Problem 1

Algorithm	Expansions	Goal Tests	New Nodes	Plan length	Time
Breadth first search	44	57	184	6	0.0285961368509089
Breadth first tree search	1440	1441	5880	6	0.8358060895580881
Depth first graph search	12	13	48	12	0.007161281121469187
Depth limited graph	96	248	391	50	0.07513992093237687
Uniform cost search	55	57	224	6	0.03370586322731328
Recursive best first search h1	4206	4207	16926	6	2.682406446456713
Greedy best first graph search h1	7	9	28	6	0.004473282183394822
A* search with h1	55	57	224	6	0.033024382015059306
A* with H ignore preconditions	41	43	170	6	0.03301015979845534
A* with h pg levelsum	11	13	50	6	0.566905059988124

Problem 2

Algorithm	Expansions	Goal Tests	New Nodes	Plan length	Time
Breadth first search	2856	4047	23715	9	12.28125737036746
Breadth first tree search	N/A	N/A	N/A	N/A	N/A
Depth first graph search	332	333	2095	315	0.7936233901734759
Depth limited graph	166397	1398585	1398962	50	620.3908731295315
Uniform cost search	N/A	N/A	N/A	N/A	N/A
Recursive best first search h1	N/A	N/A	N/A	N/A	N/A
Greedy best first graph search h1	478	480	3646	19	1.130038226203043
A* search with h1	4281	4283	35054	9	11.55249426369917
A* with H ignore preconditions	1272	1274	10732	9	5.254965534787583
A* with h pg levelsum	172	174	1314	9	73.74046991839599

Problem 3

Algorithm	Expansions	Goal Tests	New Nodes	Plan length	Time
Breadth first search	13879	17435	122778	12	167.674558153261
Breadth first tree search	N/A	N/A	N/A	N/A	N/A
Depth first graph search	266	267	2182	251	1.1453933252767001
Depth limited graph	N/A	N/A	N/A	N/A	N/A
Uniform cost search	N/A	N/A	N/A	N/A	N/A
Recursive best first search h1	N/A	N/A	N/A	N/A	N/A
Greedy best first graph search h1	5614	5616	49429	22	26.98422400623249
A* search with h1	18235	18237	159716	12	68.60460776114262
A* with H ignore preconditions	5040	5042	44944	12	23.126301974794288
A* with h pg levelsum	318	320	2934	12	333.6562087284114

Analysis

Breadth first search was able to find the shortest plan across the 3 different problems, however it's expansion and time increased dramatically with search space.

Depth first graph search is not suitable for this search problems.

Greedy best first graph search h1, seem fast enough but it fails to find the shortest plan.

A* seem to top all the other search algorithm with respect to expansions, tests, time, length, with the right heuristic function it seem to be the best choice.

Results.

Solving Air Cargo Problem 1 using breadth_first_search...

Expansions	Goal Tests	New Nodes
44	57	184

Plan length: 6 Time elapsed in seconds: 0.0285961368509089

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using breadth_first_tree_search...

Expansions	Goal Tests	New Nodes
1440	1441	5880

Plan length: 6 Time elapsed in seconds: 0.8358060895580881

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using depth_first_graph_search...

Expansions   Goal Tests   New Nodes

   12   13   48

Plan length: 12 Time elapsed in seconds: 0.007161281121469187

Fly(P2, JFK, SFO)

Fly(P1, SFO, JFK)

Load(C1, P2, SFO)

Fly(P2, SFO, JFK)

Fly(P1, JFK, SFO)

Unload(C1, P2, JFK)

Fly(P2, JFK, SFO)

Fly(P1, SFO, JFK)

Load(C2, P1, JFK)

Fly(P2, SFO, JFK)

Fly(P1, JFK, SFO)

Unload(C2, P1, SFO)

Solving Air Cargo Problem 1 using depth_limited_search...

Expansions   Goal Tests   New Nodes

   96   248   391

Plan length: 50 Time elapsed in seconds: 0.07513992093237687

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using uniform_cost_search...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.03370586322731328

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using recursive_best_first_search with h_1...

Expansions	Goal Tests	New Nodes
4206	4207	16926

Plan length: 6 Time elapsed in seconds: 2.682406446456713

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using greedy_best_first_graph_search with h_1...

Expansions	Goal Tests	New Nodes
7	9	28

Plan length: 6 Time elapsed in seconds: 0.004473282183394822

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using astar_search with h_1...

Expansions   Goal Tests   New Nodes

   55   57   224

Plan length: 6 Time elapsed in seconds: 0.033024382015059306

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using astar_search with h_ignore_preconditions...

