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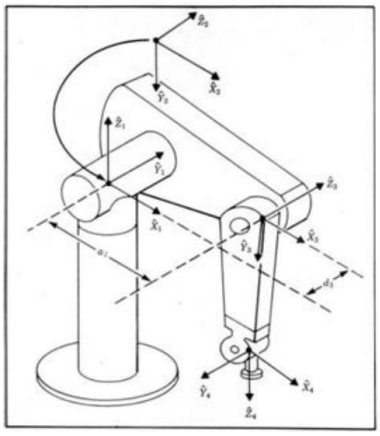
Homework #3

Mechanics and Control of Robot Manipulators

Program Forward Kinematics for Puma 560 Robots using Matlab.



Choose [a2, a3, d3, d4] as [1 0.3 0.5 1] and ${}^{6}P_{T} = [0\ 0\ 0.3]^{T}$.

a) When $\theta_1 = 30^o$, $\theta_2 = 30^o$, $\theta_3 = 30^o$, $\theta_4 = 30^o$, $\theta_5 = 30^o$, $\theta_6 = 30^o$, find ${}^{0}_{T}T$.

Matlab code:

```
clear all;
clc;

%DH parameter
alpha =  [0 -90 0 -90 90 -90] ; %link twist
a = [0 0 1 0.3 0 0]; %link length
d = [0 0  0.5 1 0 0]; %link offset
theta = [30 30 30 30 30 30]; % joint variable

P6_T = [0 0 0.3 1];

%Apply forward kinematics joints
T = [];
for n = 1:6
       matT = [cosd(theta(n)) -sind(theta(n)) 0 a(n);
           sind(theta(n))*cosd(alpha(n))  cosd(theta(n))*cosd(alpha(n)) -
sind(alpha(n)) -sind(alpha(n))*d(n);
           sind(theta(n))*sind(alpha(n))  cosd(theta(n))*sind(alpha(n))
cosd(alpha(n)) cosd(alpha(n))*d(n);
           0 0 0 1];
        T = [T; {matT}];
end


T0_6 = T{1}*T{2}*T{3}*T{4}*T{5}*T{6}
P0_T = T0_6.*P6_T
```

The result of T0_6.

```
T0_6 =

    0.2522    0.1044   -0.9620   -0.1201
   -0.7874   -0.5558   -0.2667    0.5080
   -0.5625    0.8248   -0.0580   -1.2598
         0         0         0    1.0000
```

And the result of P0_T.

```
P0_T =

         0         0   -0.2886   -0.1201
         0         0   -0.0800    0.5080
         0         0   -0.0174   -1.2598
         0         0         0    1.0000
```

b) Find 8 sets of solutions from Inverse Kinematics with the ${}^{0}_{T}T$. Confirm that one of 8 solution sets is the joint angle set in a).

Matlab code.

```
%calulate T0_T, T06 with the code in a.

%problem b: 8 set parameter
px = T0_6(1,4);
py = T0_6(2,4);
pz = T0_6(3,4);
r = T0_6(1:3,1:3);
th = zeros(6,8);

th(1,1:4) = atan2d(px,py) - atan2d(d(3), sqrt(px^2 + py^2 -d(3)^2));
th(1,5:8) = atan2d(py,px) - atan2d(d(3), sqrt(px^2 + py^2 -d(3)^2));

K = (px^2 + py^2 + pz^2 - a(2)^2 - a(3)^2 - d(3)^2 - d(4)^2)/(2*a(2));

th(3,[1,2,5,6]) = atan2d(a(3),d(4)) - atan2d(K, sqrt(a(3)^2 + d(4)^2 + K^2));
th(3,[3,4,7,8]) = atan2d(a(3),d(4)) - atan2d(K, -sqrt(a(3)^2 + d(4)^2 + K^2));

th23 = atan2d((-a(3)-a(2)*cosd(th(3,:)))*pz + (cosd(th(1,:))*px +
sind(th(1,:))*py).*(d(4)-a(2)*sind(th(3,:))),(a(2)*sind(th(3,:))-
d(4))*pz+(a(3)+a(2)*cosd(th(3,:))).*(cosd(th(1,:))*px + sind(th(1,:))*py));

th(2,:) = th23 - th(3,:);

th(4,:) = atan2d(-r(1,3)*sind(th(1,:))+r(2,3)*cosd(th(1,:)),-
r(1,3)*cosd(th(1,:)).*cosd(th23) + r(3,3)*sind(th23));

s5 = -r(1,3)*(cosd(th(1,:)).*cosd(th23).*cosd(th(4,:)) +
sind(th(1,:)).*sind(th(4,:))) - r(2,3)*(sind(th(1,:)).*cosd(th23).*cosd(th(4,:))
- cosd(th(1,:)).*sind(th(4,:))) + r(3,3)*sind(th23).*cosd(th(4,:));

c5 = -r(1,3)*cosd(th(1,:)).*sind(th23) - r(2,3)*sind(th(1,:)).*sind(th23) -
r(3,3)*cosd(th23);
```

```
th(5,:) = atan2d(s5,c5);

s6 = -r(1,1)*(cosd(th(1,:)).*cosd(th23).*sind(th(4,:)) -
sind(th(1,:)).*cosd(th(4,:))) - r(2,1)*(sind(th(1,:)).*cosd(th23).*sind(th(4,:))
+ cosd(th(1,:)).*cosd(th(4,:))) + r(3,1)*sind(th23).*sind(th(4,:));

c6 = r(1,1)*((cosd(th(1,:)).*cosd(th23).*cosd(th(4,:)) +
sind(th(1,:)).*sind(th(4,:))).*cosd(th(5,:)) -
cosd(th(1,:)).*sind(th23).*sind(th(5,:))) +
r(2,1)*((sind(th(1,:)).*cosd(th23).*cosd(th(4,:)) -
cosd(th(1,:)).*sind(th(4,:))).*cosd(th(5,:)) -
sind(th(1,:)).*sind(th23).*sind(th(5,:))) -
r(3,1)*(sind(th23).*cosd(th(4,:)).*cosd(th(5,:)) + cosd(th23).*sind(th(5,:)));

th(6,:) = atan2d(s6,c6);

th(4,[2 4 6 8]) = th(4,[2 4 6 8]) + pi;
th(5,[2 4 6 8]) = -th(5,[2 4 6 8]);
th(6,[2 4 6 8]) = th(6,[2 4 6 8]) + pi;
th
```

The result is obtained.

```
th =

  -86.6015  -86.6015  -86.6015  -86.6015   30.0000   30.0000   30.0000   30.0000
  -45.0000  -45.0000 -135.0000 -135.0000  -45.0000  -45.0000 -135.0000 -135.0000
   90.0000   90.0000  180.0000  180.0000   90.0000   90.0000  180.0000  180.0000
  -90.0408  -86.8993  -90.0408  -86.8993   24.5190   27.6606   24.5190   27.6606
   96.2512  -96.2512   96.2512  -96.2512   43.5312  -43.5312   43.5312  -43.5312
  101.1394  104.2810  101.1394  104.2810   38.4399   41.5815   38.4399   41.5815
```