1. Problem 1

a) non-heuristic search

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | BFS | Depth\_first\_graph | Uniform\_cost | Greedy\_best\_first\_graph |
| Expansion | 43 | 21 | 55 | 7 |
| Goal tests | 56 | 22 | 57 | 9 |
| New nodes | 180 | 84 | 224 | 28 |
| Time\_elapsed | 0.042 (s) | 0.018 | 0.050 | 0.006 |
| Plan length | 6 | 20 | 6 | 6 |
| Optimality | yes | no | yes | Yes. best |

b) heuristic search

|  |  |  |
| --- | --- | --- |
|  | H\_ignore\_preconditions | H\_pg\_levelsum |
| Expansion | 41 | 11 |
| Goal tests | 43 | 13 |
| New nodes | 170 | 50 |
| Time\_elapsed | 0.039 (s) | 0.079 |
| Plan length | 6 | 6 |
| Optimality | Yes. | Yes. Slightly better in expansion. |

The optimal actions are:

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

2. Problem 2

a) non-heuristic search

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | BFS | Depth\_first\_graph | Uniform\_cost | Greedy\_best\_first\_graph |
| Expansion | 3343 | 624 | 4853 | 998 |
| Goal tests | 4609 | 625 | 4855 | 1000 |
| New nodes | 30509 | 5602 | 44041 | 8972 |
| Time\_elapsed | 24.7 (s) | 6.10 | 24.5 | 4.8 |
| Plan length | 9 | 619 | 9 | 15 |
| Optimality | yes | no | yes | no |

b) heuristic search

|  |  |  |
| --- | --- | --- |
|  | H\_ignore\_preconditions | H\_pg\_levelsum |
| Expansion | 1450 | 86 |
| Goal tests | 1452 | 88 |
| New nodes | 13303 | 841 |
| Time\_elapsed | 7.44 (s) | 68.69 |
| Plan length | 9 | 9 |
| Optimality | Better in search time | Better in expansion |

The optimal actions are:

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)

2. Problem 3

a) non-heuristic search

|  |  |  |  |
| --- | --- | --- | --- |
|  | Breadth\_first | Depth\_first\_graph | Uniform\_cost |
| Expansion | 14663 | 408 | 18223 |
| Goal tests | 18098 | 409 | 18225 |
| New nodes | 129631 | 3364 | 159618 |
| Time\_elapsed | 186 (s) | 3.5 | 119 |
| Plan length | 12 | 392 | 12 |
| Optimality | yes | no | yes |

b) heuristic search

|  |  |  |
| --- | --- | --- |
|  | H\_ignore\_preconditions | H\_pg\_levelsum |
| Expansion | 5040 | 313 |
| Goal tests | 5042 | 315 |
| New nodes | 44944 | 2884 |
| Time\_elapsed | 34 (s) | 325 |
| Plan length | 12 | 12 |
| Optimality | Better in search time | Better in expansion |

The optimal actions are:

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(C4, P2, SFO)

Unload(C3, P1, JFK)

Unload(C2, P2, SFO)

Unload(C1, P1, JFK)

Summary:

a) Non-heuristic search has comparable (sometimes even better) performance in problem 1 as heuristic search – the reason is that problem 1 is very simple so brute force method works well. Another thing to note is that depth-first search could not guarantee optimal solution – depth-first search may look for longer path first and is not optimal as explained in the video in lesson 8.23 “search comparison”. In more complex problems 2 & 3, heuristic search methods are much better in both optimality and expansion of search.

b) For the two heuristic searches, ignore\_preconditions heuristic usually searches with larger expansion of nodes, and still achieves the goal with much less time. The reason is that it does not need to create the planning graph and the heuristic is much cheaper to compute, as discussed in Russel&Norvig 10.2.3. The planning graph with level sum heuristic has the advantage of smaller expansion, but uses longer time due to computation of creating planning graph and level sums. As the problem gets more complicated – with more planes/airports/cargos, the planning graph with level sum will probably be a better choice due to its better expansion performance and the overhead of creating planning graph may be compensated.