

Cargo Planning Heuristic Analysis

Artificial Intelligence Nanodegree

Written by: Will Trott

1. Non-heuristic search results

Breadth_first_search

	Air Cargo P1	Air Cargo P2	Air Cargo P3
Node Expansions Required	43	3343	14663
Number of Goal Tests	56	4609	18098
Time Elapsed	.024 sec	10.130 sec	79.155 sec
Plan Length	6	9	12

Depth_first_graph_search

	Air Cargo P1	Air Cargo P2	Air Cargo P3
Node Expansions Required	12	582	627
Number of Goal Tests	13	583	628
Time Elapsed	.006 sec	2.276 sec	2.453 sec
Plan Length	12	575	596

Uniform Cost Search

	Air Cargo P1	Air Cargo P2	Air Cargo P3
Node Expansions Required	55	4835	18235
Number of Goal Tests	57	4837	18237
Time Elapsed	.027 sec	8.516 sec	38.088 sec
Plan Length	6	9	12

The tables above show the results for each of the three non-heuristic searches that I performed. Of the three, breadth first search and uniform cost search both output plans of the same length, and had a very similar number of goal tests as well. Their first major difference is in the number of node expansions required, since breadth first search terminates node expansion as soon as a goal is found while uniform cost expands all nodes at the same depth as the goal node.¹ The other difference was in run-time where uniform cost search was about twice as fast as breadth first search.

Depth first graph search was the overall fastest of the three searches as well as being the search that performed the best when it came to number of goal tests and node expansions. However, the major drawback of this search type was that the plans that it returned were all too long to be realistic. This is caused by depth first search expanding along the deepest node until it reaches a goal state. For this reason, I think that it was the worst of the three metrics when it came to this problem.

¹ Russell, Stuart J., and Peter Norvig. "Uniform-cost Search" *Artificial Intelligence: a Modern Approach*, 3rd ed., Pearson, 2016, p. 85.

2. Heuristic Search Results

A Ignore Preconditions*

	Air Cargo P1	Air Cargo P2	Air Cargo P3
Node Expansions Required	41	1450	5040
Number of Goal Tests	43	1452	5042
Time Elapsed	.027 sec	3.143 sec	12.540 sec
Plan Length	6	9	12

A Level-Sum*

	Air Cargo P1	Air Cargo P2	Air Cargo P3
Node Expansions Required	11	86	316
Number of Goal Tests	13	88	318
Time Elapsed	0.684 sec	63.593 sec	361.318 sec
Plan Length	6	9	12

For both A* searches, the resulting plan lengths were the same. However, this is about the only similarity the two shared as far as the evaluated metrics go. The level sum search requires far fewer node expansions and goal tests, but is incredibly slow in comparison to the ignore preconditions search. This leads me to believe that level-sum is the inferior method between the two heuristic searches, although I'm sure that ignore preconditions has some weaknesses that are just not being exposed by this project.

3. Conclusions

Based on the metrics provided, the best search method is A* Ignore Preconditions. As mentioned in the heuristic search results section, while the resulting plan for both A* methods is the same, the run time of the level-sum method makes it appear infeasible for anything but easy problems. Then all that is left is to compare it to the non-heuristic methods mentioned previously. Of these three, the one that I felt was most optimal was the uniform cost search since it performed similarly to breadth first search in all aspects but run time, where it was a much better solution. However, comparing A* ignore preconditions to uniform cost search shows how much of a difference there is in the two algorithms. In all metrics but plan length, where the two tied, the A* method performed much better.

4. Optimal Plans(A* ignore preconditions)

Problem 1

Load(C1, P1, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

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

Problem 2

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

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)

Appendix

Problem 1

Solving Air Cargo Problem 1 using breadth_first_search...

Expansions	Goal Tests	New Nodes
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43	56	180
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Plan length: 6 Time elapsed in seconds: 0.023502856030687205

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Solving Air Cargo Problem 1 using depth_first_graph_search...

Expansions	Goal Tests	New Nodes
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12	13	48
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Plan length: 12 Time elapsed in seconds: 0.005857303086430218

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

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 uniform_cost_search...

Expansions	Goal Tests	New Nodes
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55	57	224
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Plan length: 6 Time elapsed in seconds: 0.027310409885554207

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
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41	43	170
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Plan length: 6 Time elapsed in seconds: 0.027484875282081614

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: 0.6840241714939324

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

Problem 2

Solving Air Cargo Problem 2 using breadth_first_search...

Expansions	Goal Tests	New Nodes
3343	4609	30509

Plan length: 9 Time elapsed in seconds: 10.130207879757396

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)

Solving Air Cargo Problem 2 using depth_first_graph_search...

Expansions	Goal Tests	New Nodes
582	583	5211

Plan length: 575 Time elapsed in seconds: 2.2763368228360896

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

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

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

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

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

Unload(C3, P1, JFK)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, SFO)

Fly(P3, SFO, ATL)

Fly(P1, SFO, JFK)

Load(C3, P2, JFK)

Fly(P3, ATL, SFO)

Fly(P2, JFK, ATL)

Fly(P3, SFO, JFK)

Fly(P2, ATL, SFO)

Fly(P1, JFK, ATL)

Fly(P2, SFO, JFK)

Fly(P1, ATL, SFO)

Load(C2, P1, SFO)

Fly(P1, SFO, ATL)

Fly(P3, JFK, ATL)

Fly(P1, ATL, JFK)

Fly(P3, ATL, SFO)

Fly(P2, JFK, ATL)

Fly(P3, SFO, JFK)

Fly(P2, ATL, SFO)

Unload(C3, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P3, JFK, ATL)

