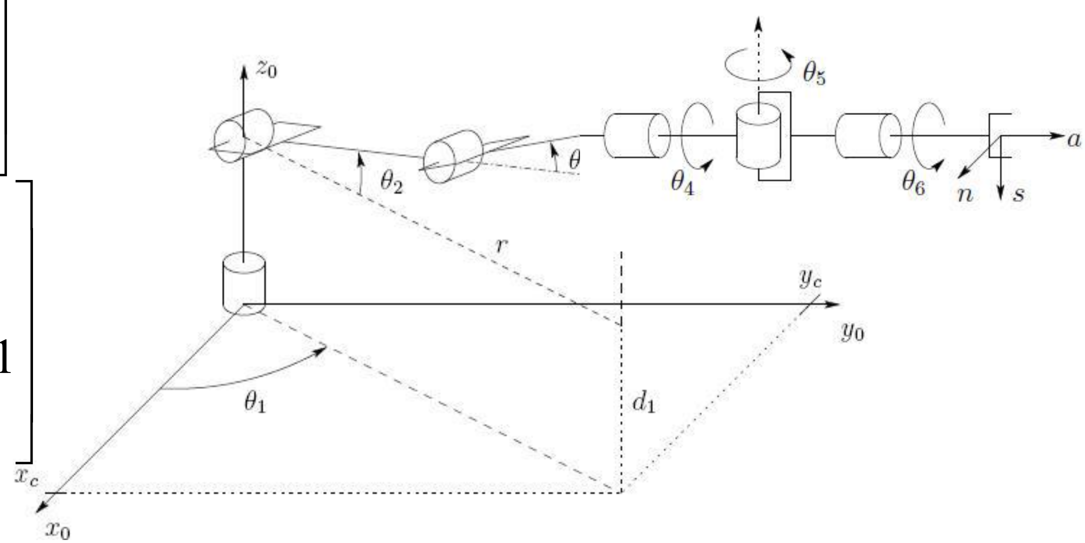
a3 = 5

d1 = 2 (Link1 offset from base)

d6 = 0 (Wrist offset)

$$T_3^0 = \begin{bmatrix} 0.25 & 0.433 & 0.866 & 2.75 \\ 0.433 & 0.75 & -0.5 & 4.76 \\ -0.866 & 0.5 & 0 & -2.3301 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_6^0 = \begin{bmatrix} 0.397 & 0.433 & 0.8095 & 2.75 \\ 0.34 & 0.75 & -0.568 & 4.76 \\ -0.853 & 0.5 & 0.1504 & -2.3301 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



Assignment 5 : Q1

RRR

Link	a_i	α_i	d_i	θ_i
1	0	90	d_1	θ_1^*
2	a_2	0	0	θ_2^*
3	a_3	0	0	θ_3^*

3 DOF Wrist

Link	a_i	α_i	d_i	θ_i
4	0	−90	0	θ_4^*
5	0	90	0	θ_5^*
6	0	0	d_6	θ_6^*

$$R_3^0 = A_1 A_2 A_3 = \begin{bmatrix} c_1 c_{23} & -c_1 s_{23} & s_1 \\ s_1 c_{23} & -s_1 s_{23} & -c_1 \\ s_{23} & c_{23} & 0 \end{bmatrix}$$

$$R_6^3 = A_4 A_5 A_6 = \begin{bmatrix} c_4 c_5 c_6 - s_4 s_6 & -c_4 c_5 s_6 - s_4 c_6 & c_4 s_5 \\ s_4 c_5 c_6 + c_4 s_6 & -s_4 c_5 s_6 + c_4 c_6 & s_4 s_5 \\ -s_5 c_6 & s_5 s_6 & c_5 \end{bmatrix}$$

Assignment 5 : Solution Q1

$$R_6^3 = R_0^3 R_6^0 = \left(R_3^0\right)^T R_6^0$$

$$R_6^0 = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} = \begin{bmatrix} 0.397 & 0.433 & 0.8095 \\ 0.34 & 0.75 & -0.568 \\ -0.853 & 0.5 & 0.1504 \end{bmatrix}$$

$$R_3^0 = \begin{bmatrix} 0.25 & 0.433 & 0.866 \\ 0.433 & 0.75 & -0.5 \\ -0.866 & 0.5 & 0 \end{bmatrix}$$

$$(R_3^0)^T = \begin{bmatrix} 0.25 & 0.433 & -0.866 \\ 0.433 & 0.75 & 0.5 \\ 0.866 & -0.5 & 0 \end{bmatrix}$$

$$R_6^3 = U = \begin{bmatrix} u_{11} & u_{12} & u_{13} \\ u_{21} & u_{22} & u_{23} \\ u_{31} & u_{32} & u_{33} \end{bmatrix}$$

```
U =
    0.9852         0   -0.1738
    0.0004    1.0000   -0.0003
    0.1738   -0.0000    0.9850
```

$$c_5 = u_{33} = 0.985$$

$$s_5 = \pm\sqrt{1-(0.985)^2} = 0.1726$$

$$\theta_5 = A\tan 2(0.985, \pm 0.1726)$$

$$\theta_5 = \pm 9.93^\circ$$

Assignment 5 : Solution Q1

If $\theta_5 = +9.93°$ is chosen

$\therefore s_5 > 0$

$+u_{13} = c_4 \; and \; +u_{23} = s_4$

$\theta_4 = A\tan 2(u_{13}, u_{23})$

$\theta_4 = 0° \;\; (-180°)$

$\therefore s_5 > 0$

$-u_{31} = c_6 \; and \; +u_{32} = s_6$

$\theta_6 = A\tan 2(-u_{31}, u_{32})$

$\theta_6 = 0° \;\; (-180°)$

If $\theta_5 = -9.93°$ is chosen

$\therefore s_5 < 0$

$-u_{13} = c_4 \; and \; -u_{23} = s_4$

$\theta_4 = A\tan 2(-u_{13}, -u_{23})$

$\theta_4 = 0°$

$\therefore s_5 < 0$

$+u_{31} = c_6 \; and \; -u_{32} = s_6$

$\theta_6 = A\tan 2(u_{31}, -u_{32})$

$\theta_6 = 0°$

Assignment 5 : Solution Q1

$$\cos\theta_3 = \frac{2.75^2 + 4.763^2 + (-2.33-2)^2 - 3^2 - 5^2}{2(3)(5)} := 0.5$$

$$\theta_3 = A\tan 2(D, \pm\sqrt{1-D^2})$$

$$\theta_3 = \pm 60^\circ$$

$$\theta_2 = A\tan 2\left(\sqrt{x_c^2 + y_c^2}, z_c - d_1\right) - A\tan 2\left(a_2 + a_3\cos(\theta_3), a_3\sin(\theta_3)\right)$$

