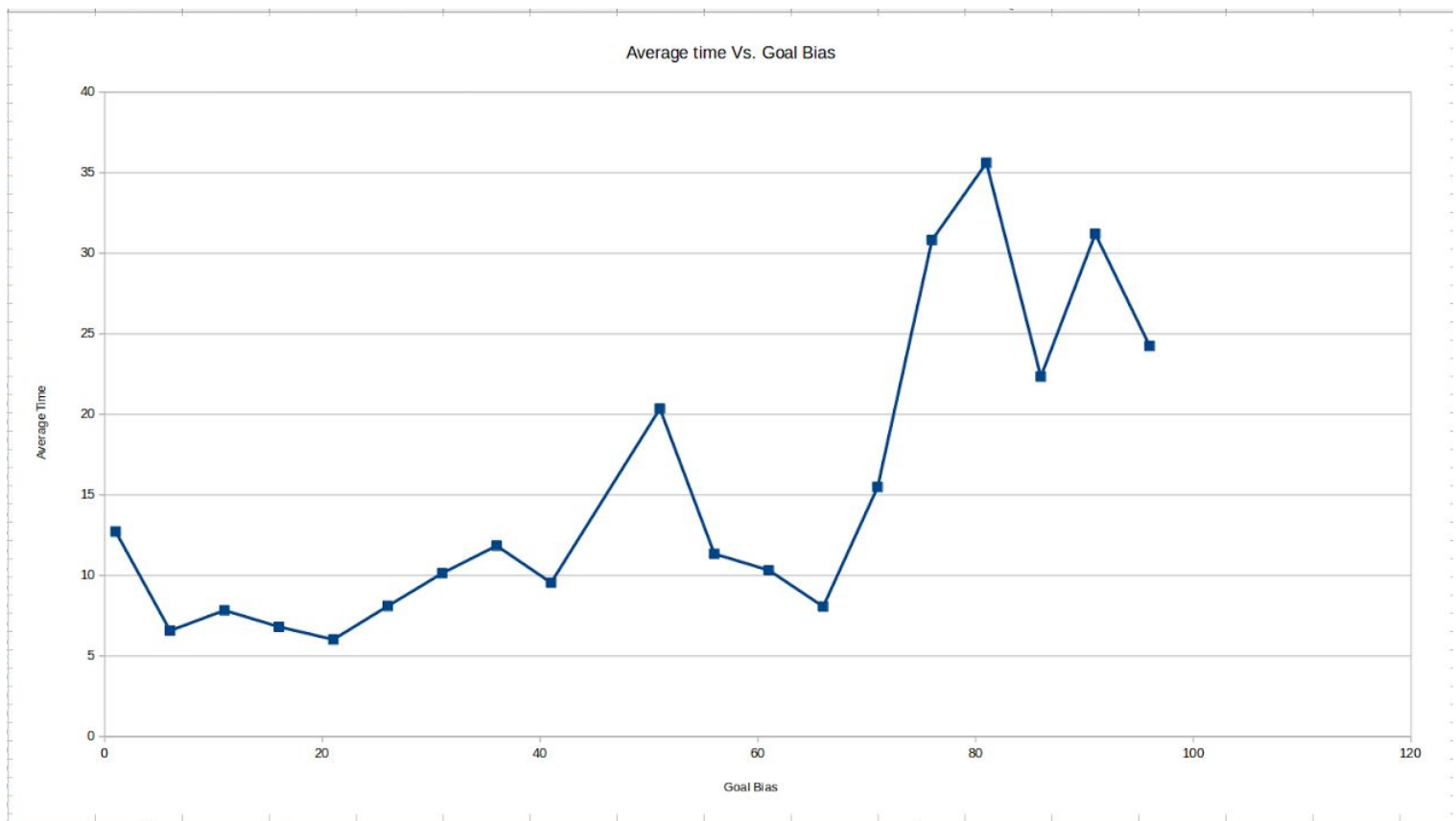


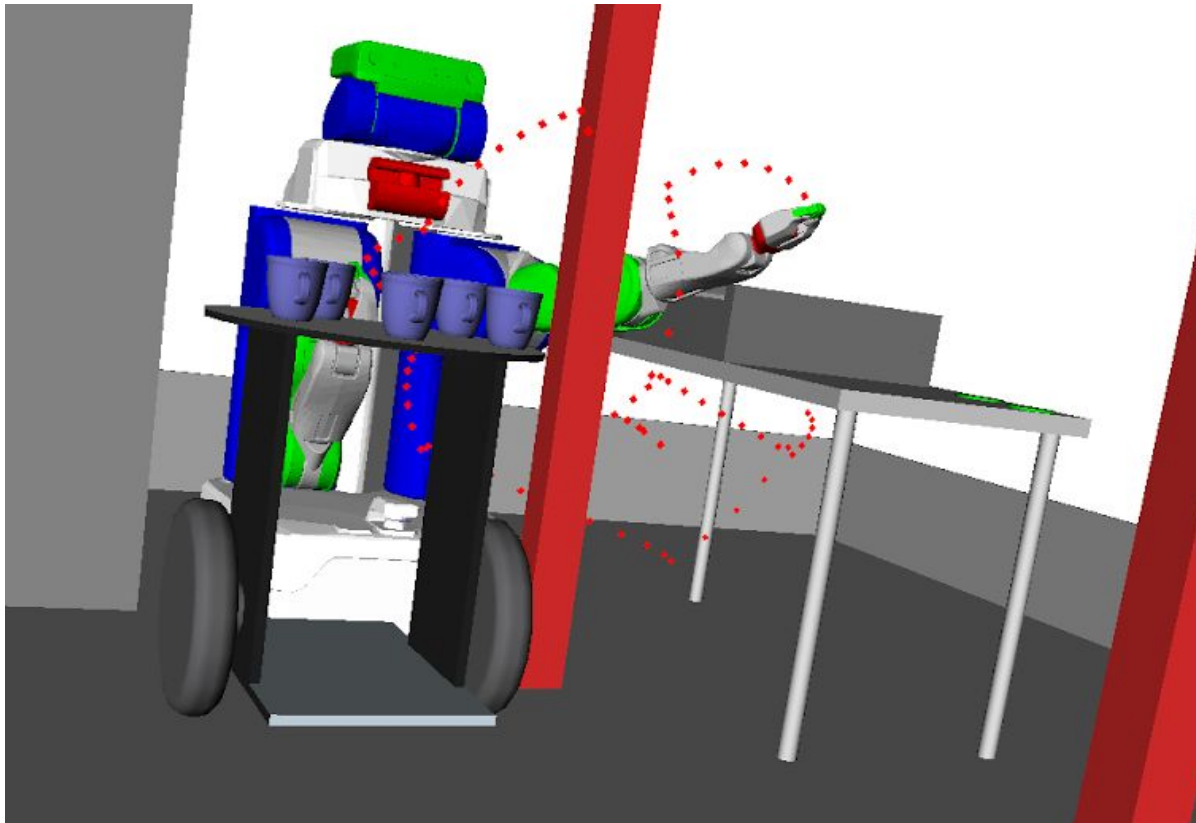
Solution 3 :

3.1) The Plot below is Average time of Computation of RRT for varying Goal bias Value. We can Deduce that :

- To generalize we see that the computation time increases as the Goal Bias is increased this is because the random node which is taken in the connect step has more probability of becoming the goal node as the tree expands , but due to obstacles the tree cannot expand in that direction, hence the computation time is increased.
- The Minimum computation time for RRT is obtained when the Goal Bias is 21.



