```
close all
clear all
clc
syms l1 l2 l3  q1(t) q2(t) q3(t)
xe=  l3*cos(q2+q3)*cos(q1) + l2*cos(q1)*cos(q2)
```

xe(t) = $l_2 \cos(q_1(t)) \cos(q_2(t)) + l_3 \cos(q_1(t)) \cos(q_2(t) + q_3(t))$

```
ye = l3*cos(q2+q3)*sin(q1 ) + l2*sin(q1)*cos(q2)
```

ye(t) = $l_2 \cos(q_2(t)) \sin(q_1(t)) + l_3 \sin(q_1(t)) \cos(q_2(t) + q_3(t))$

```
ze = l3*sin(q2+q3) + l2*sin(q2) + l1
```

ze(t) = $l_1 + l_2 \sin(q_2(t)) + l_3 \sin(q_2(t) + q_3(t))$

```
dxe = diff(xe,t)
```

dxe(t) =

$$-l_2 \cos(q_2(t)) \sin(q_1(t)) \frac{\partial}{\partial t} q_1(t) - l_2 \cos(q_1(t)) \sin(q_2(t)) \frac{\partial}{\partial t} q_2(t) - l_3 \sin(q_1(t)) \cos(\sigma_1) \frac{\partial}{\partial t} q_1(t) - l_3 \cos(q_1(t)$$

where

$$\sigma_1 = q_2(t) + q_3(t)$$

```
dye = diff(ye,t)
```

dye(t) =

$$l_2 \cos(q_1(t)) \cos(q_2(t)) \frac{\partial}{\partial t} q_1(t) - l_2 \sin(q_1(t)) \sin(q_2(t)) \frac{\partial}{\partial t} q_2(t) + l_3 \cos(q_1(t)) \cos(\sigma_1) \frac{\partial}{\partial t} q_1(t) - l_3 \sin(q_1(t))$$