$\theta_3 = +60^\circ$	$\theta_3 = -60^\circ$
$\theta_2 = -76.43^\circ$	$\theta_2 = 0^\circ$

$$\theta_1 = A\tan 2(x_c, y_c)$$

$$\theta_1 = +60^\circ, \theta_1 = +240^\circ$$

$$\theta_1 = +60^\circ, \theta_2 = 0^\circ, \theta_3 = -60^\circ, \theta_4 = 0^\circ, \theta_5 = -10^\circ, \theta_6 = 0^\circ$$

$$\theta_1 = +240^\circ, \theta_2 = -76^\circ, \theta_3 = +60^\circ, \theta_4 = -180^\circ, \theta_5 = +10^\circ, \theta_6 = -180^\circ$$

Assignment 5 : Q2

Q2. With RRR with 3 DOF wrist. (ikine function)

Obtain (theta1-theta6) by ikine() for Q1) with robotic toolbox in MATLAB. Attached your code and result.

Use IG as `[pi/10 -pi/150 pi/150 pi/100 -pi/100 pi/100]`

Assignment 5 : Q2 Solution

```
%%RRR with 3 DOF wrist
%%inv K Ass5 Q2
clear all; clc;
d1 = 2; a2 =3; a3 = 5; d6 = 0;
A1 = link([pi/2 0 0 d1,0]);
A2 = link([0 a2 0 0,0]);
A3 = link([0 a3 0 0,0]);
RRR = robot({A1 A2 A3});
%%3 DOF wrist
A4 = link([-pi/2 0 0 0,0]);
A5 = link([pi/2 0 0 0,0]);
A6 = link([0 0 0 d6,0]);
RRR_3DOFWRIST = robot({A1 A2 A3 A4 A5 A6});
position = transl(2.75,4.763,-2.33);
IG = [pi/10 -pi/150 pi/150 pi/100 -pi/100 pi/100];
M = [1 1 1 1 1 1];
values = ikine(RRR_3DOFWRIST, position, IG, M);
```

```
th1 =

   59.9993

th2 =

  -3.6000e+03

th3 =

   5.7000e+03

th4 =

  -3.9900e+03

th5 =

   -90

th6 =

   1.8300e+03
```

Assignment 5 : Q3

Q3. With RRR with 3 DOF wrist.

a). With answer (theta1-theta6) from Q1, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure with MATLAB. Attached your code and result.

b).With answer (theta1-theta6) from Q2, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure with MATLAB. Attached your code and result.

Assignment 5 : Q3 Solution

```
clear all; clc;
d1 = 2; a2 =3; a3 = 5; d6 = 0;
A1 = link([pi/2 0 0 d1,0]);
A2 = link([0 a2 0 0,0]);
A3 = link([0 a3 0 0,0]);
RRR = robot({A1 A2 A3});
%%3 DOF wrist
A4 = link([-pi/2 0 0 0,0]);
A5 = link([pi/2 0 0 0,0]);
A6 = link([0 0 0 d6,0]);
RRR_3DOFWRIST = robot({A1 A2 A3 A4 A5 A6});
position = transl(2.75,4.763,-2.33);
IG = [pi/10 -pi/150 pi/150 pi/100 -pi/100 pi/100];
M = [1 1 1 1 1 1];
values = ikine(RRR_3DOFWRIST, position, IG, M);

T06_a = fkine(RRR_3DOFWRIST, [pi/3, 0 -pi/3 0 (-10/180)*pi 0]);
Pend_a = T06_a*[0;0;0;1]
T06_b = fkine(RRR_3DOFWRIST, values);
Pend_b = T06_b*[0;0;0;1]
```

```
Pend_a =

    2.7500
    4.7631
   -2.3301
    1.0000


Pend_b =

    2.7500
    4.7630
   -2.3300
    1.0000
```

Assignment 5 : Q4

Q4. With RRP 1 DOF wrist (SCARA).

Given DH table and Transformation matrix. Obtain the formulas for θ_1, θ_2, θ_4 and d_3 with using Atan2 function. Steps must be included in your work. State possible solution values.

Find 1 possible solution for end point location P(7.5,2,3.5).

