```
clear
clc
%%
a1 = 1;
q1 = 0.2;
trchain2('R(q1) Tx(a1)', q1) %pose of end effector
```

```
ans = 3×3
    0.9801   -0.1987    0.9801
    0.1987    0.9801    0.1987
         0         0    1.0000
```

```
x = ans(1,3) %x coordinate of end effector
```

```
x = 0.9801
```

```
y = ans(2,3) %y coordinate of end effector
```

```
y = 0.1987
```

```
%%
syms q1 a1
trchain2('R(q1) Tx(a1)', q1) %pose of end effector
```

```
ans =
```

$$\begin{pmatrix} \cos(q_1) & -\sin(q_1) & a_1\cos(q_1) \\ \sin(q_1) & \cos(q_1) & a_1\sin(q_1) \\ 0 & 0 & 1 \end{pmatrix}$$

```
%%
mdl_planar1
p1.teach()
%%
a1 = 1;
a2 = 1;
q1 = 0.2;
q2 = 0.3;
trchain2('R(q1) Tx(a1) R(q2) Tx(a2)', [q1 q2])
```

```
ans = 3×3
    0.8776   -0.4794    1.8576
    0.4794    0.8776    0.6781
         0         0    1.0000
```

```
syms q1 q2 a1 a2
trchain2('R(q1) Tx(a1) R(q2) Tx(a2)', [q1 q2])
```

```
ans =
```

$$\begin{pmatrix} \sigma_1 & -\cos(q_1)\sin(q_2) - \cos(q_2)\sin(q_1) & a_2\,\sigma_1 + a_1\cos(q_1) \\ \cos(q_1)\sin(q_2) + \cos(q_2)\sin(q_1) & \sigma_1 & a_2\,(\cos(q_1)\sin(q_2) + \cos(q_2)\sin(q_1)) + a_1\sin(q_1) \\ 0 & 0 & 1 \end{pmatrix}$$

where

$$\sigma_1 = \cos(q_1)\cos(q_2) - \sin(q_1)\sin(q_2)$$

```
%%
mdl_planar2
p2.teach
p2.plot([0 pi/2])
p2.plot([pi/2 -pi/2])
%%
syms q1 q2 q3 a1 a2 a3
trchain2('R(q1) Tx(a1) R(q2) Tx(a2) R(q3) Tx(a3)', [q1 q2 q3])
```

```
ans =
```

$$\begin{pmatrix} \sigma_1 & -\cos(q_3)\,\sigma_4 - \sin(q_3)\,\sigma_3 & a_2\,\sigma_3 + a_1\cos(q_1) + a_3\,\sigma_1 \\ \sigma_2 & \sigma_1 & a_2\,\sigma_4 + a_1\sin(q_1) + a_3\,\sigma_2 \\ 0 & 0 & 1 \end{pmatrix}$$

where

$$\sigma_1 = \cos(q_3)\,\sigma_3 - \sin(q_3)\,\sigma_4$$

$$\sigma_2 = \cos(q_3)\,\sigma_4 + \sin(q_3)\,\sigma_3$$

$$\sigma_3 = \cos(q_1)\cos(q_2) - \sin(q_1)\sin(q_2)$$

$$\sigma_4 = \cos(q_1)\sin(q_2) + \cos(q_2)\sin(q_1)$$

```
x = ans(1,3) %x coordinate of end effector
```

```
x
```

$$= a_2\,(\cos(q_1)\cos(q_2) - \sin(q_1)\sin(q_2)) + a_1\cos(q_1) + a_3\,(\cos(q_3)\,(\cos(q_1)\cos(q_2) - \sin(q_1)\sin(q_2)) - \sin(q_3)\,(\cos(q_1)\sin($$

```
y = ans(2,3) %y coordinate of end effector
```

```
y
```

