Planning Heuristic Analysis

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Abstract

Implement PDDL for air cargo problem and perform analysis

1 Introduction

For this project, we define a group of problems in classical PDDL (Planning Domain Definition Language) for the air cargo domain and then perform analysis for uninformed search and automatically generated heuristics including *GraphPlan*

2 Observation

Following are the observations for each problem using 10 different search strategies. Metrics are not provided in case a particular strategy took more than 10 minutes.

2.1 Air Cargo Problem 1

$$\begin{gathered} Init(At(C1, SFO) \land At(C2, JFK) \\ \land At(P1, SFO) \land At(P2, JFK) \\ \land Cargo(C1) \land Cargo(C2) \\ \land Plane(P1) \land Plane(P2) \\ \land Airport(JFK) \land Airport(SFO)) \end{gathered}$$

$$Goal(At(C1, JFK) \land At(C2, SFO))$$

Optimal Solution Plan Length: 6

$$\begin{array}{rr} \mathit{Load}(C1, P1, SFO) & \mathit{Fly}(P2, JFK, SFO) \\ \mathit{Load}(C2, P2, JFK) & \mathit{Unload}(C1, P1, JFK) \\ \mathit{Fly}(P1, SFO, JFK) & \mathit{Unload}(C2, P2, SFO) \end{array}$$

Search Strategy	Optimal	Expansions	Goal Tests	Time elapsed
Breadth first	Yes	43	56	0.0413
Breadth first tree	Yes	1458	1459	1.2025
Depth first graph	No	21	22	0.0160
Depth limited	No	101	271	0.1165
Uniform cost	Yes	55	57	0.0482
Recursive best first h_1	Yes	4229	4230	3.3788
Greedy best first graph h_1	Yes	7	9	0.0081
Astar h_1	Yes	55	57	0.0464
Astar h_ignore_preconditions	Yes	41	43	0.0521
Astar h_pg_levelsum	Yes	11	13	1.2967

Table 1: Air Cargo Problem 1 metrics

2.2 Air Cargo Problem 2

$$\begin{gathered} \mathit{Init}(\mathit{At}(C1, SFO) \land \mathit{At}(C2, JFK) \land \mathit{At}(C3, ATL) \\ \land \mathit{At}(P1, SFO) \land \mathit{At}(P2, JFK) \land \mathit{At}(P3, ATL) \\ \land Cargo(C1) \land Cargo(C2) \land Cargo(C3) \\ \land Plane(P1) \land Plane(P2) \land Plane(P3) \\ \land \mathit{Airport}(JFK) \land \mathit{Airport}(SFO) \land \mathit{Airport}(ATL)) \end{gathered}$$

$$\mathit{Goal}(\mathit{At}(C1, JFK) \land \mathit{At}(C2, SFO) \land \mathit{At}(C3, SFO))$$

Optimal Solution Plan Length: 9

$$
\begin{array}{cc}
Load(C1, P1, SFO) & Fly(P2, JFK, SFO) \\
Load(C2, P2, JFK) & Unload(C2, P2, SFO) \\
Load(C3, P3, ATL) & Fly(P3, ATL, SFO) \\
Fly(P1, SFO, JFK) & Unload(C3, P3, SFO) \\
\multicolumn{2}{c}{Unload(C1, P1, JFK)}
\end{array}
$$

Search Strategy	Optimal	Expansions	Goal Tests	Time elapsed
Breadth first	Yes	3346	4612	15.8970
Breadth first tree	-	-	-	-
Depth first graph	No	107	108	0.3678
Depth limited	-	-	-	-
Uniform cost	Yes	4605	4607	13.5241
Recursive best first h_1	-	-	-	-
Greedy best first graph h_1	No	465	467	1.4295
Astar h_1	Yes	4605	4607	15.6382
Astar h_ignore_preconditions	Yes	1311	1313	4.7261
Astar h_pg_levelsum	Yes	74	76	181.5321

Table 2: Air Cargo Problem 2 metrics

2.3 Air Cargo Problem 3

$$
\begin{gathered}
Init(At(C1, SFO) \land At(C2, JFK) \land At(C3, ATL) \land At(C4, ORD) \\
\land At(P1, SFO) \land At(P2, JFK) \\
\land Cargo(C1) \land Cargo(C2) \land Cargo(C3) \land Cargo(C4) \\
\land Plane(P1) \land Plane(P2) \\
\land Airport(JFK) \land Airport(SFO) \land Airport(ATL) \land Airport(ORD)) \\
Goal(At(C1, JFK) \land At(C3, JFK) \land At(C2, SFO) \land At(C4, SFO))
\end{gathered}
$$

Optimal Solution Plan Length: 12

$$
\begin{array}{rl}
Load(C1, P1, SFO) & Fly(P1, ATL, JFK) \\
Load(C2, P2, JFK) & Unload(C1, P1, JFK) \\
Fly(P1, SFO, ATL) & Unload(C3, P1, JFK) \\
Load(C3, P1, ATL) & Fly(P2, ORD, SFO) \\
Fly(P2, JFK, ORD) & Unload(C2, P2, SFO) \\
Load(C4, P2, ORD) & Unload(C4, P2, SFO)
\end{array}
$$

Search Strategy	Optimal	Expansions	Goal Tests	Time elapsed
Breadth first	Yes	14120	17673	113.0744
Breadth first tree	-	-	-	-
Depth first graph	No	292	293	1.4079
Depth limited	-	-	-	-
Uniform cost	Yes	16961	16963	56.3904
Recursive best first h_1	-	-	-	-
Greedy best first graph h_1	No	3998	4000	15.8663
Astar h_1	Yes	16961	16963	64.5328
Astar h_ignore_preconditions	Yes	4444	4446	19.1797
Astar h_pg_levelsum	-	-	-	-

Table 3: Air Cargo Problem 3 metrics

3 Analysis

For the **uninformed search**, given the 10 minute time limit only *Breadth first* and *Uniform cost* search strategies produce optimal solution. Also as the problem got larger even though breadth first expanded fewer nodes uniform cost, turned out to be faster. For Problem 1, breadth first tree search also manged to find the optimal solution but expanded far more nodes than breadth first and uniform cost.

For the **informed search** strategies, all were able to produce optimal solution for problem 1. However for problem 2 and 3 only search able to produce optimal solution were Astar with h_1 and h_ignore_preconditions where the latter was almost 4 times faster than the former. Greedy best first graph with h_1 was able to produce optimal result only for problem 1.

Uniformed cost search is able to produce and optimal solution in a acceptable time period but as our intuition guides us that a strategy with a sound heuristic should outperform uninformed search, **astar with h_ignore_preconditions** is more efficient both in space and time. It was able to find solution for problem 3 by using $1/4^{\text{th}}$ space and in $1/3^{\text{rd}}$ time compared to uniform cost search

The reason ignore preconditions heuristic (h_ip) works better than levelsum (h_ls) is that h_ls works more like an uninformed search since it does not account for effects of actions. For instance when it determines a particular level reaches a goal it does not account for how many actions it will take and does it interact negatively with any other goal or action[1]. h_ip on the other hand selects action and each level the action selected sort of builds a path towards reaching all goals states.

References

[1] Sanchez, Romeo and Nguyen, Xuanlong and Kambhampati, Subbarao. (2000). *AltAlt: Combining the Advantages of Graphplan and Heuristic State Search*.
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