Report

Problem 1)

Search	Optimal	Path length	Execution time	Node expansions	Actions
breadth_first_search	Yes	6	0.0063	43	20
depth_first_graph_search	No	20	0.0035	21	20
uniform_cost_search	Yes	6	0.0096	60	20
greedy_best_first_graph_search with h_unmet_goals	Yes	6	0.0017	7	20
greedy_best_first_graph_search with h_pg_levelsum	No	9	0.0301	56	20
greedy_best_first_graph_search with h_pg_maxlevel	Yes	6	0.355	6	20
greedy_best_first_graph_search with h_pg_setlevel	Yes	6	0.5819	6	20
astar_search with h_unmet_goals	Yes	6	0.0097	50	20
astar_search with h_pg_levelsum	Yes	6	0.0313	60	20
astar_search with h_pg_maxlevel	Yes	6	1.23	43	20
astar_search with h_pg_setlevel	Yes	6	1.377	33	20

Problem 2

Search	Optimal	Path length	Execution time	Node expansions	Actions
breadth_first_search	Yes	9	2.09	3343	72
depth_first_graph_search	No	619	3.143	624	72
uniform_cost_search	Yes	9	3.534	60	72
greedy_best_first_graph_search with h_unmet_goals	Yes	9	0.0194	17	72
greedy_best_first_graph_search with h_pg_levelsum	No	14	16.982	4455	72
greedy_best_first_graph_search with h_pg_maxlevel	Yes	9	21.383	27	72
greedy_best_first_graph_search with h_pg_setlevel	Yes	9	28.9821	9	72
astar_search with h_unmet_goals	Yes	9	02.327	2467	72
astar_search with h_pg_levelsum	Yes	9	24.154	5154	72
astar_search with h_pg_maxlevel	Yes	9	2239.60	2887	72
astar_search with h_pg_setlevel	Yes	9	2251.09	1037	72

For problem 3 depth_first_graph_search can be ignored as it is not optimal for problem 1 and problem 2.

For problem 3:

Using breadth_first_search:

#Actions	Expansions	Goal Tests	New Nodes
88	14663	18098	129625

Plan length: 12 Time elapsed in seconds: 10.549945541

Air Cargo Problem 3 using greedy_best_first_graph_search with h_pg_maxlevel:

# Actions	Expansions	Goal Tests	New Nodes
88	21	23	195

Plan length: 13 Time elapsed in seconds: 29.362841286000048

Air Cargo Problem 3 using greedy_best_first_graph_search with h_unmet_goals:

# Actions	Expansions	Goal Tests	New Nodes
88	25	27	230

Plan length: 15 Time elapsed in seconds: 0.038052473000107O6

Air Cargo Problem 3 using astar_search with h_unmet_goals:

Actions Expansions Goal Tests New Nodes

88 7388 7390 65711

Plan length: 12 Time elapsed in seconds: 8.667878642999995

Air Cargo Problem 3 using astar_search with h_pg_levelsum...

Actions Expansions Goal Tests New Nodes

88 18510 18512 161936

Plan length: 12 Time elapsed in seconds: 175.60448517999998

For problem 4:

Air Cargo Problem 4 using breadth_first_search:

Actions Expansions Goal Tests New Nodes

104 99736 114953 944130

Plan length: 14 Time elapsed in seconds: 95.11615321599993

Air Cargo Problem 4 using greedy_best_first_graph_search with h_unmet_goals:

Actions Expansions Goal Tests New Nodes

104 29 31 280

Plan length: 18 Time elapsed in seconds: 0.061281463999875996

Air Cargo Problem 4 using greedy_best_first_graph_search with h_pg_maxlevel...

Actions Expansions Goal Tests New Nodes

104 56 58 580

Plan length: 17 Time elapsed in seconds: 105.02090135399976

Air Cargo Problem 4 using astar_search with h_unmet_goals...

Actions Expansions Goal Tests New Nodes

104 34330 34332 328509

Plan length: 14 Time elapsed in seconds: 57.21992111199961

Table to analyze the number of nodes expanded against number of actions in the domain for problem 1

Search	Node expansions	Actions

breadth_first_search	43	20
depth_first_graph_search	21	20
uniform_cost_search	60	20
greedy_best_first_graph_search with h_unmet_goals	7	20
greedy_best_first_graph_search with h_pg_levelsum	56	20
greedy_best_first_graph_search with h_pg_maxlevel	6	20
greedy_best_first_graph_search with h_pg_setlevel	6	20
astar_search with h_unmet_goals	50	20
astar_search with h_pg_levelsum	60	20
astar_search with h_pg_maxlevel	43	20
astar_search with h_pg_setlevel	33	20

Table to analyze the number of nodes expanded against number of actions in the domain for problem 2

Search	Node	Actions

	expansions	
breadth_first_search	3343	72
depth_first_graph_search	624	72
uniform_cost_search	60	72
greedy_best_first_graph_search with h_unmet_goals	17	72
greedy_best_first_graph_search with h_pg_levelsum	4455	72
greedy_best_first_graph_search with h_pg_maxlevel	27	72
greedy_best_first_graph_search with h_pg_setlevel	9	72
astar_search with h_unmet_goals	2467	72
astar_search with h_pg_levelsum	5154	72
astar_search with h_pg_maxlevel	2887	72
astar_search with h_pg_setlevel	1037	72

Table to analyze the number of nodes expanded against number of actions in the domain for problem 3:

Search	Node expansions	Actions

breadth_first_search	14663	88
greedy_best_first_graph_search with h_unmet_goals	25	88
greedy_best_first_graph_search with h_pg_maxlevel	21	88
astar_search with h_unmet_goals	7388	88
astar_search with h_pg_levelsum	18510	88