Expansions   Goal Tests   New Nodes

   41   43   170

Plan length: 6 Time elapsed in seconds: 0.03301015979845534

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Load(C2, P2, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
11	13	50

Plan length: 6 Time elapsed in seconds: 0.566905059988124

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Load(C2, P2, JFK)

Fly(P2, JFK, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 2 using breadth_first_search...

Expansions	Goal Tests	New Nodes
2856	4047	23715

Plan length: 9 Time elapsed in seconds: 12.28125737036746

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Load(C3, P3, ATL)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P3, ATL, SFO)

Unload(C3, P3, SFO)

Solving Air Cargo Problem 2 using depth_first_graph_search...

Expansions   Goal Tests   New Nodes

  332   333   2095

Plan length: 315 Time elapsed in seconds: 0.7936233901734759

Fly(P3, ATL, SFO)

Fly(P2, JFK, ATL)

Fly(P3, SFO, JFK)

Fly(P2, ATL, SFO)

Fly(P1, SFO, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, JFK)

Load(C2, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Unload(C2, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, JFK)

Load(C3, P1, ATL)

Fly(P2, JFK, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, JFK)

Unload(C3, P1, JFK)

Fly(P2, ATL, SFO)

Fly(P1, JFK, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Load(C3, P2, JFK)

Fly(P2, JFK, SFO)

Fly(P1, SFO, ATL)

Unload(C3, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, ATL, JFK)

Fly(P2, ATL, JFK)

Fly(P1, JFK, SFO)

Load(C2, P1, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Unload(C2, P1, JFK)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Load(C2, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, SFO, JFK)

Fly(P2, ATL, SFO)

Load(C3, P2, SFO)

Fly(P2, SFO, JFK)

Fly(P1, JFK, ATL)

Unload(C3, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, SFO)

Load(C1, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, JFK)

Unload(C2, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Unload(C1, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, JFK)

Fly(P2, ATL, JFK)

Load(C3, P1, JFK)

Fly(P2, JFK, SFO)

Fly(P1, JFK, SFO)

Fly(P2, SFO, ATL)

Load(C1, P1, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, ATL)

Fly(P2, JFK, SFO)

Fly(P1, ATL, JFK)

Unload(C3, P1, JFK)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Load(C3, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Unload(C3, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Unload(C1, P1, ATL)

Fly(P2, JFK, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, JFK)

Load(C1, P2, ATL)

Fly(P2, ATL, JFK)

Fly(P1, JFK, ATL)

Fly(P2, JFK, SFO)

Fly(P1, ATL, SFO)

Load(C3, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, JFK)

Unload(C1, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, SFO)

Unload(C3, P2, SFO)

Fly(P2, SFO, ATL)

Load(C3, P1, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, ATL)

Fly(P2, JFK, SFO)

Unload(C3, P1, ATL)

Fly(P1, ATL, SFO)

Fly(P2, SFO, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, ATL)

Load(C2, P1, JFK)

Fly(P2, ATL, SFO)

Fly(P1, JFK, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Unload(C2, P1, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Load(C2, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Load(C1, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, ATL, SFO)

Unload(C2, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, SFO, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, JFK)

Unload(C1, P2, JFK)

Fly(P2, JFK, SFO)

Fly(P1, JFK, SFO)

Fly(P2, SFO, ATL)

Load(C3, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, SFO, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, JFK)

Unload(C3, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, SFO)

Load(C2, P1, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, JFK)

Load(C3, P1, JFK)

Fly(P2, ATL, SFO)

Fly(P1, JFK, SFO)

Fly(P2, SFO, JFK)

Unload(C3, P1, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Load(C3, P2, SFO)

Fly(P2, SFO, JFK)

Load(C1, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Unload(C3, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, JFK)

Unload(C2, P1, ATL)

Fly(P2, JFK, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, JFK)

Unload(C1, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, JFK, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Load(C3, P1, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Unload(C3, P1, JFK)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Load(C3, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Load(C2, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, JFK)

Fly(P1, SFO, JFK)

Unload(C3, P2, JFK)

Fly(P2, JFK, SFO)

Fly(P1, JFK, ATL)

Unload(C2, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, JFK)

Load(C3, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, JFK, ATL)

Unload(C3, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, JFK)

Load(C2, P1, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Unload(C2, P1, JFK)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, ATL)

Unload(C2, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, JFK, SFO)

Fly(P2, SFO, JFK)

Fly(P1, SFO, ATL)

Load(C1, P1, ATL)

Fly(P2, JFK, ATL)

Fly(P1, ATL, SFO)

Unload(C1, P1, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, ATL)

Load(C3, P1, ATL)

Fly(P2, JFK, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, SFO)

Fly(P1, SFO, JFK)

Unload(C3, P1, JFK)

Fly(P2, SFO, JFK)

Fly(P1, JFK, ATL)

