

Heuristic Analysis

Optimal Solutions

	air_cargo_p1	air_cargo_p2	air_cargo_p3
1	Load(C1, P1, SF0)	Load(C1, P1, SF0)	Load(C1, P1, SF0)
2	Fly(P1, SF0, JFK)	Fly(P1, SF0, JFK)	Fly(P1, SF0, ATL)
3	Unload(C1, P1, JFK)	Unload(C1, P1, JFK)	Load(C3, P1, ATL)
4	Load(C2, P2, JFK)	Load(C2, P2, JFK)	Fly(P1, ATL, JFK)
5	Fly(P2, JFK, SF0)	Fly(P2, JFK, SF0)	Unload(C1, P1, JFK)
6	Unload(C2, P2, SF0)	Unload(C2, P2, SF0)	Unload(C3, P1, JFK)
7		Load(C3, P3, ATL)	Load(C2, P2, JFK)
8		Fly(P3, ATL, SF0)	Fly(P2, JFK, ORD)
9		Unload(C3, P3, SF0)	Load(C4, P2, ORD)
10			Fly(P2, ORD, SF0)
11			Unload(C2, P2, SF0)
12			Unload(C4, P2, SF0)

Uninformed Search

breadth_first_search	air_cargo_p1	air_cargo_p2	air_cargo_p3
optimality	✓	✓	✓
time elapsed (s)	0.24	84.01	481.47
# expansions	43	3343	14663
# goal tests	56	4609	18098
plan length	6	9	12

depth_first_graph_search	air_cargo_p1	air_cargo_p2	air_cargo_p3
optimality	✗	✗	✗
time elapsed	0.12	16.32	10.86
# expansions	21	624	408
# goal tests	22	625	409
plan length	20	619	392

depth_limited_search	air_cargo_p1	air_cargo_p2	air_cargo_p3
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optimality	✗	✗	—
time elapsed	0.60	5276.41	(stoped after 3h)
# expansions	101	222719	—
# goal tests	271	2053741	—
plan length	50	50	—

Breadth-first search was the only uninformed algorithm that found optimal solutions for all problems, and ran in a reasonable amount of time. Depth-first search took less time and expansions to find a solution, but the plan length was considerably larger, due to the fact that DFS kept adding actions to the solution until the goal was reached (path length is almost as large as the number of expansions). The worst performing algorithm was Depth limited search, searching deep into the state space, but not deep enough as to brute-force the solution (like DFS). The solutions that DLS was able to find both have the length of 50 (the depth limit of the algorithm).

A* Search

h_ignore_preconditions	air_cargo_p1	air_cargo_p2	air_cargo_p3
optimality	✓	✓	✓
time elapsed	0.23	32.56	124.65
# expansions	41	1421	4589
# goal tests	43	1423	4591
plan length	6	9	12

h_pg_levelsum	air_cargo_p1	air_cargo_p2	air_cargo_p3
optimality	✓	✓	✗
time elapsed	2.10	186.18	744.12
# expansions	11	79	242
# goal tests	13	81	244
plan length	6	9	13

The ignore preconditions heuristic (being a relaxed version of the original problem, and thus - admissible [1]) was guaranteed to find the optimal solution for all problems. It was able to find a solution faster than using a planning graph and with levelsum heuristic, which did not find an optimal solution for all problems (the heuristic is not admissible [1]). However, using levelsum resulted in considerably fewer expansions, but the time spent computing the heuristic for each expansion cancels that.

Conclusions

The heuristic that yielded the best results was ignore preconditions. Compared to non-heuristic search, it expanded less nodes than BFS, but still found optimal solutions for each problem (compared to DFS). While planning graph and with levelsum heuristic solution for the third problem was not optimal, it was very close (1 extra action on solution) while expanding fewer nodes than any other search algorithm.