

# Heuristic Analysis

## for AIND Planning Project

### Part 1 :

#### Metrics for Uninformed Planning Searches :

**Problem : air\_cargo\_p1 :**

##### Optimal Plan :

Load(C1, P1, SFO)  
Load(C2, P2, JFK)  
Fly(P2, JFK, SFO)  
Unload(C2, P2, SFO)  
Fly(P1, SFO, JFK)  
Unload(C1, P1, JFK)

The optimal plan for this problem consist of 6 steps only to achieve the goal.

Searching Algorithm	Expansions	Goal Tests	Time Elapsed(sec)	Optimal	New nodes
Breadth First Search	43	56	0.065	Yes	180
Depth First Graph Search	12	13	0.018	No	48
Uniform Cost Search	55	57	0.077	Yes	224

**Problem : air\_cargo\_p2 :**

##### Optimal Plan :

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)

The optimal plan length for this problem is 9 only.

Searching Algorithm	Expansions	Goal Tests	Time Elapsed(sec)	Optimal	New nodes
Breadth First Search	3343	4609	26.63	Yes	30509
Depth First graph Search	476	477	4.46	No	4253
Uniform Cost Search	4853	4855	23.36	Yes	44041

**Problem : air\_cargo\_p3 :**

**Optimal Plan :**

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)

The optimal plan for this problem consist of 12 steps to achieve the goal.

Searching Algorithm	Expansions	Goal Tests	Time Elapsed(sec)	Optimal	New nodes
Breadth First Search	14663	18098	195.42	Yes	129631
Depth First Graph Search	1511	1512	24.14	No	12611
Uniform Cost Search	18167	18169	102.19	Yes	159153

**Analysis :**

As expected, Breadth First Search and Uniform Cost Search always produces optimal solutions while Depth First search does not. The reason that BFS produces optimal solution is because it expands nodes level by level and since according to the problem's property each path in the search tree is of equal length, the solution that BFS finds will be present in the shallowest level hence finding the shortest solution.

Uniform cost search is expands the node n with the lowest cost path  $g(n)$ . Uniform cost search is able to find optimal solution even if step cost is not equal for each case, which actually is a requirement for BFS to be optimal. Thus, UCS is easily optimal in this case as well.

DFS on the other hand is not optimal because unlike BFS it goes on searching in depths and could find a solution in higher depth even if a much better solution is present in shallower depth in another path that it didn't pursue initially.

As far as the node expansion is concerned, it relates to the space complexity of the algorithm. As it is very well known, DFS performs much better as compared BFS and UCS when space complexity is issue but produces highly suboptimal unusable solutions.

For execution time attribute also DFS performs much better as compared to other searches. But, if optimal solution is required UCS technique is found to be empirically best as compared to other two search techniques.

## Part 2 :

### Metrics for Informed Planning Searches :

**Problem : air\_cargo\_p1 :**

Searching Algorithm	Expansions	Goal Tests	Time Elapsed(sec)	Optimal	New nodes
A* h_1	55	57	0.078	Yes	224
A* h_ignore_preconditions	41	43	0.080	Yes	170
A* h_pg_levelsum	11	13	1.11	Yes	50

**Problem : air\_cargo\_p2 :**

Searching Algorithm	Expansions	Goal Tests	Time Elapsed(sec)	Optimal	New nodes
A* h_1	4853	4855	23.71	Yes	44041
A* h_ignore_preconditions	1450	1452	8.61	Yes	13303
A* h_pg_levelsum	86	88	92.44	Yes	841

**Problem : air\_cargo\_p3 :**

Searching Algorithm	Expansions	Goal Tests	Time Elapsed(sec)	Optimal	New nodes
A* h_1	18167	18169	104.04	Yes	159153
A* h_ignore_preconditions	5035	5037	33.87	Yes	44897
A* h_pg_levelsum	316	318	451.48	Yes	2912

### Analysis :

All the informed heuristics are able to find the optimal solutions. This is because all the three heuristics are admissible in these problem descriptions.

The use of ignore preconditions heuristic makes the problem much faster to solve as compared to levelsum heuristic approach but as far as space complexity is concerned, the level sum heuristic is far more efficient as compared to ignore preconditions. This is because levelsum heuristic uses planning graph effectively which keeps restricts searching to the planning graph itself and thus reducing space complexity.

For these problems, the best heuristic seems to be ignore preconditions. It requires very less execution time even though it produces optimal solution. This is in contrast to uninformed searches BFS and UCS which finds optimal solutions but requires much more time as compared to informed search using ignore preconditions. The space complexity is also much less if we use ignore preconditions heuristic as compared to BFS and UCS.

So, in easier problems such as these ignore preconditions heuristics is much better but level sum heuristic might be more suitable as the complexity of problems increases.