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Artificial Intelligence Nanodegree
Project 2: Classical Planning

Planning Report

Total Data Collected:

ACP	Search	Actions	Expansions	Goal Tests	New Nodes	Plan Length	Time (secs)
1	(1) Breadth First	20	43	56	178	6	0.007265572
1	(2) Depth First	20	21	22	84	20	0.003778832
1	(3) Uniform Cost	20	60	62	240	6	0.010191281
1	(4) Greedy BFS with Unmet Goals	20	7	9	29	6	0.002414995
1	(5) Greedy BFS with Levelsum	20	6	8	28	6	0.315324443
1	(6) Greedy BFS with Maxlevel	20	6	8	24	6	0.219763155
1	(7) Greedy BFS with Setlevel	20	6	8	28	6	0.943312628
1	(8) A* with Unmet Goals	20	50	52	206	6	0.010168735
1	(9) A* with Levelsum	20	28	30	122	6	0.795243654
1	(10) A* with Maxlevel	20	43	45	180	6	0.834418951
1	(11) A* with Setlevel	20	33	35	138	6	2.49399301
2	(1) Breadth First	72	3343	4609	30503	9	2.241343447
2	(2) Depth First	72	624	625	5602	619	3.395382859
2	(3) Uniform Cost	72	5154	5156	46618	9	3.690821052
2	(4) Greedy BFS with Unmet Goals	72	17	19	170	9	0.021804024
2	(5) Greedy BFS with Levelsum	72	9	11	86	9	6.94092192
2	(6) Greedy BFS with Maxlevel	72	27	29	249	9	14.0941936
2	(7) Greedy BFS with Setlevel	72	9	11	84	9	20.11967389
2	(8) A* with Unmet Goals	72	2467	2469	22522	9	2.43380561
2	(9) A* with Levelsum	72	357	359	3426	9	176.1010607

2	(10) A* with Maxlevel	72	2887	2889	26594	9	1018.781422
2	(11) A* with Setlevel	72	1037	1039	9605	9	1562.542307
3	(1) Breadth First	88	14663	18098	129625	12	9.7817537
3	(2) Depth First	88	408	409	3364	392	0.6078221
3	(3) Uniform Cost	88	18510	18512	161936	12	8.6643803
3	(4) Greedy BFS with Unmet Goals	88	25	27	230	15	0.0373653
3	(5) Greedy BFS with Levelsum	88	14	16	126	14	12.2748844
3	(8) A* with Unmet Goals	88	7388	7390	65711	12	6.865257
3	(9) A* with Levelsum	88	369	371	3403	12	271.2773685
4	(1) Breadth First	104	99736	114953	944130	14	67.9557217
4	(4) Greedy BFS with Unmet Goals	104	29	31	280	18	0.0505323
4	(5) Greedy BFS with Levelsum	104	17	19	165	17	17.7839558
4	(8) A* with Unmet Goals	104	34330	34332	328509	14	38.4422508
4	(9) A* with Levelsum	104	1208	1210	12210	15	1082.55111

1. *Use a table or chart to analyze the number of nodes expanded against number of actions in the domain*

Expanded Nodes vs Actions:

ACP	Search	Actions	Expansions
1	(1) Breadth First	20	43
1	(2) Depth First	20	21
1	(3) Uniform Cost	20	60
1	(4) Greedy BFS with Unmet Goals	20	7
1	(5) Greedy BFS with Levelsum	20	6
1	(6) Greedy BFS with Maxlevel	20	6

