Table of Contents


```
%Nathaniel Goldfarb
%RBE501


clear all;
close all;
clc;

%define the constants of the arm
l1 = 0;
l2 = 70
l3 = 100;
alpha = 90;

%go to home
syms theta1 theta2 theta3
links(1,:) = [ l1  degtorad(alpha) 0 degtorad(theta1)];
links(2,:) = [ l2 0 0 degtorad(theta2)];
links(3,:) = [ l3 0 0 degtorad(theta3- 90)];
%get the A and T matrix
A = getA(links);
T = getT(A);
```

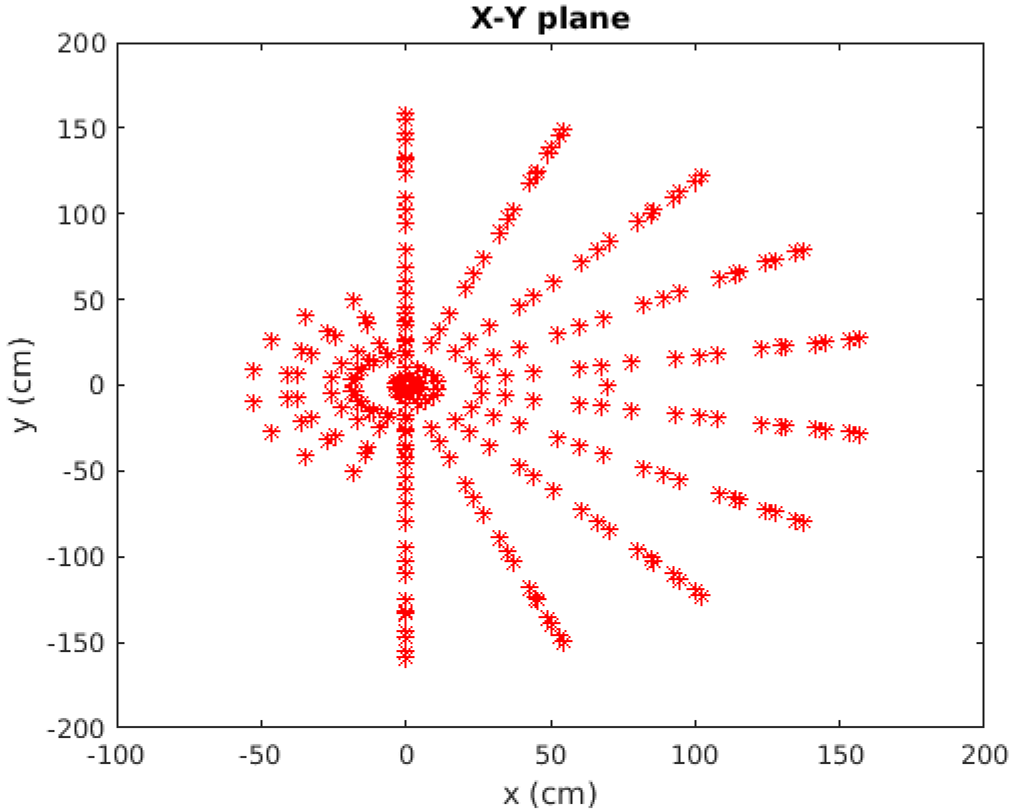
```
l2 =

    70
```

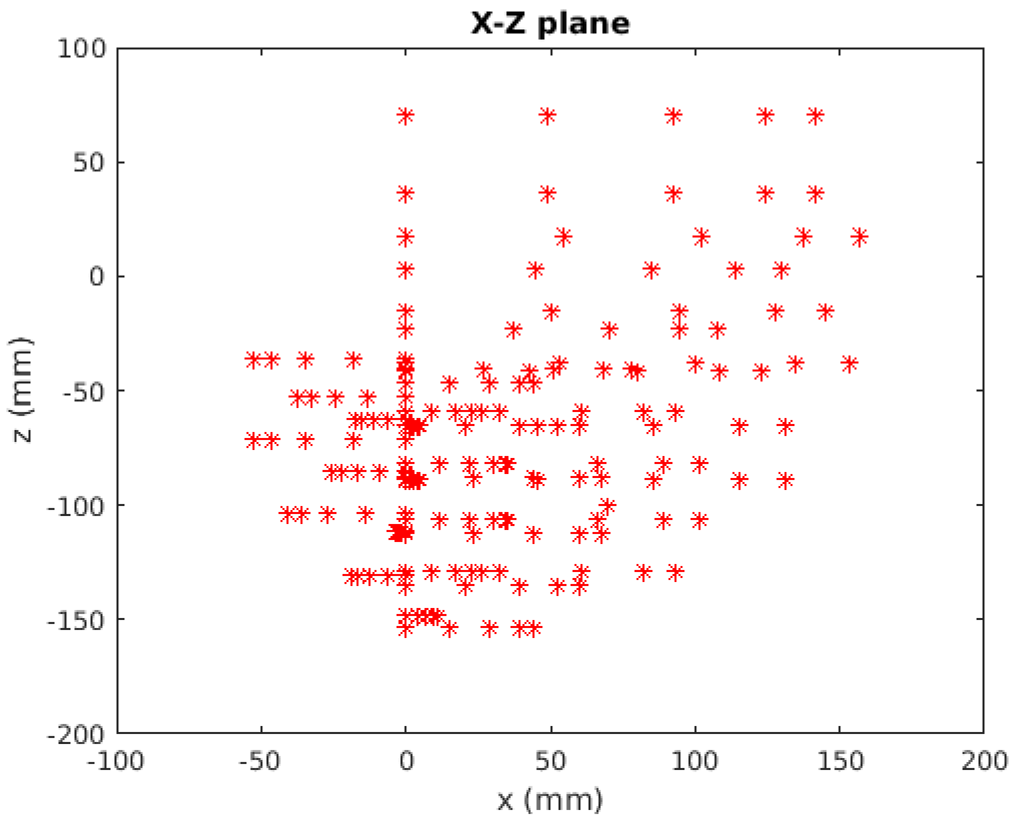
Part 1

```
%Plot the work space
T_fig =  double(simplify(subs(T, [ theta1 theta2  theta3 ], [ 0 0
 0 ])));
x = T_fig(1,4,end);
y = T_fig(2,4,end);
```

```
z = T_fig(3,4,end);

%cycle through different joint angels of the arm and save the location
 of
%the end effector.
for t1 =  -90:20:90
    for t2 =  -50:20:50
        for t3 = 0-50:20:50
            T_fig =  double(simplify(subs(T, [ theta1 theta2