Table to analyze the number of nodes expanded against number of actions in the domain for problem 4:

Search	Node expansions	Actions
breadth_first_search	99736	104
greedy_best_first_graph_search with h_unmet_goals	29	104
greedy_best_first_graph_search with h_pg_maxlevel	56	104
astar_search with h_unmet_goals	34330	104
astar_search with h_pg_levelsum		104

Analysis:

As the problem size increases there is increase in the number of actions to be performed but node expansions is something which is not predictable and depends on the type of search algorithm we are using for smaller domain problems greedy_best_first_graph_search with h_pg_setlevel returns the least no. of expansions required. But for larger domain problems there is variation in results.

table to analyze the search time against the number of actions in the domain for problem 1:

Search	Execution time	Actions
breadth_first_search	0.0063	20
depth_first_graph_search	0.0035	20
uniform_cost_search	0.0096	20
greedy_best_first_graph_search with h_unmet_goals	0.0017	20
greedy_best_first_graph_search with h_pg_levelsum	0.0301	20
greedy_best_first_graph_search with h_pg_maxlevel	0.355	20
greedy_best_first_graph_search with h_pg_setlevel	0.5819	20

astar_search with h_unmet_goals	0.0097	20
astar_search with h_pg_levelsum	0.0313	20
astar_search with h_pg_maxlevel	1.23	20
astar_search with h_pg_setlevel	1.377	20

table to analyze the search time against the number of actions in the domain for problem 2:

Search	Execution time	Actions
breadth_first_search	2.09	72
depth_first_graph_search	3.143	72
uniform_cost_search	3.534	72
greedy_best_first_graph_search with h_unmet_goals	0.0194	72
greedy_best_first_graph_search with h_pg_levelsum	16.982	72
greedy_best_first_graph_search with h_pg_maxlevel	21.383	72
greedy_best_first_graph_search with h_pg_setlevel	28.9821	72
astar_search with	02.327	72

h_unmet_goals		
astar_search with h_pg_levelsum	24.154	72
astar_search with h_pg_maxlevel	2239.60	72
astar_search with h_pg_setlevel	2251.09	72

table to analyze the search time against the number of actions in the domain for problem 3:

Search	Execution time	Actions
breadth_first_search	10.5499	88
greedy_best_first_graph_search with h_unmet_goals	0.038	88
greedy_best_first_graph_search with h_pg_maxlevel	29.362	88
astar_search with h_unmet_goals	8.667	88
astar_search with h_pg_levelsum	175.610	88

table to analyze the search time against the number of actions in the domain for problem 4:

Search	Execution time	Actions

breadth_first_search	95.116	104
greedy_best_first_graph_search with h_unmet_goals	0.0612	104
greedy_best_first_graph_search with h_pg_maxlevel	105.02	104
astar_search with h_unmet_goals	57.2199	104
astar_search with h_pg_levelsum		104

Analysis: As the problem size increases there is increase in the execution time with greedy_best_first_graph_search with h_unmet_goals returning the best execution time for all domain problems as it doesn't need to meet the goals. The actions are always increasing with increase in problem size.

Table to analyze the length of the plans returned by each algorithm on problem 1:

Search	Path length
breadth_first_search	6
depth_first_graph_search	20
uniform_cost_search	6
greedy_best_first_graph_search with h_unmet_goals	6
greedy_best_first_graph_search with h_pg_levelsum	9

greedy_best_first_graph_search with h_pg_maxlevel	6
greedy_best_first_graph_search with h_pg_setlevel	6
astar_search with h_unmet_goals	6
astar_search with h_pg_levelsum	6
astar_search with h_pg_maxlevel	6
astar_search with h_pg_setlevel	6

Table to analyze the length of the plans returned by each algorithm on problem 2:

Search	Path length
breadth_first_search	9
depth_first_graph_search	619
uniform_cost_search	9
greedy_best_first_graph_search with h_unmet_goals	9
greedy_best_first_graph_search with h_pg_levelsum	14

greedy_best_first_graph_search with h_pg_maxlevel	9
greedy_best_first_graph_search with h_pg_setlevel	9
astar_search with h_unmet_goals	9
astar_search with h_pg_levelsum	9
astar_search with h_pg_maxlevel	9
astar_search with h_pg_setlevel	9

Table to analyze the length of the plans returned by each algorithm on problem 3:

Search	Path length
breadth_first_search	12
greedy_best_first_graph_search with h_unmet_goals	15
greedy_best_first_graph_search with h_pg_maxlevel	13

astar_search with h_unmet_goals	12
astar_search with h_pg_levelsum	12

Table to analyze the length of the plans returned by each algorithm on problem 4:

Search	Path length
breadth_first_search	14
greedy_best_first_graph_search with h_unmet_goals	18
greedy_best_first_graph_search with h_pg_maxlevel	17
astar_search with h_unmet_goals	14
astar_search with h_pg_levelsum	12

Analysis: As the problem size increases there is increase in path length with optimal path length problem 1 being 6 for problem 2 being 9 for problem 3 being 12 and for problem 4 being 14 which shows that

for all domain problems there is an optimal path length and anything beyond that length is infeasible.

Q-1) 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?

A-> depth_first_graph_search and greedy_best_first_graph_search with h_pg_levelsum will be the most appropriate as they have shorter execution time where less no. of actions are there.

Q-2) 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)

A-> greedy_best_first_graph_search with h_unmet_goals will be most appropriate for planning in large domains.

Q-3)Which algorithm or algorithms would be most appropriate for planning problems where it is important to find only optimal plans?

A-> astar_search with h_unmet_goals will be good for planning problem where it is important to find optimal plans.