

Planning search

Metrics description for different planning solution searches

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Tests summary

This report contains tests result and discussion for three different non-heuristic planning solutions and A-star search with three different heuristics for three cargo-transfer tasks defined in project briefing. Non-heuristic planning solutions tested:

- breadth-first search
- depth-first search
- uniform-cost search

A-star search solutions with following heuristics tested:

- h_1 pseudo-heuristic, that returns constant value of 1 for any planning graph node
- ignore preconditions heuristic
- planning graph level sum heuristic

All test runs finished successfully, exact solutions found, runtime required and some related info provided in relevant sections of this document. By the construction of the algorithm breadth-first search and uniform cost search produced optimal solutions in terms of operations length for the path. Depth-first search produced significantly longer non-optimal paths for all test cases. All A-star searches produced optimal solutions.

Solutions comparison

Optimal plans

Optimal plans lengths for cargo problems 1, 2, 3 are as follows:

Problem No	Optimal path length
1	6
2	9
3	12

Specific examples of optimal paths may be found in the *Non-heuristic solutions / Breadth-first search* section of this document.

Non-heuristic solutions results discussion

Specific results are located in the *Non-heuristic solutions* section of this document.

Breadth-first search (BFS), depth-first search (DFS) and uniform-cost search (UCS) were chosen for non-heuristic solutions comparison.

BFS and UCS both produce optimal paths by the construction of the algorithms but it comes with a price of the number of planning graph vertices visited. Since the graph edges length for UCS is a constant during the

whole computation session UCS and BFS are almost the same in terms of solution construction. The only difference is that the vertices are added to the solution in a different order but based on a same criteria. DFS produce fast and scarce in terms of visited nodes number solution but the paths produced are definitely far from optimal in terms of length.

Heuristic solutions results discussion

Specific results are located in the *Heuristic solutions* section of this document.

A-star search with h_1 (pseudo), ignore preconditions and planning graph level sum heuristics were chosen for heuristic solutions comparison.

All three heuristics produced optimal solutions for all cases, but the time required and number of nodes explored were significantly different.

H_1 pseudoheuristic required maximum amount of added nodes along with expansions and node tests even in comparison with non-heuristic solutions, though it took less computation time among heuristic approaches due to the nature of the algorithm: this pseudo-heuristic does not require any computations (the function just return a 1).

A-star search with level sum heuristic required by an order of magnitude less expansions and new nodes than ignore preconditions, but took up to two orders of magnitude computation time. Time issue is most likely an effect of using non-optimized data structures while traversing a planning graph (Link to relevant discussion on Udacity forums)

A-star search with ignore preconditions and especially level sum heuristic are more efficient than non-heuristic methods in terms of required memory that may be crucial while applying those methods to more complicated tasks than Cargo problem test cases.

Non-heuristic solutions

Breadth-first search

Air Cargo Problem 1

Expansions	Goal Tests	New Nodes
43	56	180

Plan length: 6 Time elapsed in seconds: 0.045186803331299104

Plan produced:

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

Air Cargo problem 2

Expansions	Goal Tests	New Nodes
3346	4612	30534

Plan length: 9 Time elapsed in seconds: 23.348714683500532

Plan produced:

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)

Air Cargo Problem 3

Expansions	Goal Tests	New Nodes
14120	17673	124926

Plan length: 12 Time elapsed in seconds: 124.470103887963

Plan produced:

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

Depth first search

Air Cargo Problem 1

Expansions	Goal Tests	New Nodes
21	22	84

Plan length: 20 Time elapsed in seconds: 0.028018328618808784

Plan produced:

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

Air Cargo Problem 2

Expansions	Goal Tests	New Nodes
107	108	959

Plan length: 105 Time elapsed in seconds: 0.5501376462219696

Plan produced:

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

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

Air Cargo Problem 3

Expansions	Goal Tests	New Nodes
292	293	2388

Plan length: 288 Time elapsed in seconds: 1.532692063256472

Plan produced:

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

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

Uniform cost search

Air Cargo Problem 1

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.09636143442600302

Plan produced:

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

Expansions	Goal Tests	New Nodes
4853	4855	44041

Expansions	Goal Tests	New Nodes
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Plan length: 9 Time elapsed in seconds: 17.599227649561485

Plan produced:

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)

Air Cargo Problem 3

Expansions	Goal Tests	New Nodes
18233	18235	159697

Plan length: 12 Time elapsed in seconds: 70.27345966101211

Plan produced:

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

Heuristic solutions

A-star search with h_1 pseudo-heuristic

Air Cargo Problem 1

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.054725722040685175

Plan produced:

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

Expansions	Goal Tests	New Nodes
4853	4855	44041

Plan length: 9 Time elapsed in seconds: 15.849154030346117

Plan produced:

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)

Air Cargo Problem 3

Expansions	Goal Tests	New Nodes
18233	18235	159697

Plan length: 12 Time elapsed in seconds: 71.06583018395725

Plan produced:

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

A-star search with Ignore preconditions heuristic

Air Cargo Problem 1

Expansions	Goal Tests	New Nodes
41	43	170

Plan length: 6 Time elapsed in seconds: 0.049065529391238163

Plan produced:

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

Air Cargo Problem 2

Expansions	Goal Tests	New Nodes
1428	1430	13085

Plan length: 9 Time elapsed in seconds: 5.579498884066904

Plan produced:

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)

Air Cargo Problem 3

Expansions	Goal Tests	New Nodes
4859	4861	43129

Plan length: 12 Time elapsed in seconds: 21.878993299664558

Plan produced:

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)

A-star search with planning graph level sum heuristic

Air Cargo Problem 1

Expansions	Goal Tests	New Nodes
11	13	50

Plan length: 6 Time elapsed in seconds: 1.1715631668657478

Plan produced:

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

Air Cargo Problem 2

Expansions	Goal Tests	New Nodes
114	116	1120

Plan length: 9 Time elapsed in seconds: 321.423673255422

Plan produced:

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)

Air Cargo Problem 3

Expansions	Goal Tests	New Nodes
309	311	2851

Plan length: 12 Time elapsed in seconds: 1275.4574559883408

Plan produced:

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)