Planning Heuristics Analysis

Comparison of Breadth First Search, Depth First Search and Uniform Cost Search

Generally speaking, when comparing the breadth-first, depth-first and uniform-cost search heuristics - uniform-cost search seems to provide the best overall metrics when node expansions, plan length and time elapsed are taken into consideration.

Node Expansions

	Breadth First	Depth First	Uniform Cost
Problem 1	43	21	55
Problem 2	3346	107	4853
Problem 3	14663	408	18223

Goal Tests

	Breadth First	Depth First	Uniform Cost
Problem 1			
Problem 2			
Problem 3			

Plan Length

	Breadth First	Depth First	Uniform Cost
Problem 1	6	20	6
Problem 2	9	105	9
Problem 3	12	392	12

Time Elapsed

	Breadth First	Depth First	Uniform Cost
Problem 1	0.049 s	0.028 s	0.056 s
Problem 2	23.083 s	0.619 s	26.297 s
Problem 3	182.905 s	3.244 s	116.567 s

Depth-first search is orders of magnitude faster at finding a solution than breadth-first and uniform-cost search, however it produces action plans that are terribly inefficient and impractical. Uniform cost search seems to produce action plans that are equivalent to breadth-first however it is ~ 36% faster. It should be noted that uniform cost search performs ~24% more node expansions than breadth-first search which means that the probability of it finding the most efficient path is higher since it searches through a broader set of all possibilities. The conclusion is that, out of the 3 heuristics, uniform-cost search performs the best.

A* Search Comparisons

Node Expansions

	A* h_1	A* h_ignore_preconditions	A* h_pg_levelsum
Problem 1	55	41	55
Problem 2	4853	1450	4853
Problem 3	18223	5040	18223

Goal Tests

	A* h_1	A* h_ignore_preconditions	A* h_pg_levelsum
Problem 1	57	43	57
Problem 2	4855	1452	4855
Problem 3	18225	5042	18225

Plan Length

	A* h_1	A* h_ignore_preconditions	A* h_pg_levelsum
Problem 1	6	6	6
Problem 2	9	9	9
Problem 3	12	12	12

Time Elapsed

	A* h_1	A* h_ignore_preconditions	A* h_pg_levelsum
Problem 1	0.057 s	0.056 s	1.179 s
Problem 2	24.509 s	8.260 s	667.723 s
Problem 3	119.43 s	38.54 s	4425.78 s

The A* Search with h_ignore_preconditions seems to be the superior heuristic over the h_pg_levelsum heuristic. The Ignore Preconditions heuristic is over 100x faster than the PG Levelsum heuristic and provides an action plan with an equal plan length. There seems to be no benefit to using the PG Levelsum heuristic over the Ignore Preconditions heuristic.

Problem 1 Solutions

Solving Air Cargo Problem 1 using breadth_first_search...

```
Expansions   Goal Tests   New Nodes
   43           56         180
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Plan length: 6 Time elapsed in seconds: 0.04959469700406771

Solving Air Cargo Problem 1 using depth_first_graph_search...

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Expansions   Goal Tests   New Nodes
   21           22         84
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Plan length: 20 Time elapsed in seconds: 0.02897417900385335

Solving Air Cargo Problem 1 using uniform_cost_search...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.05672826599038672

Solving Air Cargo Problem 1 using astar_search with h_1...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.05745035200379789
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using astar_search with h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
41	43	170

Plan length: 6 Time elapsed in seconds: 0.05678745701152366
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)

Solving Air Cargo Problem 1 using astar_search with h_pg_levelsum...

Expansions Goal Tests New Nodes
55 57 224

Plan length: 6 Time elapsed in seconds: 1.1796858159941621
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)

Problem 2 Solutions

Solving Air Cargo Problem 2 using breadth_first_search...

Expansions Goal Tests New Nodes
3346 4612 30534

Plan length: 9 Time elapsed in seconds: 23.083968239996466

Solving Air Cargo Problem 2 using depth_first_graph_search...

Expansions Goal Tests New Nodes
107 108 959

Plan length: 105 Time elapsed in seconds: 0.6198255799972685

Solving Air Cargo Problem 2 using uniform_cost_search...

Expansions Goal Tests New Nodes

4853 4855 44041

Plan length: 9 Time elapsed in seconds: 26.297774580001715

Solving Air Cargo Problem 2 using astar_search with h_1...

Expansions Goal Tests New Nodes
4853 4855 44041

Plan length: 9 Time elapsed in seconds: 24.509219141007634
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)

Solving Air Cargo Problem 2 using astar_search with h_ignore_preconditions...

Expansions Goal Tests New Nodes
1450 1452 13303

Plan length: 9 Time elapsed in seconds: 8.260401924999314
Load(C3, P3, ATL)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)

Solving Air Cargo Problem 2 using astar_search with h_pg_levelsum...

Expansions Goal Tests New Nodes
4853 4855 44041

Plan length: 9 Time elapsed in seconds: 667.7238740190078
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)

Problem 3 Solutions

Solving Air Cargo Problem 3 using breadth_first_search...

Expansions Goal Tests New Nodes
14663 18098 129631

Plan length: 12 Time elapsed in seconds: 182.90545364900026

Solving Air Cargo Problem 3 using depth_first_graph_search...

Expansions Goal Tests New Nodes
408 409 3364

Plan length: 392 Time elapsed in seconds: 3.2446576380025363

Solving Air Cargo Problem 3 using uniform_cost_search...

Expansions Goal Tests New Nodes
18223 18225 159618

Plan length: 12 Time elapsed in seconds: 116.56708693499968

Solving Air Cargo Problem 3 using astar_search with h_1...

Expansions Goal Tests New Nodes
18223 18225 159618

Plan length: 12 Time elapsed in seconds: 119.4348442160117
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)

Solving Air Cargo Problem 3 using astar_search with h_ignore_preconditions...

Expansions Goal Tests New Nodes
5040 5042 44944

Plan length: 12 Time elapsed in seconds: 38.54023168099229
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Unload(C4, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)

Fly(P1, ATL, JFK)
Unload(C3, P1, JFK)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)

Solving Air Cargo Problem 3 using astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
18223	18225	159618

Plan length: 12 Time elapsed in seconds: 4425.784232381993
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)