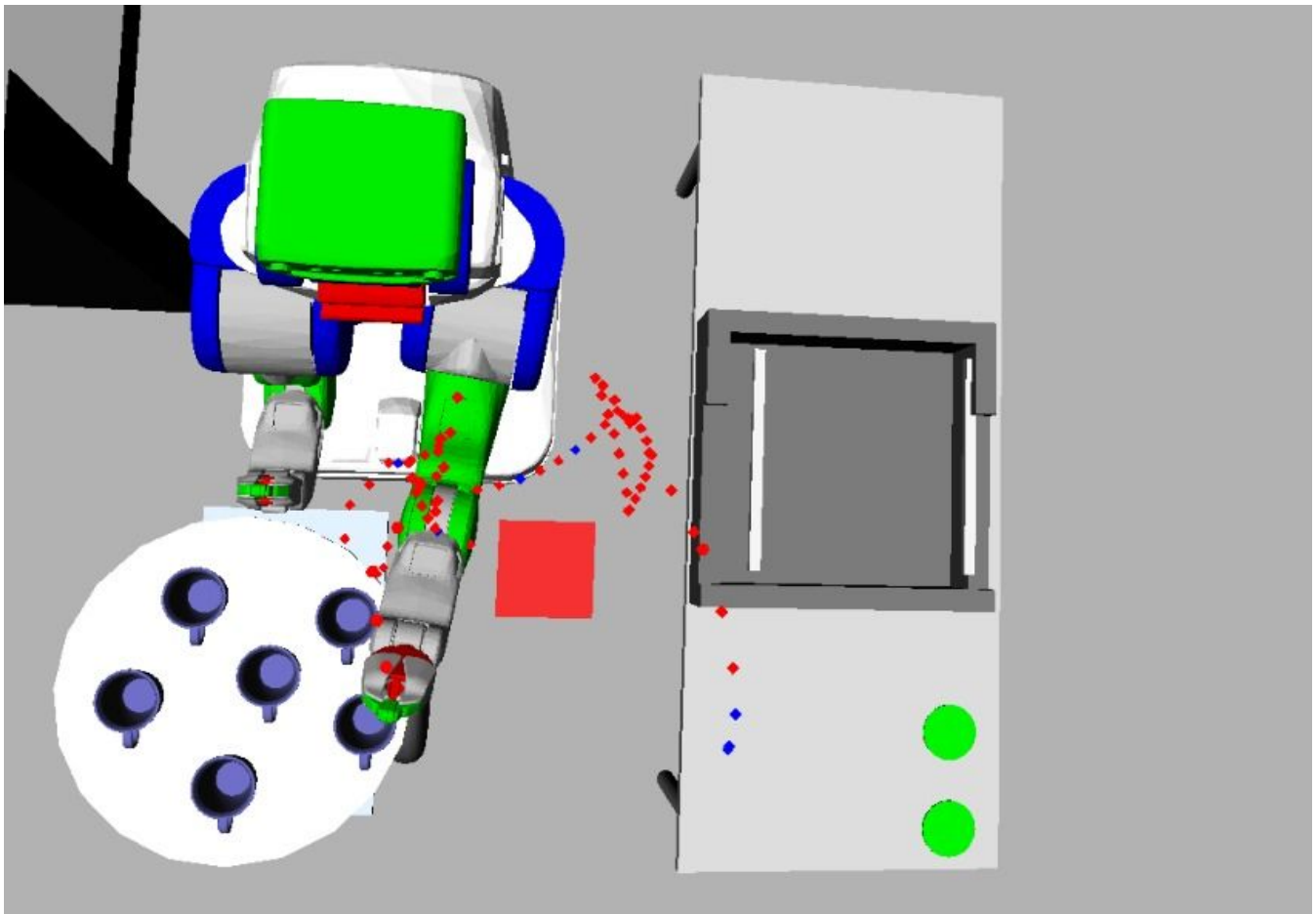
3.2)