1	(7) Greedy BFS with Setlevel	20	6
1	(8) A* with Unmet Goals	20	50
1	(9) A* with Levelsum	20	28
1	(10) A* with Maxlevel	20	43
1	(11) A* with Setlevel	20	33
2	(1) Breadth First	72	3343
2	(2) Depth First	72	624
2	(3) Uniform Cost	72	5154
2	(4) Greedy BFS with Unmet Goals	72	17
2	(5) Greedy BFS with Levelsum	72	9
2	(6) Greedy BFS with Maxlevel	72	27
2	(7) Greedy BFS with Setlevel	72	9
2	(8) A* with Unmet Goals	72	2467
2	(9) A* with Levelsum	72	357
2	(10) A* with Maxlevel	72	2887
2	(11) A* with Setlevel	72	1037
3	(1) Breadth First	88	14663
3	(2) Depth First	88	408
3	(3) Uniform Cost	88	18510
3	(4) Greedy BFS with Unmet Goals	88	25
3	(5) Greedy BFS with Levelsum	88	14
3	(8) A* with Unmet Goals	88	7388
3	(9) A* with Levelsum	88	369
4	(1) Breadth First	104	99736
4	(4) Greedy BFS with Unmet Goals	104	29

4	(5) Greedy BFS with Levelsum	104	17
4	(8) A* with Unmet Goals	104	34330
4	(9) A* with Levelsum	104	1208

Analysis:

In all the problems, the searches using Greedy BFS seem to have the least expansions. Greedy BFS with the Levelsum and Setlevel heuristics seem to have the least expanded nodes of the Greedy BFS searches. Uniform Cost Search and A* Search with the Unmet Goals heuristic seem to have the most expansions for Problem 1. Uniform Cost and Breadth First had the most expansions for Problem 2. For Problem 3, Uniform Cost and Breath First also have the most expansions. For problem 4, Breadth First and A* with Unmet Goals have the most expansions. Overall, Breadth First, Uniform Cost, and A* with Unmet Goals seem to have the most expansions.

2. *Use a table or chart to analyze the search time against the number of actions in the domain*

Search Time vs Actions:

ACP	Search	Actions	Time (secs)
1	(1) Breadth First	20	0.007265572
1	(2) Depth First	20	0.003778832
1	(3) Uniform Cost	20	0.010191281
1	(4) Greedy BFS with Unmet Goals	20	0.002414995
1	(5) Greedy BFS with Levelsum	20	0.315324443
1	(6) Greedy BFS with Maxlevel	20	0.219763155
1	(7) Greedy BFS with Setlevel	20	0.943312628
1	(8) A* with Unmet Goals	20	0.010168735
1	(9) A* with Levelsum	20	0.795243654
1	(10) A* with Maxlevel	20	0.834418951
1	(11) A* with Setlevel	20	2.49399301
2	(1) Breadth First	72	2.241343447

2	(2) Depth First	72	3.395382859
2	(3) Uniform Cost	72	3.690821052
2	(4) Greedy BFS with Unmet Goals	72	0.021804024
2	(5) Greedy BFS with Levelsum	72	6.94092192
2	(6) Greedy BFS with Maxlevel	72	14.0941936
2	(7) Greedy BFS with Setlevel	72	20.11967389
2	(8) A* with Unmet Goals	72	2.43380561
2	(9) A* with Levelsum	72	176.1010607
2	(10) A* with Maxlevel	72	1018.781422
2	(11) A* with Setlevel	72	1562.542307
3	(1) Breadth First	88	9.7817537
3	(2) Depth First	88	0.6078221
3	(3) Uniform Cost	88	8.6643803
3	(4) Greedy BFS with Unmet Goals	88	0.0373653
3	(5) Greedy BFS with Levelsum	88	12.2748844
3	(8) A* with Unmet Goals	88	6.865257
3	(9) A* with Levelsum	88	271.2773685
4	(1) Breadth First	104	67.9557217
4	(4) Greedy BFS with Unmet Goals	104	0.0505323
4	(5) Greedy BFS with Levelsum	104	17.7839558
4	(8) A* with Unmet Goals	104	38.4422508
4	(9) A* with Levelsum	104	1082.55111

Analysis:

The fastest times for Problem 1 were Depth First and Greedy BFS with Unmet Goals. For Problem 2, Greedy BFS with Unmet Goals was the fastest by a lot. Greedy BFS with Unmet Goals was also fastest in Problems 3 and 4. Depth First was also pretty fast for Problem 3 and Problem 1. Breadth First was fairly fast for 1 and 2, but much slower for 3 and 4. The slowest time was A* with Setlevel for Problems 1 and 2

and A* with Levelsum for 3 and 4. I had to decide not to run A* with Maxlevel or Setlevel with Problems 3 and 4 because they were so slow in comparison to the other two A* searches for 1 and 2. For Problem 4, Breadth First was slow in comparison with other searches aside form A* with Levelsum.

