

ME145 Robotic Planning and Kinematic: Lab 6

Robotic Planning and kinematics

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Part 1: Plot environment Function:

```
1 function plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
2
3 %% Calculate the positions of the links
4 x1 = L1 * cos(alpha);
5 y1 = L1 * sin(alpha);
6
7 x2 = x1 + L2 * cos(alpha + beta);
8 y2 = y1 + L2 * sin(alpha + beta);
9
10
11 %% Plotting
12
13 % Link 2 -----
14
15 % plot semi circle on link2 front
16 theta = linspace(alpha+beta-pi/2,alpha+beta+pi/2 , 100);
17 semi0x = x1 - W*cos(theta);
18 semi0y = y1 - W *sin(theta);
19 fill(semi0x, semi0y,[0.9290 0.6940 0.1250])
20 hold on
21
22 % Semi circle link 2 end
23 theta = linspace(beta+alpha-pi/2,beta+alpha+pi/2 , 100);
24 semi2x = x2 + W*cos(theta);
25 semi2y = y2 + W * sin(theta);
26 fill(semi2x, semi2y,[0.9290 0.6940 0.1250])
27
28 % plotting square
29 xx1 = x1 - W*cos(alpha+beta+pi/2);
30 xx2 = x1 - W*cos(alpha+beta-pi/2);
31 xx4 = x2 - W*cos(alpha+beta+pi/2);
32 xx3 = x2 - W*cos(alpha+beta-pi/2);
33
34 yy1 = y1 - W *sin(alpha+beta-pi/2);
35 yy2 = y1 - W *sin(alpha+beta+pi/2);
36 yy3 = y2 + W *sin(alpha+beta-pi/2);
37 yy4 = y2 + W *sin(alpha+beta+pi/2);
38
```

```
% Link 1 -----

%plot first semi circle on link1
theta = linspace(alpha-pi/2,alpha+pi/2 , 100);
semi0x = 0 - W*cos(theta);
semi0y = 0 - W *sin(theta);
fill(semi0x, semi0y,[0 0.4470 0.7410])
hold on

%plot semi circle on link1 end
theta = linspace(alpha-pi/2,alpha+pi/2 , 100);
semi0x = x1 + W*cos(theta);
semi0y = y1 + W *sin(theta);
fill(semi0x, semi0y,[0 0.4470 0.7410])
hold on

%plotting square

xx1 = 0 - W*cos(alpha-pi/2);
xx2 = 0 - W*cos(alpha+pi/2);
xx4 = x1 + W*cos(alpha+pi/2);
xx3 = x1 + W*cos(alpha-pi/2);

yy1 = 0 - W *sin(alpha-pi/2);
yy2 = 0 - W *sin(alpha+pi/2);
yy3 = y1 + W *sin(alpha-pi/2);
yy4 = y1 + W *sin(alpha+pi/2);

fill([xx1 xx2 xx3 xx4],[yy1 yy2 yy3 yy4],[0.3010 0.7450 0.9330])
```

```
74 %% Plotting Obstacle
75
76
77 theta = linspace(0,2*pi, 100);
78 semi0x = xo + r*cos(theta);
79 semi0y = yo + r *sin(theta);
80 fill(semi0x, semi0y,[0.6350 0.0780 0.1840])
81 hold on
82
83
84 xlim([-L2-L1-1 L2+L1+1])
85 ylim([-L2-L1-1 L2+L1+1])
86 axis square
87 grid on
88
```

The complete code for `plotEnvironment` is provided above. It begins by calculating the positions of the two links using their respective kinematic equations. To plot Link 1, the center point's direction was adjusted to $[-y, x]$, and the unit vector was determined. The x-coordinates for the link's corners were found by adding and subtracting the width multiplied by the unit vector from the x-coordinate. The same approach was used to determine the y-coordinates. Once the positions of the four corners were established, they were used to create a solid rectangle with MATLAB's built-in `fill()` function. This method was also applied to plot Link 2. The circular obstacle and semi-circles were generated using the `fill()` function as well. To approximate a circular shape, 100 theta values were evenly spaced between 0 and $-\pi/\pi$ and substituted into cosine and sine functions, producing 100 corresponding x and y coordinates. These points were then plotted to create a close representation of a circle and semi-circle.

