CS 593 : Robotics | Assignment 3

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1. This question contains results for the 2D motion planning network

    a. The first run was a test run for paths 4000-4100 in all 100 test environments (0-99) of the simple2d dataset. The reported results are given below. Note that these results are cumulative in nature, i.e., each result is indicative of all environments upto the current environment.

Environment	Metrics	NMP	NMP w/o Dropout	NMP w/o LVC
0	success rate	0.99	0.63	0.86
	computation time (min max avg std_dev)	0.01 8.36 1.02 1.5	0.01 16.37 2.68 3.67	0.02 22.49 1.77 3.54
1	success rate	0.99	0.66	0.86
	computation time (min max avg std_dev)	0.01 10.43 1.05 1.62	0.01 16.37 2.22 3.17	0.02 22.49 1.78 3.5
2	success rate	0.97	0.71	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.14 2.05	0.01 24.83 2.04 3.36	0.02 43.15 2.09 5.3
3	success rate	0.98	0.73	0.87
	computation time (min max avg std_dev)	0.01 16.14 1.04 1.87	0.01 24.83 1.84 3.14	0.02 43.15 1.98 5.01
4	success rate	0.97	0.74	0.87
	computation time	0.01 16.14 1.04 1.86	0.01 24.83 1.77 3.07	0.02 43.15 1.88 4.7

	(min max avg std_dev)			
5	success rate	0.96	0.74	0.87
	computation time (min max avg std_dev)	0.01 16.14 1.11 1.99	0.01 24.83 1.77 3.07	0.02 43.15 1.84 4.55
6	success rate	0.97	0.72	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.08 1.91	0.01 24.83 1.77 3.02	0.02 54.08 1.98 5.1
7	success rate	0.96	0.71	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.13 1.98	0.01 24.83 1.84 3.03	0.02 58.31 2.35 6.14
8	success rate	0.97	0.69	0.84
	computation time (min max avg std_dev)	0.01 16.14 1.18 2.01	0.01 24.83 1.97 3.16	0.02 58.31 2.43 6.1
9	success rate	0.97	0.68	0.84
	computation time (min max avg std_dev)	0.01 16.14 1.17 1.98	0.01 24.83 2.02 3.28	0.02 58.31 2.43 6.07
10	success rate	0.97	0.7	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.13 1.93	0.01 24.83 1.93 3.19	0.02 58.31 2.31 5.87

11	success rate	0.97	0.7	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.12 1.9	0.01 24.83 1.93 3.22	0.01 58.31 2.2 5.65
12	success rate	0.97	0.7	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.11 1.88	0.01 24.83 1.94 3.22	0.01 58.31 2.15 5.5
13	success rate	0.97	0.7	0.87
	computation time (min max avg std_dev)	0.01 16.14 1.09 1.85	0.01 24.83 1.89 3.15	0.01 58.31 2.07 5.34
14	success rate	0.98	0.7	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.09 1.86	0.01 24.83 1.94 3.2	0.01 58.31 2.07 5.24
15	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.11 1.88	0.01 24.83 1.95 3.17	0.01 58.31 2.15 5.34
16	success rate	0.98	0.7	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.11 1.87	0.01 24.83 1.94 3.16	0.01 58.31 2.12 5.3
17	success rate	0.98	0.7	0.86
	computation time (min max avg	0.01 16.14 1.09 1.83	0.01 24.83 1.9 3.11	0.01 58.31 2.07 5.19

	std_dev)			
18	success rate	0.98	0.7	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.08 1.83	0.01 24.83 1.89 3.09	0.01 58.31 2.04 5.13
19	success rate	0.98	0.7	0.87
	computation time (min max avg std_dev)	0.01 16.14 1.09 1.86	0.01 24.83 1.9 3.1	0.01 58.31 2.01 5.04
20	success rate	0.98	0.7	0.87
	computation time (min max avg std_dev)	0.01 16.14 1.08 1.85	0.01 24.83 1.91 3.1	0.01 58.31 1.99 4.99
21	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.09 1.84	0.01 35.57 1.96 3.21	0.01 58.31 2.04 4.98
22	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.11 1.89	0.01 35.57 1.96 3.2	0.01 58.31 2.02 4.95
23	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.12 1.89	0.01 35.57 1.99 3.23	0.01 58.31 2.05 4.96
24	success rate	0.98	0.69	0.86

