```
% Derive the forward kinematics equations
close all
clear all
clc
syms l_pp l_dp l_ip  theta_mcp(t) theta_dip(t) theta_pip(t) theta_abd(t) t
x1 = l_pp* cos(theta_mcp);
y1 = l_pp* sin(theta_mcp);
x2 = x1 + l_ip*cos(theta_mcp-theta_pip);
y2 = y1 + l_ip*sin(theta_mcp-theta_pip);
xe = x2 + l_dp*cos(theta_mcp-theta_pip-theta_dip)
```

xe(t) = $l_{pp}\cos(\theta_{mcp}(t)) + l_{dp}\cos(\theta_{dip}(t) - \theta_{mcp}(t) + \theta_{pip}(t)) + l_{ip}\cos(\theta_{mcp}(t) - \theta_{pip}(t))$

```
ye = y2 + l_dp*sin(theta_mcp-theta_pip-theta_dip)
```

ye(t) = $l_{pp}\sin(\theta_{mcp}(t)) - l_{dp}\sin(\theta_{dip}(t) - \theta_{mcp}(t) + \theta_{pip}(t)) + l_{ip}\sin(\theta_{mcp}(t) - \theta_{pip}(t))$

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

dxe(t) =

$$-l_{ip}\sin(\theta_{mcp}(t) - \theta_{pip}(t))\left(\frac{\partial}{\partial t}\theta_{mcp}(t) - \frac{\partial}{\partial t}\theta_{pip}(t)\right) - l_{dp}\sin(\theta_{dip}(t) - \theta_{mcp}(t) + \theta_{pip}(t))\left(\frac{\partial}{\partial t}\theta_{dip}(t) - \frac{\partial}{\partial t}\theta_{mcp}(t\right.$$

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

dye(t) =

$$l_{pp}\cos(\theta_{mcp}(t))\frac{\partial}{\partial t}\theta_{mcp}(t) - l_{dp}\cos(\theta_{dip}(t) - \theta_{mcp}(t) + \theta_{pip}(t))\left(\frac{\partial}{\partial t}\theta_{dip}(t) - \frac{\partial}{\partial t}\theta_{mcp}(t) + \frac{\partial}{\partial t}\theta_{pip}(t)\right) + l_{ip}\cos(t$$

```
% Clearly we have 2 equations and 3 unknowns
% There exists infinitely many solutions

theta_e=theta_mcp-theta_pip-theta_dip
```

theta_e(t) = $\theta_{mcp}(t) - \theta_{dip}(t) - \theta_{pip}(t)$

```
% We will have 3 equations with 3 unknowns,
% there will be two solutions DIP up and DIP down.
```

```
%define coordinates to plot the workspace of the fingertip
q1i=-45;
q1f=90;
q2i=0;
q2f=100;
q3i=0;
q3f=80;
l_pp =45;
```

```
l_dp = 30;
l_ip = 25;
theta_mcp= deg2rad(linspace(q1i,q1f,20));
theta_pip = deg2rad(linspace(q2i,q2f,20));
theta_dip = deg2rad(linspace(q3i,q3f,20));
a=1;
for i=1:length(theta_mcp)
    for j=1:length(theta_pip)
        for k=1:length(theta_dip)
            x0=0;
            y0=0;
            x1 = l_pp* cos(theta_mcp(i));
            y1 = l_pp* sin(theta_mcp(i));
            x2 = x1 + l_ip*cos(theta_mcp(i)-theta_pip(j));
            y2 = y1 + l_ip*sin(theta_mcp(i)-theta_pip(j));
            x_e(a,1) = x2 + l_dp*cos(theta_mcp(i)-theta_pip(j)-theta_dip(k));
            y_e(a,1) = y2 + l_dp*sin(theta_mcp(i)-theta_pip(j)-theta_dip(k));
            a=a+1;
        end
    end
end

scatter(x_e,y_e)
```