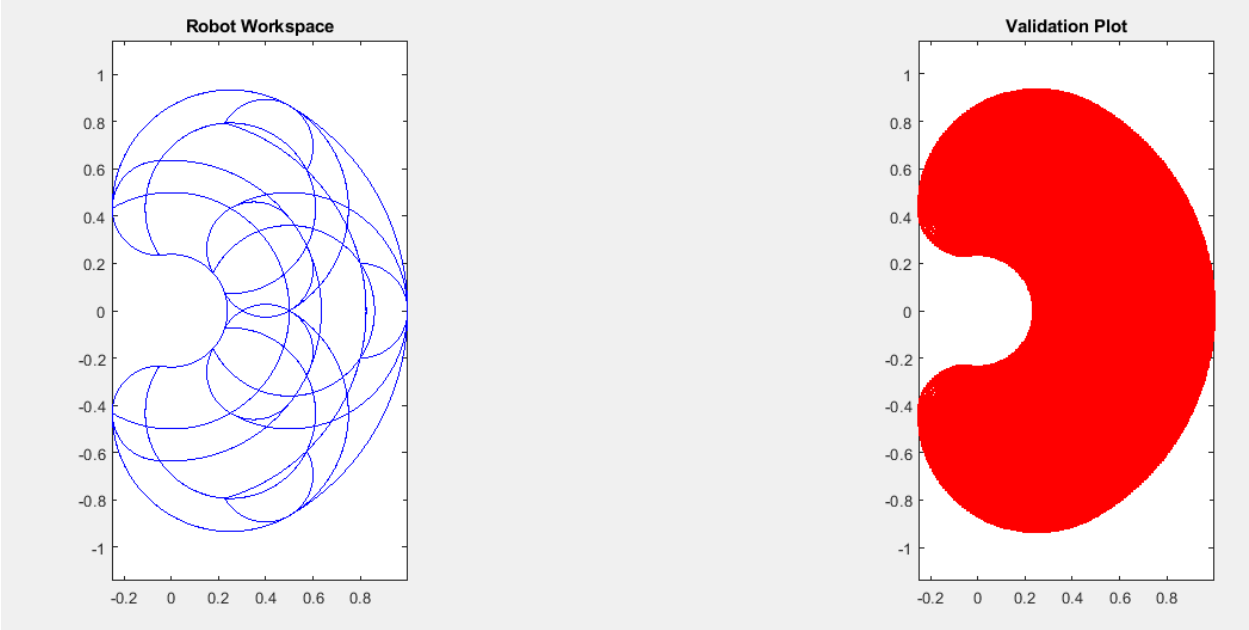
Problem 1:

With the following data:
a1 = 0.5
a2 = 0.3
a3 = 0.2

$-\pi/3 \leq q1 \leq \pi/3$
$-2\pi/3 \leq q2 \leq 2\pi/3$
$-\pi/2 \leq q3 \leq \pi/2$

Create the robot Workspace

Solution:
Result:



Steps:

1. Define all the link lengths and the joint angle limits.
2. Following the steps to generate the mapping from joint to Cartesian coordinates
    a. Generate all the possible matrices with all the joints at their limits → We have 3 joints and there are only 2 possible values, Max and Min so we have 2^n possible matrices. Total 8 matrices.
    b. Keep any one of the joints to its limit and rest of all the joints to 0, repeat the step for all the joints, We get 2 possibilities for 1 joint and repeat the step for 2 more joints → resulting in 6 more matrices.
    c. Keep any two of the joints to its limit and rest of all the joints to 0, repeat the steps for all the combination joints → we get 12 such combinations
    d. We have a total of 26 matrix combinations where all the 2 joints take value from lower limit to upper limit and 0.

