Heuristic Analysis

Planning Search for Air Cargo Transport System

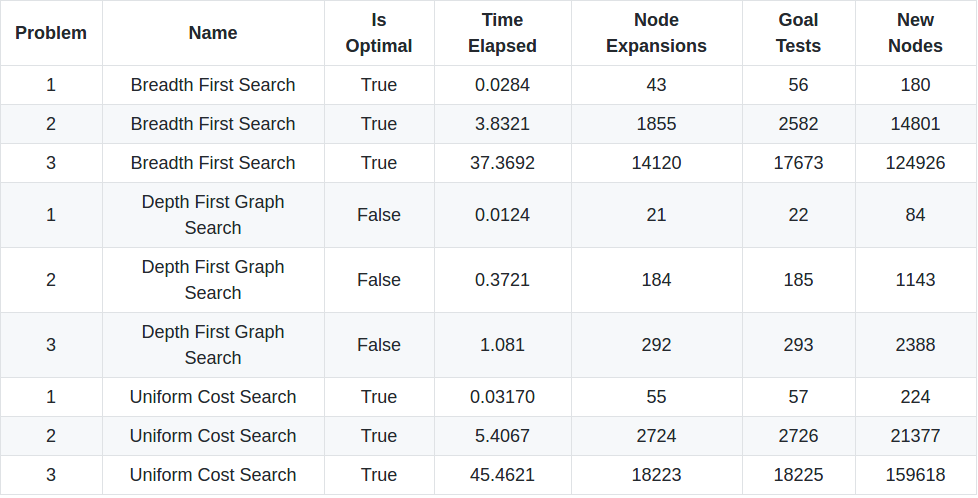
**Optimal Sequence of Actions**

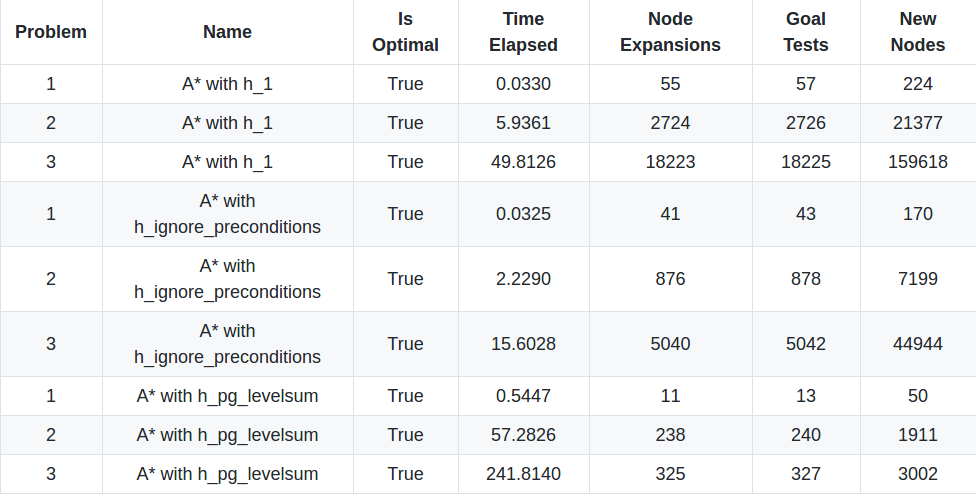
Optimal sequence of actions for the three problems are as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| **Action ID** | **Problem 1** | **Problem 2** | **Problem 3** |
| 1 | Load(C1, P1, SFO) | Load(C2, P2, JFK) | Load(C2, P2, JFK) |
| 2 | Fly(P1, SFO, JFK) | Fly(P2, JFK, ATL) | Fly(P2, JFK, ORD) |
| 3 | Load(C2, P2, JFK) | Load(C3, P2, ATL) | Load(C4, P2, ORD) |
| 4 | Fly(P2, JFK, SFO) | Fly(P2, ATL, SFO) | Fly(P2, ORD, SFO) |
| 5 | Unload(C2, P2, SFO) | Load(C1, P1, SFO) | Load(C1, P1, SFO) |
| 6 | Unload(C1, P1, JFK) | Fly(P1, SFO, JFK) | Fly(P1, SFO, ATL) |
| 7 |  | Unload(C3, P2, SFO) | Load(C3, P1, ATL) |
| 8 |  | Unload(C2, P2, SFO) | Fly(P1, ATL, JFK) |
| 9 |  | Unload(C1, P1, JFK) | Unload(C4, P2, SFO) |
| 10 |  |  | Unload(C3, P1, JFK) |
| 11 |  |  | Unload(C2, P2, SFO) |
| 12 |  |  | Unload(C1, P1, JFK) |

**Performance Summary**

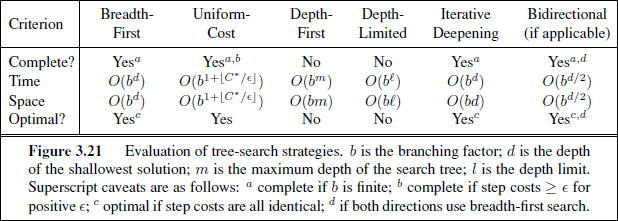
Three **uninformed** **search** algorithms are evaluated and their respective KPIs are as follows.

Three **automatic heuristics with A\* search** algorithms are evaluated and their respective KPIs are as follows.



**Performance Analysis for Uninformed Search**

According to the above results, among the three uninformed search algorithms, **Breadth First Search** and **Uniform Cost Search** are the only algorithms attain optimality. **Depth First Search** is the fastest one and has the least space complexity although it is not complete. This agrees very well with the justification from **section 3.4.7 of *Artificial Intelligence: A Modern Approach* by Norvig and Russell.**

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**Performance Analysis for Heuristic Search**

According to the above results, the two A\* search algorithms with non-trivial heuristic, namely **A\* with h\_ignore\_preconditions** and **A\* with h\_pg\_levelsum**, have better performance than uninformed ones. The two algorithms both attain optimality. **A\* with h\_ignore\_preconditions** has both better time and space complexity than BFS and UCS. **A\* with h\_pg\_levelsum** has the least space complexity among all candidates(its extra high time complexity is caused by overhead incurred by dynamic planning graph construction). This agrees very well with the the justification from **section 3.5 of *Artificial Intelligence: A Modern Approach* by Norvig and Russell: I**nformed search strategy — one that uses problem-specific knowledge beyond the definition of the problem itself — can find solutions more efficiently than can an uninformed strategy.

**Optimal Search Strategy**

From the above performance summary, **the A\* search with h\_ignore\_preconditions heuristic appears to be the best planning algorithm for air cargo planning**. The reasons are as follows.

1. The algorithm is optimal.

2. Among all optimal algorithms, it has the second least node expansions, that is, the second least resource constraints on target system.

3. Among all optimal algorithms, it has the fastest running time and scales well as the problem complexity goes up.

Compared with uninformed algorithms, namely BFS, UCS and A\* with trivial heuristic, the best one has far less node expansions due to the knowledge induced by informative heuristic. Since less node expansions means less resource constraints on target system, the best algorithm is on the one hand resource friendly.

On the other hand, although the A\* with h\_pg\_levelsum has the least number of node expansions, it suffers from significant runtime overhead incurred by the dynamic construction of planning graph. It makes the algorithm not scalable as the problem complexity goes up.

To sum up, the A\* search with h\_ignore\_preconditions heuristic is the best planning algorithm for air cargo planning.