where

$$\sigma_1 = q_2(t) + q_3(t)$$

```
dze = diff(ze,t)
```

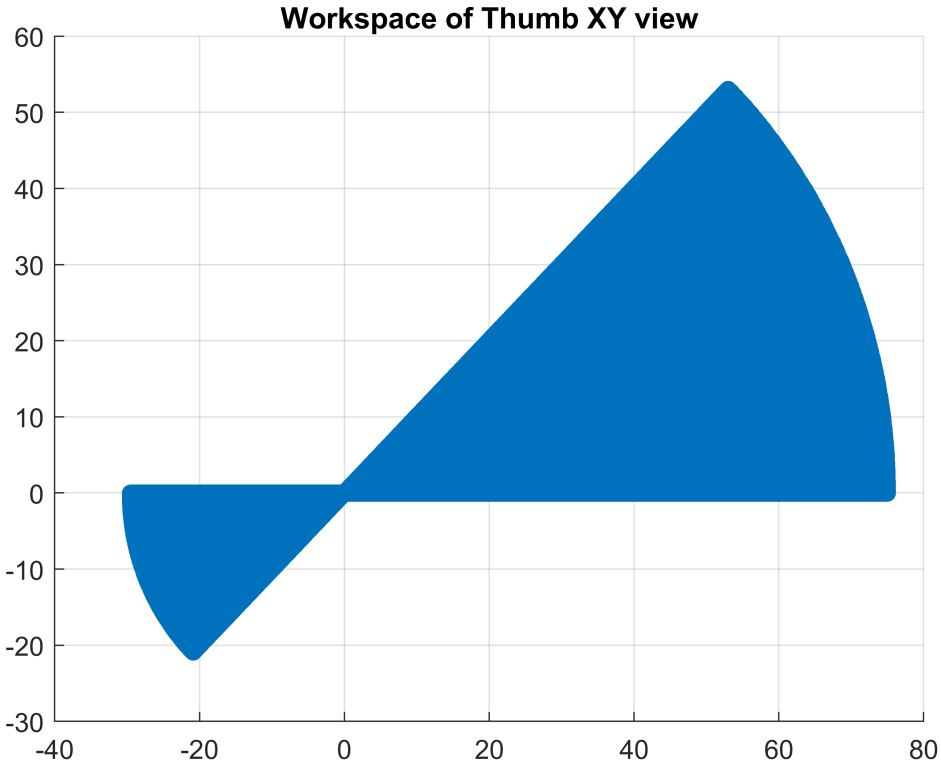
dze(t) =

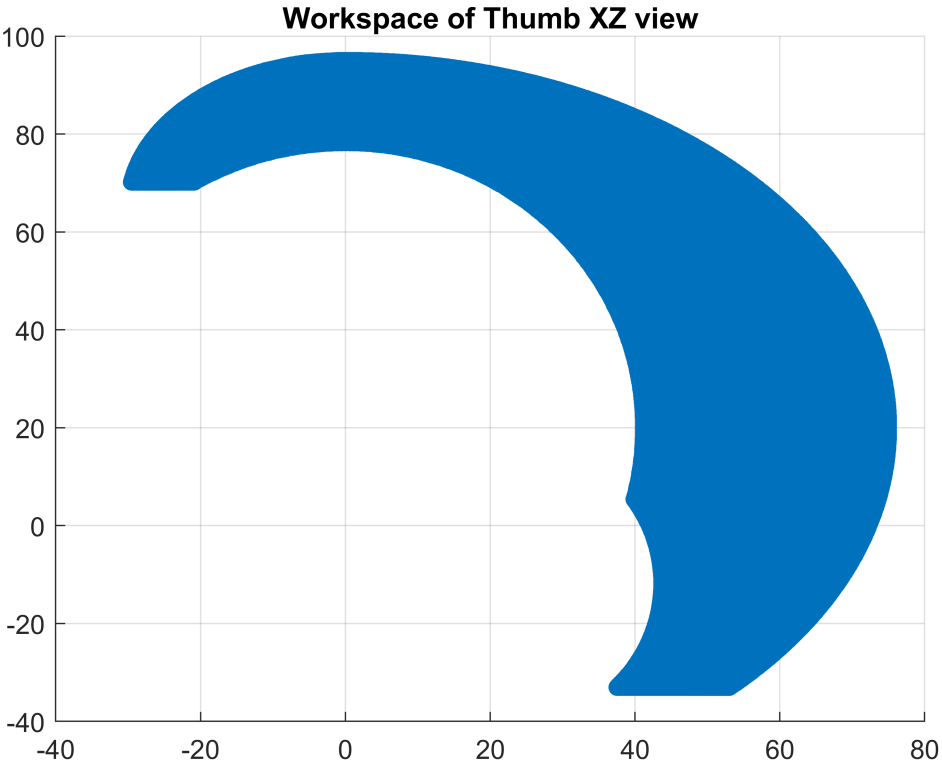
$$l_3 \cos(q_2(t) + q_3(t)) \left(\frac{\partial}{\partial t} q_2(t) + \frac{\partial}{\partial t} q_3(t) \right) + l_2 \cos(q_2(t)) \frac{\partial}{\partial t} q_2(t)$$

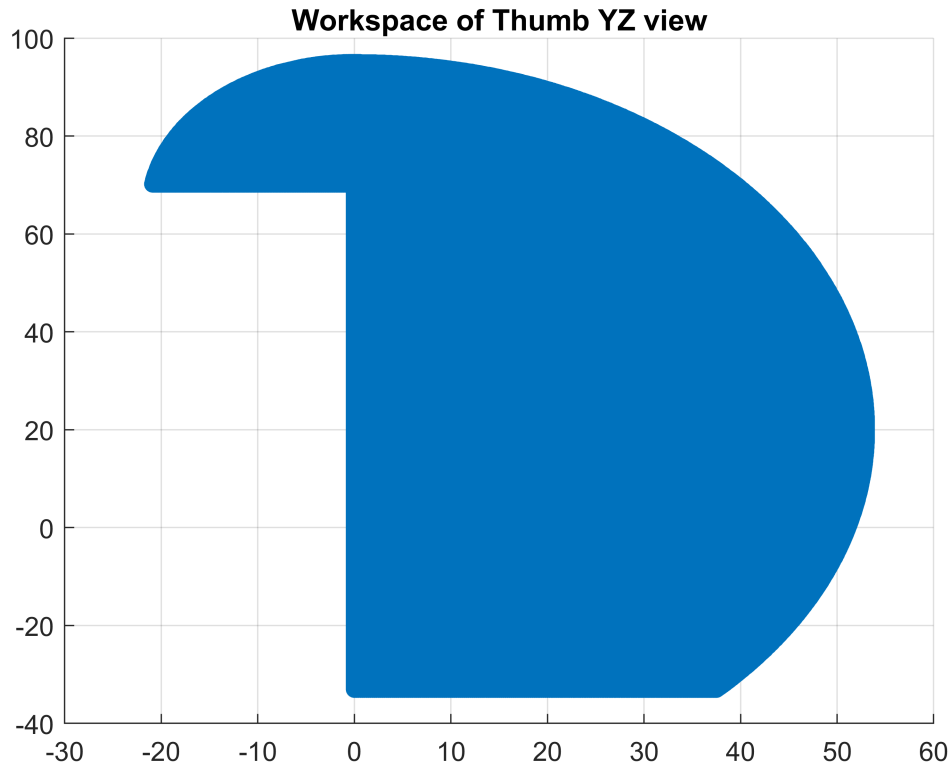
```
% We have three equations and three unknowns.
% If exists, there is only one or infinite solutions.
% Due to configuration of the model, there is only one solution
```

