

## Heuristic Analysis

### Solutions all 3 problems:

Problem 1 Solution:

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

Problem 2 Solution:

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

Problem 3 Solution:

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(C1, P1, JFK)  
Unload(C2, P2, SFO)  
Unload(C3, P1, JFK)  
Unload(C4, P2, SFO)

## Non-heuristic search result metrics

Algorithm used	Problem	Expansions	Goal Tests	New Nodes	Plan length	Time	Is Optimal Solution
Breath First Search (BFS)	1	43	56	180	6	0.162692781	Yes
BFS	2	3343	4609	30509	9	53.54991759	Yes
BFS	3	14663	18098	128551	12	313.766296	Yes
Uniform Cost Search (UCS)	1	55	57	224	6	0.202693804	Yes
UCS	2	4853	4855	44041	9	69.99976728	Yes
UCS	3	18151	18153	157616	12	316.2943911	Yes
Depth First Graph Search (DFGS)	1	12	13	48	12	0.046710741	No
DFGS	2	582	583	5811	575	9.430785943	No
DFGS	3	627	628	5176	596	13.46314095	No

The DFGS takes the shortest time to find a solution for all 3 problems. However, they are not the optimal solutions. Both BFS and UCS find the optimal solutions.

In the aspect of execution time, DFGS has the least execution time, BFS is the second, and UCS is the third.

In the aspect of the expanded node, DFGS has the lowest expanded nodes, BFS is the second, and UCS is the third.

## A\* search with heuristics

a* Heuristic	Problem	Expansions	Goal Tests	New Nodes	Plan length	Time	Is Optimal Solution
h <sub>1</sub>	1	55	57	224	6	0.211212962	Yes
h <sub>1</sub>	2	4853	4855	44041	9	70.9125615	Yes
h <sub>1</sub>	3	18151	18153	157616	12	320.3799815	Yes
h <sub>ignore_preconditions</sub>	1	55	57	224	6	0.206694425	Yes
h <sub>ignore_preconditions</sub>	2	4853	4855	44041	9	67.97921701	Yes

h_ignore_preconditions	3	18151	18153	157616	12	326.0243982	Yes
h_pg_levelsum	1	11	13	50	6	0.531227899	Yes
h_pg_levelsum	2	86	88	841	9	42.53313228	Yes
h_pg_levelsum	3	395	397	3578	12	292.5049591	Yes

The h\_1 heuristic and h\_ignore\_preconditions heuristic have very similar performance in terms of execution time, expansion,

Levelsum heuristic requires fewer expansions and new nodes. However, the heuristic has more complicated computation tasks which balance out its execution time. Comparing to none-heuristic search algorithms, a\* search with level sum heuristic is also slightly faster and always find the optimal solutions with fewer expansions and new nodes.

Overall, a\* search with levels heuristic is the best option to find the optimal solution in the cases I have observed.