Planning Search Heuristic Analysis
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Action Schema:

```
Action(Load(c, p, a),
      PRECOND: At(c, a) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)
      EFFECT: ¬ At(c, a) ∧ In(c, p))
Action(Unload(c, p, a),
      PRECOND: In(c, p) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)
      EFFECT: At(c, a) ∧ ¬ In(c, p))
Action(Fly(p, from, to),
      PRECOND: At(p, from) ∧ Plane(p) ∧ Airport(from) ∧ Airport(to)
      EFFECT: ¬ At(p, from) ∧ At(p, to))
```

The above action schema is shared by all the three problems.

Problem 1:

```
Init(At(C1, SFO) ∧ At(C2, JFK)
      ∧ At(P1, SFO) ∧ At(P2, JFK)
      ∧ Cargo(C1) ∧ Cargo(C2)
      ∧ Plane(P1) ∧ Plane(P2)
      ∧ Airport(JFK) ∧ Airport(SFO))
Goal(At(C1, JFK) ∧ At(C2, SFO))
```

Optimal Plan
 length 6

```
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

	optimal	Node expansions	Goal tests	Time elapsed
Breadth First	yes	43	56	0.035
Depth First	no	12	13	0.011
Uniform Cost	yes	55	57	0.043
Greedy Best first with h1	yes	7	9	0.005

Problem 1 uninformed search metrics

	optimal	Node expansions	Goal tests	Time elapsed
A* With h1	yes	55	57	0.049
A* with ignore precond	yes	41	43	0.044
A* with pg_levelsum	yes	11	13	1.077

Problem 1 A* search with heuristics metrics

Problem 2:
Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL)

      ∧ At(P1, SFO) ∧ At(P2, JFK) ∧ At(P3, ATL)

      ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3)

      ∧ Plane(P1) ∧ Plane(P2) ∧ Plane(P3)

      ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL))

Goal(At(C1, JFK) ∧ At(C2, SFO) ∧ At(C3, SFO))

Optimal Plan length 9
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)

	optimal	Node expansions	Goal tests	Time elapsed
Breadth First	yes	3346	4612	18.65
Depth First	no	859	860	6.90
Uniform Cost	yes	4853	4855	15.02
Greedy Best first with h1	no	998	1000	3.03

Problem 2 uninformed search metrics

	optimal	Node expansions	Goal tests	Time elapsed
A* With h1	yes	554853	4855	14.65
A* with ignore precond	yes	1450	1452	5.33

| A* with pg_levelsum | yes | 86 | 88 | 202.2 |

Problem 2 A* search with heuristics metrics

Problem 3:

Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL) ∧ At(C4, ORD)

      ∧ At(P1, SFO) ∧ At(P2, JFK)

      ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3) ∧ Cargo(C4)

      ∧ Plane(P1) ∧ Plane(P2)

      ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL) ∧ Airport(ORD))

Goal(At(C1, JFK) ∧ At(C3, JFK) ∧ At(C2, SFO) ∧ At(C4, SFO))

Optimal Plan length 12

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(P1, ATL, JFK)

Unload(C1, P1, JFK)

Unload(C3, P1, JFK)

Fly(P2, ORD, SFO)

Unload(C2, P2, SFO)

Unload(C4, P2, SFO)

	optimal	Node expansions	Goal tests	Time elapsed
Breadth First	yes	14120	17673	139.66
Depth First	no	1401	1402	15.09
Uniform Cost	yes	18223	18225	29.26
Greedy Best first with h1	no	5578	5580	9.26

Problem 3 uninformed search metrics

	optimal	Node expansions	Goal tests	Time elapsed
A* With h1	yes	18223	18225	87.40
A* with ignore precond	yes	5040	5042	23.33
A* with pg_levelsum	----	----	----	----

Problem 3 A* search with heuristics metrics

Uninformed Search Analysis

Breadth first search always gives optimal results where each action is of equal cost[1]. Depth first search executes faster but returns un-optimal path [1].

A* with heuristics

A* with ignore preconditions gives optimal path and executes much faster than A* with h1. A* with pg_levelsum takes the longest amount of time for execution, for problem 3 it exceeds threshold time (10mins). Ignore preconditions heuristic takes lot less time to calculate than level sum. Though level sum explores much lesser nodes it is slower because of the time expensive nature of the heuristic.

References

[1] AIND Search lesson.