-

Matlab Exercise 3

Question [a]:

The DH parameters:

i	a_{i-1}	α_{i-1}	d_i	θ_i
1	0	0°	0	θ_1
2	L_1	0°	0	θ_2
3	L_2	0°	0	θ_3
4	L_3	0°	0	0°

Question [b]:

Link Transformations:

$$ {}^{0}_{1}T = \begin{bmatrix} C_1 & -S_1 & 0 & 0 \\ S_1 & C_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{1}_{2}T = \begin{bmatrix} C_2 & -S_2 & 0 & L_1 \\ S_2 & C_2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{2}_{3}T = \begin{bmatrix} C_3 & -S_3 & 0 & L_2 \\ S_3 & C_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ {}^{3}_{H}T = \begin{bmatrix} 1 & 0 & 0 & L_3 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

Question [c]:

The forward pose kinamatics solutions:

$$ \therefore {}^{0}_{3}T = {}^{0}_{1}T \cdot {}^{1}_{2}T \cdot {}^{2}_{3}T = \begin{bmatrix} C_{123} & -S_{123} & 0 & L_1C_1 + L_2C_{12} \\ S_{123} & C_{123} & 0 & L_1S_1 + L_2S_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ \therefore {}^{0}_{H}T = {}^{0}_{3}T \cdot {}^{3}_{H}T = \begin{bmatrix} C_{123} & -S_{123} & 0 & L_1C_1 + L_2C_{12} + L_3C_{123} \\ S_{123} & C_{123} & 0 & L_1S_1 + L_2S_{12} + L_3S_{123} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

i)

Matlab program is as follows:

```
clear all
clc
```

```
%Constants
L1=4;
L2=3;
L3=2;
theta1=30;
theta2=0;
theta3=0;



%DH parameters
alpha(1)=0; a(1)=0;  d(1)=0; theta(1)=theta1;
alpha(2)=0; a(2)=L1; d(2)=0; theta(2)=theta2;
alpha(3)=0; a(3)=L2; d(3)=0; theta(3)=theta3;
alpha(4)=0; a(4)=L3; d(4)=0; theta(4)=0;

%Transformation matrices

T0_1=trotx(alpha(1),'deg') * transl(a(1),0,0) * trotz(theta(1),'deg')
* transl(0,0,d(1));
T1_2=trotx(alpha(2),'deg') * transl(a(2),0,0) * trotz(theta(2),'deg')
* transl(0,0,d(2));
T2_3=trotx(alpha(3),'deg') * transl(a(3),0,0) * trotz(theta(3),'deg')
* transl(0,0,d(3));
T3_H=trotx(alpha(4),'deg') * transl(a(4),0,0) * trotz(theta(4),'deg')
* transl(0,0,d(4));

T0_3 = T0_1 * T1_2 * T2_3

T0_H = T0_3 * T3_H
```

Results:

T0_3 =

1	0	0	7
0	1	0	0
0	0	1	0
0	0	0	1

T0_H =

1	0	0	9

0 1 0 0

0 0 1 0

0 0 0 1

ii)

Matlab program is as follows:

```
clear all
clc

%Constants
L1=4;
L2=3;
L3=2;
theta1=10;
theta2=20;
theta3=30;



%DH parameters
alpha(1)=0; a(1)=0;  d(1)=0; theta(1)=theta1;
alpha(2)=0; a(2)=L1; d(2)=0; theta(2)=theta2;
alpha(3)=0; a(3)=L2; d(3)=0; theta(3)=theta3;
alpha(4)=0; a(4)=L3; d(4)=0; theta(4)=0;

%Transformation matrices

T0_1=trotx(alpha(1),'deg') * transl(a(1),0,0) * trotz(theta(1),'deg')
* transl(0,0,d(1));
T1_2=trotx(alpha(2),'deg') * transl(a(2),0,0) * trotz(theta(2),'deg')
* transl(0,0,d(2));
T2_3=trotx(alpha(3),'deg') * transl(a(3),0,0) * trotz(theta(3),'deg')
* transl(0,0,d(3));
T3_H=trotx(alpha(4),'deg') * transl(a(4),0,0) * trotz(theta(4),'deg')
* transl(0,0,d(4));

T0_3 = T0_1 * T1_2 * T2_3

T0_H = T0_3 * T3_H
```

Results:

T0_3 =

0.5000	-0.8660	0	6.5373
0.8660	0.5000	0	2.1946
0	0	1.0000	0
0	0	0	1.0000

T0_H =

0.5000	-0.8660	0	7.5373
0.8660	0.5000	0	3.9266
0	0	1.0000	0
0	0	0	1.0000

ii)

Matlab program is as follows:

```
clear all
clc

%Constants
L1=4;
L2=3;
L3=2;
theta1=90;
theta2=90;
theta3=90;



%DH parameters
alpha(1)=0; a(1)=0;  d(1)=0; theta(1)=theta1;
alpha(2)=0; a(2)=L1; d(2)=0; theta(2)=theta2;
alpha(3)=0; a(3)=L2; d(3)=0; theta(3)=theta3;
alpha(4)=0; a(4)=L3; d(4)=0; theta(4)=0;

%Transformation matrices

T0_1=trotx(alpha(1),'deg') * transl(a(1),0,0) * trotz(theta(1),'deg')
* transl(0,0,d(1));
T1_2=trotx(alpha(2),'deg') * transl(a(2),0,0) * trotz(theta(2),'deg')
* transl(0,0,d(2));
T2_3=trotx(alpha(3),'deg') * transl(a(3),0,0) * trotz(theta(3),'deg')
* transl(0,0,d(3));
T3_H=trotx(alpha(4),'deg') * transl(a(4),0,0) * trotz(theta(4),'deg')
* transl(0,0,d(4));

T0_3 = T0_1 * T1_2 * T2_3
```

```
T0_H = T0_3 * T3_H
```

Results:

T0_3 =

0	1.0000	0	-3.0000
-1.0000	0	0	4.0000
0	0	1.0000	0
0	0	0	1.0000

T0_H =

0	1.0000	0	-3.0000
-1.0000	0	0	2.0000
0	0	1.0000	0
0	0	0	1.0000

where :

$T0_3 \equiv {}^0_3T$

$T0_H \equiv {}^0_HT$

Question [d]:

Using Robotics Toolbox :

```
clear all
clc

%Constants
L1=4;
L2=3;
L3=2;
theta1=0;
theta2=0;
theta3=0;

%DH parameters
alpha(1)=0; a(1)=0;  d(1)=0; theta(1)=theta1;
alpha(2)=0; a(2)=L1; d(2)=0; theta(2)=theta2;
alpha(3)=0; a(3)=L2; d(3)=0; theta(3)=theta3;
alpha(4)=0; a(4)=L3; d(4)=0; theta(4)=0;

%Link() function
L(1) = Link([alpha(1) a(1) theta(1) d(1)],'standard');
L(2) = Link([alpha(2) a(2) theta(2) d(2)],'standard');
L(1) = Link([alpha(3) a(3) theta(3) d(3)],'standard');

%robot() function "same as SerialLink"
threelink = SerialLink(L,'name','threelink')
```

Results:

```
threelink =

threelink (2 axis, RR, stdDH, slowRNE)

+---+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |
+---+-----------+-----------+-----------+-----------+
|  1|         q1|          3|          0|          0|
|  2|         q2|          4|          0|          0|
+---+-----------+-----------+-----------+-----------+

grav =    0  base = 1  0  0  0   tool =  1  0  0  0
          0         0  1  0  0           0  1  0  0
       9.81         0  0  1  0           0  0  1  0
                    0  0  0  1           0  0  0  1
```