

Heuristic Analysis

This analysis compares the performance of the algorithms in the *Air Cargo Problems*, including optimality, time elapsed, and number of node expansions required. See results on Fig. 1, 2 & 3.

Fig. 1. Air Cargo Problem 1 Results Table

Search	Length	Expansions	Goal Tests	New Nodes	Time (sec)	Optimal
BREATH FIRST	6	43	56	180	0.048	Yes
DEPTH FIRST GRAPH	20	21	22	84	0.019	No
UNIFORM COST	6	55	57	224	0.059	Yes
A* H1	6	55	57	224	0.060	Yes
A* IGNORE PRECOND	6	41	43	170	0.063	Yes
A* LEVEL SUM	6	11	13	50	5.352	Yes

Fig. 2. Air Cargo Problem 2 Results Table

Search	Length	Expansions	Goal Tests	New Nodes	Time (sec)	Optimal
BREATH FIRST	9	3343	4609	30509	18.501	Yes
DEPTH FIRST GRAPH	619	624	625	5602	4.524	No
UNIFORM COST	9	4852	4854	44030	59.717	Yes
A* H1	9	4852	4854	44030	63.208	Yes
A* IGNORE PRECOND	9	1506	1508	13820	20.498	Yes
A* LEVEL SUM	9	86	88	841	1196.907	Yes

Fig. 3. Air Cargo Problem 3 Results Table

Search	Length	Expansions	Goal Tests	New Nodes	Time (sec)	Optimal
BREATH FIRST	12	14663	18098	129631	140.925	Yes
DEPTH FIRST GRAPH	392	408	409	3364	2.355	No
UNIFORM COST	12	18235	18237	159716	530.175	Yes
A* H1	12	18235	18237	159716	642.133	Yes
A* IGNORE PRECOND	12	5118	5120	45650	121.807	Yes
A* LEVEL SUM	12	404	406	3718	8736.479	Yes

Non-Heuristic Search Strategies

Even though all three non-heuristic strategies (BFS¹, DFGS² and UCS³) do find a solution for the air cargo problems, only BFS and UCS are optimal strategies and produce the shortest path. With DFGS out of contention due to lack of optimality, our results show that BFS is the best non-heuristic strategy to solve all three problems (based on the time elapsed).

It's worth noting that DFGS have small memory requirements and is considerably faster than BFS and UCS, making it suitable for solving problems where optimality is not critical, as long as there's no need to keep track of the explored nodes.

Heuristic Search Strategies

All three heuristic strategies are optimal and complete. Based on the time elapsed, we can conclude that *A*⁴ Search with ignore preconditions* is the best strategy, as it relaxes the problem making it easier to solve. However, note that it only outperforms BFS in the third problem.

The time complexity of *A* Search with level sum* is just too costly.

Conclusion:

Considering problems 1 and 2 are quite simple, with small state spaces, a non-heuristic approach such as BFS is all there's needed to reach a satisfactory solution. However, for more complex problems, finding a good plan can be too expensive without an heuristic strategy.

Fig. 4. Best Search Strategies for each Air Cargo Problem

PROBLEM 1	PROBLEM 2	PROBLEM 3
Best Strategy - length 6: BREATH FIRST SEARCH	Best Strategy - length 9: BREATH FIRST SEARCH	Best Strategy - length 12: A* W/ IGNORE PRECOND
Load(C1, P1, SFO) Load(C2, P2, JFK) Fly(P2, JFK, SFO) Unload(C2, P2, SFO) Fly(P1, SFO, JFK) Unload(C1, P1, JFK)	Load(C1, P1, SFO) Load(C2, P2, JFK) 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)	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)

¹ BFS - Breath First Search

² DFGS - Depth First Graph Search

³ UCS - Uniform Cost Search

⁴ A* - A Star