 theta3 ], [ t1 t2 t3 ])));
            x = [x,T_fig(1,4,end)];
            y = [y,T_fig(2,4,end)];
            z = [z,T_fig(3,4,end)];
        end
    end
end

%plot the X-Y plane
figure(1);
plot(x,y,'r*')
title('X-Y plane');
xlabel('x (cm)');
ylabel('y (cm)');

%plot the X-Z plane
figure(2);
plot(x,z,'r*')
title('X-Z plane');
xlabel('x (mm)');
ylabel('z (mm)');
```

Warning: Imaginary parts of complex X and/or Y arguments ignored
Warning: Imaginary parts of complex X and/or Y arguments ignored


X-Y plane
200
150
100
50
0
-50
-100
-150
-200
-100
-50
0
50
100
150
200
y (cm)
x (cm)


X-Z plane
100
50
0
-50
-100
-150
-200
-100
-50
0
50
100
150
200
z (mm)
x (mm)

Part 3

DH table for the arm $\begin{bmatrix} a & alpha & d & theta \\ 0 & \frac{\pi}{2} & 0 & \frac{\pi\,\mathrm{theta1}}{180} \\ 70 & 0 & 0 & \frac{\pi\,\mathrm{theta2}}{180} \\ 100 & 0 & 0 & \frac{\pi\,(\mathrm{theta3}-90)}{180} \end{bmatrix}$$

