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) | 0.030416929977945983 |
| depth\_first\_graph\_search | 21 | 22 | 84 | 20 | … | 0.011472599988337606 |
| 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) | 0.02910526201594621 |
| 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) | 0.004433488997165114 |
| 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) | 0.03316174499923363 |
| 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)  Unload(C2, P2, SFO) | 0.029355097998632118 |
| 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) | 0.7615637669805437 |

## 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) | 9.547364213998662 |
| depth\_first\_graph\_search | 624 | 625 | 5602 | 619 | … | 2.504053176002344 |
| 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) | 8.883482015982736 |
| greedy\_best\_first\_graph\_search h\_1 | 990 | 992 | 8910 | 17 | … | 1.8944037890178151 |
| astar\_search h\_1 | 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) | 9.508161014004145 |
| 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) | 3.307744445017306 |
| 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) | 124.48658949299715 |

## Problem 3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Search Function | Expan  -sions | Goal tests | New nodes | Plan length | Detailed plan | Time  (s) |
| breadth\_first\_search | 14663 | 18098 | 129631 | 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) | 76.29949170700274 |
| depth\_first\_graph\_search | 408 | 409 | 3364 | 392 | … | 1.4178026690206025 |
| uniform\_cost\_search | 18235 | 18237 | 159716 | 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) | 40.78848320498946 |
| greedy\_best\_first\_graph\_search h\_1 | 5614 | 5616 | 49429 | 22 | … | 14.084161309001502 |
| astar\_search h\_1 | 18235 | 18237 | 159716 | 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) | 41.19934570702026 |
| 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) | 12.900956204015529 |
| astar\_search h\_pg\_levelsum | … | … | … | … | … | Too long! |

# 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\_ignore\_preconditions and A\* search with h\_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***, 3rd edition.