	computation time (min max avg std_dev)	0.01 16.14 1.13 1.89	0.01 35.57 1.99 3.24	0.01 58.31 2.04 4.92
25	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.14 1.9	0.01 35.57 2.02 3.26	0.01 58.31 2.03 4.87
26	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.14 1.91	0.01 35.57 1.99 3.23	0.01 58.31 2.01 4.83
27	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.16 1.94	0.01 35.57 1.99 3.22	0.01 58.31 2.01 4.78
28	success rate	0.98	0.68	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.16 1.93	0.01 35.57 2.01 3.23	0.01 58.31 1.99 4.72
29	success rate	0.98	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.16 1.93	0.01 35.57 2.01 3.23	0.01 58.31 1.98 4.71
30	success rate	0.97	0.68	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.2 2.02	0.01 35.57 2.04 3.28	0.01 74.76 2.14 5.28

31	success rate	0.97	0.69	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.19 2.01	0.01 35.57 2.01 3.26	0.01 74.76 2.1 5.21
32	success rate	0.97	0.68	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.19 2	0.01 35.57 2.04 3.29	0.01 74.76 2.13 5.25
33	success rate	0.97	0.68	0.86
	computation time (min max avg std_dev)	0.01 16.14 1.19 2	0.01 35.57 2.05 3.29	0.01 74.76 2.12 5.2
34	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.2 2.01	0.01 35.57 2.05 3.28	0.01 84.98 2.3 5.93
35	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.2 2.01	0.01 39.2 2.05 3.33	0.01 84.98 2.28 5.87
36	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.19 2	0.01 39.2 2.04 3.31	0.01 84.98 2.28 5.85
37	success rate	0.97	0.69	0.85
	computation	0.01 16.14 1.18	0.01 39.2 2.01	0.01 84.98 2.28

	time (min max avg std_dev)	2	3.28	5.86
38	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.18 1.98	0.01 39.2 2.01 3.28	0.01 84.98 2.27 5.8
39	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.17 1.98	0.01 39.2 2.01 3.28	0.01 84.98 2.29 5.83
40	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.18 1.99	0.01 39.2 2.02 3.27	0.01 84.98 2.31 5.85
41	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.18 1.98	0.01 39.2 2.04 3.28	0.01 84.98 2.32 5.88
42	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 16.14 1.19 2	0.01 39.2 2.06 3.3	0.01 84.98 2.3 5.83
43	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 17.73 1.2 2.02	0.01 39.2 2.07 3.33	0.01 84.98 2.31 5.81

44	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 17.73 1.2 2.02	0.01 39.2 2.07 3.34	0.01 84.98 2.35 6.01
45	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.06	0.01 39.2 2.08 3.34	0.01 84.98 2.35 5.97
46	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.06	0.01 39.2 2.09 3.34	0.01 84.98 2.33 5.93
47	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.06	0.01 39.2 2.08 3.35	0.01 84.98 2.33 5.91
48	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.23 2.06	0.01 39.2 2.1 3.36	0.01 85.5 2.38 6.15
49	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.06	0.01 39.2 2.1 3.37	0.01 85.5 2.36 6.11
50	success rate	0.97	0.68	0.85
	computation	0.01 22.07 1.23	0.01 39.2 2.11	0.01 85.5 2.37

	time (min max avg std_dev)	2.07	3.38	6.08
51	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.23 2.06	0.01 39.2 2.12 3.38	0.01 85.5 2.36 6.05
52	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.23 2.06	0.01 39.2 2.13 3.4	0.01 85.5 2.34 6
53	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.05	0.01 39.2 2.13 3.41	0.01 85.5 2.32 5.95
54	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.04	0.01 39.2 2.12 3.4	0.01 85.5 2.33 5.96
55	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.03	0.01 39.2 2.12 3.39	0.01 85.5 2.31 5.92
56	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.04	0.01 39.2 2.12 3.41	0.01 85.5 2.31 5.9