Fly(P2, ATL, JFK)

Fly(P3, ATL, SFO)

Fly(P1, JFK, ATL)

Fly(P3, SFO, JFK)

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

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

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

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

Unload(C3, P1, ATL)

Fly(P3, ATL, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, ATL)

Fly(P3, SFO, JFK)

Fly(P2, ATL, JFK)

Fly(P1, SFO, ATL)

Load(C2, P1, ATL)

Fly(P2, JFK, SFO)

Load(C1, P1, ATL)

Fly(P1, ATL, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, JFK)

Fly(P2, ATL, JFK)

Fly(P3, JFK, ATL)

Fly(P1, JFK, ATL)

Fly(P3, ATL, SFO)

Fly(P1, ATL, SFO)

Unload(C1, P1, SFO)

Fly(P3, SFO, ATL)

Fly(P2, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P3, ATL, SFO)

Fly(P2, ATL, SFO)

Fly(P3, SFO, JFK)

Fly(P1, ATL, JFK)

Load(C1, P2, SFO)

Fly(P2, SFO, ATL)

Fly(P1, JFK, ATL)

Fly(P2, ATL, JFK)

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

Unload(C1, P3, SFO)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Fly(P3, SFO, ATL)

Fly(P2, SFO, ATL)

Fly(P3, ATL, JFK)

Fly(P2, ATL, JFK)

Load(C1, P1, SFO)

Fly(P1, SFO, ATL)

Fly(P3, JFK, ATL)

Fly(P1, ATL, JFK)

Fly(P2, JFK, ATL)

Fly(P3, ATL, SFO)

Fly(P2, ATL, SFO)

Fly(P3, SFO, JFK)

Unload(C2, P3, JFK)

Fly(P3, JFK, ATL)

Fly(P2, SFO, ATL)

Fly(P3, ATL, SFO)

Fly(P2, ATL, JFK)

Load(C2, P2, JFK)

Fly(P3, SFO, ATL)

Fly(P2, JFK, ATL)

Fly(P3, ATL, JFK)

Fly(P1, JFK, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Fly(P2, SFO, JFK)

Unload(C1, P1, SFO)

Fly(P2, JFK, ATL)

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

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

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

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

Unload(C3, P1, SFO)

Fly(P2, SFO, ATL)

Fly(P1, SFO, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, JFK)

Fly(P3, JFK, ATL)

Fly(P2, JFK, ATL)

Load(C2, P1, JFK)

Fly(P3, ATL, SFO)

Fly(P2, ATL, SFO)

Fly(P3, SFO, JFK)

Fly(P1, JFK, ATL)

Fly(P2, SFO, ATL)

Fly(P1, ATL, SFO)

Fly(P2, ATL, JFK)

Fly(P3, JFK, ATL)

Fly(P1, SFO, ATL)

Fly(P3, ATL, SFO)

Load(C1, P2, JFK)

Fly(P1, ATL, SFO)

Fly(P2, JFK, ATL)

Fly(P3, SFO, ATL)

Fly(P2, ATL, SFO)

Fly(P3, ATL, JFK)

Fly(P1, SFO, ATL)

Fly(P2, SFO, ATL)

Fly(P1, ATL, JFK)

Unload(C1, P2, ATL)

Fly(P2, ATL, SFO)

Fly(P3, JFK, ATL)

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

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

Solving Air Cargo Problem 2 using uniform_cost_search...

Expansions Goal Tests New Nodes

4835 4837 43877

Plan length: 9 Time elapsed in seconds: 8.515902360163206

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

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

Expansions	Goal Tests	New Nodes
1450	1452	13303

Plan length: 9 Time elapsed in seconds: 3.1425274161996235

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

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

Expansions	Goal Tests	New Nodes
86	88	841

Plan length: 9 Time elapsed in seconds: 63.59331093240503

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(C2, P2, SFO)

Unload(C1, P1, JFK)

Problem 3

Solving Air Cargo Problem 3 using breadth_first_search...

Expansions Goal Tests New Nodes

14663 18098 129631

Plan length: 12 Time elapsed in seconds: 79.15549805633275

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Fly(P2, JFK, ORD)

Load(C4, P2, ORD)

Fly(P1, SFO, ATL)

Load(C3, P1, ATL)

Fly(P1, ATL, JFK)

Unload(C1, P1, JFK)

Unload(C3, P1, JFK)

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

627 628 5176

Plan length: 596 Time elapsed in seconds: 2.452578727144882

Fly(P1, SFO, ORD)

Fly(P2, JFK, ORD)

Fly(P1, ORD, ATL)

Fly(P2, ORD, ATL)

Fly(P1, ATL, JFK)

Fly(P2, ATL, SFO)

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(P1, SFO, ORD)

Fly(P2, JFK, ORD)

Fly(P1, ORD, ATL)

Fly(P2, ORD, ATL)

Fly(P1, ATL, JFK)

Fly(P2, ATL, SFO)

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

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

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

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

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

Unload(C4, 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)

Fly(P1, ORD, ATL)

Fly(P2, ATL, SFO)

Fly(P1, ATL, SFO)

Unload(C3, P1, 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)

Load(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)

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

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

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

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

Solving Air Cargo Problem 3 using uniform_cost_search...

Expansions	Goal Tests	New Nodes
18235	18237	159716

Plan length: 12 Time elapsed in seconds: 38.08794458721839

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

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: 12.540093433964117

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)

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

Expansions Goal Tests New Nodes

316 318 2912

Plan length: 12 Time elapsed in seconds: 361.31819361392354

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(C2, P2, SFO)

Unload(C1, P1, JFK)