Example:

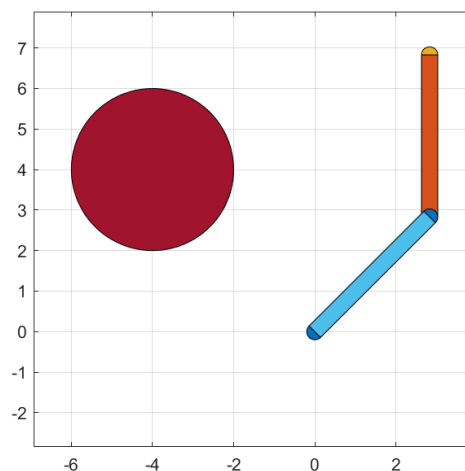
Input:

```
% plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
|
figure
L1 = 4;
L2 = 4;
W = 0.2; % width
xo = -4;
yo = 4;
r = 2;

alpha = pi/4;
beta = pi/4;

plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
```

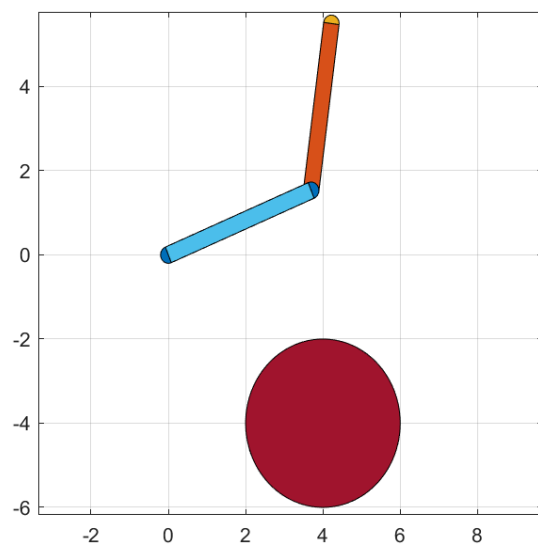
Output:



Input

```
7   figure
8   L1 = 4;
9   L2 = 4;
10  W = 0.2; % width
11  xo = 4;
12  yo = -4;
13  r = 2;
14
15  alpha = pi/8;
16  beta = pi/8;
17
18  plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
```

Output:



Part 2: checkCollisionTwpLink

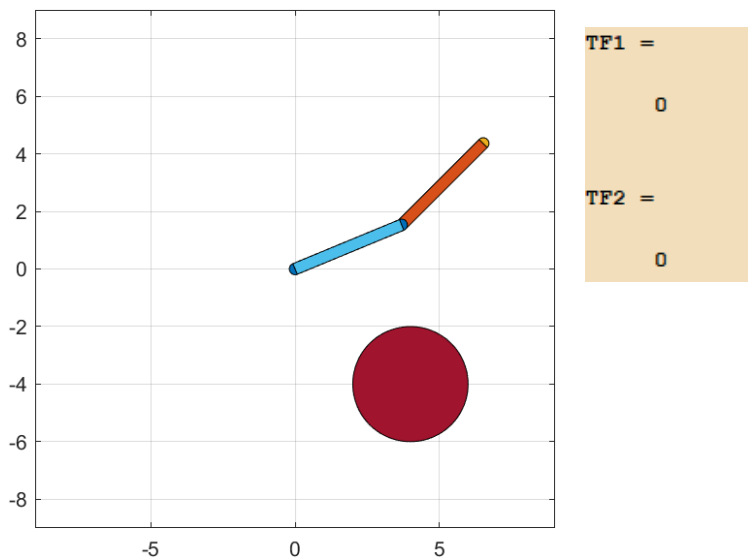
```
1 function [one] = checkCollisionTwoLink(L1,L2,W,alpha,beta,xo,yo,r)
2
3 %% Position
4 x1 = L1 * cos(alpha);
5 y1 = L1 * sin(alpha);
6
7 x2 = x1 + L2 * cos(alpha + beta);
8 y2 = y1 + L2 * sin(alpha + beta);
9
10 %% Check rectangle first (easy)
11
12 % Define link 1 body
13
14 xx1 = 0 - W*cos(alpha-pi/2);
15 xx2 = 0 - W*cos(alpha+pi/2);
16 xx4 = x1 + W*cos(alpha+pi/2);
17 xx3 = x1 + W*cos(alpha-pi/2);
18
19 yy1 = 0 - W *sin(alpha-pi/2);
20 yy2 = 0 - W *sin(alpha+pi/2);
21 yy3 = y1 + W *sin(alpha-pi/2);
22 yy4 = y1 + W *sin(alpha+pi/2);
23
24 Link1 = [[xx1 xx2 xx3 xx4]' [yy1 yy2 yy3 yy4]'];
25
26 % Define Body Link 2
27
28 xx1 = x1 - W*cos(alpha+beta+pi/2);
29 xx2 = x1 - W*cos(alpha+beta-pi/2);
30 xx4 = x2 - W*cos(alpha+beta+pi/2);
31 xx3 = x2 - W*cos(alpha+beta-pi/2);
32
33 yy1 = y1 - W *sin(alpha+beta-pi/2);
34 yy2 = y1 - W *sin(alpha+beta+pi/2);
35 yy3 = y2 + W *sin(alpha+beta-pi/2);
36 yy4 = y2 + W *sin(alpha+beta+pi/2);
37
38 Link2 = [[xx1 xx2 xx3 xx4]' [yy1 yy2 yy3 yy4]'];
39
40
41
42 %% Define obstacle as a poly with alot of points
43
44 theta = linspace(0,2*pi, 100);
45 semi0x = xo + r*cos(theta);
46 semi0y = yo + r *sin(theta);
47
48 obstacle = [[semi0x' ] semi0y'];
49
50 %-----
51
52 %Link 1 end
53 theta = linspace(alpha-pi/2,alpha+pi/2 , 100);
54 semi0x = x1 + W*cos(theta);
55 semi0y = y1 + W *sin(theta);
56 Link1_end = [[semi0x' ] semi0y'];
57
58 %Link 2 start
59 theta = linspace(alpha+beta-pi/2,alpha+beta+pi/2 , 100);
60 semi0x = x1 - W*cos(theta);
61 semi0y = y1 - W *sin(theta);
62 Link2_start = [[semi0x' ] semi0y'];
63
64 % Semi circle link 2 end
65 theta = linspace(beta+alpha-pi/2,beta+alpha+pi/2 , 100);
66 semi0x = x2 + W*cos(theta);
67 semi0y = y2 + W * sin(theta);
68 Link2_end = [[semi0x' ] semi0y'];
69
70 %% Check for collisions
71
72 TF1 = doTwoConvexPolygonsIntersect(obstacle,Link1);
73 TF2 = doTwoConvexPolygonsIntersect(obstacle,Link2);
74 TF3 = doTwoConvexPolygonsIntersect(obstacle,Link1_end);
75 TF4 = doTwoConvexPolygonsIntersect(obstacle,Link2_start);
76 TF5 = doTwoConvexPolygonsIntersect(obstacle,Link2_end);
77
78
79 if (TF1 ==1) || (TF3 ==1)
80     one = 1;
81 else
82     one = 0;
83 end
84
85 if (TF2 ==1) || (TF4 ==1) || (TF5 ==1)
86     two = 1;
87 else
88     two = 0;
89 end
90
91 end
```

This code primarily constructs the polygons representing the two-link robot and the circular obstacle. The robot consists of five distinct polygonal shapes. To determine the interactions between the robot and the obstacle, I utilized a function from the previous lab to check whether each segment intersects with the circle. If Link 1 collides with the obstacle, TF1 is set to 1; otherwise, it remains 0. Similarly, if Link 2 makes contact, TF2 is assigned a value of 1; otherwise, it remains 0.

