Kinematics and Dynamics of Mechatronic Systems

3rd laboratory task

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Determine a Homogeneous Transformation matrix

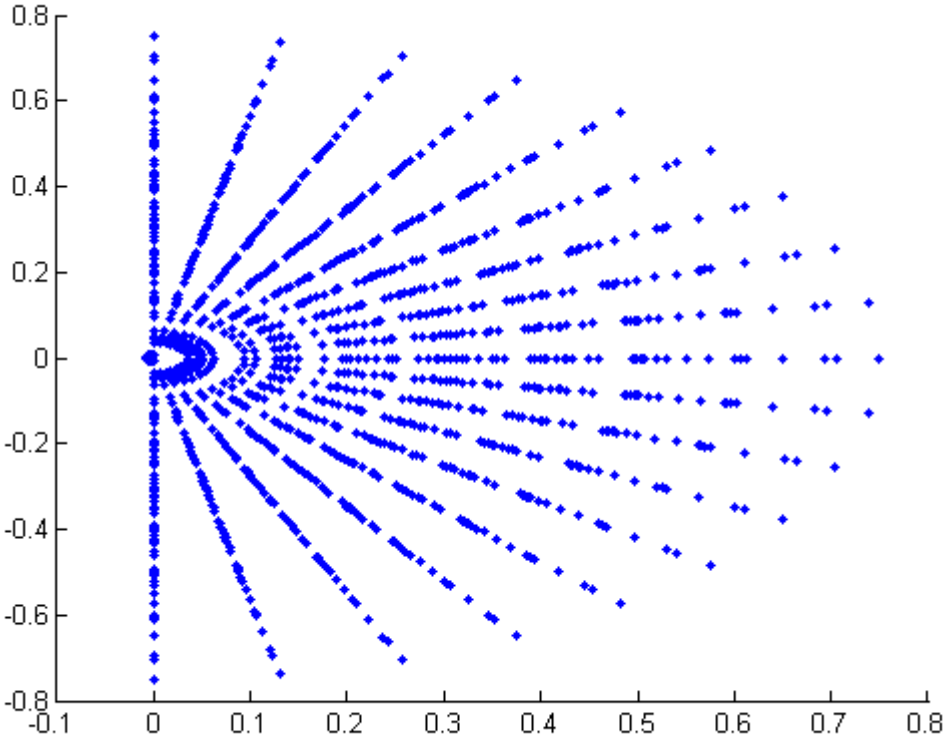
```
clear all; clc
% declaration of symbols
syms th1 d1 th2 a3 th4 d5 q1 q2 q3
% Determination of a symbolic form of HT matrices - application of mA function
A1=mA(th1,d1,0,sym(pi/2));
A2=mA(th2,0,0,0);
A3=mA(0,0,a3,0);
A4=mA(th4,0,0,sym(pi/2));
A5=mA(sym(pi/2),d5,0,0);

%
% multiplication of matrices to obtain HTM
T01=A1;
T05=A1*A2*A3*A4*A5;
```