57	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.03	0.01 39.2 2.11 3.4	0.01 85.5 2.32 5.93
58	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.03	0.01 39.2 2.11 3.4	0.01 85.5 2.34 5.98
59	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.02	0.01 39.2 2.1 3.4	0.01 85.5 2.33 5.97
60	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.02	0 39.2 2.1 3.41	0.01 85.5 2.31 5.93
61	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.02	0 39.2 2.11 3.41	0.01 85.5 2.32 5.95
62	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.02	0 39.2 2.1 3.41	0.01 85.5 2.32 5.93
63	success rate	0.97	0.68	0.85
	computation	0.01 22.07 1.21	0 39.2 2.11 3.42	0.01 85.5 2.34

	time (min max avg std_dev)	2.05		5.97
64	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.04	0 39.2 2.13 3.45	0.01 85.5 2.32 5.94
65	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.04	0 39.2 2.13 3.45	0.01 85.5 2.32 5.97
66	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.06	0 39.2 2.13 3.45	0.01 85.5 2.32 5.94
67	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.06	0 39.2 2.12 3.44	0.01 149.48 2.38 6.36
68	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.05	0 39.2 2.12 3.43	0.01 149.48 2.37 6.34
69	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.05	0 39.2 2.12 3.46	0.01 149.48 2.38 6.34

70	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.22 2.05	0 39.2 2.12 3.45	0.01 149.48 2.4 6.37
71	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.05	0 39.2 2.12 3.45	0.01 149.48 2.4 6.35
72	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.04	0 39.2 2.1 3.43	0.01 149.48 2.37 6.31
73	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.04	0 39.2 2.11 3.44	0.01 149.48 2.37 6.29
74	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.04	0 39.2 2.11 3.45	0.01 149.48 2.36 6.26
75	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.21 2.05	0 39.2 2.11 3.46	0.01 149.48 2.38 6.35
76	success rate	0.97	0.68	0.85
	computation	0.01 22.07 1.21	0 39.2 2.11 3.46	0.01 149.48

	time (min max avg std_dev)	2.05		2.38 6.32
77	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.04	0 39.2 2.1 3.46	0.01 149.48 2.36 6.28
78	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.04	0 39.2 2.1 3.46	0.01 149.48 2.35 6.26
79	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.03	0 39.2 2.11 3.47	0.01 149.48 2.34 6.22
80	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.03	0 39.2 2.1 3.47	0.01 149.48 2.34 6.23
81	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.03	0 39.2 2.1 3.46	0.01 149.48 2.34 6.23
82	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.05	0 39.2 2.1 3.45	0.01 149.48 2.38 6.32

83	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.04	0 39.2 2.09 3.44	0.01 149.48 2.37 6.31
84	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.09 3.47	0.01 149.48 2.4 6.41
85	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.1 3.47	0.01 149.48 2.39 6.38
86	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.05	0 39.2 2.11 3.49	0.01 149.48 2.38 6.36
87	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.12 3.49	0.01 149.48 2.38 6.34
88	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.05	0 39.2 2.11 3.49	0.01 149.48 2.37 6.31
89	success rate	0.97	0.69	0.85
	computation	0.01 22.07 1.19	0 39.2 2.11 3.48	0.01 149.48

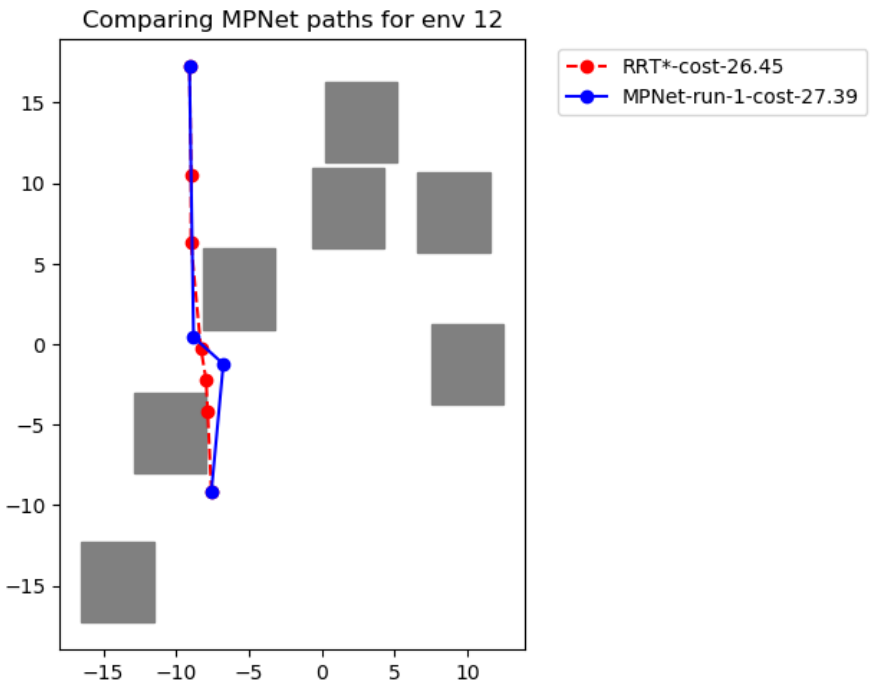
	time (min max avg std_dev)	2.05		2.37 6.29
90	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.11 3.47	0.01 149.48 2.36 6.27
91	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.11 3.47	0.01 149.48 2.39 6.34
92	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.06	0 39.2 2.11 3.48	0.01 149.48 2.37 6.31
93	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.05	0 39.2 2.11 3.47	0.01 149.48 2.36 6.29
94	success rate	0.97	0.69	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.05	0 39.2 2.11 3.47	0.01 149.48 2.35 6.26
95	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.05	0 39.2 2.11 3.47	0.01 149.48 2.36 6.26