Input: No collision

```
7 figure
8 L1 = 4;
9 L2 = 4;
0 W = 0.2; % width
1 xo = 4;
2 yo = -4;
3 r = 2;
4
5 alpha = pi/8;
6 beta = pi/8;
7
8 plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
9 [TF1,TF2] = checkCollisionTwoLink(L1,L2,W,alpha,beta,xo,yo,r)
0
```

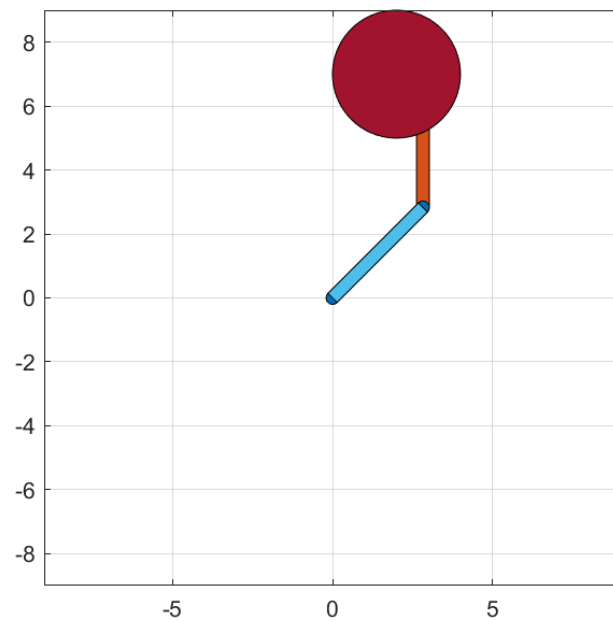
Output



Input: Link 2 collision

```
7 figure
8 L1 = 4;
9 L2 = 4;
10 W = 0.2; % width
11 xo = 2;
12 yo = 7;
13 r = 2;
14
15 alpha = pi/4;
16 beta = pi/4;
17
18 plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
19 [TF1,TF2] = checkCollisionTwoLink(L1,L2,W,alpha,beta,xo,yo,r)
20
```

Output:



TF1 =

0

TF2 =

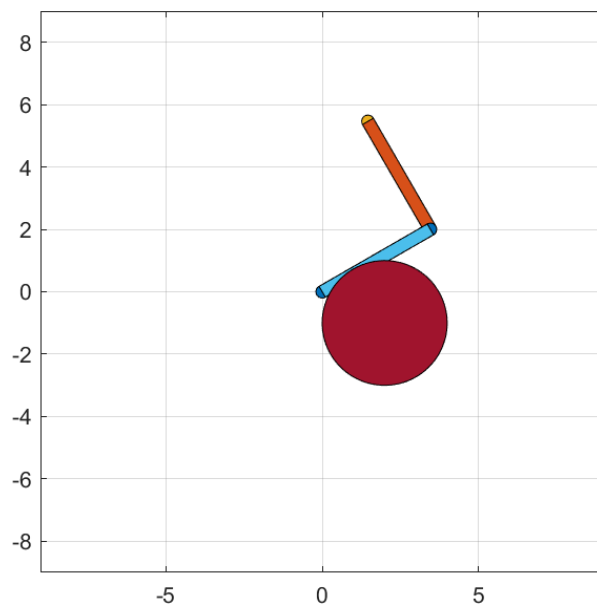
1

TF2 = 1 since link two is in collision

Input: Link one collision

```
7   figure
8   L1 = 4;
9   L2 = 4;
10  W = 0.2; % width
11  xo = 2;
12  yo = -1;
13  r = 2;
14
15  alpha = pi/6;
16  beta = pi/2;
17
18  plotEnvironment(L1, L2, W, alpha, beta, xo, yo, r)
19  [TF1,TF2] = checkCollisionTwoLink(L1,L2,W,alpha,beta,xo,yo,r)
20
```

Output:



TF1 =

1

TF2 =

0

TF1 = 1, since link one is in collision.

