REPORT

Analyse the search complexity as a function of domain size, search algorithm, and heuristic.

Air Cargo Problem 1

Air Cargo Problem	Search Function	Actions	Expansions	Goal Tests	New Nodes	Plan length	Time
P1	breadth_first_search	20	43	56	178	6	0.02325
P1	depth_first_graph_search	20	21	22	84	20	0.00785
P1	uniform_cost_search	20	60	62	240	6	0.02107
P1	greedy_best_first_graph_search h_unmet_goals	20	7	9	29	6	0.00237
P1	greedy_best_first_graph_search h_pg_levelsum	20	6	8	28	6	0.69445
P1	greedy_best_first_graph_search h_pg_maxlevel	20	6	8	24	6	0.09188
P1	greedy_best_first_graph_search h_pg_setlevel	20	6	8	28	6	0.63573
P1	astar_search h_unmet_goals	20	50	52	206	6	0.01588
P1	astar_search h_pg_levelsum	20	28	30	122	6	0.33609
P1	astar_search h_pg_maxlevel	20	43	45	180	6	0.15900
P1	astar_search h_pg_setlevel	20	33	35	138	6	0.49946

Air Cargo Problem 2

Air Cargo Problem	Search Function	Actions	Expansions	Goal Tests	New Nodes	Plan length	Time
P2	breadth_first_search	72	3343	4609	30503	9	0.55923
P2	depth_first_graph_search	72	624	625	5602	619	0.71108
P2	uniform_cost_search	72	5154	5156	46618	9	0.68662
P2	greedy_best_first_graph_search h_unmet_goals	72	17	19	170	9	0.01386
P2	greedy_best_first_graph_search h_pg_levelsum	72	9	11	86	9	2.14908
P2	greedy_best_first_graph_search h_pg_maxlevel	72	27	29	249	9	0.79066
P2	greedy_best_first_graph_search h_pg_setlevel	72	9	11	84	9	2.51402
P2	astar_search h_unmet_goals	72	2467	2469	22522	9	0.69489
P2	astar_search h_pg_levelsum	72	357	359	3426	9	29.92905
P2	astar_search h_pg_maxlevel	72	2887	2889	26594	9	75.78469
P2	astar_search h_pg_setlevel	72	1037	1039	9605	9	174.01865

Air Cargo Problem 3

	Search Function	Actions	Expansions	Goal Tests	New Nodes	Plan length	Time
Air Cargo Problem							
P3	breadth_first_search	88	14663	18098	129625	12	1.037600
P3	depth_first_graph_search	88	408	409	3364	392	0.275660
P3	uniform_cost_search	88	18510	18512	161936	12	1.886340
P3	greedy_best_first_graph_search h_unmet_goals	88	25	27	230	15	0.022540
P3	greedy_best_first_graph_search h_pg_levelsum	88	14	16	126	14	3.707645
P3	greedy_best_first_graph_search h_pg_maxlevel	88	21	23	195	13	1.322740
P3	greedy_best_first_graph_search h_pg_setlevel	88	35	37	345	17	11.482200
P3	astar_search h_unmet_goals	88	7388	7390	65711	12	1.492040
P3	astar_search h_pg_levelsum	88	369	371	3403	12	45.353400
P3	astar_search h_pg_maxlevel	88	9580	9582	86312	12	418.932100
P3	astar_search h_pg_setlevel	88	3423	3425	31596	12	910.472870

Air Cargo Problem 4

	Search Function	Actions	Expansions	Goal Tests	New Nodes	Plan length	Time
Air Cargo Problem							
P4	breadth_first_search	104	99736	114953	944130	14	6.596620
P4	depth_first_graph_search	104	25174	25175	228849	24132	1130.513000
P4	uniform_cost_search	104	113339	113341	1066413	14	9.475090
P4	greedy_best_first_graph_search h_unmet_goals	104	29	31	280	18	0.040180
P4	greedy_best_first_graph_search h_pg_levelsum	104	17	19	165	17	5.425209
P4	greedy_best_first_graph_search h_pg_maxlevel	104	56	58	580	17	3.194630
P4	greedy_best_first_graph_search h_pg_setlevel	104	107	109	164	23	46.474760
P4	astar_search h_unmet_goals	104	34330	34332	328509	14	5.047560
P4	astar_search h_pg_levelsum	104	1208	1210	12210	15	230.280300
P4	astar_search h_pg_maxlevel	104	62077	62079	599376	14	4418.028400
P4	astar_search h_pg_setlevel	104	22606	22608	224229	14	10609.878000

Table to analyze the number of nodes expanded against number of actions in the domain.