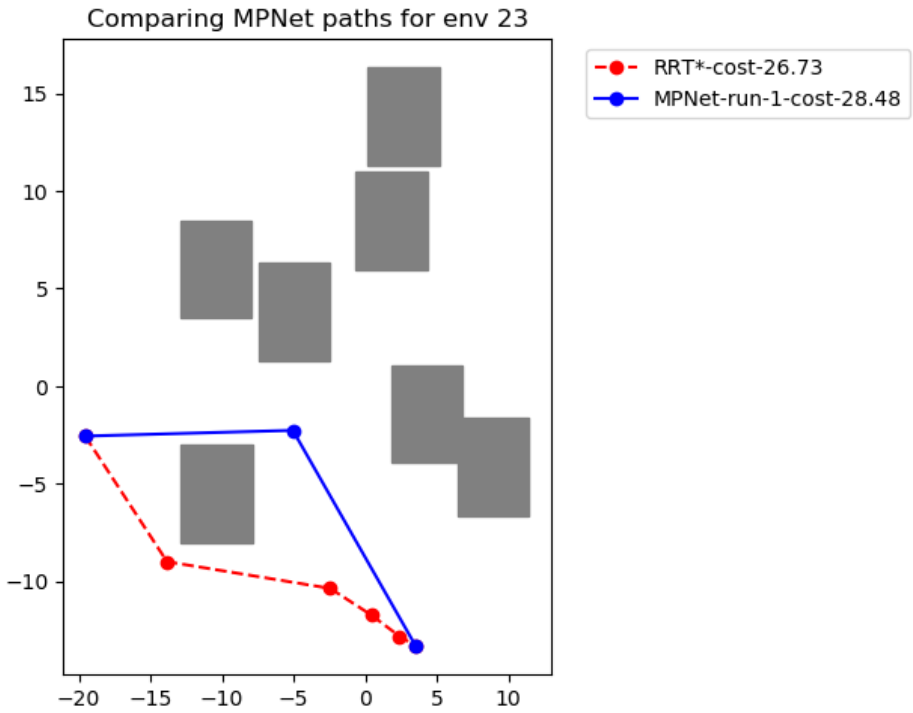
96	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.06	0 39.2 2.11 3.47	0.01 149.48 2.47 6.92
97	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.19 2.06	0 39.2 2.11 3.47	0.01 149.48 2.46 6.9
98	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.11 3.47	0.01 149.48 2.46 6.87
99	success rate	0.97	0.68	0.85
	computation time (min max avg std_dev)	0.01 22.07 1.2 2.06	0 39.2 2.11 3.47	0.01 149.48 2.46 6.88