Determining the constants and random values of joint coordinates in the ranges

input constants

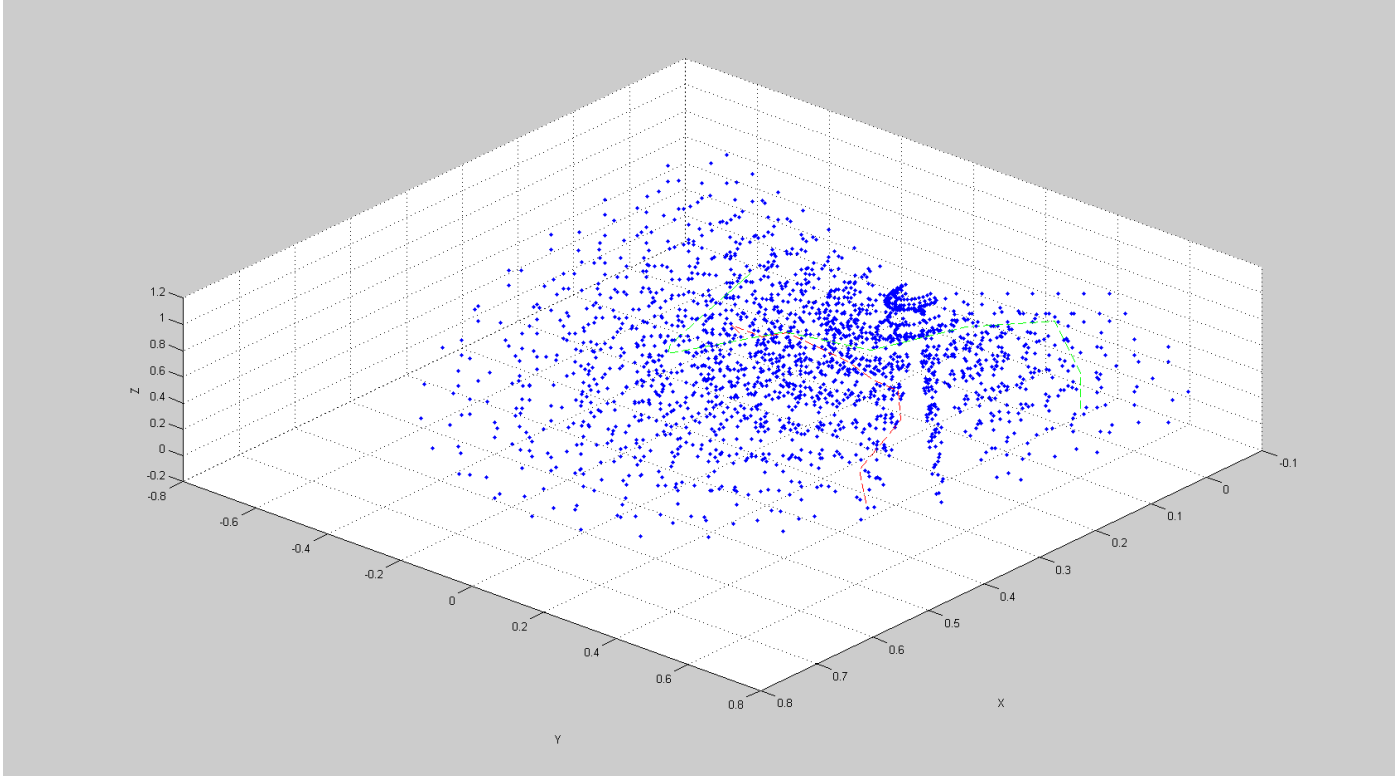
```
d1_input = 0.4;
d5_input = 0.15;

% Drawing the workspace on the 1st figure
figure(1);
hold on
for th1_input=-pi/2:pi/18:pi/2
   for th2_input=-pi/4:pi/8:pi/4
       for a3_input=0.2:0.1:0.6
           for th4_input=-pi/2:pi/4:pi/2
               T05_r=subs(T05,{th1,d1,th2,a3,th4,d5},{th1_input,d1_input, th2_input, a3_input, th4_input,
d5_input});
               P_r = [T05_r(1,4); T05_r(2,4); T05_r(3,4)];
               plot3(P_r(1,1),P_r(2,1),P_r(3,1),'.')
           end
       end
   end
end
%
% Determine the paths
%Determine the 1st path
x1=[0.39 0.39 0.29 0.23 0.21 0.19  0.17  0.15 0.14 0.12];
y1=[0.46 0.44 0.40 0.30 0.20 0.10 -0.10 -0.2 -0.3 -0.3];
z1=[0.03 0.29 0.43 0.43 0.37 0.37  0.35  0.18 0.15 0.02];
path1=[x1; y1; z1];
```

```
%Determine the 2nd path
x2=[0.00  0.00 0.00 0.14 0.24 0.24 0.32 0.27  0.03  0.00];
y2=[0.45  0.45 0.38 0.35 0.24 0.00 -0.2 -0.27 -0.42 -0.53];
z2=[-0.05 0.24 0.57 0.78 0.70 0.60 0.4  0.3   0.2   -0.13];
path2=[x2; y2; z2];
```



Draw both paths on the 2nd figure

```
hold on
plot3(x1,y1,z1,'--r')
%hold on
plot3(x2,y2,z2,'--g')
grid on
xlabel('X')
ylabel('Y')
zlabel('Z')
hold off
```

