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AIND Project 3: Implement a Planning Search

Air Cargo Planning Heuristic Analysis

The following tables show the results gathered after solving the air cargo problems for this project with both uninformed and heuristic based search. The goal of this analysis is to document the results obtained from each search type and find an optimal solution for each air cargo problem, that is; a search algorithm that finds the lowest path among all possible paths from start to goal.
For each set of problems, the optimal and fastest solution has been highlighted with green color.

For each problem I ran 4 uninformed non-heuristic planning searches and 3 domain independent heuristic A* searches. The information about No. of nodes expanded, goal tests, new nodes created and time elapsed (in sec.) for each search has been recorded in below tables.

Problem 1:

Problem 1	Expansions	Goal Tests	New Nodes	Plan length	Time elapsed in seconds:
breadth_first_search	43	56	180	6	0.03826916
breadth_first_tree_search	1458	1459	5960	6	1.067740363
depth_first_graph_search	21	22	84	20	0.02299407
uniform_cost_search	55	57	224	6	0.044319216
astar_search with h_1	55	57	224	6	0.043737062
astar_search with h_ignore	55	57	224	6	0.08772561
astar_search h_pg_levelsum	11	13	50	6	0.637703159

Problem 2:

Problem 2	Expansions	Goal Tests	New Nodes	Plan length	Time elapsed in seconds:
breadth_first_search	3343	4609	30509	9	15.55023048
breadth_first_tree_search	~	~	~	~	~
depth_first_graph_search	624	625	5602	619	4.105884954
uniform_cost_search	4852	4854	44030	9	16.01704572
astar_search with h_1	4852	4854	44030	9	13.50043364
astar_search with h_ignore	1450	1452	13303	9	4.745629956
astar_search h_pg_levelsum	86	88	841	9	56.6833876

Problem 3:

Problem 3	Expansions	Goal Tests	New Nodes	Plan length	Time elapsed in seconds:
breadth_first_search	14663	18098	129631	12	147.2521579
breadth_first_tree_search	~	~	~	~	~
depth_first_graph_search	408	409	3364	392	1.912805066
uniform_cost_search	18235	18237	159716	12	63.5214814
astar_search with h_1	18235	18237	159716	12	58.06639784
astar_search with h_ignore	5040	5042	44944	12	20.0829615
astar_search h_pg_levelsum	318	320	2934	12	301.011895

Analysis:

Non-heuristic search:
From the above table we can see that BFS is optimal and guaranteed to find shortest path but as complexity increases (Problem 2 and 3) it becomes less optimal since it has exponential space complexity. DFS finds solution in short time but it lacks optimality due to linear space complexity. As you can see in above table, its plan length is always longest. Uniform cost is very much similar to BFS except in UCS we expand node with smallest path cost, which means UCS is equivalent to BFS if all the costs are equal hence UCS does more work by expanding nodes at depth d unnecessarily.

Heuristic Search:
Heuristic based search did perform better as the problem complexity increased. This is more evident in the air cargo problem 2 and 3, where the “A* Search with ‘h_ignore_preconditions’” performance was optimal and the fastest amongst those that were optimal. ‘levelsum’ heuristic expands less and gives optimal result but takes more time compared to ‘ignore precondition’ heuristic as it is inadmissible i.e. it could overestimate the optimal cost from the current state and the goal state but it largely works well for problems that are largely decomposable.

BFS gives optimal results with simple problem such as problem 1 but as complexity increases it becomes slow and that is where we require heuristics to optimize our search, and ‘h_ignore_preconditions’ is found to optimal in my test results.

Optimal Sequence of Actions:

The following table describes an optimal sequence of actions to solve each of the air cargo problems provided using the highlighted approaches from the tables above.

Problem	Search Type	Optimal Sequence Action
Air Cargo Problem 1	breadth_first_search	Load(C1, P1, SFO) Load(C2, P2, JFK) Fly(P2, JFK, SFO) Unload(C2, P2, SFO) Fly(P1, SFO, JFK) Unload(C1, P1, JFK)
Air Cargo Problem 2	astar_search with h_ignore	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)
Air Cargo Problem 3	astar_search with h_ignore	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(C1, P1, JFK) Unload(C2, P2, SFO)

References:

Stuart J. Russell, Peter Norvig (2010), Artificial Intelligence: A Modern Approach (3rd Edition).