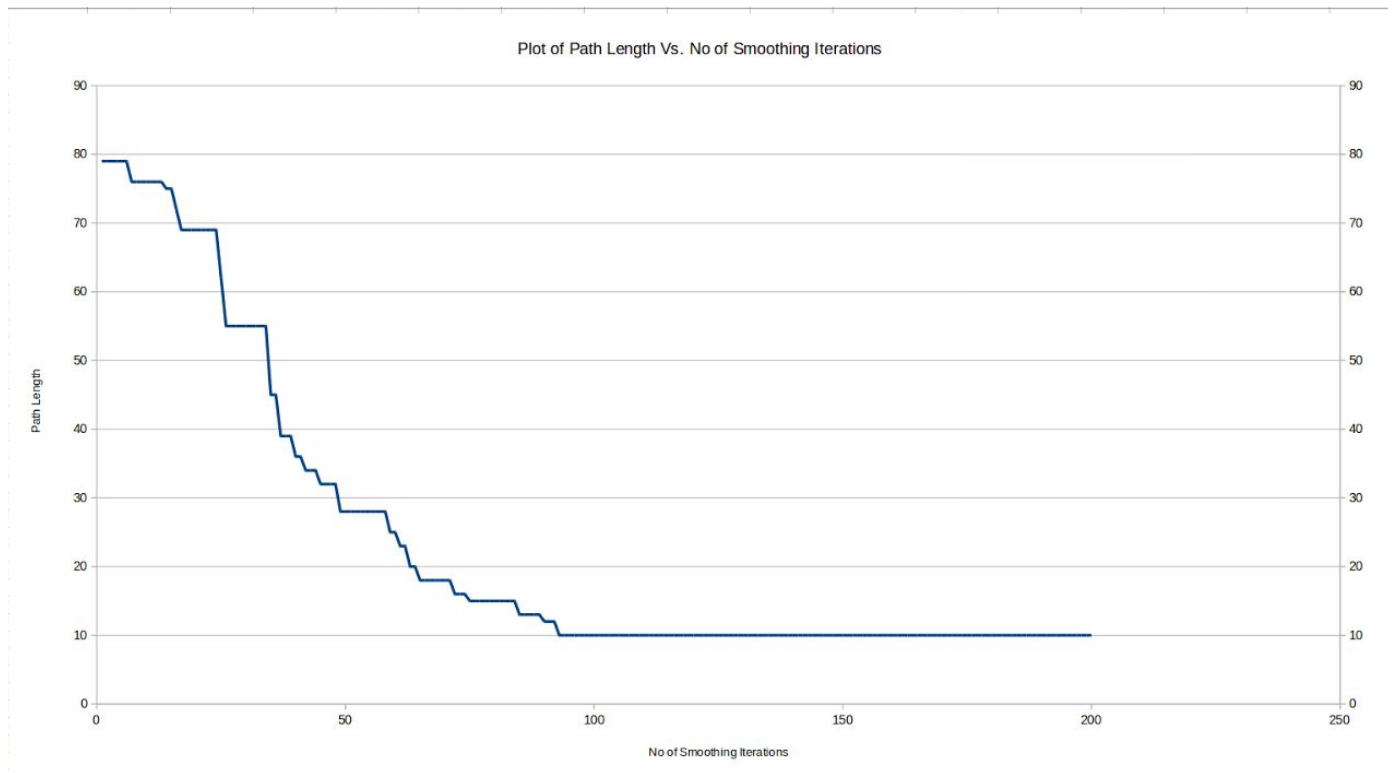
3.3) Please Run HW3.py to see the trajectory followed by the robot's end effector.

Solution 4

4.1) The blue dots represent the smoothed configurations and red represent the total unsmoothed path.