Load(C3, P2, JFK)

Fly(P2, JFK, ATL)

Fly(P1, ATL, JFK)

Fly(P2, ATL, SFO)

Fly(P1, JFK, SFO)

Load(C1, P1, SFO)

Fly(P2, SFO, JFK)

Fly(P1, SFO, ATL)

Load(C2, P1, ATL)

Fly(P2, JFK, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, SFO)

Unload(C3, P2, SFO)

Fly(P1, SFO, ATL)

Fly(P2, SFO, ATL)

Unload(C2, P1, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Unload(C1, P1, JFK)

Fly(P2, SFO, ATL)

Fly(P1, JFK, SFO)

Fly(P2, ATL, JFK)

Load(C3, P1, SFO)

Fly(P2, JFK, SFO)

Fly(P1, SFO, JFK)

Load(C1, P1, JFK)

Fly(P2, SFO, ATL)

Load(C2, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P1, JFK, ATL)

Unload(C2, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, ATL, JFK)

Fly(P2, ATL, JFK)

Fly(P1, JFK, SFO)

Load(C2, P1, SFO)

Fly(P1, SFO, ATL)

Unload(C1, P1, ATL)

Fly(P1, ATL, SFO)

Fly(P2, JFK, ATL)

Fly(P1, SFO, JFK)

Fly(P2, ATL, SFO)

Unload(C3, P1, JFK)

Fly(P2, SFO, JFK)

Load(C3, P2, JFK)

Fly(P2, JFK, SFO)

Fly(P1, JFK, SFO)

Unload(C3, P2, SFO)

Unload(C2, P1, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, JFK)

Load(C1, P1, ATL)

Fly(P2, JFK, SFO)

Fly(P1, ATL, JFK)

Fly(P2, SFO, ATL)

Unload(C1, P1, JFK)

Solving Air Cargo Problem 2 using depth_limited_search...

Expansions   Goal Tests   New Nodes

 166397   1398585   1398962

Plan length: 50 Time elapsed in seconds: 620.3908731295315
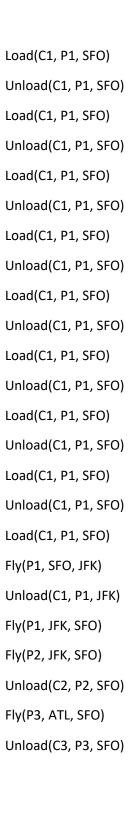
Load(C1, P1, SFO)

Load(C2, P2, JFK)

Load(C3, P3, ATL)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Unload(C1, P1, SFO)

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P1, JFK, SFO)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P3, ATL, SFO)

Unload(C3, P3, SFO)

Solving Air Cargo Problem 2 using greedy_best_first_graph_search with h_1...

Expansions   Goal Tests   New Nodes

478   480   3646

Plan length: 19 Time elapsed in seconds: 1.130038226203043

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Load(C3, P3, ATL)

Fly(P1, SFO, ATL)

Fly(P2, JFK, ATL)

Fly(P3, ATL, SFO)

Unload(C1, P1, ATL)

Load(C1, P2, ATL)

Fly(P2, ATL, SFO)

Unload(C2, P2, SFO)

Load(C2, P3, SFO)

Fly(P2, SFO, ATL)

Unload(C1, P2, ATL)

Load(C1, P1, ATL)

Fly(P1, ATL, JFK)

Unload(C1, P1, JFK)

Fly(P1, JFK, ATL)

Unload(C3, P3, SFO)

Unload(C2, P3, SFO)

Solving Air Cargo Problem 2 using astar_search with h_1...

Expansions   Goal Tests   New Nodes

 4281   4283   35054

Plan length: 9 Time elapsed in seconds: 11.55249426369917

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(C3, P3, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 2 using astar_search with h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
1272	1274	10732

Plan length: 9 Time elapsed in seconds: 5.254965534787583

Load(C3, P3, ATL)

Fly(P3, ATL, SFO)

Unload(C3, P3, SFO)

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Load(C2, P2, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 2 using astar_search with h_pg_levelsum...

Expansions   Goal Tests   New Nodes

172   174   1314

Plan length: 9 Time elapsed in seconds: 73.74046991839599

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Load(C2, P2, JFK)

Fly(P2, JFK, SFO)

Load(C3, P3, ATL)

Fly(P3, ATL, SFO)

Unload(C3, P3, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 3 using breadth_first_search...

Expansions   Goal Tests   New Nodes

13879   17435   122778

Plan length: 12 Time elapsed in seconds: 167.674558153261

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, ATL)

Load(C3, P1, ATL)

Fly(P1, ATL, JFK)

Unload(C1, P1, JFK)

Unload(C3, P1, JFK)

Fly(P2, JFK, ORD)

Load(C4, P2, ORD)

Fly(P2, ORD, SFO)

Unload(C2, P2, SFO)

Unload(C4, P2, SFO)

Solving Air Cargo Problem 3 using depth_first_graph_search...