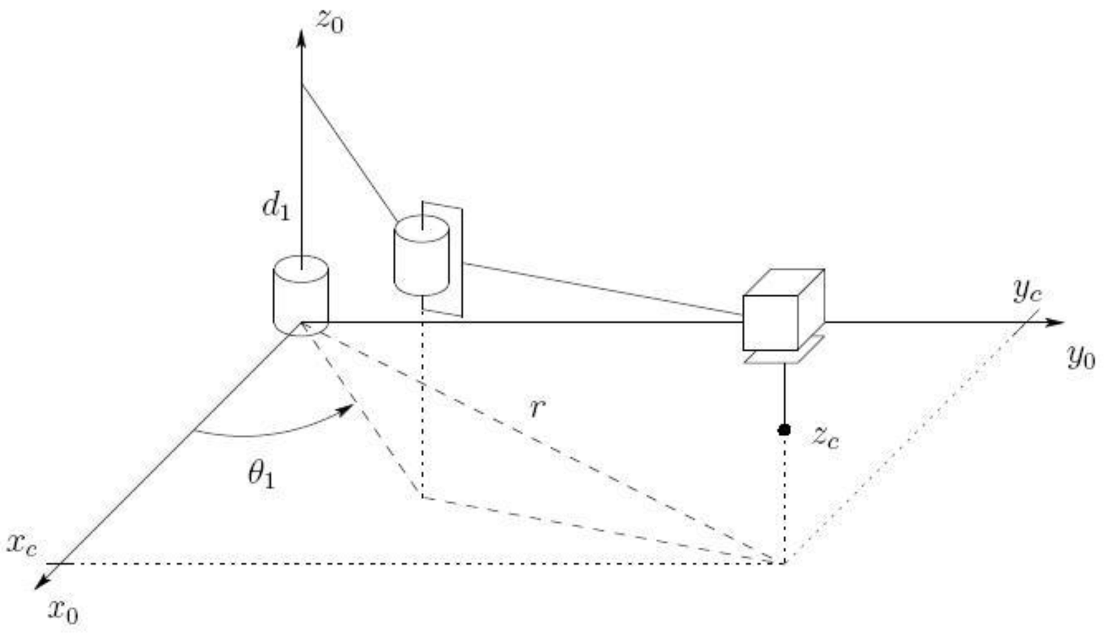
Given

a1 = 3

a2 = 5

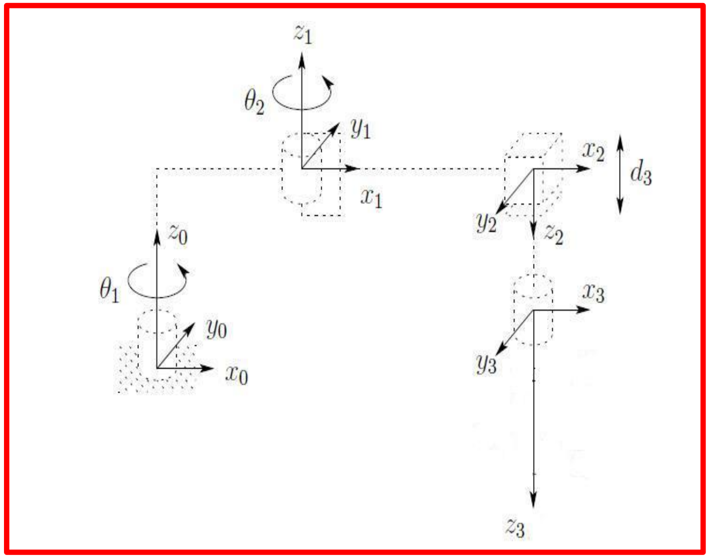
d1 = 5 (Link1 offset from base)

d4 = 1 (Wrist offset)

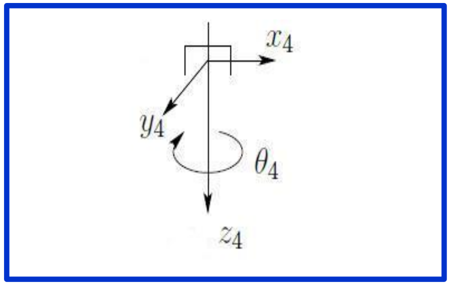


Assignment 5 : Q4

RRP



Link	a_i	α_i	d_i	θ_i
1	a_1	0	d_1	$\theta_1^\star$
2	a_2	180	0	$\theta_2^\star$
3	0	0	$d_3^\star$	0
4	0	0	d_4	$\theta_4^\star$



1 DOF Wrist Mechanism

$$
\begin{aligned}
T_4^0 &= A_1 \cdots A_4 \\
&= \begin{bmatrix} c_{12}c_4 + s_{12}s_4 & -c_{12}s_4 + s_{12}c_4 & 0 & a_1c_1 + a_2c_{12} \\ s_{12}c_4 - c_{12}s_4 & -s_{12}s_4 - c_{12}c_4 & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & -1 & d_1 - d_3 - d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}
\end{aligned}
$$

Assignment 5 : Solution Q4

RRP (SCARA) with 1DOF wrist. no offset.

DH. Table

	a	α	d	θ
l_1	a_1	0	d_1	θ_1^*
l_2	a_2	180	0	θ_2^*
l_3	0	0	d_3^*	0
l_4	0	0	d_4	θ_4^*

$Z_c = d_1 - d_3 - d_4$

$d_3 = \cancel{Z_c - d_1 - d_4}\; d_1 - Z_c - d_4$

$$\cos\theta_2 = \frac{x_c^2 + y_c^2 - a_1^2 - a_2^2}{2a_1a_2} = D \quad \therefore \quad \sin\theta_2 = \pm\sqrt{1-D^2}$$

$$\theta_2 = \mathrm{Atan2}\left(D, \pm\sqrt{1-D^2}\right)$$

$$\theta_1 = \mathrm{Atan2}(x_c, y_c) - \mathrm{Atan2}(a_1 + a_2\cos\theta_2, a_2\sin\theta_2)$$

$$R_4^3 = R_0^3 \; R_4^0$$

$$\therefore R_4^3 = (R_3^0)^T . R_4^0 = u.$$

$$R_4^3 = A_4 = \begin{bmatrix} C_4 & -S_4 & 0 \\ S_4 & C_4 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R_4^0 = \begin{bmatrix} C_{12}C_4 + S_{12}S_4 & -C_{12}S_4 + S_{12}C_4 & 0 \\ S_{12}C_4 - C_{12}S_4 & -S_{12}S_4 - C_{12}C_4 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

$$(R_3^0)^T = \begin{bmatrix} C_1C_2 - S_1S_2 & C_1S_2 + C_2S_1 & 0 \\ C_1S_2 + C_2S_1 & S_1S_2 - C_1C_2 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} C_{12} & S_{12} & 0 \\ S_{12} & -C_{12} & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

$$\therefore u = \begin{bmatrix} C_4 & S_{-4} & 0 \\ S_4 & C_4 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

Assignment 5 : Solution Q4

$$u = \begin{bmatrix} C_{12}(C_{12-4}) + S_{12}(S_{12-4}) & C_{12}(S_{12-4}) + S_{12}\cdot(C_{12-4}) & 0 \\ S_{12}(C_{12-4}) + -C_{12}(S_{12-4}) & S_{12}(S_{12-4}) + (-C_{12})(-)(C_{12-4}) & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} C_{12}(C_{12-4}) + S_{12}(S_{12-4}) & C_{12}(S_{12-4}) - S_{12}(C_{12-4}) & 0 \\ S_{12}(C_{12-4}) - C_{12}(S_{12-4}) & S_{12}(S_{12-4}) + C_{12}(C_{12-4}) & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} C_{12-(12-4)} & S_{(12-4)-12} & 0 \\ S_{12-(12-4)} & C_{12-(12-4)} & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

$$= \begin{bmatrix} C_4 & S_4 & 0 \\ S_4 & C_4 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

θ_4 can be any value.