Part 3: plotSampleConfigurationTwoLink

```

1 function Grid = plotSampleConfigurationSpaceTwoLink(L1,L2,W,xo,yo,r,sampling_method,n)
2 %% Define method and obtaining grid
3 if strcmp(sampling_method, 'Sukharev')
4     Grid = computeGridSukharev(n);
5     Grid = Grid';
6 elseif strcmp(sampling_method, 'Random')
7     Grid = computeGridRandom(n);
8
9 elseif strcmp(sampling_method, 'Halton')
10    Grid = computeGridHalton(n,2,3);
11
12 else
13     error("Unknown sampling method")
14 end
15
16 %% Defining possible configuration expansion
17
18 alpha_net = (Grid(:,1) * 2 - 1) * pi;
19 beta_net = (Grid(:,2) * 2 - 1) * pi;
20
21
22 %% Define Geometry
23 for i = 1:length(alpha_net)
24
25     alpha = alpha_net(i);
26     beta = beta_net(i);
27     % Position
28     x1 = L1 .* cos(alpha);
29     y1 = L1 .* sin(alpha);
30
31     x2 = x1 + L2 .* cos(alpha + beta);
32     y2 = y1 + L2 .* sin(alpha + beta);
33
34     % Define link 1 body
35
36     xx1 = 0 - W.*cos(alpha-pi/2);
37     xx2 = 0 - W.*cos(alpha+pi/2);
38     xx4 = x1 + W.*cos(alpha+pi/2);
39     xx3 = x1 + W.*cos(alpha-pi/2);
40
41     yy1 = 0 - W .*sin(alpha-pi/2);
42     yy2 = 0 - W .*sin(alpha+pi/2);
43     yy3 = y1 + W .*sin(alpha-pi/2);
44     yy4 = y1 + W .*sin(alpha+pi/2);
45
46     Link1 = [[xx1 xx2 xx3 xx4]' [yy1 yy2 yy3 yy4]'];

```

```

48 % Define Body Link 2
49
50 xx1 = x1 - W.*cos(alpha+beta+pi/2);
51 xx2 = x1 - W.*cos(alpha+beta-pi/2);
52 xx4 = x2 - W.*cos(alpha+beta+pi/2);
53 xx3 = x2 - W.*cos(alpha+beta-pi/2);
54
55 yy1 = y1 - W .*sin(alpha+beta-pi/2);
56 yy2 = y1 - W .*sin(alpha+beta+pi/2);
57 yy3 = y2 + W .*sin(alpha+beta-pi/2);
58 yy4 = y2 + W .*sin(alpha+beta+pi/2);
59
60 Link2 = [[xx1 xx2 xx3 xx4]' [yy1 yy2 yy3 yy4]'];
61
62 % Define obstacle as a poly with alot of points
63
64 theta = linspace(0,2*pi, 100);
65 semi0x = xo + r.*cos(theta);
66 semi0y = yo + r.*sin(theta);
67
68 obstacle = [[semi0x' ] [semi0y']];
69
70 %-----
71
72 %Link 1 end
73 theta = linspace(alpha-pi/2,alpha+pi/2 , 100);
74 semi0x = x1 + W.*cos(theta);
75 semi0y = y1 + W.*sin(theta);
76 Link1_end = [[semi0x' ] [semi0y']];
77
78 %Link 2 start
79 theta = linspace(alpha+beta-pi/2,alpha+beta+pi/2 , 100);
80 semi0x = x1 - W.*cos(theta);
81 semi0y = y1 - W.*sin(theta);
82 Link2_start = [[semi0x' ] [semi0y']];
83
84 % Semi circle link 2 end
85 theta = linspace(beta+alpha-pi/2,beta+alpha+pi/2 , 100);
86 semi0x = x2 + W.*cos(theta);
87 semi0y = y2 + W.* sin(theta);
88 Link2_end = [[semi0x' ] [semi0y']];