Expansions   Goal Tests   New Nodes

  266   267   2182

Plan length: 251 Time elapsed in seconds: 1.1453933252767001

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Load(C1, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Unload(C1, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Load(C2, P1, JFK)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Unload(C2, P1, SFO)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Load(C2, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Load(C3, P1, ATL)

Fly(P2, JFK, ORD)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, SFO)

Fly(P1, SFO, JFK)

Unload(C2, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, ATL)

Load(C1, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Unload(C3, P1, SFO)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Load(C3, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Unload(C3, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Load(C2, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, JFK)

Unload(C2, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Load(C1, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, JFK)

Unload(C1, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Load(C4, P1, ORD)

Fly(P2, ATL, SFO)

Fly(P1, ORD, ATL)

Fly(P2, SFO, ORD)

Fly(P1, ATL, SFO)

Fly(P2, ORD, JFK)

Fly(P1, SFO, JFK)

Unload(C4, P1, JFK)

Fly(P2, JFK, ORD)

Load(C3, P1, JFK)

Fly(P2, ORD, ATL)

Fly(P1, JFK, ORD)

Fly(P2, ATL, SFO)

Fly(P1, ORD, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Unload(C3, P1, SFO)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

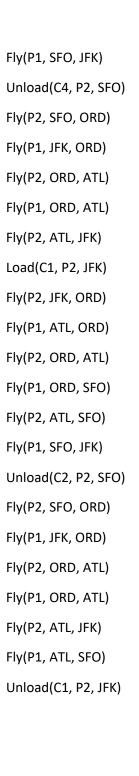Fly(P1, ATL, JFK)

Load(C3, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Load(C4, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Unload(C4, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Load(C2, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, JFK)

Unload(C3, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Unload(C2, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, JFK)

Load(C2, P1, JFK)

Fly(P2, ATL, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, SFO)

Fly(P1, ORD, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Unload(C2, P1, SFO)

Fly(P2, JFK, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Load(C4, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, JFK)

Fly(P1, SFO, JFK)

Unload(C4, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Load(C3, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, JFK)

Unload(C3, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Load(C2, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, SFO, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Load(C4, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, SFO)

Fly(P1, SFO, JFK)

Unload(C4, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Load(C1, P2, JFK)

Fly(P2, JFK, ORD)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, SFO)

Fly(P2, ATL, SFO)

Fly(P1, SFO, JFK)

Unload(C2, P2, SFO)

Fly(P2, SFO, ORD)

Fly(P1, JFK, ORD)

Fly(P2, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Unload(C1, P2, JFK)

Solving Air Cargo Problem 3 using greedy_best_first_graph_search with h_1...

Expansions	Goal Tests	New Nodes
5614	5616	49429

Plan length: 22 Time elapsed in seconds: 19.163303046596326

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, ORD)

Load(C4, P1, ORD)

Fly(P2, JFK, ATL)

Load(C3, P2, ATL)

Fly(P2, ATL, ORD)

Fly(P1, ORD, ATL)

Unload(C4, P1, ATL)

Fly(P1, ATL, ORD)

Fly(P2, ORD, ATL)

Load(C4, P2, ATL)

Fly(P2, ATL, ORD)

Unload(C3, P2, ORD)

Load(C3, P1, ORD)

Fly(P1, ORD, JFK)

Unload(C3, P1, JFK)

Unload(C1, P1, JFK)

Fly(P1, JFK, ORD)

Fly(P2, ORD, SFO)

Unload(C4, P2, SFO)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 3 using astar_search with h_1...

Expansions	Goal Tests	New Nodes
18235	18237	159716

Plan length: 12 Time elapsed in seconds: 71.5953818882442

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(C4, P2, SFO)

Unload(C3, P1, JFK)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 3 using astar_search with h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
5040	5042	44944

Plan length: 12 Time elapsed in seconds: 19.18313000172642

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(C1, P1, JFK)

Unload(C2, P2, SFO)

Solving Air Cargo Problem 3 using astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
318	320	2934

Plan length: 12 Time elapsed in seconds: 296.1958296510303

Load(C2, P2, JFK)

Fly(P2, JFK, ORD)

Load(C4, P2, ORD)

Fly(P2, ORD, SFO)

Load(C1, P1, SFO)

Fly(P1, SFO, ATL)

Load(C3, P1, ATL)

Fly(P1, ATL, JFK)

Unload(C4, P2, SFO)

Unload(C3, P1, JFK)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)