

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, SF0)
Load(C2, P2, JFK)
Fly(P1, SF0, JFK)
Fly(P2, JFK, SF0)
Unload(C1, P1, JFK)
Unload(C2, P2, SF0)
```

b. Problem 2:

```
Load(C1, P1, SF0)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SF0, JFK)
Fly(P2, JFK, SF0)
Fly(P3, ATL, SF0)
Unload(C3, P3, SF0)
Unload(C1, P1, JFK)
Unload(C2, P2, SF0)
```

c. Problem 3:

```
Load(C1, P1, SF0)
Fly(P1, SF0, 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, SF0)
Unload(C4, P2, SF0)
Unload(C2, P2, SF0)
```

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, but P3-DFS cannot find an optimal solution for problem 3.

- An accurate heuristic needs fewer node expansion than a less accurate one, but requires more time to compute. For example, based on the statistics above, ignore-precondition heuristics is less accurate than level-sum heuristics, takes fewer time to compute and requires more node expansion.
- DFS can't guarantee an optimal plan
- BFS can find an optimal plan, but it also requires more time and node expansion.
- Uniform cost takes almost same amount of time and node expansion as BFS, but it can find an optimal plan.