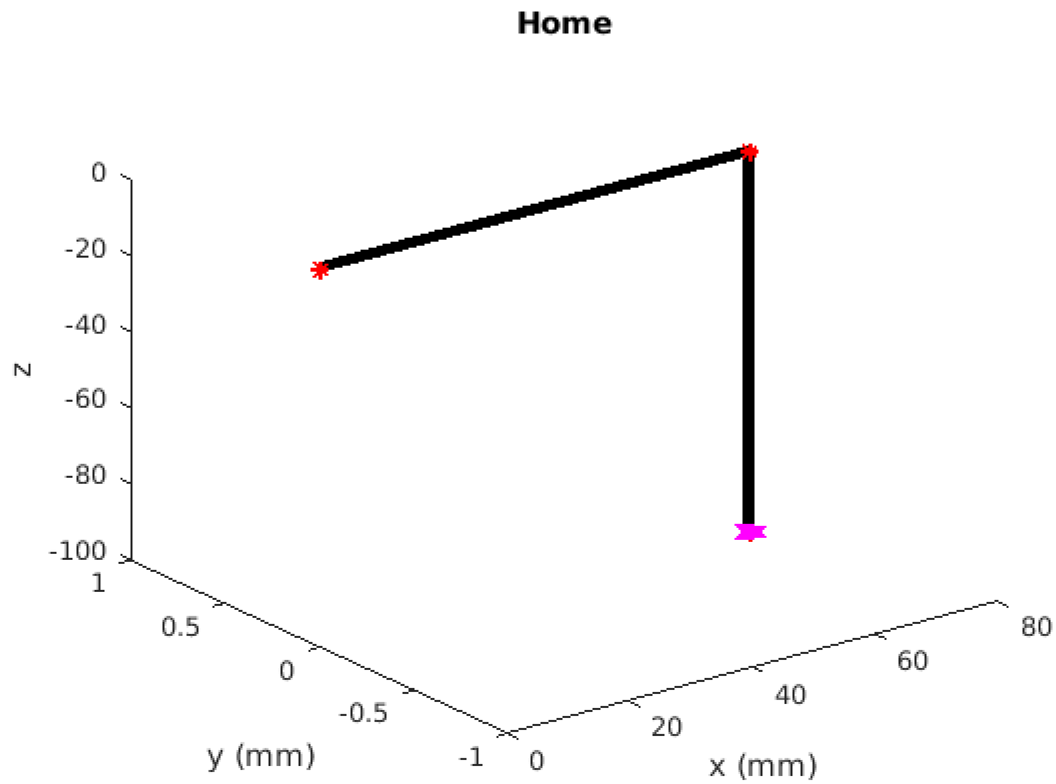
Part 4

```
%The transforms for the leg are:
T


T(:,:,1) =

[ cos((pi*theta1)/180), 0,  sin((pi*theta1)/180), 0]
[ sin((pi*theta1)/180), 0, -cos((pi*theta1)/180), 0]
[                    0, 1,                     0, 0]
[                    0, 0,                     0, 1]


T(:,:,2) =

[ cos((pi*theta1)/180)*cos((pi*theta2)/180), -
cos((pi*theta1)/180)*sin((pi*theta2)/180),  sin((pi*theta1)/180),
 70*cos((pi*theta1)/180)*cos((pi*theta2)/180)]
[ cos((pi*theta2)/180)*sin((pi*theta1)/180), -
sin((pi*theta1)/180)*sin((pi*theta2)/180), -cos((pi*theta1)/180),
 70*cos((pi*theta2)/180)*sin((pi*theta1)/180)]
[                       sin((pi*theta2)/180),
 cos((pi*theta2)/180),                     0,
 70*sin((pi*theta2)/180)]
[                                          0,
                0,                     0,
               1]


T(:,:,3) =

[ cos((pi*theta1)/180)*cos((pi*theta2)/180)*cos((pi*(theta3 -
 90))/180) - cos((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3
 - 90))/180), -
 cos((pi*theta1)/180)*cos((pi*theta2)/180)*sin((pi*(theta3 - 90))/180)
 - cos((pi*theta1)/180)*sin((pi*theta2)/180)*cos((pi*(theta3 -
 90))/180),  sin((pi*theta1)/180),
 70*cos((pi*theta1)/180)*cos((pi*theta2)/180) +
 100*cos((pi*theta1)/180)*cos((pi*theta2)/180)*cos((pi*(theta3 -
 90))/180) -
 100*cos((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180)]
```

```
[ cos((pi*theta2)/180)*sin((pi*theta1)/180)*cos((pi*(theta3 -
 90))/180) - sin((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3
 - 90))/180), -
 cos((pi*theta2)/180)*sin((pi*theta1)/180)*sin((pi*(theta3 - 90))/180)
 - sin((pi*theta1)/180)*sin((pi*theta2)/180)*cos((pi*(theta3 -
 90))/180), -cos((pi*theta1)/180),
 70*cos((pi*theta2)/180)*sin((pi*theta1)/180) +
 100*cos((pi*theta2)/180)*sin((pi*theta1)/180)*cos((pi*(theta3 -
 90))/180) -
 100*sin((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180)]
[
  cos((pi*theta2)/180)*sin((pi*(theta3 - 90))/180) +
 sin((pi*theta2)/180)*cos((pi*(theta3 - 90))/180),
                             cos((pi*theta2)/180)*cos((pi*(theta3
 - 90))/180) - sin((pi*theta2)/180)*sin((pi*(theta3 - 90))/180),
                    0,
                              70*sin((pi*theta2)/180) +
 100*cos((pi*theta2)/180)*sin((pi*(theta3 - 90))/180) +
 100*sin((pi*theta2)/180)*cos((pi*(theta3 - 90))/180)]
[

  0,

       0,                      0,


                 1]
```