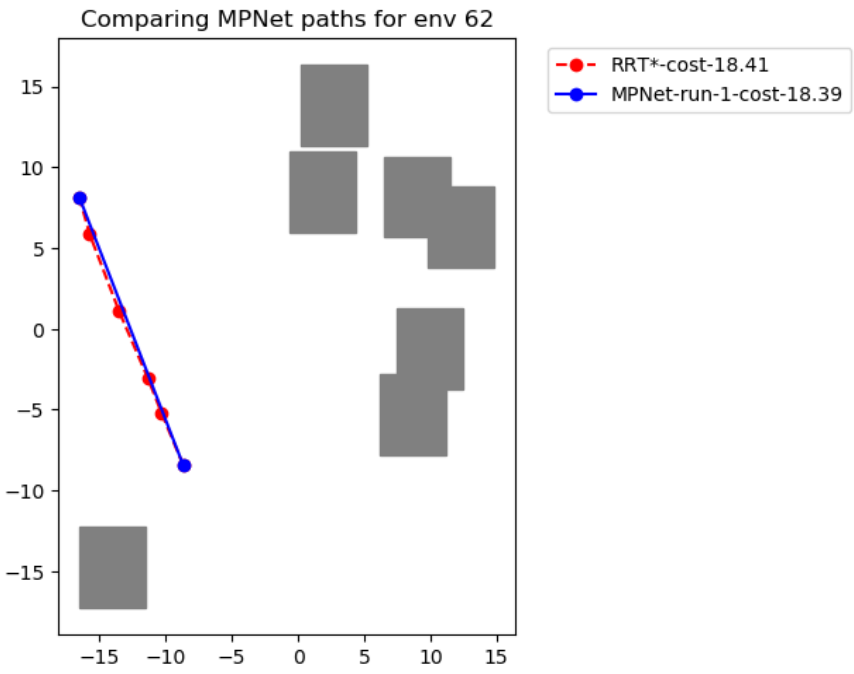
My system specs are reported below :

3.0-4.0 GHZ X 6 AMD Ryzen 5 4600H processor, 16 GB RAM, and GeForce GTX 1660 Ti Mobile with 6GB VRAM

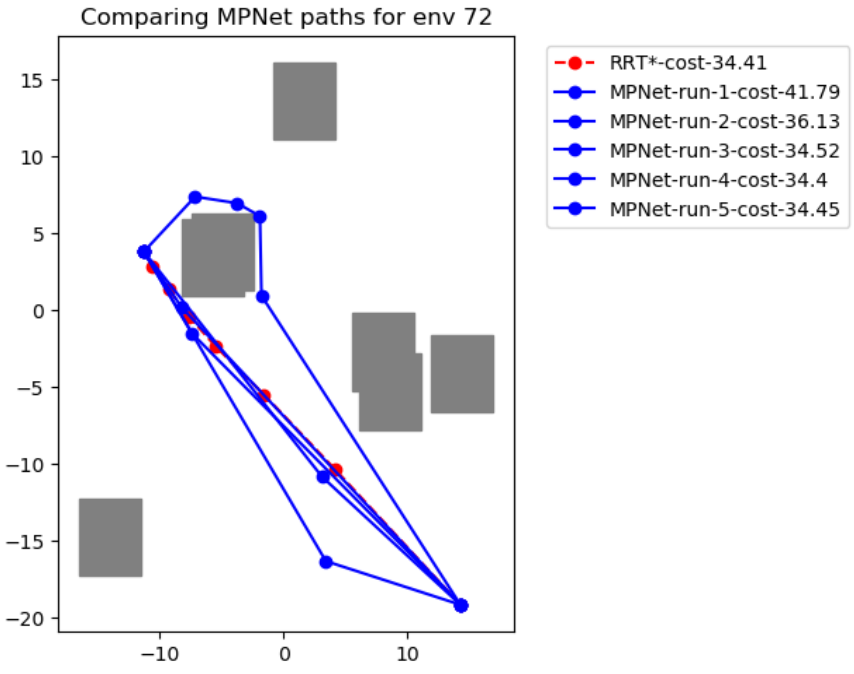
b. Comparison of expert demonstrations against MPNet paths for 3 different environments (12,23 and 62) of the simple 2d dataset are given below:


Comparing MPNet paths for env 12
RRT*-cost-26.45
MPNet-run-1-cost-27.39
15
10
5
0
−5
−10
−15
−15
−10
−5
0
5
10


Comparing MPNet paths for env 23
RRT*-cost-26.73
MPNet-run-1-cost-28.48
15
10
5
0
−5
−10
−20
−15
−10
−5
0
5
10



c. 5 independent runs of MPNet are obtained for a random environment (72) to show stochasticity of the planning network which uses dropout :



d. As the network is trained using expert demonstrations, the sampling becomes informed, but this is directly applicable only in trained or already seen problems. To better generalize to unknown environments, dropout is used, which induces stochasticity in the network. This enables random sampling. This enables new paths to be found.

   Lazy Vertex Contraction enables redundant nodes to be removed from the path. This reduces cost and enables the generation of near-optimal paths. It also decreases the computation time for the replanning step since fewer nodes are searched over in those steps.

