**Planning Search Analysis**

1. **Problem Analysis**

This report describes the analysis of different state-space search methods applied to three different situations of Air Cargo Planning Problem, described with the Planning Domain Definition Language. The description of the problems is the following:

PROBLEM 1

Planes: P1, P2 Cargos: C1, C2 Airports: JFK, SFO

Initial state: *At(C1, SFO), At(C2, JFK), At(P1, SFO), At(P2, JFK)*

Goal: *At(C1, JFK), At(C2, SFO)*

PROBLEM 2

Planes: P1, P2, P3 Cargos: C1, C2, C3 Airports: JFK, SFO, ATL

Initial state: *At(C1, SFO), At(C2, JFK), At(C3, ATL), At(P1, SFO), At(P2, JFK), At(P3, ATL)*

Goal: *At(C1, JFK), At(C2, SFO), At(C3, SFO)*

PROBLEM 3

Planes: P1, P2 Cargos: C1, C2, C3, C4 Airports: JFK, SFO, ATL, ORD

Initial state: *At(C1, SFO), At(C2, JFK), At(C3, ATL), At(C4, ORD), At(P1, SFO), At(P2, JFK)*

Goal: *At(C1, JFK), At(C2, SFO), At(C3, JFK), At(C4, SFO)*

Table 1 presents one of the possible optimal sequence of actions to perform to reach the goal for each problem, where the optimality is given by the sequence length. For each problem multiple optimal sequences are available since it is possible to invert the order of some actions without affecting the final result.

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| --- | --- | --- |
| **PROBLEM 1** | **PROBLEM 2** | **PROBLEM 3** |
| |  | | --- | | Load(C2, P2, JFK) | | Load(C1, P1, SFO) | | Fly(P2, JFK, SFO) | | Unload(C2, P2, SFO) | | Fly(P1, SFO, JFK) | | Unload(C1, P1, JFK) | | |  | | --- | | Load(C2, P2, JFK) | | Load(C1, P1, SFO) | | 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) | | |  | | --- | | Load(C2, P2, JFK) | | Load(C1, P1, SFO) | | 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) | |

Table 1: Optimal Solutions for Air Cargo Planning Problems

1. **Search Methods Analysis**

The search methods analyzed belongs to two categories, uninformed and informed:

Uninformed

* BFS: Breath First Search
* BFTS: Breath First Tree Search
* DFS: Depth First Search
* DLS: Depth Limited Search
* UCS: Uniform Cost Search

Informed

* RBFS\_H1: Recursive Breath First Search with heuristic H1
* GBFS\_H1: Greedy Breath First Search with heuristic H1
* A\*\_H1: A Star Search with heuristic H1
* A\*\_NoPrecond: A Star Search with heuristic “Ignore Precondition”
* A\*\_LevelSum: A Star Search with heuristic “LevelSum”

Table 2 presents the performance of 5 selected methods: BFS, DFS, UCS and A\* with no\_precondition and levelsum heuristics. Results for BFTS, DLS and RBFS\_H1 are not presented since they not provide a solution for problems 2 and 3 in a reasonable time (10 minutes). They provide a solution only for problem 1. A\* with heuristic H1 is not considered since it provides the same results of UCS, since H1 returns always the same value for all the nodes. GBFS\_H1 is not considered since it does not provide an optimal solution.

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| --- | --- | --- | --- | --- | --- |
|  | Expansion | Goal Tests | New Nodes | Solution len | Running Time [s] |
| BFS P1 | 43 | 56 | 180 | 6 | < 1 |
| DFS P1 | 12 | 13 | 48 | 12 | < 1 |
| UCS P1 | 55 | 57 | 224 | 6 | < 1 |
| A\*\_NoPrecond P1 | 41 | 43 | 170 | 6 | < 1 |
| A\*\_LevelSum P1 | 11 | 13 | 50 | 6 | 1.5 |
| BFS P2 | 3343 | 4609 | 30509 | 9 | 14 |
| DFS P2 | 582 | 583 | 5211 | 575 | 3 |
| UCS P2 | 4853 | 4855 | 44041 | 9 | 43 |
| A\*\_NoPrecond P2 | 1506 | 1508 | 13820 | 9 | 14 |
| A\*\_LevelSum P2 | 86 | 88 | 841 | 9 | 131 |
| BFS P3 | 14663 | 18098 | 129631 | 12 | 97 |
| DFS P3 | 627 | 628 | 5176 | 596 | 3 |
| UCS P3 | 18233 | 18235 | 159697 | 12 | 372 |
| A\*\_NoPrecond P3 | 5118 | 5120 | 45650 | 12 | 86 |
| A\*\_LevelSum P3 | 405 | 407 | 3724 | 12 | 873 |

Table 2: Performance analysis for selected search methods

Considerazione 1 : ottimalità soluzione

Considerazione 2 : tempo elaborazione

Considerazione 3: espansione nodi

Considerazione 4: confronto metodi uninformed

Considerazione 5: confronto metodi informed