# Heuristic Analysis

## Heuristics

Among the non-heuristic methods, BFS and UCS perform similarly with UCS expanding more nodes but getting a better time. DFG is the fastest and expand less nodes but it does not provided an optimal solution.

Among the heuristic methods, A\* ignore preconditions is the fastest. It also expands more nodes that A\* level sum although less than A\* h\_1. A\* level sum expands fewer nodes than the others do but it is very slow.

Comparing all we can observe that, for small problems (problem 1), heuristic and non-heuristic methods performance are similar. However, with bigger problems, non-heuristic methods perform worse, both in time elapsed and nodes expanded.

Besides, it is important to notice the difference between heuristic. Like the metrics for ignore precondition and level sum show for the second problem, one heuristic can run more than twenty times faster than other do although expanding many more nodes.

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| --- | --- | --- | --- | --- | --- |
| Air Cargo Problem 1 | Optimal? | Time Elapsed (s) | Node Expansions | Goal Tests | Path Length |
| Breadth First Search | YES | 0.045 | 43 | 56 | 6 |
| Breadth First Tree Search | YES | 1.402 | 1458 | 1459 | 6 |
| Depth First Graph Search | NO | 0.012 | 12 | 13 | 12 |
| Depth Limited Search | NO | 0.14 | 101 | 271 | 50 |
| Uniform Cost Search | YES | 0.059 | 55 | 57 | 6 |
| Recursive Best First Search | YES | 4.176 | 4229 | 4230 | 6 |
| Greedy Best First Graph Search | YES | 0.008 | 7 | 9 | 6 |
| A\* h\_1 | YES | 0.061 | 55 | 57 | 6 |
| A\* h\_ignore\_preconditions | YES | 0.06 | 41 | 43 | 6 |
| A\* h\_pg\_levelsum | YES | 1.103 | 11 | 13 | 6 |

## Optimal Solution

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

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| --- | --- | --- | --- | --- | --- |
| Air Cargo Problem 2 | Optimal? | Time Elapsed (a) | Node Expansions | Goal Tests | Path Length |
| Breadth First Search | YES | 18.589 | 3343 | 4609 | 9 |
| Breadth First Tree Search |  | >10min | -- | -- | -- |
| Depth First Graph Search | NO | 4.533 | 582 | 583 | 575 |
| Depth Limited Search |  | >10min | -- | -- | -- |
| Uniform Cost Search | YES | 17.264 | 4852 | 4854 | 9 |
| Recursive Best First Search |  | >10min | -- | -- | -- |
| Greedy Best First Graph Search | NO | 3.406 | 990 | 992 | 15 |
| A\* h\_1 | YES | 17.344 | 4852 | 4854 | 9 |
| A\* h\_ignore\_preconditions | YES | 6.355 | 1450 | 1452 | 9 |
| A\* h\_pg\_levelsum | YES | 159.318 | 86 | 88 | 9 |

## Optimal Solution

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

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| --- | --- | --- | --- | --- | --- |
| Air Cargo Problem 3 | Optimal? | Time Elapsed (s) | Node Expansions | Goal Tests | Path Length |
| Breadth First Search | YES | 140.976 | 14663 | 18098 | 12 |
| Breadth First Tree Search |  | >10min | -- | -- | -- |
| Depth First Graph Search | NO | 4.352 | 627 | 628 | 596 |
| Depth Limited Search |  | >10min | -- | -- | -- |
| Uniform Cost Search | YES | 74.658 | 18235 | 18237 | 12 |
| Recursive Best First Search |  | >10min | -- | -- | -- |
| Greedy Best First Graph Search | NO | 23.483 | 5614 | 5616 | 22 |
| A\* h\_1 | YES | 78.374 | 18235 | 18237 | 12 |
| A\* h\_ignore\_preconditions | YES | 25.781 | 5040 | 5042 | 12 |
| A\* h\_pg\_levelsum | YES | 776.59 | 315 | 317 | 12 |

## Optimal Solution

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