2. This question contains results for the 3D motion planning network

   a. The first run was a test run for paths 2000-2100 in all 10 test environments (0-9) of the complex 3d dataset. The reported results are given below. Note that these results are cumulative in nature, i.e., each result is indicative of all environments upto the current environment.

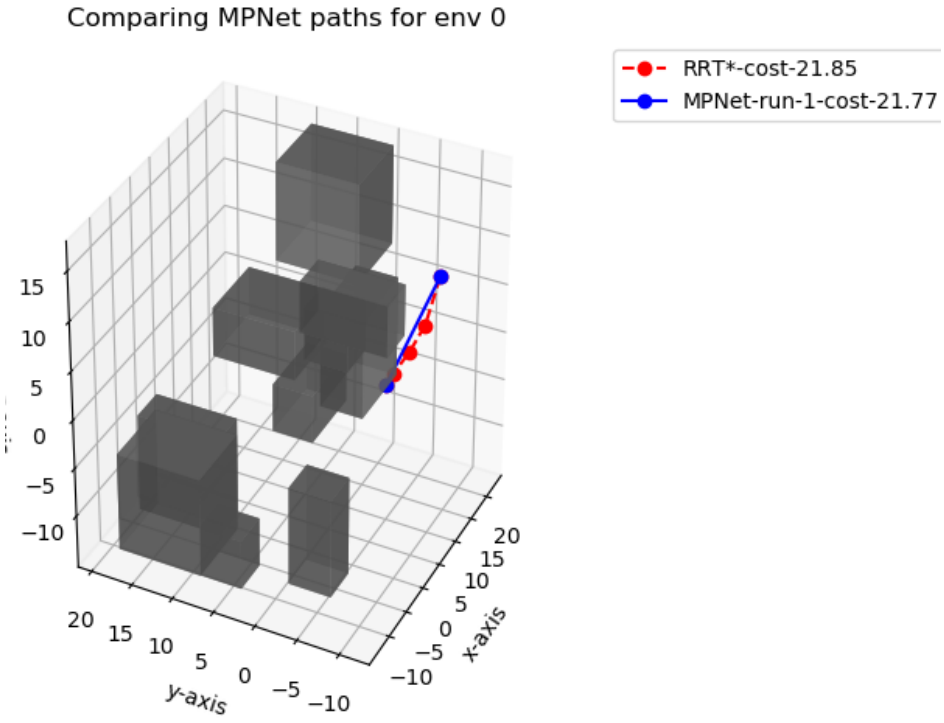
Environment	Metrics	NMP	NMP w/o Dropout	NMP w/o LVC
0	success rate	0.99	0.73	0.73
	computation time	[0.07 1.51 12.7 2.66]	[0.04 23.57 3.51 5.8]	[0.04 3.62 25.53 6.03]
1	success rate	0.99	0.89	0.81
	computation time	[0.07 1.32 21.74 2.55]	[0.04 23.57 1.94 3.53]	[0.04 2.82 25.53 5.05]
2	success rate	0.99	0.86	0.83
	computation time	[0.07 1.38 21.74 2.61]	[0.04 34.53 2.88 5.16]	[0.04 2.92 36.45 5.2]
3	success rate	0.99	0.87	0.84
	computation time	[0.07 1.36 21.74 2.54]	[0.04 34.53 2.06 3.45]	[0.04 2.72 36.45 4.86]
4	success rate	0.99	0.66	0.8
	computation time	[0.07 1.52 21.74 2.7]	[0.04 34.53 4.28 5.89]	[0.04 2.99 36.45 5.03]