$P(7.5, 2, 3.5)$

$a_1 = 3$

$a_2 = 5$

$d_1 = 5$

$d_4 = 1$

$\therefore d_3 = d_1 - z_c - d_4$

$= 5 - 3.5 - 1$

$d_3 = 0.5$

$\theta_2 = \text{Atan2}(D, \pm\sqrt{1-D^2})$

$$D = \frac{7.5^2 + 2^2 - 3^2 - 5^2}{2(3)(5)} = 0.875$$

$\therefore \pm\sqrt{1-D^2} = \pm 0.484$

$\theta_2 = \text{Atan2}(0.875, \pm 0.484)$

$\theta_2 = 28.95^\circ, -28.95^\circ$

$\theta_1 = \text{Atan2}(7.5, 2) - \text{Atan2}(7.375, \pm 2.42)$

$= 14.93^\circ - (\pm 18.167^\circ)$

$\theta_1 = -3.237^\circ$, $\theta_2 = \cancel{\pm 18.167^\circ}\ 28.95^\circ$

$\theta_1 = 33.097^\circ$, $\theta_2 = \cancel{-18.167^\circ}\ -28.95^\circ$

Assignment 5 : Q5

Q5. With RRP 1 DOF wrist (SCARA).

Given DH table and Transformation matrix. Find 1 possible posture solution for end point location P(7.5,2,3.5) using Inverse Kinematic function ikine() from **MATLAB**. Plot this location.

Given

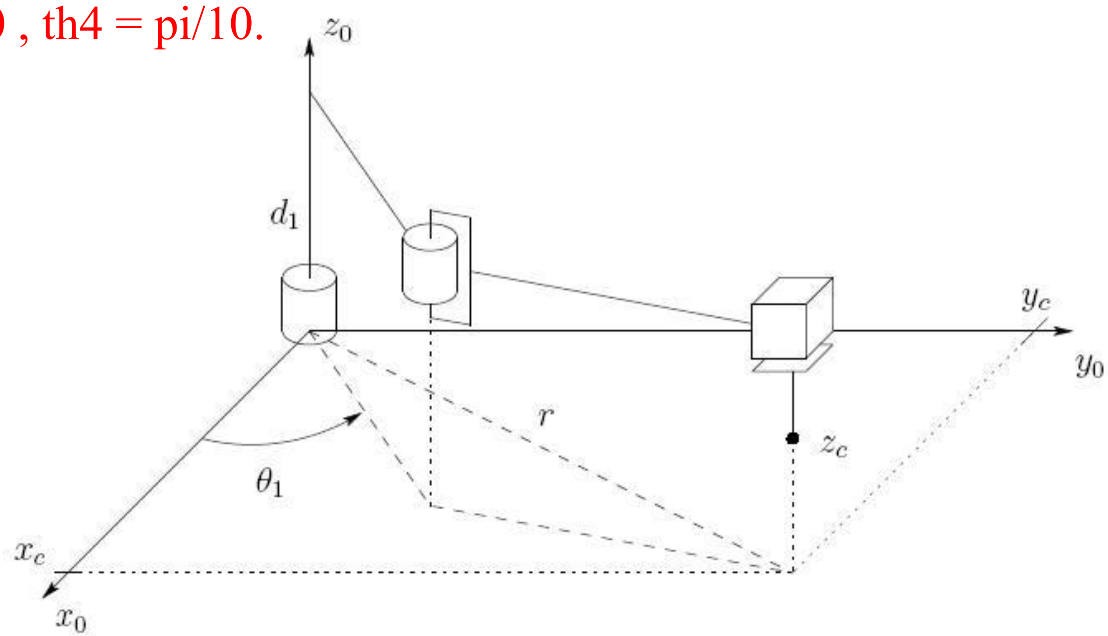
a1 = 3

a2 = 5

d1 = 5 (Link1 offset from base)

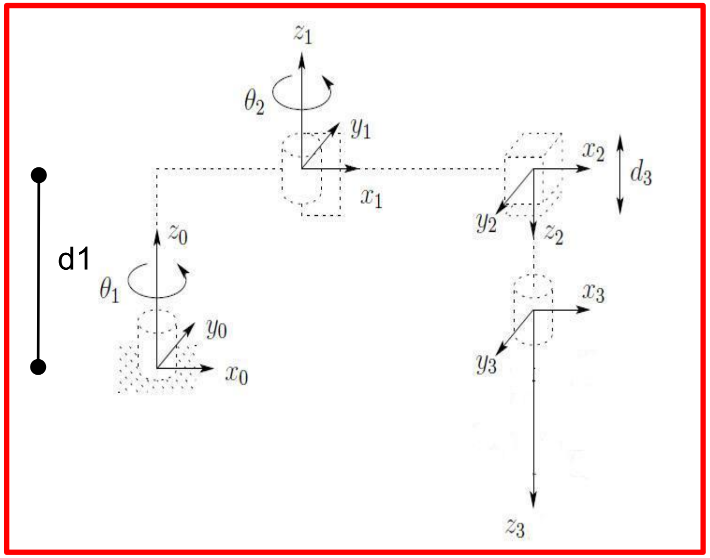
d4 = 1 (Wrist offset)

Use IG : th1 = pi/10, th2 = 0, th3 = 0 , th4 = pi/10.