Part 5

```
%Calculat the Pose
T_fig =  double(simplify(subs(T, [ theta1 theta2  theta3 ], [ 0 0
 0 ])));
%Plot the arm
figure(3);
plotArm(T_fig);
title('Home')
xlabel('x (mm)');
ylabel('y (mm)');
```



Part 6

```
f = [0 0 10]
%add a '1' so the math works
P_f = [ f 1]'
inv(T_fig(:,:,end))
vector = inv(T_fig(:,:,end))*P_f ;
%remove the last element
vector = vector(1:3)
```

```
f =

     0     0    10


P_f =

     0
     0
    10
     1


ans =
```

```
     0     0    -1   -100
     1     0     0    -70
     0    -1     0      0
     0     0     0      1


vector =

  -110
   -70
     0
```

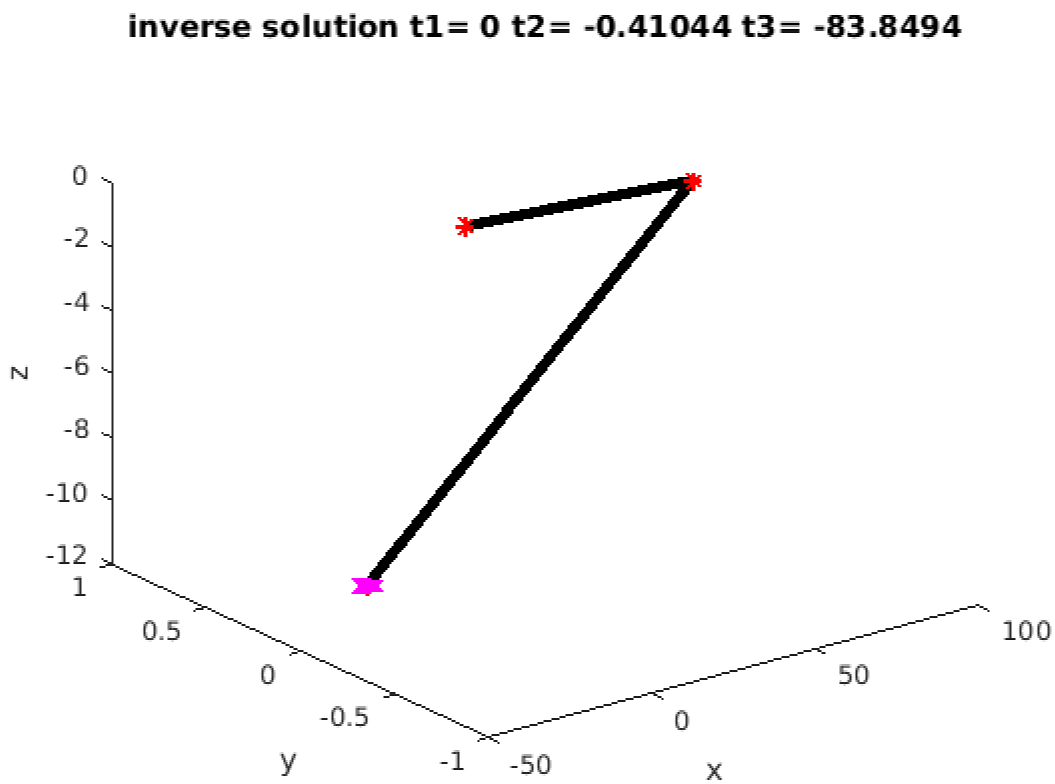
Part 7

the joints are going to be decoupled and solved geometericly the elbow "up" config is going to be used, the opposite will also work.

```
%Pose
Px = 80;
Py = 0;
Pz = -100;

%set up
a1 = l2;
a2 = l3;
r =  (a1*a1 + a2*a2)

%Answer
t3_IK = -acosd( ( (Px*Px) + (Pz*Pz) - r)/(2*a1*a2))
t2_IK = atan2d(Pz,Px)-atan2d( (a2*sind(t3_IK)), (a1 + a2*cosd(t3_IK)))
t1_IK = atan2d(Py,Px)

%Plot the arm in the inverse configuration
figure(4);
T_IK =  double(simplify(subs(T, [ theta1 theta2  theta3 ], [ t1_IK
 t2_IK t3_IK ])));
%get the A and T matrix
plotArm(T_IK)
title(['inverse solution t1= '  num2str(t1_IK) ' t2= '
 num2str(t2_IK) ' t3= ' num2str(t3_IK)])
```

```
r =

       14900


t3_IK =

  -83.8494


t2_IK =
```

```
   -0.4104


t1_IK =

     0
```



Part 8

```
%calculate the Jacobian
j1 = getRevJ( T(1:3,3,1), T(1:3,4,end),T(1:3,4,1));
j2 = getRevJ( T(1:3,3,2), T(1:3,4,end),T(1:3,4,2));
j3 = getRevJ( T(1:3,3,3), T(1:3,4,end),T(1:3,4,3));
J = [j1 j2 j3 ]
```

```
J =

[



                     -cos((pi*theta1)/180)*(70*sin((pi*theta2)/180)
 + 100*cos((pi*theta2)/180)*sin((pi*(theta3 - 90))/180) +
```

```
 100*sin((pi*theta2)/180)*cos((pi*(theta3 - 90))/180)),



   -cos((pi*theta1)/180)*(100*cos((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180) + 100*sin((pi*theta2)/180)*cos((pi*(theta3 - 90))/180)),
                  0]
[



