Non-Heuristic Search Analysis

Three non-heuristic searches have been compared: Breadth First Search, Depth First Search and Uniform Cost Search. From these three only Breadth First Search and Uniform Cost Search were able to find optimal solutions for all three problems. Depth First Search resulted in longer plans than necessary, which was to be expected given the nature of how the search algorithm works. The benefit of Depth First Search was instead how quickly it found a solution, which became especially evident for problems two and three, where it was on average 50 times faster than the other two non-heuristic searches.

For the given problems it makes sense to spend a little more time on planning, because making unnecessary plane flights would be more costly. However given a planning problem for which a few unnecessary steps are cheap and planning time is crucial one might consider using Depth First Search instead.

Heuristic Search Analysis

Both heuristic searches were able to find optimal solutions to all problems. A-Star Search with the 'Ignore Preconditions' heuristic was almost 20 times faster on average than with the 'Levelsum' heuristic, even though the latter expanded less nodes and performed fewer goal tests. This is due to the complexity of constructing the planning graph. Compared to the non-heuristic searches, 'Ignore Preconditions' was slower only compared to Depth First Search. For problem 1 Breadth First and Uniform Cost Search required similar time, but for the other two problems they were outperformed. The explanation for this is that when the search space is small, using good heuristics is less important, because all solutions can be explored time-efficiently anyway and calculating complicated heuristics might be even more time consuming.

The 'Levelsum' heuristic was slower than all of the non-heuristic searches for all of the problems. It might become more effective when the search space grows even larger.

Therefore 'Ignore Preconditions' should be the preferred heuristic for planning problems of this kind and it should be favored over non-heuristic strategies for all non-trivial problems.
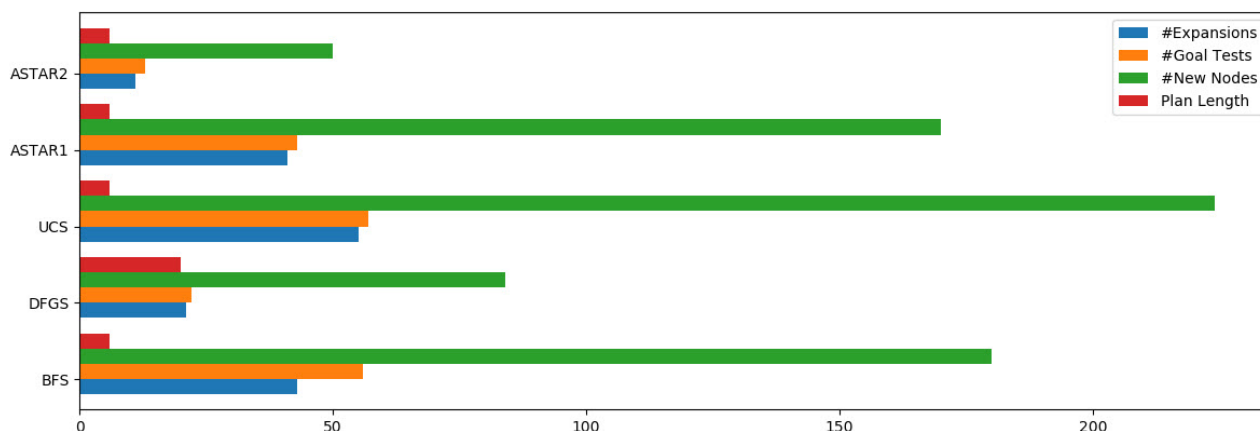
Results

The results of solving the three air cargo problems using Breadth First Search, Depth First Search, Uniform Cost Search and A-Star Search with the 'Ignore Preconditions' and 'Levelsum' heuristics follow.
For each problem one optimal solution

