R E P O R T

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Program Forward Kinematics for Puma 560 Robots using Matlab

a. Find ${}^{0}_{7}T$s

Matlab code:

```
%Parameter of Manipulator
th1 = pi/4;
th2 = pi/4;
th3 = pi/4;
th4 = pi/4;
th5 = pi/4;
th6 = pi/4;

a2 = 1; a3 = 0.3; d3 = 0.5; d4 = 1;
T6_T = [1 0 0 0;0 1 0 0;0 0 1 0.2;0 0 0 1];

%D-H parameters
syms a1 a d th,

T = [cos(th) -sin(th) 0 a;
    sin(th)*cos(a1) cos(th)*cos(a1) -sin(a1) -sin(a1)*d;
    sin(th)*sin(a1) cos(th)*sin(a1) cos(a1) cos(a1)*d;
    0 0 0 1];

T01 = vpa(subs(T,{a1,a,d,th},{[0,0,0,th1]}),2);
T12 = vpa(subs(T,{a1,a,d,th},{[-pi/2,0,0,th2]}),2);
T23 = vpa(subs(T,{a1,a,d,th},{[0,a2,d3,th3]}),2);
T34 = vpa(subs(T,{a1,a,d,th},{[-pi/2,a3,d4,th4]}),2);
T45 = vpa(subs(T,{a1,a,d,th},{[pi/2,0,0,th5]}),2);
T56 = vpa(subs(T,{a1,a,d,th},{[-pi/2,0,0,th6]}),2);

T06 = vpa(T01*T12*T23*T34*T45*T56,2)
T0_T = T06*T6_T
```

The output of Matlab: T06

```
T06 =

[  0.25, 0.46, -0.85, -0.56]
[ -0.96, 0.25, -0.15,  0.15]
[  0.15, 0.85,   0.5,  -1.0]
[     0,    0,     0,   1.0]


T0_T =

[  0.25000000000230980622800560353033, 0.45710678120096681473972471016373, -0.85355339061741065398468687918174, -0.73137084991493452497586687163042]
[ -0.95710678121673915824054643249845, 0.25000000001346253727281611880439, -0.14644660941413403301695656548769,  0.11715728751784468914077489423339]
[  0.14644660940855766749455130785066, 0.85355339062298701950709213681878,  0.50000000001577234350082172233472, -0.90710678118205959209026346464577]
[                                   0,                                   0,                                   0,                                 1.0]
```

b. 8 sets of solution:

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

%problem b: 8 set parameter
px = T06(1,4);
py=T06(2,4);
pz=T06(3,4);
r=T06(1:3,1:3);
th = zeros(6,8);

th(1,1:4) = atan2(px,py) - atan2(d3, sqrt(px^2 + py^2 -d3^2));
th(1,5:8) = atan2(py,px) - atan2(d3, sqrt(px^2 + py^2 -d3^2));

K = (px^2 + py^2 + pz^2 - a2^2 - a3^2 - d3^2 - d4^2)/(2*a2);

th(3,[1,2,5,6]) = atan2(a3,d4) - atan2(K, sqrt(a3^2 + d4^2 + K^2));
th(3,[3,4,7,8]) = atan2(a3,d4) - atan2(K, -sqrt(a3^2 + d4^2 + K^2));

th23 = atan2((-a3-a2*cos(th(3,:)))*pz + (cos(th(1,:))*px +
sin(th(1,:))*py).*(d4-a2*sin(th(3,:))),(a2*sin(th(3,:))-
d4)*pz+(a3+a2*cos(th(3,:))).*(cos(th(1,:))*px + sin(th(1,:))*py));

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

th(4,:) = atan2(-r(1,3)*sin(th(1,:))+r(2,3)*cos(th(1,:)),-
r(1,3)*cos(th(1,:)).*cos(th23) + r(3,3)*sin(th23));

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

c5 = -r(1,3)*cos(th(1,:)).*sin(th23) - r(2,3)*sin(th(1,:)).*sin(th23) -
r(3,3)*cos(th23);

th(5,:) = atan2(s5,c5);

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

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

th(6,:) = atan2(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 output of the matlab code:

```
th =

   -2.3562   -2.3562   -2.3562   -2.3562    1.8452    1.8452    1.8452    1.8452
    0.3557    0.3557   -3.5946   -3.5946    0.3557    0.3557   -3.5946   -3.5946
    0.6962    0.6962    3.0283    3.0283    0.6962    0.6962    3.0283    3.0283
   -1.3073    1.8343   -2.5701    0.5714    1.2156    4.3572    2.0644    5.2060
    2.6121   -2.6121    1.6134   -1.6134    1.9040   -1.9040    1.9558   -1.9558
   -3.0357    0.1059    1.4273    4.5689    0.6102    3.7517    2.3987    5.5403
```