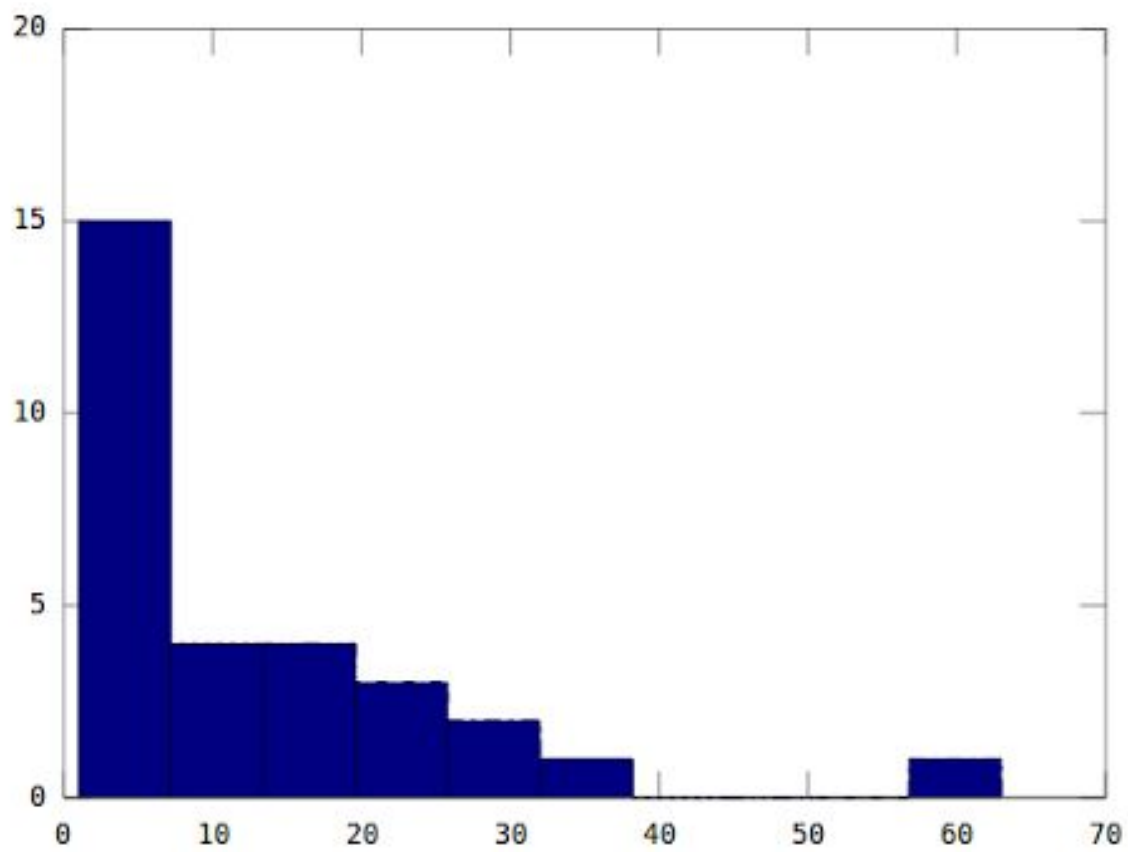


4.2) The plot below shows variation of path length Vs. Smoothing iterations, We can see that the path length becomes constant after certain number of iterations, Here it converges to 9 at 100 iterations.



Solution 5.1)

L	M	N	O	P
RRT				
Nodes	RRT-Time	RRT-Path size	Smoothened Path Size	Smooth time
3174	28	88	10	0.59
2069	7	83	8	0.59
2324	8	107	14	0.69
1685	4	80	9	0.61
3112	16	93	9	0.87
3345	17	83	8	0.58
2754	7	87	9	0.49
1674	4	56	7	0.56
1536	2	66	9	0.49
4103	23	84	8	0.67
1666	4	50	7	0.56
1565	3	69	8	0.69
2687	7	82	9	0.58
472	1	57	8	0.76
2179	5	78	7	0.62
1115	15	77	8	0.53
1802	9	86	7	0.56
3861	5	63	6	0.68
2110	7	90	8	0.944
2198	2	78	6	0.63
2280	3	63	8	0.49
1585	23	89	7	0.87
1187	11	78	8	0.77
4133	2	47	8	0.8
2849	27	89	9	0.81
1053	63	96	9	0.6
4574	13	55	8	0.6
6751	38	78	7	0.77
2677	15	77	7	0.4
----	--	--	-	--




5.2) Histogram of computation time with iterations for RRT

- mean=12.966 sec
- Variance =175.68 sec²

Extra Credit:

	BI RRT	
Path Size	Time	Nodes
66	0.628190994	214
65	1.672760963	531
86	2.076285124	702
60	1.161761999	403
69	1.880048037	616
99	7.76987195	1654
72	4.852708101	1166
66	2.725662947	813
75	0.772438049	252
93	3.695645094	986
71	3.803657055	994
78	4.197317123	999
75	4.380634069	1127
80	4.998042107	1296
58	3.480633974	941
70	2.335503817	771
62	1.303098917	405
92	6.637380123	1405
107	4.61135602	1172
83	2.096945047	592
62	0.840456009	250
87	2.611777067	668
69	1.453866005	453
94	7.842199087	1582
91	2.815444946	710
78	1.546831131	491
89	1.73457408	546
89	9.427713156	1857
69	3.085837841	815
60	0.598365068	218



```
4.8527081013
2.7256629467
0.7724380493
3.6956450939
3.8036570549
4.1973171234
4.3806340694
4.9980421066
3.4806339741
2.3355038166
1.303098917
6.6373801231
4.61135602
2.0969450474
0.8404560089
2.6117770672
1.4538660049
7.8421990871
2.8154449463
1.546831131
1.7345740795
9.4277131558
```

6) The Histogram of Bi-RRT computation time

- We can see from the histograms of both RRT and Bi-RRT , that computation time in case of the Bi-RRT is less compared to RRT , this is because of expansion of trees from both goal and start.
- Mean= 3.1205 sec
- Variance = 6.69139 sec²

HOW to RUN:

- For RRT , keep the biRRTflag=0 in HW3.py
- For Bi-RRT Keep the biRRTflag=1 in HW3.py