Planning Search Heuristic Analysis

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Uninformed Search Method Results

We measured the performances of each method considering whether the solution is optimal (measured by plan length), the execution time as well as memory usage (measured by expansions).

Problem 1

For problem 1, we tried all uninformed search methods and the result is shown below:

Search Method	Expansions	Goal Tests	New Nodes	Plan length	Time (s)
*breadth_first_search	44	57	184	6	0.029
breadth_first_tree_search	1440	1441	5880	6	0.879

depth_first_graph_search	21	22	84	20	0.013
depth_limited_search	96	248	391	50	0.082
uniform_cost_search	55	57	224	6	0.041
recursive_best_first_search	4206	4207	16926	6	2.884
greedy_best_first_graph_search	7	9	28	6	0.006

* : the best approach for this problem

In this problem, the best approach is greedy_best_first_graph_search.

Problem 2

We tested all methods except Breadth First Tree Search, Depth Limited Search, and Recursive Best First Search because these methods have execution time more than 10 minutes.

Search Method	Expansions	Goal Tests	New Nodes	Plan length	Time (s)
*breadth_first_search	3343	4609	30509	9	14.757
depth_first_graph_search	624	625	5602	619	3.586
*uniform_cost_search	4853	4855	44041	9	12.846
greedy_best_first_graph_search	998	1000	8982	21	2.533

* : the best approach for this problem. Note that there are two best approaches in this problem.

Problem 3

For the same time limitation reasons, we only compared the same approaches in problem 2.

Search Method	Expansions	Goal Tests	New Nodes	Plan length	Time (s)
breadth_first_search	14663	18098	128554	12	107.946

depth_first_graph_search	408	409	3364	392	1.921
*uniform_cost_search	18223	18225	158186	12	56.122
greedy_best_first_graph_search	6943	6945	59435	22	20.758

* : the best approach for this problem

Informed Search Method Results

Problem 1

Search Method	Expansions	Goal Tests	New Nodes	Plan length	Time (s)
astar_search with h_1	55	57	224	6	0.035
* astar_search with h_ignore_preconditions	41	43	170	6	0.035
astar_search with h_pg_levelsum	39	41	158	6	1.155

* : the best approach for this problem.

Problem 2

Search Method	Expansions	Goal Tests	New Nodes	Plan length	Time (s)
astar_search with h_1	4853	4855	44041	9	12.573
*astar_search with h_ignore_preconditions	1450	1452	13303	9	4.359
astar_search with h_pg_levelsum	1129	1131	10232	9	393.465

* : the best approach for this problem.

Problem 3

Search Method	Expansions	Goal Tests	New Nodes	Plan length	Time (s)
astar_search with h_1	18223	18225	158186	12	57.552
*astar_search with h_ignore_preconditions	5040	5042	44720	12	17.942

* : the best approach for this problem.

Optimal Actions

Problem 1

Results is obtained by Breadth First Search
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)

Problem 2

Results is obtained by A* Search with Ignore Preconditions
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)

Problem 3

Results is obtained by A* Search with Ignore Preconditions
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)

Analysis

Uninformed Search Method

Breadth First Search and Uniform Cost Search are the only two uninformed search strategies that yield an optimal action plan for all the problems under the 10 minutes time limit. It seem that Greedy Best First Graph Search is the best method for the 1st problems given its execution time and memory usage, however, in problem 2 and 3 it failed to find the optimal path. In addition, Depth First Graph Search is the most time-consuming strategy (comparing with all other methods under 10 minutes time limit) and it did not find the optimal path for all of the problems. In this sense, it is the worse strategy for this air cargo planning problem.

Breadth First Search is always expanding the shortest path first[1] so it's going to find the goal by trying no longer paths. And it obtains the optimal solutions in a reasonable amount of time. Comparably, Depth First Search tries to go as deep as it can so it necessarily find the shortest path and it is not optimal.

Informed Search Method

It turned out that Astar Search with Ignore Preconditions Heuristic is the best option for all three problems. However, this approach is not as good as Greedy Best First Graph Search for problem 1 in terms of execution time and memory usage. For problem 2 and 3, this search strategy is better than any of the optimal uninformed search method. Overall, this Air Cargo problem demonstrate that informed search strategies with custom heuristics has more advantages than uninformed search techniques when searching for an optimal plan, especially when the complexity of the problem increases.

[1] Russell S. and Norvig P., Artificial Intelligence: A Modern Approach (3rd Edition).