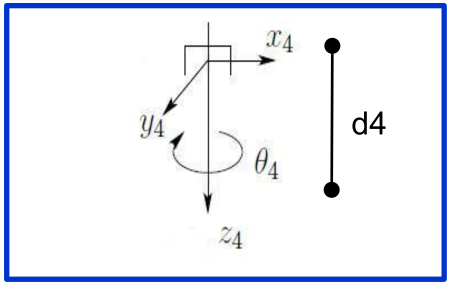


Assignment 5 : Q5

RRP



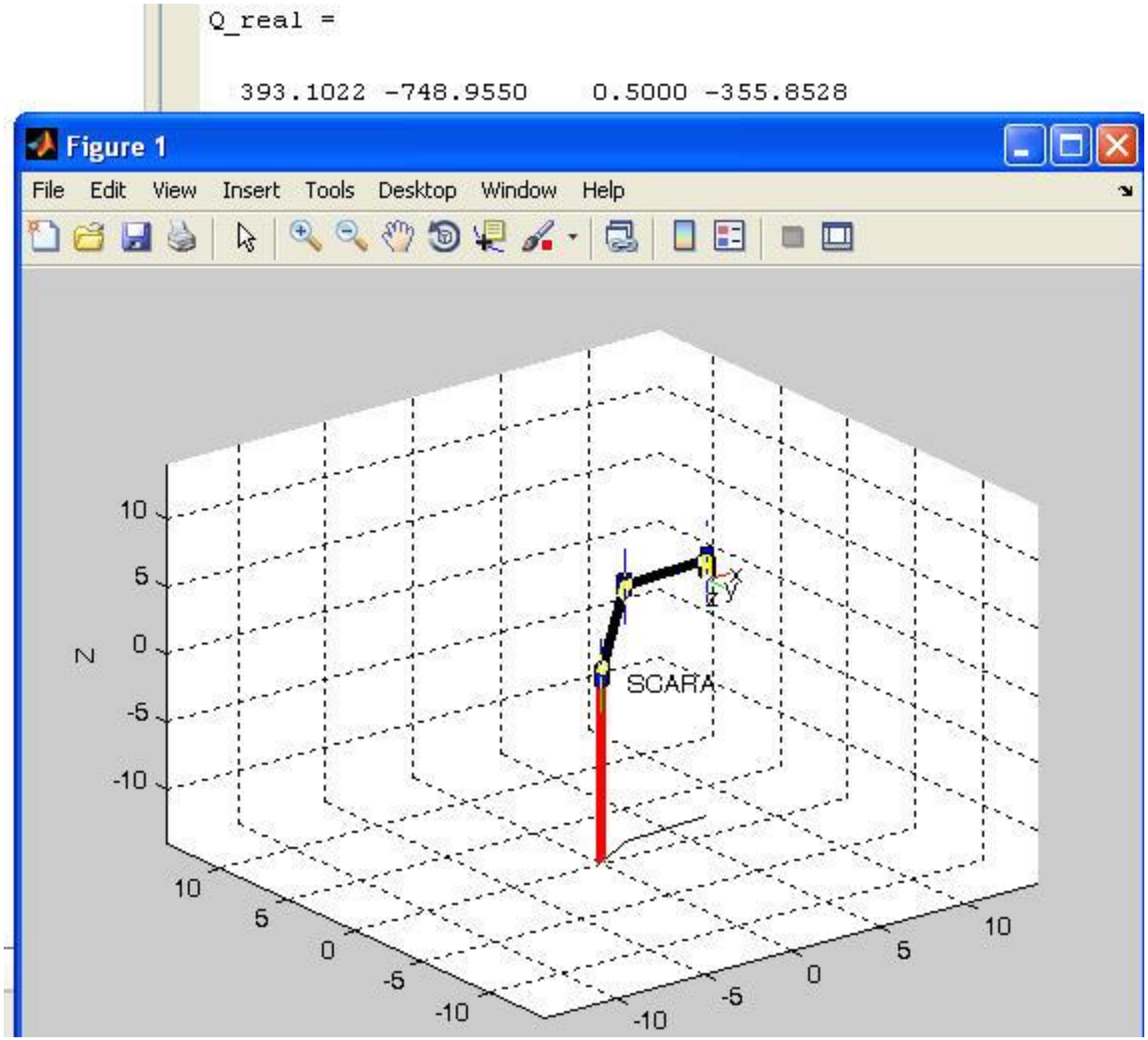
Link	a_i	α_i	d_i	θ_i
1	a_1	0	d_1	$\theta^\star$
2	a_2	180	0	$\theta^\star$
3	0	0	$d^\star$	0
4	0	0	d_4	$\theta^\star$



$$
\begin{aligned}
T_4^0 &= A_1 \cdots A_4 \\
&= \begin{bmatrix} c_{12}c_4 + s_{12}s_4 & -c_{12}s_4 + s_{12}c_4 & 0 & a_1c_1 + a_2c_{12} \\ s_{12}c_4 - c_{12}s_4 & -s_{12}s_4 - c_{12}c_4 & 0 & a_1s_1 + a_2s_{12} \\ 0 & 0 & -1 & d_1 - d_3 - d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}
\end{aligned}
$$

1 DOF Wrist Mechanism

Assignment 5 : Q5 (1 possible posture answer)



Assignment 5 : Solution Q5

```
%SCARA with 1 DOF Wrist
%alpha a theta D
clear all;
clc;
a1 = 3;
a2 = 5;
d4 = 1;
th1 = 0;
th2 = 0;
th4 = 0;
d3 = 0; %when Pz is 3.5, d3 must be 0.5

%RRP
L1 = Link([0,a1,th1,5],'standard');
L2 = Link([pi,a2,th2,0],'standard');
L3 = Link([0,0,0,d3,1],'standard');  %%To have pristmatic joint must set to 1
%1 DOF Writs
L4 = Link([0,0,th4,d4],'standard');

RRP = robot({L1 L2 L3 L4});
pos = transl(7.5,2,3.5);
%INVK for RRP with 1 DOF
Q = ikine(RRP, pos,[pi/10 0 0 pi/10],[1 1 1 1 0 0])
Q_d3 = Q(1,3); %%d3
Q_deg(1,1) = (Q(1,1)/pi)*180;
Q_deg(1,2) = (Q(1,2)/pi)*180;
Q_deg(1,4) = (Q(1,4)/pi)*180;

Q_real =[Q_deg(1,1) Q_deg(1,2) Q_d3 Q_deg(1,4)]

RRP.name = 'SCARA';
plot(RRP,[Q]);
hold on;
hold off;
```

Assignment 5 : Q6

Q6. With RRP 1 DOF wrist (SCARA).

a). With answer (theta1, theta2, theta4 and d3) from Q4, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure with MATLAB. Attached your code and result.

b).With answer (theta1, theta2, theta4 and d3) from Q5, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure with MATLAB. Attached your code and result.