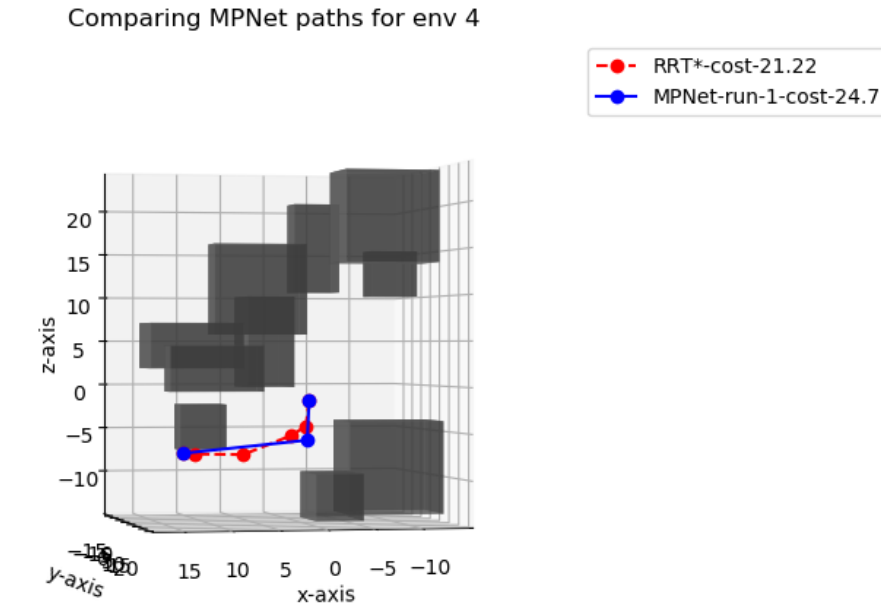
5	success rate	0.99	0.9	0.82
	computation time	[0.05 1.41 21.74 2.52]	[0.04 34.53 2.05 4.55]	[0.04 2.81 36.45 4.92]
6	success rate	0.99	0.86	0.82
	computation time	[0.05 1.34 21.74 2.39]	[0.04 34.53 2.13 4.71]	[0.04 2.72 36.45 4.93]
7	success rate	0.99	0.79	0.82
	computation time	[0.05 1.39 21.74 2.49]	[0.04 34.53 3.44 5.6]	[0.04 2.82 36.45 5.04]
8	success rate	0.99	0.83	0.82
	computation time	[0.05 1.33 21.74 2.39]	[0.04 34.53 2.4 4.18]	[0.04 2.78 36.45 4.96]
9	success rate	0.99	0.89	0.83
	computation time	[0.05 1.3 21.74 2.34]	[0.04 34.53 1.87 3.28]	[0.04 2.69 36.45 4.83]

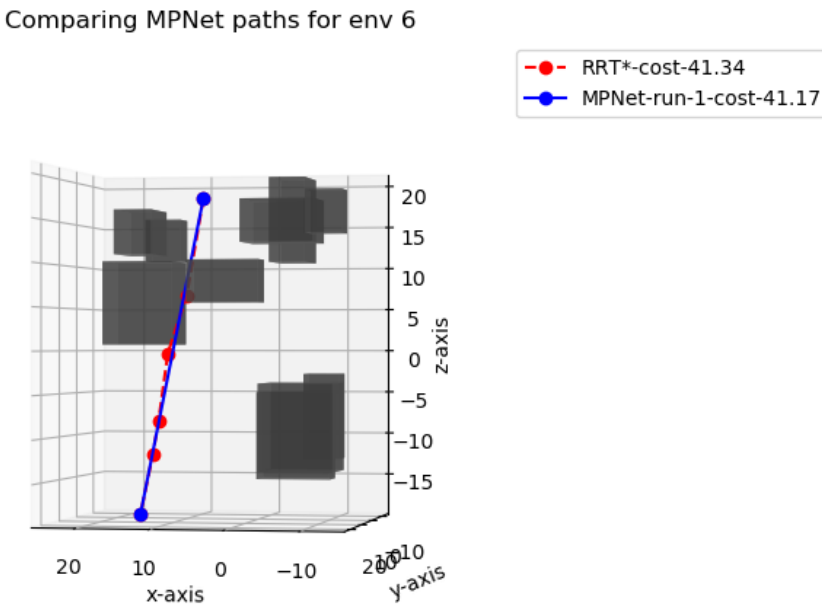
My system specs are reported below :

3.0-4.0 GHZ X 6 AMD Ryzen 5 4600H processor, 16 GB RAM, and GeForce GTX 1660 Ti Mobile with 6GB VRAM

b. Comparison of expert demonstrations against MPNet paths for 3 different environments (0,4 and 6) of the complex 3d dataset are given below:


Comparing MPNet paths for env 0
RRT*-cost-21.85
MPNet-run-1-cost-21.77
15
10
5
0
−5
−10
20
15
10
5
0
−5
−10
y-axis
20
15
10
5
0
−5
−10
x-axis


Comparing MPNet paths for env 4
RRT*-cost-21.22
MPNet-run-1-cost-24.7
20
15
10
5
0
−5
−10
z-axis
y-axis
15
10
5
0
−5
−10
x-axis



c. 5 independent runs of MPNet are obtained for a random environment (5) to show stochasticity of the planning network which uses dropout :