e. Find combinations of 2 matrices which have only one of the elements in respective matrices as different.
    i. To find the combinations, Check the similarities in the matrices by comparing (== symbol), we get the resulting matrix as 1's and 0', where if the values are same, we get the result as 1 and if different, the value is 0.
    ii. Since we need to have combinations with only one value different, we check the count of non 0 values, if the count is 2, Both the matrices are a combination.
    iii. Repeat the comparisons of all the 26 matrices with each other.
f. To generate the workspace of the robot, we need to plot the values of x and y of the end effector.
    i. We use the equations below to find the pose of x and y

```
%Xp =
a1*cos(m(:,1))+a2*cos(m(:,1)+m(:,2))+a3*cos(m(:,1)+m(:,2)
+m(:,3));
%Yp =
a1*sin(m(:,1))+a2*sin(m(:,1)+m(:,2))+a3*sin(m(:,1)+(:,2)+
m(:,3));
```

    ii. Split the difference angle in 50 steps, for eg : m1 = [0,0,q1_max] and m2 = [0 0 q1_min], we split the q1 angle in 50 steps starting from the lower limit to upper limit and pass the angle to the above equations.
    iii. If the different values is the 3rd angle, the new equation will be as shown below

x = a1*cos(splits(end,:))+a2*cos(splits(end,:)+m(i,2))+a3*cos(splits(end,:)+m(i,2)+m(i,3));
y = a1*sin(splits(end,:))+a2*sin(splits(end,:)+m(i,2))+a3*sin(splits(end,:)+m(i,2)+m(i,3));

    iv. If the different values is the 2nd angle, the new equation will be as shown below

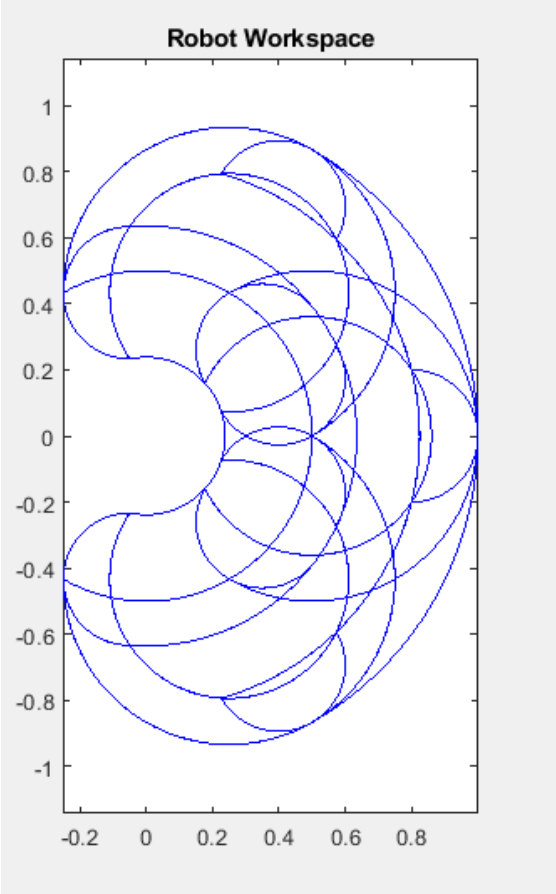
x = a1*cos(m(i,1))+a2*cos(m(i,1)+splits(end,:))+a3*cos(m(i,1)+splits(end,:)+m(i,3));
y = a1*sin(m(i,1))+a2*sin(m(i,1)+splits(end,:))+a3*sin(m(i,1)+splits(end,:)+m(i,3));

    v. If the different values is the 1st angle, the new equation will be as shown below

x = a1*cos(m(i,1))+a2*cos(m(i,1)+m(i,2))+a3*cos(m(i,1)+m(i,2)+splits(end,:));
y = a1*sin(m(i,1))+a2*sin(m(i,1)+m(i,2))+a3*sin(m(i,1)+m(i,2)+splits(end,:));

g. Plot the x and y values

Result Graph :



Part 2:

Validate the above workspace:

Step:

1. We split the limit of joint angles in 50 steps each.
2. Plot the x and y values of all the new values of q1,q2 and q3.
3. Below is the resulting graph.

Graph :