```

```

[TF1 TF2] = checkCollisionTwoLink(L1,L2,W,alpha,beta,xo,yo,r);

if TF1 ==1
    black(i,1) = alpha;
    black(i,2) = beta;
    red(i,1) = 0;
    red(i,2) = 0;
    blue(i,2) = 0;
    blue(i,1) = 0;

elseif TF2 ==1
    black(i,1) = 0;
    black(i,2) = 0;
    red(i,1) = alpha;
    red(i,2) = beta;
    blue(i,1) = 0;
    blue(i,2) = 0;

else
    black(i,1) = 0;
    black(i,2) = 0;
    red(i,1) = 0;
    red(i,2) = 0;
    blue(i,1) = alpha;
    blue(i,2) = beta;
end

end

plot(black(:,1), black(:,2), 'ko', 'MarkerFaceColor', 'k') % Black circles
hold on
plot(red(:,1), red(:,2), 'ro', 'MarkerFaceColor', 'r') % Red circles
hold on
plot(blue(:,1), blue(:,2), 'bo', 'MarkerFaceColor', 'b') % Blue circles
hold on
grid on

end

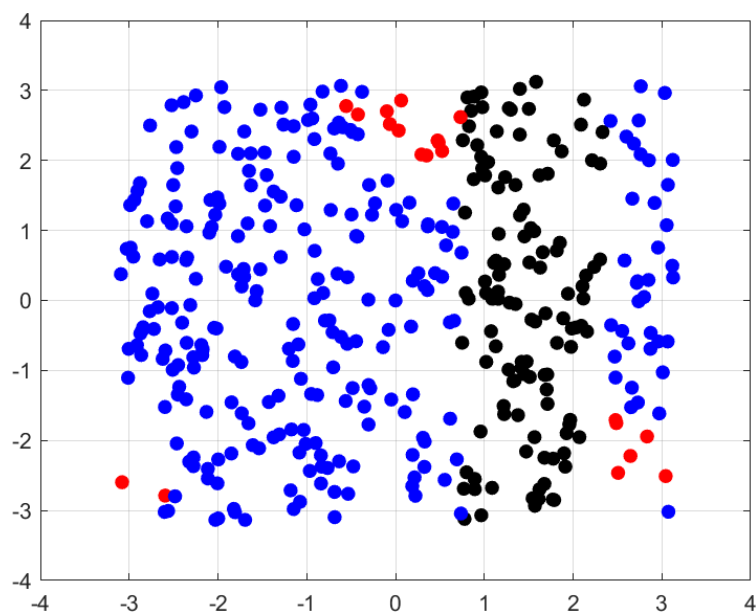
```

The complete code for the `plotSampleConfigurationSpaceTwoLink` function is provided above. This function allows the user to choose between three sampling methods—Sukharev, random, and Halton—by entering their respective names. To visualize the free configuration space, black points represent collisions with Link 1, red points indicate collisions with Link 2, and blue points denote no collisions. To achieve this, three alpha and three beta arrays were created to store the respective outcomes. The sampling functions for each method were developed in the previous lab and are integrated into this code. Three if statements determine the selected sampling method, and a for loop runs until the specified number of samples is reached. The configuration space is then plotted with both the x-axis and y-axis spanning from $-\pi$ to π .

Input: $N = 20^2$, “random”

```
35 %% Sampling
36 L1 = 4;
37 L2 = 4;
38 W = 0.2; % width
39 alpha = 0;
40 beta = 0;
41 xo = 0;|
42 yo = 3;
43 r = 2;
44 n = 20^2;
45 % sampling_method = "Sukharev";
46 % sampling_method = "Halton";
47 sampling_method = "Random";
48 grid = plotSampleConfigurationSpaceTwoLink(L1,L2,W,xo,yo,r,sampling_method,n);
49
```

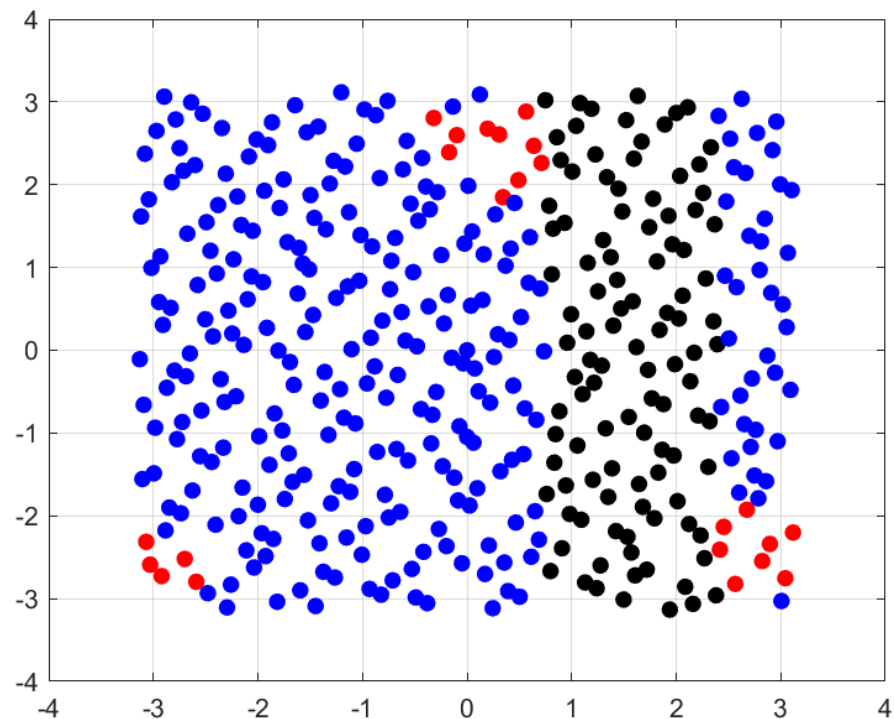
Output:



