**Air Cargo Problem Result Analysis**

The paper contains non-heuristic search(breadth\_first\_search, depth\_first\_search and uniform\_cost\_search) and heuristic search(astar\_search *with,*h\_ignore\_preconditions,h\_pg\_levelsum) results of Air cargo problem.

**AIR CARGO PROBLEM 1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Method | expansions | goal tests | New Nodes | Length | time elapsed | optimality of solution |
| breadth\_first\_search | 43 | 56 | 180 | 6 | 0.03 | true |
| depth\_first\_graph\_search | 12 | 13 | 48 | 12 | 0.02 | false |
| uniform\_cost\_search | 55 | 57 | 224 | 6 | 0.047 | true |
| astar\_search with h\_1 | 55 | 57 | 224 | 6 | 0.043 | true |
| astar\_search with h\_ignore\_preconditions | 41 | 43 | 170 | 6 | 0.038 | true |
| astar\_search with h\_pg\_levelsum | 11 | 13 | 50 | 6 | 1.155 | true |

**AIR CARGO PROBLEM 2**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Method | expansions | goal tests | New Nodes | Length | time elapsed | optimality of solution |
| breadth\_first\_search | 477 | 1110 | 4317 | 6 | 1.524 | true |
| depth\_first\_graph\_search | 322 | 333 | 2964 | 328 | 1.312 | false |
| uniform\_cost\_search | 1670 | 1672 | 15294 | 6 | 3.745 | true |
| astar\_search with h\_1 | 1670 | 1672 | 15294 | 6 | 3.725 | true |
| astar\_search with h\_ignore\_preconditions | 17 | 19 | 162 | 6 | 52.779 | true |
| astar\_search with h\_pg\_levelsum | 14491 | 17947 | 128184 | 12 | 99.28 | false |

**AIR CARGO PROBLEM 3**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Method | expansions | goal tests | New Nodes | Length | time elapsed | optimality of solution |
| breadth\_first\_search | 14491 | 17947 | 128184 | 12 | 99.28 | true |
| depth\_first\_graph\_search | 1948 | 1949 | 16253 | 1878 | 19.153 | false |
| uniform\_cost\_search | 17783 | 17785 | 155920 | 12 | 51.9 | true |
| astar\_search with h\_1 | 17783 | 17785 | 155920 | 12 | 53.86 | true |
| astar\_search with h\_ignore\_preconditions | 5003 | 5005 | 44586 | 12 | 17.6 | true |
| astar\_search with h\_pg\_levelsum | - | - | - | - | >10 min | - |

Depth\_first\_ graph search always gives the shortest time elapsed with fewest expansions and goal tests, but can’t reach the optimal solution because it doesn’t consider which nodes are better options, it just search as deep as it can(Norvig and Russell’s).On the other hand, breadth\_first\_search and uniform\_cost search can get the optimal solustion with more expansions, goal tests and longer time elapsed. The uniform\_cost\_search usually gets slightly more expansion nodes, goal tests time.

All heuristic search can make sure the optimality of the solution. According to their performance on expansions, goal tests and time elapsed. Astar\_ searh with h\_ignore\_precondition seems to perform better on more complex problems than h\_1 and h\_pg\_levelsum does. The time elaspsed for h\_pg\_levelsum dramatically increase with the increasing complexity of the problem and it can’t find the solution within 10 minutes for the problem 3. It was slow because the high cost of the calculation of the heuristic(Norvig and Russell’s).

The best heuristic used in the problem are highlighted in green and the best searching plans are highlighted in yellow. As the results show, only in problem 3 the heuristic perform better than the no\_heuristic because the heuristic searching methods like astar\_h1 and h\_ignore are observed to be more good at solving complex problems. In other words, breadth\_first\_search should be always the first option to try, considering its efficiency and optimality on solving simple problems. When the problems become more complex, h1 and h\_ignore should be considered.

**Optimal Plans**

Air Cargo Problem 1 using breadth\_first\_search

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Air Cargo Problem 2 using breadth\_first\_search

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Air Cargo Problem 3 using astar\_search with h\_ignore\_preconditions

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)

**Reference:**

1. **Stuart. Russell,Peter Norvig(2010), Artificial intelligence: Amodern Approach**