                     -sin((pi*theta1)/180)*(70*sin((pi*theta2)/180)
 + 100*cos((pi*theta2)/180)*sin((pi*(theta3 - 90))/180) +
 100*sin((pi*theta2)/180)*cos((pi*(theta3 - 90))/180)),



   -sin((pi*theta1)/180)*(100*cos((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180) + 100*sin((pi*theta2)/180)*cos((pi*(theta3 - 90))/180)),
                  0]
[ cos((pi*theta1)/180)*(70*cos((pi*theta1)/180)*cos((pi*theta2)/180)
 + 100*cos((pi*theta1)/180)*cos((pi*theta2)/180)*cos((pi*(theta3 -
 90))/180) -
 100*cos((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180)) +
 sin((pi*theta1)/180)*(70*cos((pi*theta2)/180)*sin((pi*theta1)/180)
 + 100*cos((pi*theta2)/180)*sin((pi*theta1)/180)*cos((pi*(theta3 -
 90))/180) -
 100*sin((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180)),
 cos((pi*theta1)/180)*(100*cos((pi*theta1)/180)*cos((pi*theta2)/180)*cos((pi*(thet
 - 90))/180) -
 100*cos((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180)) +
 sin((pi*theta1)/180)*(100*cos((pi*theta2)/180)*sin((pi*theta1)/180)*cos((pi*(thet
 - 90))/180) -
 100*sin((pi*theta1)/180)*sin((pi*theta2)/180)*sin((pi*(theta3 -
 90))/180)),                     0]
[




   sin((pi*theta1)/180),




  sin((pi*theta1)/180),  sin((pi*theta1)/180)]
[
```

```
  -cos((pi*theta1)/180),

 -cos((pi*theta1)/180), -cos((pi*theta1)/180)]
[

                      0,

                     0,                       0]
```

Part 9

```
%Find the determinant of the Jacobian of matix,

det(J(1:3,:))

%Since the determinant is zero the are no sigularities

ans =

0
```

Part10

```
J_s = simplify(subs(J, [ theta1 theta2  theta3 ], [ 0 0 0 ]))
jV = J_s(1:3,:);
xdot = [ 0 0 10 0 0 0 ]';
pinv(J_s)
thetadot = pinv(J_s)*xdot

J_s =

[ 100, 100,  0]
[   0,   0,  0]
[  70,   0,  0]
[   0,   0,  0]
[  -1,  -1, -1]
[   0,   0,  0]
```

```
ans =

[       0, 0,  1/70, 0,  0, 0]
[  1/100, 0, -1/70, 0,  0, 0]
[ -1/100, 0,     0, 0, -1, 0]


thetadot =

  1/7
 -1/7
    0
```

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