Assignment 5 : Q6 Solution

```
a1 = 3;
a2 = 5;
d1 = 5;
d4 = 1;

syms th1 th2 th4 d3
%RRP
L1 = link([0,a1,th1,d1],'standard');
L2 = link([pi,a2,th2,0],'standard');
L3 = link([0,0,0,d3,1],'standard');  %%To have pristmatic joint must set to 1
%1 DOF Writs
L4 = link([0,0,th4,d4],'standard');

RRP = robot({L1 L2 L3 L4});
%FK for RRP with 1 DOF
qzRRP =[(-3.237/180)*pi (28.95/180)*pi 0.5 0];
TRRP = fkine(RRP,qzRRP);
LOCATION = double(TRRP*[0;0;0;1])
```

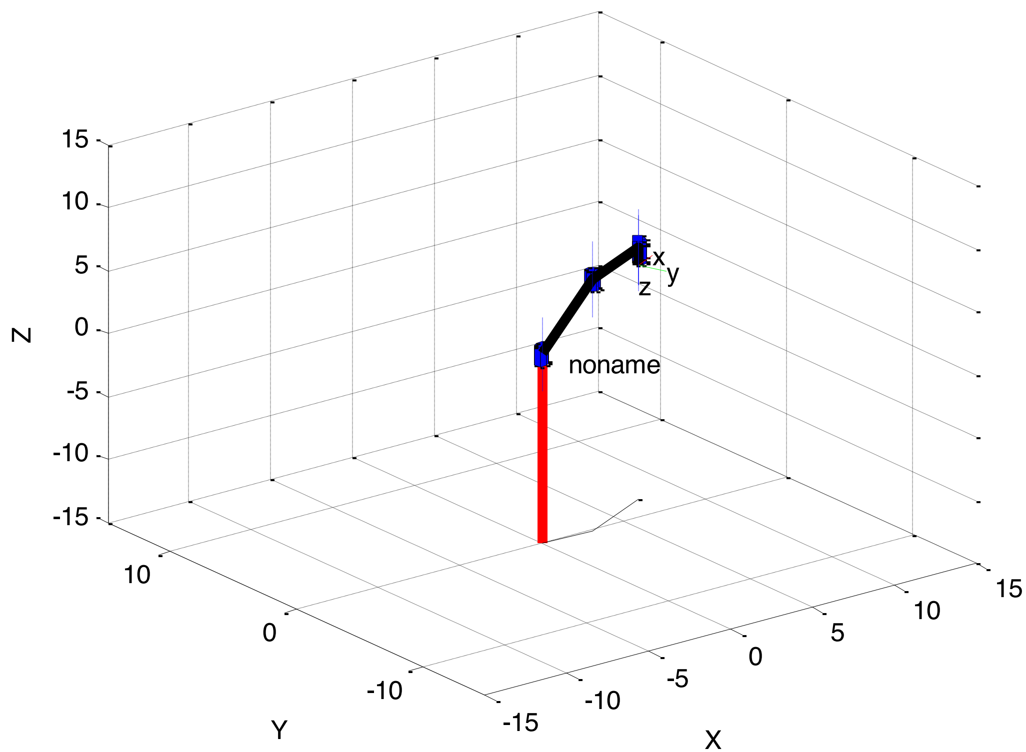
Assignment 5 : Q6 Solution

a) With answer (theta1, theta2 and d3) from Q4, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure.

```
qzRRP =[(-3.237/180)*pi (28.95/180)*pi 0.5 0];
```

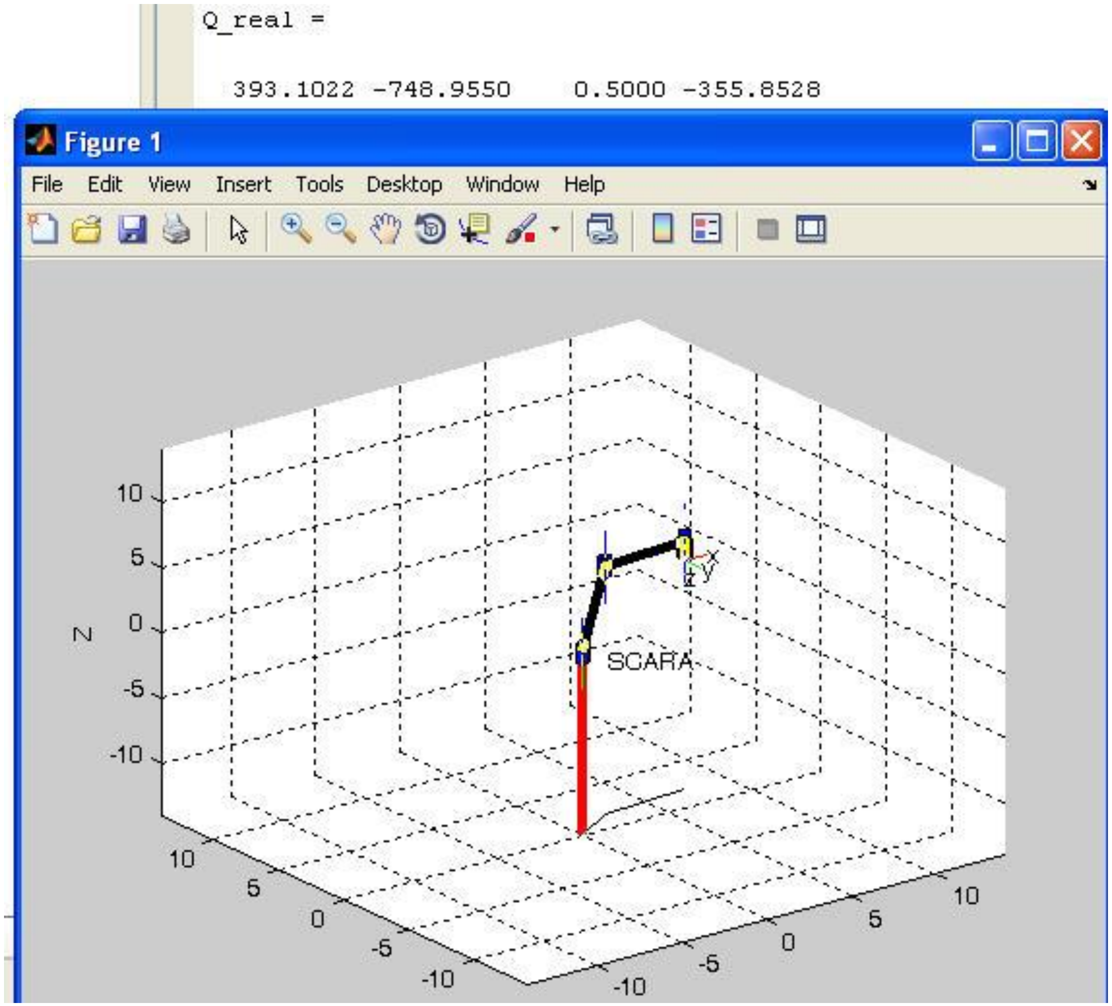
```
LOCATION =

    7.5001
    1.9999
    3.5000
    1.0000
```