$$= a_2\,(\cos(q_1)\sin(q_2) + \cos(q_2)\sin(q_1)) + a_1\sin(q_1) + a_3\,(\cos(q_3)\,(\cos(q_1)\sin(q_2) + \cos(q_2)\sin(q_1)) + \sin(q_3)\,(\cos(q_1)\cos($$

```
mdl_planar3
p3.teach
%%
syms a1 a2 a3 a4 q1 a2 q3 q4
```

```
trchain('Rz(q1)Tz(a1)Ry(q2)Tz(a2)Ry(q3)Tz(a3)Ry(q4)Tz(a4)', [q1 q2 q3 q4])
```

ans =

$$\begin{pmatrix} \cos(q_4)\,\sigma_7 - \sin(q_4)\,\sigma_6 & -\sin(q_1) & \sigma_2 & a_4\,\sigma_2 + a_3\,\sigma_6 + a_2\cos(q_1)\sin(q_2) \\ -\cos(q_4)\,\sigma_5 - \sin(q_4)\,\sigma_4 & \cos(q_1) & \sigma_1 & a_3\,\sigma_4 + a_4\,\sigma_1 + a_2\sin(q_1)\sin(q_2) \\ -\cos(q_4)\,\sigma_9 - \sin(q_4)\,\sigma_8 & 0 & \sigma_3 & a_1 + a_3\,\sigma_8 + a_2\cos(q_2) + a_4\,\sigma_3 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

where

$$\sigma_1 = \cos(q_4)\,\sigma_4 - \sin(q_4)\,\sigma_5$$

$$\sigma_2 = \cos(q_4)\,\sigma_6 + \sin(q_4)\,\sigma_7$$

$$\sigma_3 = \cos(q_4)\,\sigma_8 - \sin(q_4)\,\sigma_9$$

$$\sigma_4 = \cos(q_2)\sin(q_1)\sin(q_3) + \cos(q_3)\sin(q_1)\sin(q_2)$$

$$\sigma_5 = \sin(q_1)\sin(q_2)\sin(q_3) - \cos(q_2)\cos(q_3)\sin(q_1)$$

$$\sigma_6 = \cos(q_1)\cos(q_2)\sin(q_3) + \cos(q_1)\cos(q_3)\sin(q_2)$$

$$\sigma_7 = \cos(q_1)\cos(q_2)\cos(q_3) - \cos(q_1)\sin(q_2)\sin(q_3)$$

$$\sigma_8 = \cos(q_2)\cos(q_3) - \sin(q_2)\sin(q_3)$$

$$\sigma_9 = \cos(q_2)\sin(q_3) + \cos(q_3)\sin(q_2)$$

```
x = ans(1,4) %x coordinate of end effector
```

x =

$$a_4\,(\cos(q_4)\,\sigma_1 + \sin(q_4)\,(\cos(q_1)\cos(q_2)\cos(q_3) - \cos(q_1)\sin(q_2)\sin(q_3))) + a_3\,\sigma_1 + a_2\cos(q_1)\sin(q_2)$$

where

$$\sigma_1 = \cos(q_1)\cos(q_2)\sin(q_3) + \cos(q_1)\cos(q_3)\sin(q_2)$$

```
y = ans(2,4) %y coordinate of end effector
```

y =

$$a_3\,\sigma_1 + a_4\,\left(\cos(q_4)\,\sigma_1 - \sin(q_4)\,\left(\sin(q_1)\,\sin(q_2)\,\sin(q_3) - \cos(q_2)\,\cos(q_3)\,\sin(q_1)\right)\right) + a_2\,\sin(q_1)\,\sin(q_2)$$

where

$$\sigma_1 = \cos(q_2)\,\sin(q_1)\,\sin(q_3) + \cos(q_3)\,\sin(q_1)\,\sin(q_2)$$

```
z = ans(3,4) %z coordinate of end effector
```

```
z
```

