Heuristic Analysis

Optimal Plans for Problems 1, 2 and 3

Optimal Plan for Problem 1

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

Optimal Plan for Problem 2

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

Optimal Plan for Problem 3

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

Note that several of the algorithms found similar plans for each problem but sometimes in different orders. I listed the plans which returned the plan in the shortest amount of time as a tiebreaker.

Problem 1					
Search	Expansions	Goal Tests	New Nodes	Plan Length	Time (s)
Breadth-First Search	43	56	180	6	0.019780733
Depth-First Graph Search	12	13	48	12	0.005433533
Uniform Cost Search	55	57	224	6	0.02713597
A* Search with h1	55	57	224	6	0.025768444
A* Search with ignore preconditons	41	43	170	6	0.028960639
A* Search with h_pg_levelsum	11	13	50	6	0.900867156
Problem 2					
Search	Expansions	Goal Tests	New Nodes	Plan Length	Time (s)
Breadth-First Search	3343	4609	30509	9	9.025683355
Depth-First Graph Search	582	583	5211	575	1.989941649
Uniform Cost Search	4852	4854	44030	9	28.95371013
A* Search with h1	4852	4854	44030	9	28.90516015
A* Search with ignore preconditons	1506	1508	13820	9	9.183697597
A* Search with h_pg_levelsum	86	88	841	9	88.30492346
Problem 3					
Search	Expansions	Goal Tests	New Nodes	Plan Length	Time (s)
Breadth-First Search	14663	18090	129631	12	66.86886378
Depth-First Graph Search	627	628	5176	596	2.075218813
Uniform Cost Search	18234	18236	159707	12	245.1031857
A* Search with h1	18234	18236	159707	12	243.542892
A* Search with ignore preconditons	5118	5120	45650	12	56.0995617
A* Search with h_pg_levelsum	404	406	3718	12	594.5792284

Non-Heuristic Search Results Metrics

The first three search methods listed in the table (breadth-first search, depth-first search graph, search, and uniform cost search) were the non-heuristic search algorithms that were evaluated. Breadth-first search was superior to both depth-first graph search and uniform cost search. Breadth-first search and uniform cost search returned similar plans (although not necessarily in the same order). Breadth-first search completed in a shorter time for all 3 problems compared to uniform cost search. Depth-first search was actually faster due to having less expansions, goal tests, and new nodes. However, the plan lengths returned were much longer. This is consistent with depth-first search not being an optimal whereas breadth-first search and uniform cost search are both optimal.

Heuristic Search Results Metrics

The three A* search algorithms were evaluated. Note that A* search with h1 is the same as uniform cost search but was included for comparison. The results for uniform cost search and A* search with h1 were the same except for a slight difference in the time each algorithm needed to complete. Both A* search with ignore preconditions as well with h_pg_levelsum had less expansions, goal tests, and new nodes when compared with breadth-first search and uniform cost search (the h_pg_levelsum variant had an order of magnitude less of each metric when compared with ignore preconditions). However, A* search with h_pg_levelsum needed much more time to complete and for problem 3 was close to the suggested 600 second time limit. A* search with ignore preconditions did not return an optimal solution as quickly as breadth-first search except for Problem 3. It may be that breath-first search is superior until the problem becomes large enough that A* search with ignore preconditions becomes a superior option.