Number of nodes expanded against the number of actions for P1

	Actions	Expansions
Search Function		
breadth_first_search	20	43
depth_first_graph_search	20	21
uniform_cost_search	20	60
greedy_best_first_graph_search h_unmet_goals	20	7
greedy_best_first_graph_search h_pg_levelsum	20	6
greedy_best_first_graph_search h_pg_maxlevel	20	6
greedy_best_first_graph_search h_pg_setlevel	20	6
astar_search h_unmet_goals	20	50
astar_search h_pg_levelsum	20	28
astar_search h_pg_maxlevel	20	43
astar_search h_pg_setlevel	20	33

Number of nodes expanded against the number of actions for P2

	Actions	Expansions
Search Function		
breadth_first_search	72	3343
depth_first_graph_search	72	624
uniform_cost_search	72	5154
greedy_best_first_graph_search h_unmet_goals	72	17
greedy_best_first_graph_search h_pg_levelsum	72	9
greedy_best_first_graph_search h_pg_maxlevel	72	27
greedy_best_first_graph_search h_pg_setlevel	72	9
astar_search h_unmet_goals	72	2467
astar_search h_pg_levelsum	72	357
astar_search h_pg_maxlevel	72	2887
astar_search h_pg_setlevel	72	1037

Table to analyze the search time against the number of actions in the domain for P1 and P2

Search time against the number of actions for P1

	Actions	Time
Search Function		
breadth_first_search	20	0.02325
depth_first_graph_search	20	0.00785
uniform_cost_search	20	0.02107
greedy_best_first_graph_search h_unmet_goals	20	0.00237
greedy_best_first_graph_search h_pg_levelsum	20	0.69445
greedy_best_first_graph_search h_pg_maxlevel	20	0.09188
greedy_best_first_graph_search h_pg_setlevel	20	0.63573
astar_search h_unmet_goals	20	0.01588
astar_search h_pg_levelsum	20	0.33609
astar_search h_pg_maxlevel	20	0.15900
astar_search h_pg_setlevel	20	0.49946

Search time against the number of actions for P2

	Actions	Time
Search Function		
breadth_first_search	20	0.02325
depth_first_graph_search	20	0.00785
uniform_cost_search	20	0.02107
greedy_best_first_graph_search h_unmet_goals	20	0.00237
greedy_best_first_graph_search h_pg_levelsum	20	0.69445
greedy_best_first_graph_search h_pg_maxlevel	20	0.09188
greedy_best_first_graph_search h_pg_setlevel	20	0.63573
astar_search h_unmet_goals	20	0.01588
astar_search h_pg_levelsum	20	0.33609
astar_search h_pg_maxlevel	20	0.15900
astar_search h_pg_setlevel	20	0.49946

Discussion of these results that analyzes the growth trends as the problem size increases.

In case of optimality and length of plans **Depth First Graph Search** performs poorly because in case of Depth-First Graph Search it starts expanding nodes irrespective of where the goal is and is not a good choice whether is it a good choice or not.

With the increase in the number of Actions, **Greedy Best first graph search** fails to find the optimal path because greedy-search doesn't focus on cost but instead tries to find the fastest solution.

- **Q1. 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?**

  In case of small domains with only for action like **Air Cargo Problem 1** which has 20 actions every search problem is able to give optimal path length of 6 except **Depth First Graph Search(20).**But for the systems that operate in real time, **Time** is more important than **cost** therefore **Greedy Best first graph search** can be used as it tries to find the fastest solution. Other algorithms that can be chosen is **Breadth First Search** if and only if cost is not an important factor.

- **Q2. 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)?**

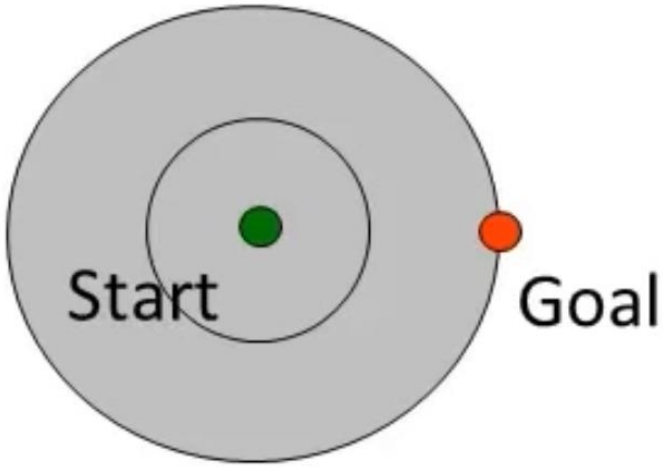
  In case of very large domains **Cost** is an important factor so **Uniform Cost Search** could be an appropriate choice for planning in very large domains.

	Air Cargo Problem	Actions	Expansions	Goal Tests	New Nodes	Plan length	Time
Search Function							
uniform_cost_search	P1	20	60	62	240	6	0.02107
uniform_cost_search	P2	72	5154	5156	46618	9	0.68662
uniform_cost_search	P3	88	18510	18512	161936	12	1.88634
uniform_cost_search	P4	104	113339	113341	1066413	14	9.47509

- **Q3. Which algorithm or algorithms would be most appropriate for planning problems where it is important to find only optimal plans?**

  A-star Search will the most appropriate algorithm for finding optimal plans because it keeps track of both **Goal** and **Cost**. **Uniform Cost Search** can also find optimal paths but the number of expansions are more in case of Uniform Cost Search as it doesn't track **Goal** but only focuses on **Cost**.

  Uniform Cost Search :



A-star Search :