$$= a_1 + a_3\,\left(\cos(q_2)\,\cos(q_3) - \sin(q_2)\,\sin(q_3)\right) + a_2\,\cos(q_2) + a_4\,\left(\cos(q_4)\,\left(\cos(q_2)\,\cos(q_3) - \sin(q_2)\,\sin(q_3)\right) - \sin(q_4)\,\left(\cos(q_2)\right.$$

```
%%
dh = [
    0 0 1 0 % theta d a alpha for joint 1
    0 0 1 0 % theta d a alpha for joint 2
    ]
```

```
dh = 2×4
     0     0     1     0
     0     0     1     0
```

```
r = SerialLink(dh)
```

```
r =

noname:: 2 axis, RR, stdDH, slowRNE
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          1|          0|          0|
|  2|         q2|          0|          1|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
```

```
r.plot([0.2 0.3])
r.teach
r.fkine([0.2 0.3]) %return homogeneous transformation matrix of end effector pose
```

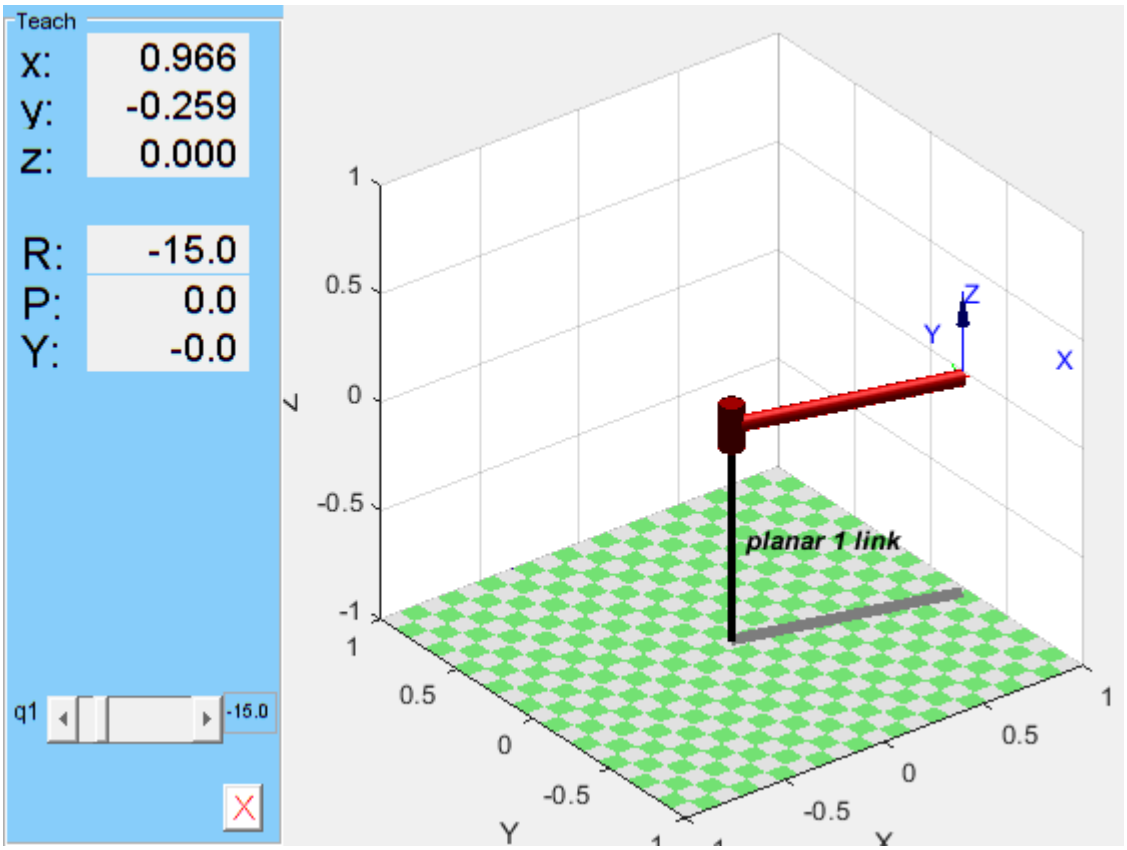
```
ans =
    0.8776   -0.4794         0     1.858
    0.4794    0.8776         0    0.6781
         0         0         1         0
         0         0         0         1
```

```
%%
mdl_puma560
p560
```

```
p560 =
```

```
Puma 560 [Unimation]:: 6 axis, RRRRRR, stdDH, slowRNE
 - viscous friction; params of 8/95;
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          0|     1.5708|          0|
|  2|         q2|          0|     0.4318|          0|          0|
|  3|         q3|    0.15005|     0.0203|    -1.5708|          0|
|  4|         q4|     0.4318|          0|     1.5708|          0|
|  5|         q5|          0|          0|    -1.5708|          0|
|  6|         q6|          0|          0|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
```

```
p560.plot(qz)
p560.plot(qr)
p560.teach
```




```
p560.fkine([.1 .2 .3 0 0 0])
```

```
ans =
    0.8732   -0.0998   -0.4770    0.2478
    0.0876    0.9950   -0.0479   -0.1259
    0.4794         0    0.8776    0.4745
         0         0         0         1
```

```
%%
p560.base = transl(10, 15, 2)
```

```
p560 =

Puma 560 [Unimation]:: 6 axis, RRRRRR, stdDH, slowRNE
 - viscous friction; params of 8/95;
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          0|     1.5708|          0|
|  2|         q2|          0|     0.4318|          0|          0|
|  3|         q3|    0.15005|     0.0203|    -1.5708|          0|
|  4|         q4|     0.4318|          0|     1.5708|          0|
