

# Heuristic Analysis

## Results from three problems

*Note: The optimal plans are fully displayed in the detailed column of the three table*

### Problem 1

Search Function	Expan -sions	Goal tests	New nodes	Plan length	Detailed plan	Time (s)
breadth_first_search	43	56	180	6	Load(C1, P1, SFO) Load(C2, P2, JFK) Fly(P2, JFK, SFO) Unload(C2, P2, SFO) Fly(P1, SFO, JFK) Unload(C1, P1, JFK)	0.0304 169299 779459 83
depth_first_graph_search	21	22	84	20	...	0.0114 725999 883376 06
uniform_cost_search	55	57	224	6	Load(C1, P1, SFO) Load(C2, P2, JFK) Fly(P1, SFO, JFK) Fly(P2, JFK, SFO) Unload(C1, P1, JFK) Unload(C2, P2, SFO)	0.0291 052620 159462 1
greedy_best_first_graph_search h_1	7	9	28	6	Load(C1, P1, SFO) Load(C2, P2, JFK) Fly(P1, SFO, JFK) Fly(P2, JFK, SFO) Unload(C1, P1, JFK) Unload(C2, P2, SFO)	0.0044 334889 971651 14
astar_search h_1	55	57	224	6	Load(C1, P1, SFO) Load(C2, P2, JFK) Fly(P1, SFO, JFK) Fly(P2, JFK, SFO) Unload(C1, P1, JFK) Unload(C2, P2, SFO)	0.0331 617449 992336 3
astar_search h_ignore_preconditions	41	43	170	6	Load(C1, P1, SFO) Fly(P1, SFO, JFK) Unload(C1, P1, JFK) Load(C2, P2, JFK) Fly(P2, JFK, SFO)	0.0293 550979 986321 18

					Unload(C2, P2, SFO)	
astar_search h_pg_levelsum	11	13	50	6	Load(C1, P1, SFO) Fly(P1, SFO, JFK) Load(C2, P2, JFK) Fly(P2, JFK, SFO) Unload(C1, P1, JFK) Unload(C2, P2, SFO)	0.7615 637669 805437

## Problem 2

Search Function	Expan- sions	Goal tests	New nodes	Plan length	Detailed plan	Time (s)
breadth_first_search	3343	4609	30509	9	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)	9.5473 64213 99866 2
depth_first_graph_search	624	625	5602	619	...	2.5040 53176 00234 4
uniform_cost_search	4852	4854	44030	9	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)	8.8834 82015 98273 6
greedy_best_first_graph_search h_1	990	992	8910	17	...	1.8944 03789 01781 51
astar_search h_1	4852	4854	44030	9	Load(C1, P1, SFO) Load(C2, P2, JFK)	9.5081 61014

					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)	00414 5
astar_search h_ignore_preconditions	1450	1452	13303	9	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)	3.3077 44445 01730 6
astar_search h_pg_levelsum	86	88	841	9	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)	124.48 65894 92997 15

## Problem 3

Search Function	Expan- sions	Goal tests	New nodes	Plan length	Detailed plan	Time (s)
breadth_first_search	14663	1809 8	12963 1	12	Load(C1, P1, SFO) Load(C2, P2, JFK) 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)	76.299 49170 70027 4
depth_first_graph_search	408	409	3364	392	...	1.4178 02669

						02060 25
uniform_cost_search	18235	1823 7	15971 6	12	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)	40.788 48320 49894 6
greedy_best_first_graph_search h_1	5614	5616	49429	22	...	14.084 16130 90015 02
astar_search h_1	18235	1823 7	15971 6	12	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)	41.199 34570 70202 6
astar_search h_ignore_preconditions	5014	5042	44944	12	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)	12.900 95620 40155 29

astar_search h_pg_levelsum	...	...	...	...	...	Too long!
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## Non-heuristic search methods analysis

The three non-heuristic search methods tested are Breadth First Search, Depth First Graph Search and Uniform Cost Search.

In all three problems, the three methods are able to return a solution with acceptable time.

- Depth First Graph Search achieves the best speed of all three methods and of all methods tested here but does not guarantee optimality due to the way it works (expanding the node and explore the first child first, recursively) [1].
- Breadth First Search and Uniform Cost Search takes more time to find the solution comparing with Depth First Graph Search. However, in returns, they always give the optimal solutions, (given the step cost is identical for the case of Breadth First Search) [1].

## Heuristic search methods analysis

The four heuristic search methods tested are Greedy Best First Graph Search with  $h_1$ , A\* Search with  $h_1$ , A\* Search with  $h_{\text{ignore\_preconditions}}$  and A\* search with  $h_{\text{pg\_levelsum}}$ . Except from Greedy Best First Search, which as the name says it all, only finds the local maxima solution, which may or may not be an optimal solution, other methods successfully finds the optimal solution due to the fact that the A\* will guarantee the optimality if the heuristic function is admissible and consistent [1].

## Conclusion

It points out from the results of three problems that as the complexity of the problem grows, heuristic plays a more and more important part in finding the optimal solution in reasonable amount of time.

## Reference

[1] Peter Norvig and Stuart J. Russell, **Artificial Intelligence: A Modern Approach**, 3<sup>rd</sup> edition.