heuristic_analysis

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Part 1 - Planning problems

Problem 1

A.Solving Air Cargo Problem 1 using breadth_first_search…

```
Expansions    Goal Tests    New Nodes
    43            56           180
```

Plan length: 6 Time elapsed in seconds: 0.03546692700183485

Can find an optimal solution.

B.Solving Air Cargo Problem 1 using depth_first_graph_search…

```
Expansions    Goal Tests    New Nodes
    12            13            48
```

Plan length: 12 Time elapsed in seconds: 0.010756155999843031

Can't find an optimal solution.

C.Solving Air Cargo Problem 1 using uniform_cost_search…

```
Expansions    Goal Tests    New Nodes
    55            57           224
```

Plan length: 6 Time elapsed in seconds: 0.04722273099832819

Can find an optimal solution.

Problem 2

A.Solving Air Cargo Problem 2 using breadth_first_search…

```
Expansions    Goal Tests    New Nodes
   3346          4612          30534
```

Plan length: 9 Time elapsed in seconds: 13.357075322001037

Can find an optimal solution.

B.Solving Air Cargo Problem 2 using depth_first_graph_search...

```
Expansions    Goal Tests    New Nodes
   859           860           7745
```

Plan length: 846   Time elapsed in seconds: 5.017339144000289

Can't find an optimal solution.

C.Solving Air Cargo Problem 2 using uniform_cost_search...

```
Expansions    Goal Tests    New Nodes
  4714          4716          42806
```

Plan length: 9   Time elapsed in seconds: 50.23530941900026

Can find an optimal solution.

Problem 3

A.Solving Air Cargo Problem 3 using breadth_first_search...

```
Expansions    Goal Tests    New Nodes
 14120         17673         124926
```

Plan length: 12   Time elapsed in seconds: 108.30074011100078

Can find an optimal solution.

B.Solving Air Cargo Problem 3 using depth_first_graph_search...

```
Expansions    Goal Tests    New Nodes
  1401          1402          11649
```

Plan length: 1345   Time elapsed in seconds: 12.390295859000616

Can't find an optimal solution.

C.Solving Air Cargo Problem 3 using uniform_cost_search...

```
Expansions    Goal Tests    New Nodes
 17259         17261         151533
```

Plan length: 12   Time elapsed in seconds: 334.0809108530011

Can find an optimal solution.

Part 2 - Domain-independent heuristics

Problem 1

A.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: 0.034630326998012606

Can find an optimal solution.

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

```
Expansions    Goal Tests    New Nodes
    11            13            50
```

Plan length: 6 Time elapsed in seconds: 2.9545704900010605

Can find an optimal solution.

Problem 2

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

```
Expansions    Goal Tests    New Nodes
   1447          1449         13271
```

Plan length: 9 Time elapsed in seconds: 11.095083012005489

Can find an optimal solution.

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

```
Expansions    Goal Tests    New Nodes
    82            84            803
```

Plan length: 9 Time elapsed in seconds: 838.8579387490026

Can find an optimal solution.

Problem 3

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

```
Expansions    Goal Tests    New Nodes
   4940          4942         43911
```

Plan length: 12 Time elapsed in seconds: 84.11933344900172

Can find an optimal solution.

B.Takes longer than 10 minutes. No result

Part 3 - Written Analysis

1. Optimal plan:

   a. Problem 1:
   ```
   Load(C1, P1, SFO)
   Load(C2, P2, JFK)
   Fly(P1, SFO, JFK)
   Fly(P2, JFK, SFO)
   Unload(C1, P1, JFK)
   Unload(C2, P2, SFO)
   ```

   b. Problem 2:
   ```
   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(C1, P1, JFK)
   Unload(C2, P2, SFO)
   ```

   c. Problem 3:
   ```
   Load(C1, P1, SFO)
   Fly(P1, SFO, ATL)
   Load(C3, P1, ATL)
   Fly(P1, ATL, JFK)
   Unload(C3, P1, JFK)
   Unload(C1, P1, JFK)
   Load(C2, P2, JFK)
   Fly(P2, JFK, ORD)
   Load(C4, P2, ORD)
   Fly(P2, ORD, SFO)
   Unload(C4, P2, SFO)
   Unload(C2, P2, SFO)
   ```

2. Compare and contrast non-heuristic search result metrics

	Optimality	Goal test	Time	Node expansion
P1-BFS	YES	56	0.035	43
P1-DFS	NO	13	0.010	12
P1-Uniform	YES	57	0.047	55
P2-BFS	YES	4612	13.357	3346
P2-DFS	NO	860	5.017	859
P2-Uniform	YES	4716	50.235	4714
P3-BFS	YES	17673	108.3	14120
P3-DFS	NO	1402	12.39	1401
P3-Uniform	YES	17261	334.08	17259

3. Compare and contrast heuristic search result metrics using A* with the "ignore preconditions" and "level-sum"

	Optimality	Goal test	Time	Node expansion
P1-ignore	YES	43	0.034	41
P1-levelsum	YES	13	2.954	11
P2-ignore	YES	1449	11.095	1447
P2-levelsum	YES	84	838.85	82
P3-ignore	YES	4942	84.119	4940

4. What was the best heuristic used in these problems? Was it better than non-heuristic search planning methods for all problems? Why or why not?

For problem 1, it looks like the best heuristics is ignore preconditions. The performance of P1-ignore is almost the same as P1-BFS.

For problem 2, it looks like the best heuristics is ignore preconditions. And it is better than non-heuristic search planning, because it is faster than P2-BFS, as well as fewer node expansion.

For problem 3, I failed to get results for level sum, because it takes more than 10 minutes to finish. P3-ignore takes much longer time than P3-DFS.