Problem 1

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

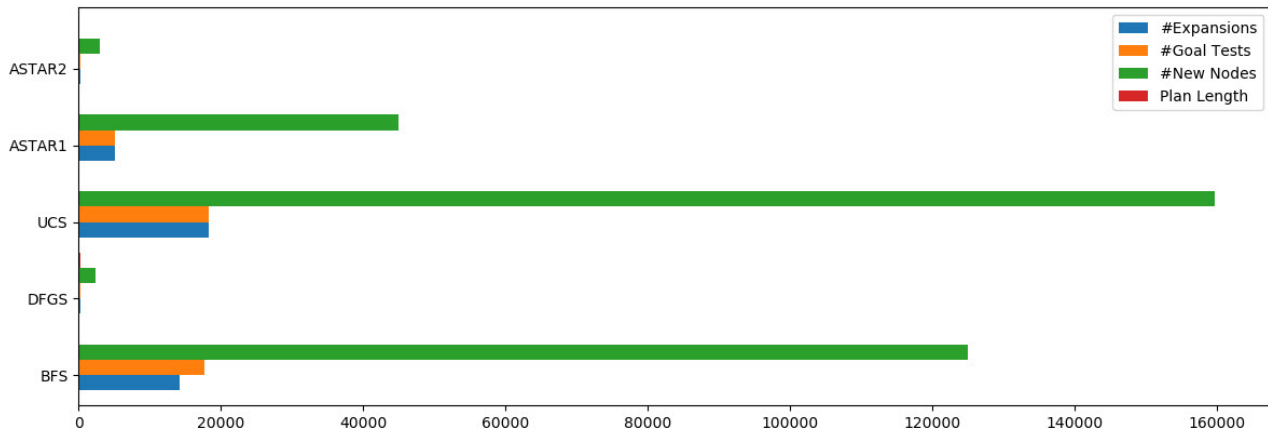|	Expansions	Goal Tests	New Nodes	Plan Length	Time Elapsed (sec)
Breadth First Search	43	56	180	6	0.04
Depth First Search	21	22	84	20	0.01
Uniform Cost Search	55	57	224	6	0.03
A* [Ignore Preconditions]	41	43	170	6	0.04
A* [Levelsum]	11	13	50	6	0.77

Problem 2

$Load(C1, P1, SFO) \rightarrow Fly(P1, SFO, JFK) \rightarrow Load(C2, P2, JFK) \rightarrow Fly(P2, JFK, SFO) \rightarrow Load(C3, P3, ATL) \rightarrow Fly(P3, ATL, SFO) \rightarrow Unload(C3, P3, SFO) \rightarrow Unload(C2, P2, SFO) \rightarrow Unload(C1, P1, JFK)$
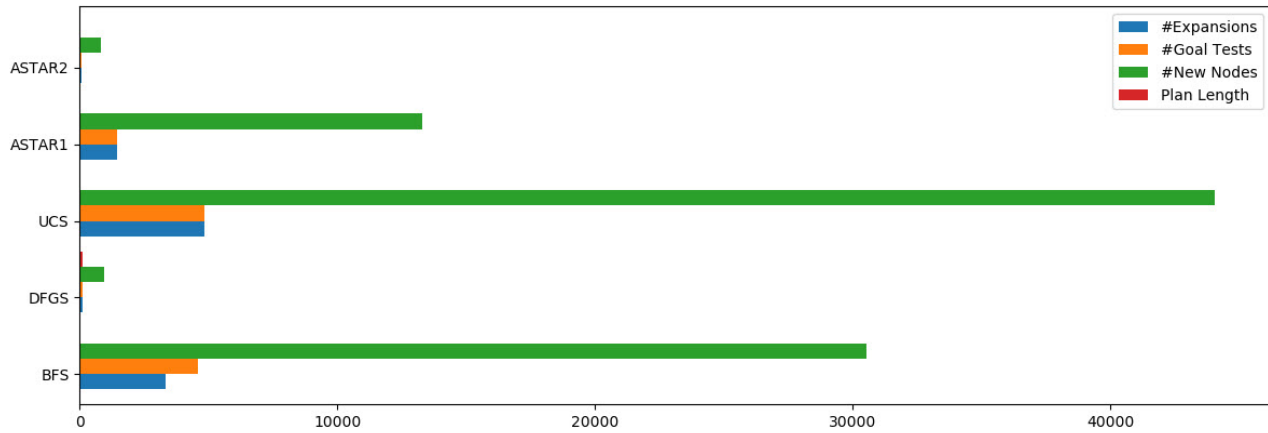
	Expansions	Goal Tests	New Nodes	Plan Length	Time Elapsed (sec)
Breadth First Search	3346	4612	30534	9	13.50
Depth First Search	107	108	959	105	0.32
Uniform Cost Search	4853	4855	44041	9	11.91
A* [Ignore Preconditions]	1450	1452	13303	9	4.29
A* [Levelsum]	86	88	841	9	68.31

Problem 3

$Load(C2, P2, JFK) \rightarrow Fly(P2, JFK, ORD) \rightarrow Load(C4, P2, ORD) \rightarrow Fly(P2, ORD, SFO) \rightarrow Load(C1, P1, SFO) \rightarrow Fly(P1, SFO, ATL) \rightarrow Load(C3, P1, ATL) \rightarrow Fly(P1, ATL, JFK) \rightarrow Unload(C4, P2, SFO) \rightarrow Unload(C3, P1, JFK) \rightarrow Unload(C2, P2, SFO) \rightarrow Unload(C1, P1, JFK)$

	Expansions	Goal Tests	New Nodes	Plan Length	Time Elapsed (sec)
Breadth First Search	14120	17673	124926	12	98.33
Depth First Search	292	293	2388	288	1.16
Uniform Cost Search	18223	18225	159618	12	55.00
A* [Ignore Preconditions]	5040	5042	44944	12	17.70
A* [Levelsum]	315	317	2902	12	358.67