3. *Use a table or chart to analyze the length of the plans returned by each algorithm on all search problems*

Plan Lengths:

ACP	Search	Plan Length
1	(1) Breadth First	6
1	(2) Depth First	20
1	(3) Uniform Cost	6
1	(4) Greedy BFS with Unmet Goals	6
1	(5) Greedy BFS with Levelsum	6
1	(6) Greedy BFS with Maxlevel	6
1	(7) Greedy BFS with Setlevel	6
1	(8) A* with Unmet Goals	6
1	(9) A* with Levelsum	6
1	(10) A* with Maxlevel	6
1	(11) A* with Setlevel	6
2	(1) Breadth First	9
2	(2) Depth First	619
2	(3) Uniform Cost	9
2	(4) Greedy BFS with Unmet Goals	9
2	(5) Greedy BFS with Levelsum	9
2	(6) Greedy BFS with Maxlevel	9
2	(7) Greedy BFS with Setlevel	9

2	(8) A* with Unmet Goals	9
2	(9) A* with Levelsum	9
2	(10) A* with Maxlevel	9
2	(11) A* with Setlevel	9
3	(1) Breadth First	12
3	(2) Depth First	392
3	(3) Uniform Cost	12
3	(4) Greedy BFS with Unmet Goals	15
3	(5) Greedy BFS with Levelsum	14
3	(8) A* with Unmet Goals	12
3	(9) A* with Levelsum	12
4	(1) Breadth First	14
4	(4) Greedy BFS with Unmet Goals	18
4	(5) Greedy BFS with Levelsum	17
4	(8) A* with Unmet Goals	14
4	(9) A* with Levelsum	15

Analysis:

In Problems 1 and 2, the plan lengths were the same except for Depth First Search, where the plan lengths were considerably longer than the rest. In Problem 3, Depth First is also considerably longer. In Problem 4, I had to quit the program for Depth First because it was taking so long, probably to fetch the long plan. The Greedy BFS searches also had plans somewhat longer than the rest in both Problem 3 and 4. Breadth First seemed to consistently have the shortest plan, but A* with Unmet Goals also reached the same short plan.

4. *Which algorithm or algorithms would be most appropriate for planning in a very restricted domain (i.e., one that has only a few actions) and needs to operate in real time?*

Greedy BFS with the Unmet Goals heuristic would probably be the most appropriate for planning in a very restricted domain and needs to operate in real time. Greedy BFS with Unmet Goals was generally the fastest kind of search out of all the algorithms. It was the fastest algorithm in Problem 1, where the actions were lowest out of the four problems.

5. *Which algorithm or algorithms would be most appropriate for planning in very large domains (e.g., planning delivery routes for all UPS drivers in the U.S. on a given day)?*

Breadth First Search or A* Search with the heuristic Unmet Goals would be most appropriate for planning in very large domains. Both found the shortest plans in every problem, even Problem 4. In large domains like in Problem 4, A* Search with Unmet Goals is actually faster than Breadth First Search, so the best algorithm could be A* Search with Unmet Goals.

6. *Which algorithm or algorithms would be most appropriate for planning problems where it is important to find only optimal plans?*

Breadth First, Uniform Cost, And A* with Unmet Goals are most appropriate for planning problems where it is important to find only optimal plans. In each problem, they always found the optimal (shortest) plan length. All the other searches found plans longer than these three searches in at least one of the four problems.