|  5|         q5|          0|          0|    -1.5708|          0|
|  6|         q6|          0|          0|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
base:    t = (10, 15, 2), RPY/xyz = (0, 0, 0) deg
```

```
p560.fkine([.1 .2 .3 0 0 0])
```

```
ans =
    0.8732   -0.0998   -0.4770     10.25
    0.0876    0.9950   -0.0479     14.87
    0.4794         0    0.8776     2.474
         0         0         0         1
```

```
%%
p560.base = transl(10, 15, 2) * trotx(pi)
```

```
p560 =

Puma 560 [Unimation]:: 6 axis, RRRRRR, stdDH, slowRNE
 - viscous friction; params of 8/95;
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          0|     1.5708|          0|
|  2|         q2|          0|     0.4318|          0|          0|
|  3|         q3|    0.15005|     0.0203|    -1.5708|          0|
|  4|         q4|     0.4318|          0|     1.5708|          0|
|  5|         q5|          0|          0|    -1.5708|          0|
|  6|         q6|          0|          0|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
base:    t = (10, 15, 2), RPY/xyz = (0, 0, -180) deg
```

```
p560.fkine([.1 .2 .3 0 0 0])
```

```
ans =
    0.8732   -0.0998   -0.4770     10.25
   -0.0876   -0.9950    0.0479     15.13
   -0.4794         0   -0.8776     1.526
         0         0         0         1
```

```
%%
```

```
p560.tool = transl(0, 0, 0.2)
```

```
p560 =

Puma 560 [Unimation]:: 6 axis, RRRRRR, stdDH, slowRNE
 - viscous friction; params of 8/95;
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|          0|          0|     1.5708|          0|
|  2|         q2|          0|     0.4318|          0|          0|
|  3|         q3|    0.15005|     0.0203|    -1.5708|          0|
|  4|         q4|     0.4318|          0|     1.5708|          0|
|  5|         q5|          0|          0|    -1.5708|          0|
|  6|         q6|          0|          0|          0|          0|
+---+-----------+-----------+-----------+-----------+-----------+
base:    t = (10, 15, 2), RPY/xyz = (0, 0, -180) deg
tool:    t = (0, 0, 0.2), RPY/xyz = (0, 0, 0) deg
```

```
p560.fkine([.1 .2 .3 0 0 0])
```

```
ans =
    0.8732   -0.0998   -0.4770     10.15
   -0.0876   -0.9950    0.0479     15.14
   -0.4794         0   -0.8776      1.35
         0         0         0         1
```