Input: $N = 20^2$, Halton

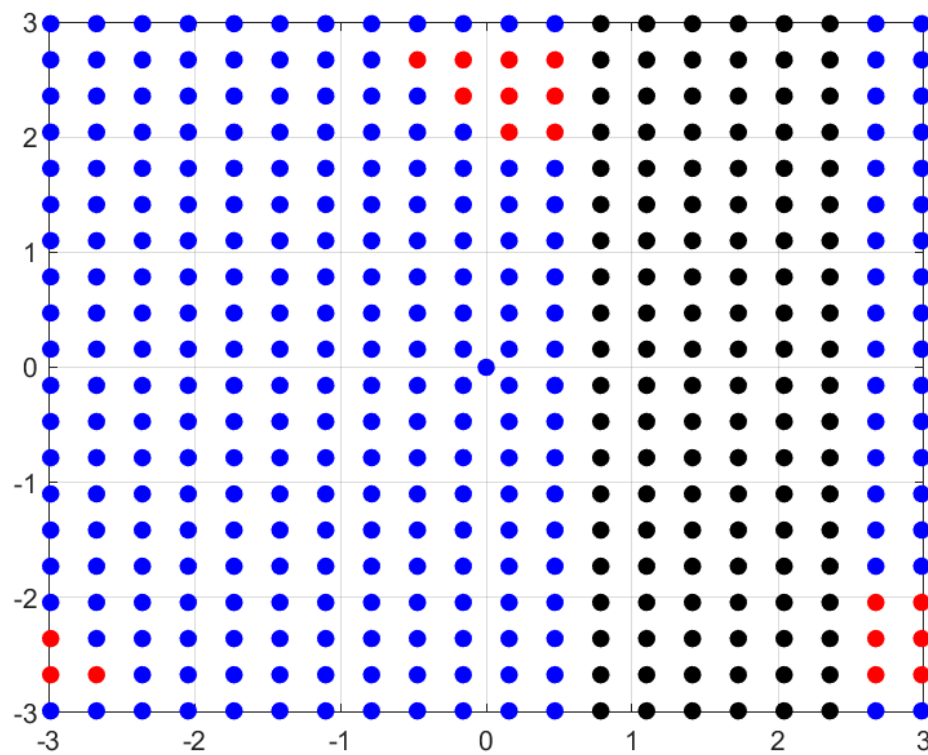
```
36 L1 = 4;  
37 L2 = 4;  
38 W = 0.2; % width  
39 alpha = 0;  
40 beta = 0;  
41 xo = 0;  
42 yo = 3;  
43 r = 2;  
44 n = 20^2;  
45 % sampling_method = "Sukharev";  
46 sampling_method = "Halton";  
47 % sampling_method = "Random";  
48 grid = plotSampleConfigurationSpaceTwoLink(L1,L2,W,xo,yo,r,sampling_method,n);  
49
```

Output:



Input: $N=20^2$, "Sukharev"

```
35 %% Sampling
36 L1 = 4;
37 L2 = 4;
38 W = 0.2; % width
39 alpha = 0;
40 beta = 0;
41 xo = 0;
42 yo = 3;
43 r = 2;
44 n = 20^2;
45 sampling_method = "Sukharev";
46 %sampling_method = "Halton";
47 % sampling_method = "Random";
48 grid = plotSampleConfigurationSpaceTwoLink(L1,L2,W,xo,yo,r,sampling_method,n);
```



For fun. I made an interactive live plot. You can move your cursor in the configuration space and the plot will live to update and animate the Robot arm.

