

Heuristic Analysis

Optimal sequence

Both BFS, Uniform cost search (UCS), A-star Ignore preconditions (*AHIP*) and A-star level-sum (*AHPL*) can output optimal sequence. Here is the output of A-star level-sum.

Problem 1

Problem

```
Init(At(C1, SF0) ∧ At(C2, JFK)
    ∧ At(P1, SF0) ∧ At(P2, JFK)
    ∧ Cargo(C1) ∧ Cargo(C2)
    ∧ Plane(P1) ∧ Plane(P2)
    ∧ Airport(JFK) ∧ Airport(SF0))
Goal(At(C1, JFK) ∧ At(C2, SF0))
```

Plan

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

Problem 2

Problem

```
Init(At(C1, SF0) ∧ At(C2, JFK) ∧ At(C3, ATL)
    ∧ At(P1, SF0) ∧ At(P2, JFK) ∧ At(P3, ATL)
    ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3)
    ∧ Plane(P1) ∧ Plane(P2) ∧ Plane(P3)
    ∧ Airport(JFK) ∧ Airport(SF0) ∧ Airport(ATL))
Goal(At(C1, JFK) ∧ At(C2, SF0) ∧ At(C3, SF0))
```

Plan

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

Problem 3

Problem

```
Init(At(C1, SF0) ∧ At(C2, JFK) ∧ At(C3, ATL) ∧ At(C4, ORD)
    ∧ At(P1, SF0) ∧ At(P2, JFK)
    ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3) ∧ Cargo(C4)
    ∧ Plane(P1) ∧ Plane(P2)
    ∧ Airport(JFK) ∧ Airport(SF0) ∧ Airport(ATL) ∧ Airport(ORD))
Goal(At(C1, JFK) ∧ At(C3, JFK) ∧ At(C2, SF0) ∧ At(C4, SF0))
```

Plan

Load(P1, SF0, C1)
 Load(P2, JFK, C2)
 Fly(P1, SF0, ORD)
 Load(P1, ORD, C4)
 Fly(P2, JFK, ATL)
 Load(P2, ATL, C3)
 Fly(P1, ORD, SF0)
 Unload(P1, SF0, C4)
 Fly(P1, SF0, JFK)
 Fly(P2, ATL, JFK)
 Unload(P2, JFK, C3)
 Fly(P2, JFK, SF0)
 Unload(P2, SF0, C2)
 Unload(P1, JFK, C1)

Performance Result

Algo	Problem	Expansions	Goal Tests	New Nodes	Plan length	Time	Filename
Breadth first search	1	43	56	180	6	0.025	p1s1.log
Breadth first search	2	3343	4609	30509	9	11.67	p2s1.log
Breadth first search	3	14663	18098	129631	12	87.47	p3s1.log
Depth first search	1	12	13	48	12	0.006	p1s3.log
Depth first search	2	582	583	5211	575	2.641	p2s3.log
Depth first search	3	627	628	5176	596	2.836	p3s3.log
Uniform cost search	1	55	57	224	6	0.033	p1s5.log
Uniform cost search	2	4823	4825	43774	9	37.190	p2s5.log
Uniform cost search	3	18235	18237	159716	12	314.1	p3s5.log
A* ignore preconditions	1	41	43	170	6	0.039	p1s9.log
A* ignore preconditions	2	1494	1496	13708	9	12.13	p2s9.log
A* ignore preconditions	3	5118	5120	45650	12	115.1	p3s9.log
A* level sum	1	7	9	28	6	1.377	p1s10.log
A* level sum	2	13	15	123	9	35.58	p2s10.log
A* level sum	3	46	48	449	14	178.2	p3s10.log

Analysis

- Depth first search is the quickest among all search algorithms. However, its plan length is not optimal. Because depth first search is not optimized for cost reduction.
- The number of expansion, goal tests and new node are lowest in A* level sum algorithm. That is because GRAPHPLAN and level-sum heuristic can reduce the search space. However, the time used is high, that is because the algorithm build GRAPHPLAN in every heuristic estimation, and the run time cost is high.
- Beside above algorithms, the number of expansion, goal tests and new node are lowest in A* ignore preconditions. That is because the heuristic function can reduce the search space. Time used is high since there is run time cost in heuristic function.

- The number of expansion, goal tests and new node are high in breadth first search and uniform cost search. Since they does not have heuristic function to reduce the search space.
- For problem which have obvious good heuristic function, BFS and A-star with provided heuristic function can be a good chooce. For more complex problem, we can consider A-star level sum as it can highly reduce search space.