**Heuristic Analysis**

This project to solve deterministic logistics planning problems for an Air Cargo transport system using a planning search agent (AI: A Modern Approach by Norvig And Russel) given classical PDDL. The goal of this project run both uninformed non heuristic and domain independent heuristic with A\* search and obtain an optimal and fastest solution for this problem.

All problems are in the Air Cargo domain. They have the same action schema.

* Air Cargo Action Schema:

Action(Load(c, p, a), PRECOND: At(c, a) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a) EFFECT: ¬ At(c, a) ∧ In(c, p)) Action(Unload(c, p, a), PRECOND: In(c, p) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a) EFFECT: At(c, a) ∧ ¬ In(c, p)) Action(Fly(p, from, to), PRECOND: At(p, from) ∧ Plane(p) ∧ Airport(from) ∧ Airport(to) EFFECT: ¬ At(p, from) ∧ At(p, to))

* Problem 1 initial state and goal:

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))

* Problem 2 initial state and goal:

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))

* Problem 3 initial state and goal:

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))

**Uninformed Non-heuristic Search Analysis:**

The Uninformed non-heuristic search agent ran with Breadth first search (BFS), and Depth first search (DFS) and Uniform cost search (UCS) . Here results table.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Search Type | Expansions | Goal Tests | New Nodes | Path Length | Execution Time (s) | Optimal |
| P1 | BFS | 43 | 56 | 180 | 6 | 0.029 | YES |
| P1 | DFS | 101 | 271 | 414 | 50 | 0.074 | NO |
| P1 | UCS | 55 | 57 | 224 | 6 | 0.030 | YES |
| P2 | BFS | 3343 | 4609 | 30509 | 9 | 2.369 | YES |
| P2 | DFS | 624 | 625 | 5602 | 619 | 0.033 | NO |
| P2 | UCS | 4843 | 4855 | 44041 | 9 | 0.038 | YES |
| P3 | BFS | 14663 | 18098 | 129631 | 12 | 90.39 | YES |
| P3 | DFS | 408 | 409 | 3364 | 392 | 1.53 | NO |
| P3 | UCS | 18223 | 18225 | 159618 | 12 | 44.59 | YES |

Comparison between search agents for Uninformed Non-heuristic

* Node Expansion: Depth First Search (DFS) taking less memory compare to BFS and UCS, because expanding less nodes. UCS > BFS > DFS
* Execution Time: Depth First Search (DFS) is faster than BFS and UCS. UCS > BFS > DFS
* Optimal: Based on Path length (P1->6, P2->9, P3->12) Breadth First Search (BFS) And Uniform cost search (UCS) is provide optimal action plan. DFS not provide optimal action plan based on path lengths 50,619,392 instead of 6,9,12.

Based on factor (memory, Time, Optimal) Breadth First Search (BFS) is recommended uninformed non-heuristic search agent,

**Domain independent heuristic with A\* Search Analysis:**

The domain independent heuristic with A\* search agent ran with

* Greedy\_best\_first\_graph\_search with h\_1
* A \* Search h\_1
* A\* Search h\_ignore\_preconditions
* A\* Search h\_pg\_levelsum

Here results table.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Problem | Search Type | Expansions | Goal Tests | New Nodes | Path Length | Execution Time (s) | Optimal |
| P1 | Greedy\_best\_first\_graph\_search with h\_1 | 7 | 9 | 28 | 6 | 0.004 | YES |
| P1 | A \* Search h\_1 | 55 | 57 | 224 | 6 | 0.033 | YES |
| P1 | A\* Search h\_ignore\_preconditions | 41 | 43 | 170 | 6 | 0.032 | YES |
| P1 | A\* Search h\_pg\_levelsum | 11 | 13 | 50 | 6 | 0.038 | YES |
|  |  |  |  |  |  |  |  |
| P2 | Greedy\_best\_first\_graph\_search with h\_1 | 998 | 1000 | 8982 | 9 | 2.07 | YES |
| P3 | A \* Search h\_1 | 4853 | 4855 | 44041 | 9 | 10.07 | YES |
| P3 | A\* Search h\_ignore\_preconditions | 1450 | 1452 | 13303 | 9 | 3.63 | YES |
| P3 | A\* Search h\_pg\_levelsum | 86 | 88 | 841 | 9 | 29.32 | YES |
|  |  |  |  |  |  |  |  |
| P3 | Greedy\_best\_first\_graph\_search with h\_1 | 5577 | 5579 | 49141 | 21 | 13.80 | NO |
| P3 | A \* Search h\_1 | 18223 | 18225 | 159618 | 12 | 44.70 | YES |
| P3 | A\* Search h\_ignore\_preconditions | 5040 | 5042 | 44994 | 12 | 14.39 | YES |
| P3 | A\* Search h\_pg\_levelsum | 328 | 330 | 3032 | 12 | 145.62 | YES |

Comparison between search agents for domain independent heuristic with A\* search

* Node Expansion: A\* Search h\_pg\_levelsum taking less memory compare to BFS and UCS, because expanding less nodes. UCS > BFS > DFS
* Execution Time: Depth First Search (DFS) is faster than BFS and UCS. UCS > BFS > DFS
* Optimal: Based on Path length (P1->6, P2->9, P3->12) Breadth First Search (BFS) And Uniform cost search (UCS) is provide optimal action plan. DFS not provide optimal action plan based on path lengths 50,619,392 instead of 6,9,12.

Based on factor (memory, Time, Optimal) Breadth First Search (BFS) is recommended uninformed non-heuristic search agent,