Heuristic Analysis

Optimal Plan

Air Cargo Problem 1

Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)

Air Cargo Problem 2

Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
Unload(C3, P3, SFO)

Air Cargo Problem 3

Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ATL, JFK)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
Unload(C3, P1, JFK)
Unload(C4, P2, SFO)

Raw Data

Air Cargo Problem 1	Expansions	Goal Tests	New Nodes	Time Elapsed	Plan Length
uniform_cost_graph_search	55	57	224	0.05726813792716712	6
breadth_first_graph_search	43	56	180	0.03135633503552526	6
depth_first_graph_search	12	13	48	0.01813720096834004	12
astar_search_h_ignore_preconditions	41	43	170	0.03671667599701322	6
astar_search_h_pg_levelsum	11	13	50	0.5377221890084911	6

Air Cargo Problem 2	Expansions	Goal Tests	New Nodes	Time Elapsed	Plan Length
uniform_cost_graph_search	4853	4855	44041	17.179727443959564	9
breadth_first_graph_search	3343	4609	30509	17.76466659794096	9
depth_first_graph_search	582	583	5211	5.575963828945532	575
astar_search_h_ignore_preconditions	1450	1452	13303	4.635786358994665	9
astar_search_h_pg_levelsum	86	88	841	51.386474351005745	9

Air Cargo Problem 3	Expansions	Goal Tests	New Nodes	Time Elapsed	Plan Length
uniform_cost_graph_search	18151	18153	159038	59.015274920035154	12
breadth_first_graph_search	14663	18098	129631	124.94671371090226	12
depth_first_graph_search	627	628	5176	3.7411767470184714	596
astar_search_h_ignore_preconditions	5038	5040	44926	19.484844123988296	12
astar_search_h_pg_levelsum	314	316	2894	247.7471174020029	12

Compare and Contrast Non-heuristic Search Result Metrics

All Air Cargo Problem	Expansions	Time Elapsed	Optimality
uniform_cost_graph_search	Large	Median	Yes
breadth_first_graph_search	Large	Long	Yes
depth_first_graph_search	Small	Short	No

Athough all non-heuristic search finally find the solution, their length of solution are quiet different. The plan length of Depth first search(DFS)'s is much larger than others. In real world, its solution is obviously intolerant, which means it is not optimal for air cargo problems. Also Dr. Norvig points out that in DFS "For similar reasons, both versions are nonoptimal. "[1] But it is worthy to note that according to the raw data, DFS can find out a solution much faster than others and it has the smallest momery requirments because it has the least expansions. As for breadth first search(BFS) and uniform cost search(UCS), they are optimal and produce shortest plan. Futhermore, compared with the average of time elapsed, UCS is the best non-heuristic to solve these kind of air cargo problems.

Compare and Contrast Heuristic Search Result Metrics

All Air Cargo Problem	Expansions	Time Elapsed	Optimality
astar_search_h_ignore_preconditions	Median	Short	Yes
astar_search_h_pg_levelsum	Small	Long	Yes

Accroding to the plan length of these two heuristic search methods, we can find out that they are both optimal. Because the computation of astar_search_h_pg_levelsum uses a planning graph, it is more time-consuming but its heuristics makes the search more accurate towards the goal, so its expansions reamin the least. However, although astar_search_h_ignore_preconditions expanses more nodes, its time elapsed is much shorter than astar_search_h_pg_levelsum. In conclusion, astar_search_h_ignore_preconditions is the best strategy to solve air cargo problem.

Questions

All Air Cargo Problem	Expansions	Time Elapsed	Optimality
uniform_cost_graph_search	Large	Median	Yes
breadth_first_graph_search	Large	Long	Yes
depth_first_graph_search	Small	Short	No
astar_search_h_ignore_preconditions	Median	Short	Yes
astar_search_h_pg_levelsum	Small	Long	Yes

What was the best heuristic used in these problems? ¶

According to the compared table, we select the best heuristics from those which are optimal, and under overall consideration of time elapsed and expansion, astar_search_h_ignore_preconditions is the best heuristic used in these problems.

Was it better than non-heuristic search planning methods for all problems?

In small problem as air cargo problem 1, the result of BFS and astar_search_h_ignore_preconditions is almost the same considering expansions and time eplased. But in problem larger than problem 1, the power of astar_search_h_ignore_preconditions shows up. Dr. Norvig also said that "one that uses problem-specific knowledge beyond the definition of the problem itself — can find solutions more efficiently than can an uninformed strategy."[2]

Why or why not?

In small problem, the search spaces are so small that the power of heuristics is not obvious. As the search spaces increase, the value of heuristics emerges.

References

1 Russell, S. and Norvig, P. (2009). Artificial intelligence. Upper Saddle River, N.J.: Prentice Hall, p.86.
2 Russell, S. and Norvig, P. (2009). Artificial intelligence. Upper Saddle River, N.J.: Prentice Hall, p.92.