Assignment 5 : Q6 Solution

b) With answer (theta1, theta2 and d3) from Q5, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure.



Assignment 5 : Q7

Q7. With RPP 3-DOF wrist.

Given DH table and Transformation matrices. Find possible posture solutions for end point location P(1.5, 2.75, 5).

Given $L_1 = 2.5, L_2 = 0 \; and \; L_6 = 0.15$

and transformation data are given as

T06 =

-1.0000	-0.0000	0.0000	1.5000
0.0000	-0.0000	1.0000	2.7500
0	1.0000	0.0000	5.0000
0	0	0	1.0000

T03 =

-0.8660	-0.0000	0.5000	1.5000
0.5000	-0.0000	0.8660	2.5981
0	1.0000	0.0000	5.0000
0	0	0	1.0000

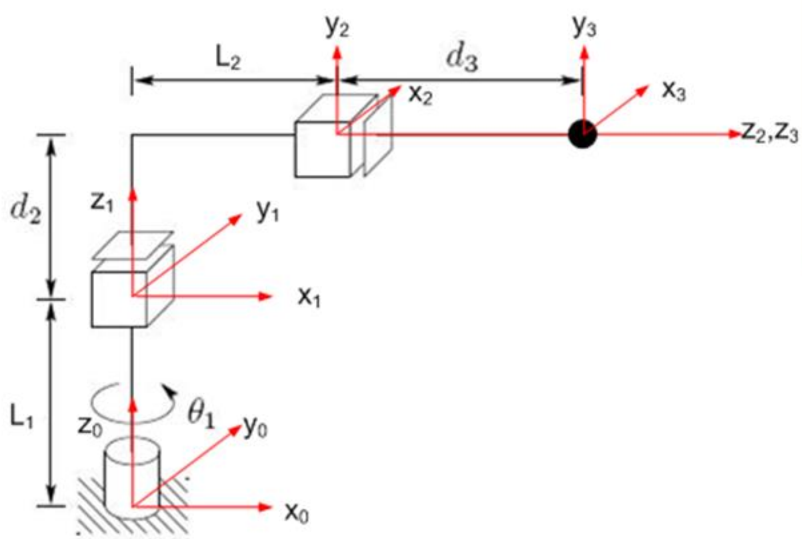
Assignment 5 : Q7

Link	α	a	d	θ
1	0	0	L_1	θ_1^*
2	90°	0	d_2^*	90°
3	0	0	$L_2 + d_3^*$	0

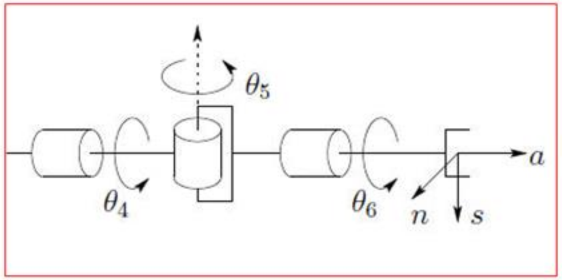
RPP

Link	a_i	α_i	d_i	θ_i
4	0	-90	0	θ_4^*
5	0	90	0	θ_5^*
6	0	0	d_6	θ_6^*

3 DOF Wrist



Wrist mechanism



Assignment 5 : Solution Q7

$$c_1 = 0.5$$

$$s_1 = 0.866$$

$$\theta_1 = A\tan 2(0.5, 0.866)$$

$$\theta_1 = 60^\circ$$

$$c_1(d_3) = 1.5 \quad \Rightarrow \quad d_3 = 3$$

$$L_1 + d_2 = 5 \quad \Rightarrow \quad d_2 = 2.5$$

Assignment 5 : Solution Q7

$$c_5 = u_{33} = 0.866$$

$$s_5 = \pm\sqrt{1-(0.866)^2}$$

$$\theta_5 = A\tan 2(0.866, \pm\sqrt{1-(0.866)^2})$$

$$\theta_5 = \pm 30°$$

$$\theta_5 = +30°$$

$$\therefore s_5 > 0$$

$$+u_{13} = c_4 \; and \; +u_{23} = s_4$$

$$\theta_4 = A\tan 2(u_{13}, u_{23})$$

$$\theta_4 = 0°$$

$$\therefore s_5 > 0$$

$$-u_{31} = c_6 \; and \; +u_{32} = s_6$$

$$\theta_6 = A\tan 2(-u_{31}, u_{32})$$

$$\theta_6 = 0°$$

$$\theta_5 = -30°$$

$$\therefore s_5 < 0$$

$$-u_{13} = c_4 \; and \; -u_{23} = s_4$$

$$\theta_4 = A\tan 2(-u_{13}, -u_{23})$$

$$\theta_4 = 180°$$

$$\therefore s_5 < 0$$

$$+u_{31} = c_6 \; and \; -u_{32} = s_6$$

$$\theta_6 = A\tan 2(u_{31}, -u_{32})$$

$$\theta_6 = 180°$$

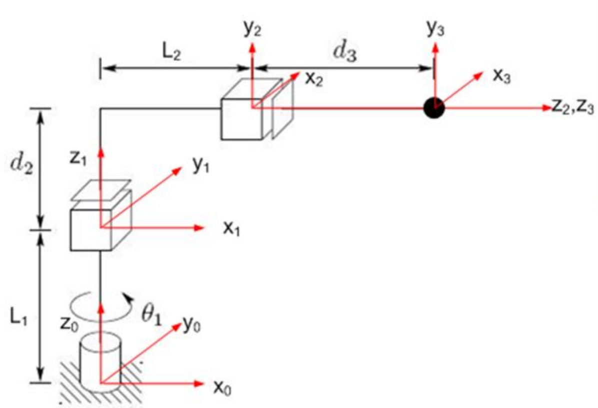
Assignment 5 : Q8

Q8. With RPP 3-DOF wrist. (ikine function)

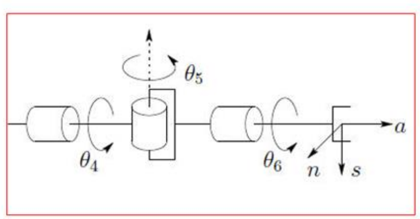
Given DH table and Transformation matrices. Find possible posture solutions for end point location P(1.5, 2.75, 5), using Inverse Kinematic function ikine() from **MATLAB**. Plot this location.

Given $L_1 = 2.5, L_2 = 0 \; and \; L_6 = 0.15$

IG [0.1 0.5 0 0 0 0]



Wrist mechanism



RPP

Link	α	a	d	θ
1	0	0	L_1	θ_1^*
2	90°	0	d_2^*	90°