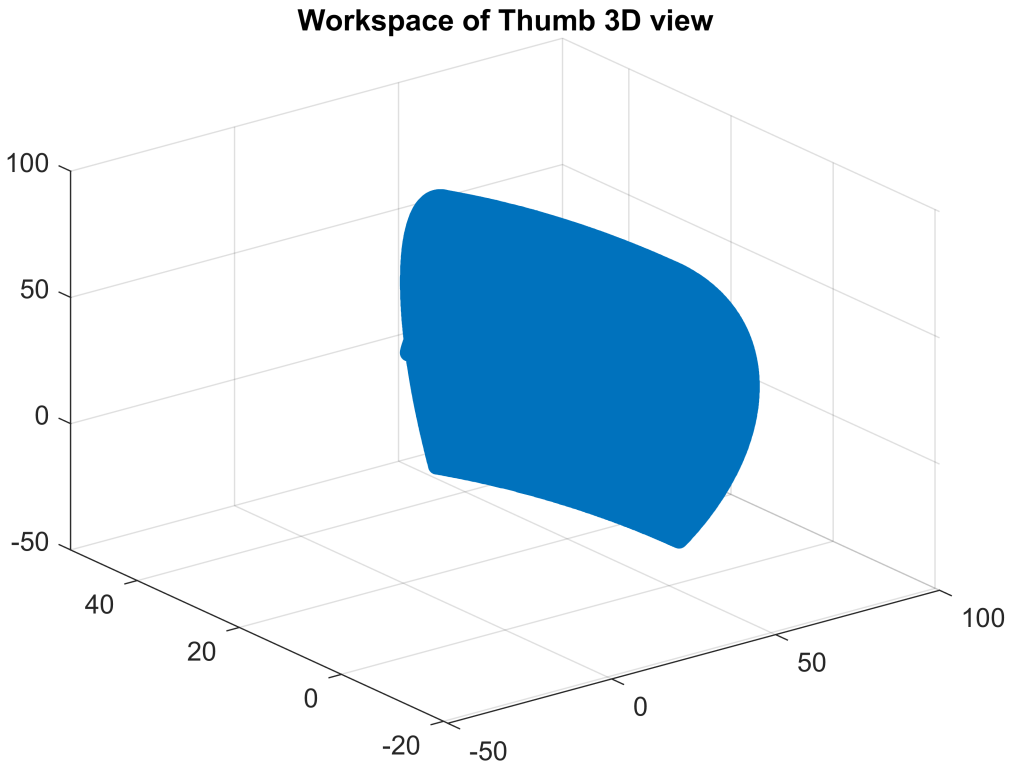
```
% Plot workspace
```

```
Reachableworkspace
```






Workspace of Thumb YZ view
100
80
60
40
20
0
-20
-40
-30
-20
-10
0
10
20
30
40
50
60


Workspace of Thumb 3D view
100
50
0
-50
40
20
0
-20
-50
0
50
100

```
% Find singularities
syms q1 q2 q3 l1 l2 l3
J=str2sym('[- l3*cos(q2 + q3)*sin(q1) - l2*cos(q2)*sin(q1),- l3*sin(q2 + q3)*cos(q1) - l2*cos(q
```

J =

$$\begin{pmatrix} -l_3\cos(q_2+q_3)\sin(q_1)-l_2\cos(q_2)\sin(q_1) & -\sigma_2-l_2\cos(q_1)\sin(q_2) & -\sigma_2 \\ l_3\cos(q_2+q_3)\cos(q_1)+l_2\cos(q_1)\cos(q_2) & -\sigma_1-l_2\sin(q_1)\sin(q_2) & -\sigma_1 \\ 0 & \sigma_3+l_2\cos(q_2) & \sigma_3 \end{pmatrix}$$

where

$$\sigma_1 = l_3\sin(q_2+q_3)\sin(q_1)$$

$$\sigma_2 = l_3\sin(q_2+q_3)\cos(q_1)$$

$$\sigma_3 = l_3\cos(q_2+q_3)$$

```
eqn = simplify(det(J))==0
```

eqn = $-l_2 l_3\left(l_3\sin(q_2)\cos(q_3)^2+l_3\cos(q_2)\sin(q_3)\cos(q_3)-l_3\sin(q_2)+l_2\cos(q_2)\sin(q_3)\right)=0$

```

```

```
xyz=[x,y,z];
B = unique(xyz,'rows');
if length(xyz)==length(B)
    singularity=0 %there is no singularity
else
    singularity=length(xyz)-length(B) %there are singularity at infinity point. this number sho
end
```

```
singularity = 0
```