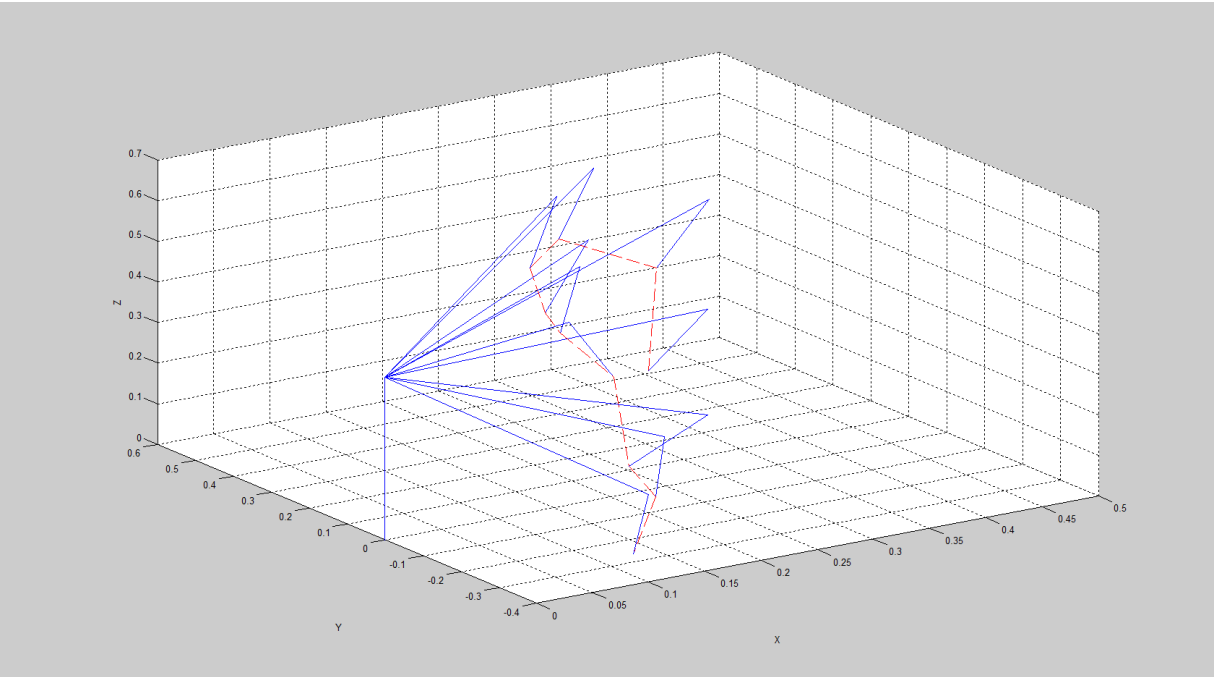


1st path: Generating motion path for each joint

```
%Placeholder for cartesian coordinates gathering
JointCoordinates1 = zeros(10,4);
```

Drawing motion path for each joint

```
figure(2)
hold on
grid on
xlabel('X')
ylabel('Y')
zlabel('Z')
plot3(x1,y1,z1,'--r');

for i=1:10
    joint4=path1(:,i);
    %calculation of q1,q2,q3,q4 with inverse kinematics
    th1_inverse=atan2(joint4(2,1),joint4(1,1));
    th2_inverse=atan2((joint4(3,1)-d1_input),sqrt(joint4(1,1)^2+joint4(2,1)^2));
    a3_inverse= sqrt(joint4(1,1)^2+joint4(2,1)^2+(joint4(3,1)-d1_input)^2);
    th4_inverse = pi/4-(pi/2)*rand; %not possible to select specific range for q4, so that it will be
generated randomly
    %determining the matrix for points belonging to path
    T01_real=subs(T01,{th1,d1},{th1_inverse,d1_input});
    T05_real=subs(T05,{th1,d1,th2,a3,th4,d5},{th1_inverse,d1_input, th2_inverse, a3_inverse, th4_inverse,
d5_input});
    Pw = [T05_real(1,3);T05_real(2,3);T05_real(3,3)]*d5_input;
    joint3=joint4-Pw;
    joint1=[T01_real(1,4); T01_real(2,4); T01_real(3,4)];
    pts34=[joint4'; joint3'];
    pts13=[joint3'; joint1'];
    pts01=[joint1'; [0 0 0]];
    line(pts34(:,1), pts34(:,2),pts34(:,3));
    line(pts13(:,1), pts13(:,2),pts13(:,3));
    line(pts01(:,1), pts01(:,2),pts01(:,3));
end
CartesianCoordinates1=path1';
hold off
```



Cartesian coordinates table:

	X	Y	Z
1	0,39	0,46	0,03
2	0,39	0,44	0,29
3	0,29	0,4	0,43
4	0,23	0,3	0,43
5	0,21	0,2	0,37
6	0,19	0,1	0,37
7	0,17	-0,1	0,35
8	0,15	-0,2	0,18
9	0,14	-0,3	0,15
10	0,12	-0,3	0,02

Joint coordinates table:

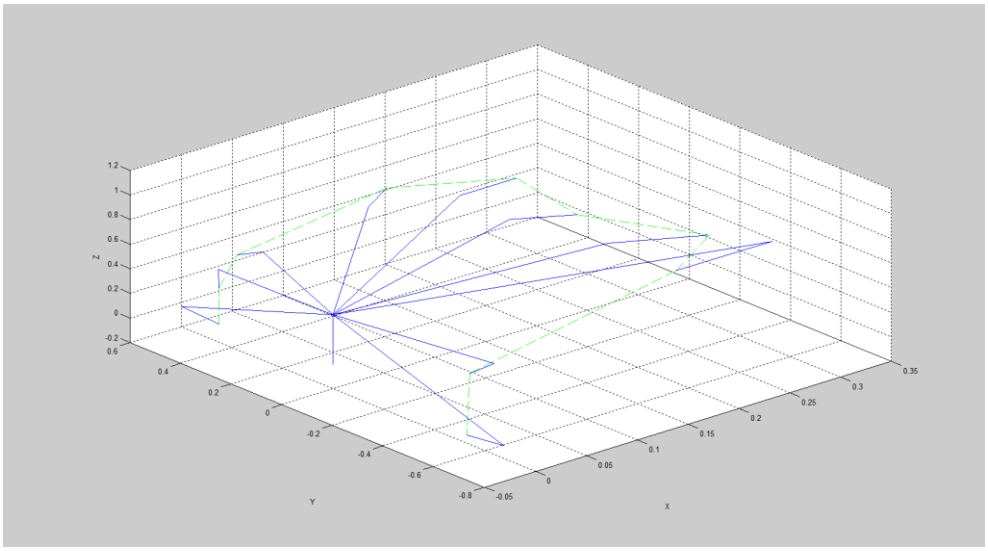
	Theta1	Theta2	A3	Theta4
1	0,867566	-0,5503	0,707531	0,696327
2	0,845566	-0,18495	0,598164	-0,03438
3	0,943488	0,060646	0,494975	0,257848
4	0,916714	0,079195	0,37921	0,509458
5	0,761013	-0,10308	0,291548	0,457185
6	0,484478	-0,13883	0,216795	-0,63641
7	-0,53172	-0,24828	0,20347	-0,2755
8	-0,9273	-0,72165	0,333017	0,04953
9	-1,13417	-0,64679	0,414849	-0,64738
10	-1,19029	-0,86613	0,498799	0,622017

2nd path: Generating motion path for each joint

```
%Placeholder for cartesian coordinates gathering
JointCoordinates2 = zeros(10,4);
```

Drawing motion path for each joint

```
figure(3)
hold on
grid on
xlabel('X')
ylabel('Y')
zlabel('Z')
plot3(x2,y2,z2,'--g');

for i=1:10
    joint4=path2(:,i);
    %calculation of q1,q2,q3,q4 with inverse kinematics
    th1_inverse=atan2(joint4(2,1),joint4(1,1));
    th2_inverse=atan2((joint4(3,1)-d1_input),sqrt(joint4(1,1)^2+joint4(2,1)^2));
    a3_inverse= sqrt(joint4(1,1)^2+joint4(2,1)^2+(joint4(3,1)-d1_input)^2);
    th4_inverse = pi/4-(pi/2)*rand; %not possible to select specific range for q4, so that it will be
generated randomly
    %determining the matrix for points belonging to path
    T01_real=subs(T01,{th1,d1},{th1_inverse,d1_input});
    T05_real=subs(T05,{th1,d1,th2,a3,th4,d5},{th1_inverse,d1_input, th2_inverse, a3_inverse, th4_inverse,
d5_input});
    Pw = [T05_real(1,3);T05_real(2,3);T05_real(3,3)]*d5_input;
    joint3=joint4-Pw;
    joint1=[T01_real(1,4); T01_real(2,4); T01_real(3,4)];
    pts34=[joint4'; joint3'];
    pts13=[joint3'; joint1'];
    pts01=[joint1'; [0 0 0]];
    line(pts34(:,1), pts34(:,2),pts34(:,3));
    line(pts13(:,1), pts13(:,2),pts13(:,3));
    line(pts01(:,1), pts01(:,2),pts01(:,3));

JointCoordinates2(i,1)=th1_inverse;JointCoordinates2(i,2)=th2_inverse;JointCoordinates2(i,3)=a3_inverse;Join
tCoordinates2(i,4)=th4_inverse; %gather joint coordinates
end

CartesianCoordinates2 = path2'; %inversing the path to easier gathering to table
hold off
```



Cartesian coordinates table:

	X	Y	Z
1	0	0,45	-0,05
2	0	0,45	0,24
3	0	0,38	0,57
4	0,14	0,35	0,78
5	0,24	0,24	0,7
6	0,24	0	0,6
7	0,32	-0,2	0,4
8	0,27	-0,27	0,3
9	0,03	-0,42	0,2
10	0	-0,53	-0,13

Joint coordinates table:

	Theta1	Theta2	A3	Theta4
1	1,570796	-0,7854	0,636396	-0,32503
2	1,570796	-0,34162	0,477598	-0,7846
3	1,570796	0,420663	0,416293	0,333245
4	1,19029	0,789412	0,535257	0,134268
5	0,785398	0,723839	0,45299	0,055229
6	0	0,694738	0,31241	-0,41462
7	-0,5586	0	0,377359	-0,49983
8	-0,7854	-0,25614	0,394715	0,627971
9	-1,49949	-0,44343	0,466154	0,505613
10	-1,5708	-0,7854	0,749533	0,220485