Heuristic Analysis

**Problem 1 initial state and goal: [Cargo - 2, Airports - 2, Planes - 2]**

Init(At(C1, SFO) ∧ At(C2, JFK)

∧ At(P1, SFO) ∧ At(P2, JFK)

∧ Cargo(C1) ∧ Cargo(C2)

∧ Plane(P1) ∧ Plane(P2)

∧ Airport(JFK) ∧ Airport(SFO))

Goal(At(C1, JFK) ∧ At(C2, SFO))

Search Results:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Algorithm** | **Nodes Expanded** | **Goal Test** | **New Nodes** | **Plan length** | **Time in seconds** |
| breadth\_first\_search | 43 | 56 | 180 | 6 | 0.749 |
| breadth\_first\_tree\_search | 1458 | 1459 | 5960 | 6 | 2.289 |
| depth\_first\_graph\_search | 12 | 13 | 48 | 12 | 0.221 |
| depth\_limited\_search | 101 | 271 | 414 | 50 | 0.2209 |
| uniform\_cost\_search | 55 | 57 | 224 | 6 | 0.1055 |
| recursive\_best\_first\_search h\_1 | 4229 | 4230 | 17029 | 6 | 6.437 |
| greedy\_best\_first\_graph\_search h\_1 | 7 | 9 | 28 | 6 | 0.119 |
| astar\_search h\_1 | 55 | 57 | 224 | 6 | 0.1051 |
| astar\_search h\_ignore\_preconditions | 41 | 43 | 170 | 6 | 0.1014 |
| astar\_search h\_pg\_levelsum | 11 | 13 | 50 | 6 | 2.001 |

**Problem 2 initial state and goal: [Cargo - 3, Airports - 3, Planes - 3]**

Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL)

∧ At(P1, SFO) ∧ At(P2, JFK) ∧ At(P3, ATL)

∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3)

∧ Plane(P1) ∧ Plane(P2) ∧ Plane(P3)

∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL))

Goal(At(C1, JFK) ∧ At(C2, SFO) ∧ At(C3, SFO))

Search Results:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Algorithm** | **Nodes Expanded** | **Goal Test** | **New Nodes** | **Plan length** | **Time in seconds** |
| breadth\_first\_search | 3343 | 4609 | 30509 | 9 | 21.854 |
| breadth\_first\_tree\_search | - | - | - | - | timeout |
| depth\_first\_graph\_search | 582 | 583 | 5211 | 575 | 7.456 |
| depth\_limited\_search | - | - | - | - | timeout |
| uniform\_cost\_search | 4853 | 4855 | 44041 | 9 | 15.3959 |
| recursive\_best\_first\_search h\_1 | - | - | - | - | timeout |
| greedy\_best\_first\_graph\_search h\_1 | 998 | 1000 | 8982 | 13 | 6.0061 |
| astar\_search h\_1 | 4853 | 4855 | 44041 | 9 | 29.1073 |
| astar\_search h\_ignore\_preconditions | 1450 | 1452 | 13303 | 9 | 18.6803 |
| astar\_search h\_pg\_levelsum | 86 | 88 | 841 | 9 | 181.9675 |

**Problem 3 initial state and goal: [Cargo - 4, Airports - 4, Planes - 2]**

Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL) ∧ At(C4, ORD)

∧ At(P1, SFO) ∧ At(P2, JFK)

∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3) ∧ Cargo(C4)

∧ Plane(P1) ∧ Plane(P2)

∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL) ∧ Airport(ORD))

Goal(At(C1, JFK) ∧ At(C3, JFK) ∧ At(C2, SFO) ∧ At(C4, SFO))

Search Results:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Algorithm** | **Nodes Expanded** | **Goal Test** | **New Nodes** | **Plan length** | **Time in seconds** |
| breadth\_first\_search | 14663 | 18098 | 129631 | 12 | 196.91 |
| breadth\_first\_tree\_search | - | - | - | - | timeout |
| depth\_first\_graph\_search | 627 | 628 | 5176 | 596 | 14.3278 |
| depth\_limited\_search | - | - | - | - | timeout |
| uniform\_cost\_search | 18223 | 18225 | 159618 | 12 | 68.365 |
| recursive\_best\_first\_search h\_1 | - | - | - | - | timeout |
| greedy\_best\_first\_graph\_search h\_1 | 5579 | 5581 | 49159 | 22 | 63.2218 |
| astar\_search h\_1 | 18223 | 18225 | 159618 | 12 | 159.08988 |
| astar\_search h\_ignore\_preconditions | 5040 | 5042 | 44944 | 12 | 230.2545 |
| astar\_search h\_pg\_levelsum | 324 | 326 | 2993 | 12 | 1208.524 |

**Comparison:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Algorithm** | **Problem** | **Nodes Expanded** | **Goal Test** | **New Nodes** | **Plan length** | **Time in seconds** |
| breadth\_first\_search | 1 | 43 | 56 | 180 | 6 | 0.749 |
| 2 | 3343 | 4609 | 30509 | 9 | 21.854 |
| 3 | 14663 | 18098 | 129631 | 12 | 196.91 |
| depth\_first\_graph\_search | 1 | 12 | 13 | 48 | 12 | 0.221 |
| 2 | 582 | 583 | 5211 | 575 | 7.456 |
| 3 | 627 | 628 | 5176 | 596 | 14.3278 |
| uniform\_cost\_search | 1 | 55 | 57 | 224 | 6 | 0.1055 |
| 2 | 4853 | 4855 | 44041 | 9 | 15.3959 |
| 3 | 18223 | 18225 | 159618 | 12 | 68.365 |
| astar\_search [h\_ignore\_preconditions] | 1 | 41 | 43 | 170 | 6 | 0.1014 |
| 2 | 1450 | 1452 | 13303 | 9 | 18.6803 |
| 3 | 5040 | 5042 | 44944 | 12 | 230.2545 |
| astar\_search [level-sum] | 1 | 11 | 13 | 50 | 6 | 2.001 |
| 2 | 86 | 88 | 841 | 9 | 181.9675 |
| 3 | 324 | 326 | 2993 | 12 | 1208.524 |

By comparing all the three problems with other searches we see

* Breath First Search (BFS): Shortest way to reach the goal, but it takes more compared to the other searches.
* Depth First Search (DFS): Faster compared to the breath first search, but it takes more length to reach the goal, not an optimal solution.
* Uniform Cost Search (UCS): Comparing with BFS and DFS for the given problem this search will be optimal.
* A\* Search: Ignore precondition needs more expansion compared to the level-sum.

For better heuristics negative effects of the problem makes more complicated so removing will easier to calculate.

**Optimal Solution:**

Problem1:

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

Problem2:

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(C2, P2, SFO)

Unload(C1, P1, JFK)

Problem3:

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)