3	0	0	$L_2 + d_3^*$	0

3 DOF Wrist

Link	a_i	α_i	d_i	θ_i
4	0	−90	0	θ_4^*
5	0	90	0	θ_5^*
6	0	0	d_6	θ_6^*

Assignment 5 : Q8 Solution

```
th1_deg =

   61.3895


d2 =

    2.3500


d3 =

    3.1325


th4_deg =

  -270


th5_deg =

  -270


th6_deg =

  118.6105
```

```matlab
clear all; clc;
L1 = 2.5; L2 = 0; d6 = 0.15;
th1 = pi/3; d2 = 2.5; d3 = 3; th4 = 0; th5 = pi/6; th6 = 0;
%%RPP
A1 = link([0 0 0 L1,0]);
A2 = link([pi/2 0 pi/2 0,1]);
A3 = link([0 0 0 0,1]);
RPP_A5 = robot({A1 A2 A3});
T03 = fkine(RPP_A5,[th1 d2 d3])
%%3 DOF wrist
A4 = link([-pi/2 0 0 0,0]);
A5 = link([pi/2 0 0 0,0]);
A6 = link([0 0 0 d6,0]);
Wrist_A5 = robot({A4 A5 A6});
T36 = fkine(Wrist_A5,[th4 th5 th6])

RPP_3DOF_WRIST = robot({A1 A2 A3 A4 A5 A6});

position = transl([1.5,2.75,5]);
IG = [0.1 0.5 0 0 0 0]
values = ikine(RPP_3DOF_WRIST, position, IG, [1 1 1 1 1 1]);
th1_deg = (values(1,1)/pi)*180
d2 = values(1,2)
d3 = values(1,3)
th4_deg = (values(1,4)/pi)*180
th5_deg = (values(1,5)/pi)*180
th6_deg = (values(1,6)/pi)*180
```

Assignment 5 : Q9

Q9. With RPP 3-DOF wrist.

a). With answer (theta1, d2, d3, theta4, theta5, theta6) from Q7, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure with MATLAB. Attached your code and result.

b).With answer (theta1, d2, d3, theta4, theta5, theta6) from Q8, check your answer with Forward Kinematic function in MATLAB, whether you obtain the correct desirable position. Plot the figure with MATLAB. Attached your code and result.

Assignment 5 : Q9 Solution

```
Pend_ikine =

    1.5000
    2.7500
    5.0000
    1.0000
```

```
L1 = 2.5; L2 = 0; d6 = 0.15;
th1 = pi/3; d2 = 2.5; d3 = 3; th4 = 0; th5 = pi/6; th6 = 0;
%%RPP
A1 = link([0 0 0 L1,0]);
A2 = link([pi/2 0 pi/2 0,1]);
A3 = link([0 0 0 0,1]);
RPP_A5 = robot({A1 A2 A3});
T03 = fkine(RPP_A5,[th1 d2 d3])
%%3 DOF wrist
A4 = link([-pi/2 0 0 0,0]);
A5 = link([pi/2 0 0 0,0]);
A6 = link([0 0 0 d6,0]);

RPP_3DOF_WRIST = robot({A1 A2 A3 A4 A5 A6});

position = transl([1.5,2.75,5]);
IG = [0.1 0.5 0 0 0 0]
values = ikine(RPP_3DOF_WRIST, position, IG, [1 1 1 1 1 1]);
th1_deg = (values(1,1)/pi)*180
d2 = values(1,2)
d3 = values(1,3)
th4_deg = (values(1,4)/pi)*180
th5_deg = (values(1,5)/pi)*180
th6_deg = (values(1,6)/pi)*180
%%check answer
T06_ikine = fkine(RPP_3DOF_WRIST, values);
Pend_ikine = T06_ikine*[0;0;0;1]
```