

Heuristic Analysis

1. Optimal Plans for Each Problem

- Problem 1

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

- Problem 2

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

- Problem 3

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

2. Comparison of Non-heuristic Search Result Metrics

- Problem 1

Three different tests are applied on Problem 1, among three non-heuristic search functions breadth first and uniform cost search gave plans having same optimality, depth first graph search gave a non-optimal plan. Breadth first beat uniform cost search in node expansion quantity.

breadth_first_search

Expansions	Goal Tests	New Nodes
43	56	180

Plan length: 6 Time elapsed in seconds: 0.06621367900015684

depth_limited_search

Expansions	Goal Tests	New Nodes
101	271	414

Plan length: 50 Time elapsed in seconds: 0.1415906210004323

uniform_cost_search

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.06600838800022757

- Problem 2

Three different tests are applied on Problem 2, among three non-heuristic search functions breadth first and uniform cost search gave plans having same optimality, depth first graph search gave a non-optimal plan. Breadth first beat uniform cost search in terms of node expansion and duration of finding optimal plan.

breadth_first_search

Expansions	Goal Tests	New Nodes
3343	4609	30509

Plan length: 9 Time elapsed in seconds: 21.703926118999334

depth_first_graph_search

Expansions	Goal Tests	New Nodes
624	625	5602

Plan length: 619 Time elapsed in seconds: 5.364816544999485

uniform_cost_search

Expansions	Goal Tests	New Nodes
4780	4782	43381

Plan length: 9 Time elapsed in seconds: 70.79437830299958

- Problem 3

Three different tests are applied on Problem 3, among three non-heuristic search functions breadth first and uniform cost search gave plans having same optimality, depth first graph search gave a non-optimal plan. Breadth first beat uniform cost search in terms of node expansion and duration of finding optimal plan. In the experiment depth first search took more than 10 minutes of processing time so result is not collected.

breadth_first_search

Expansions	Goal Tests	New Nodes
14663	18098	129631

Plan length: 12 Time elapsed in seconds: 114.83620004252481

depth_first_search

Took more than 10 minutes to find a plan.

uniform_cost_search

Expansions Goal Tests New Nodes

18151 18153 159038

Plan length: 12 Time elapsed in seconds: 669.70731574

3. Comparison of Heuristic Search Result Metrics

- Problem 1

A* search with “ignore preconditions” and “planning graph level sum” heuristics were applied on Problem 1. Optimality of plans were equal since plan lengths of results of heuristics were equal. Node expansion of PG level sum was better than ignore preconditions heuristic however PG heuristic consumed more time.

astar_search with h_ignore_preconditions

Expansions Goal Tests New Nodes

41 43 170

Plan length: 6 Time elapsed in seconds: 0.07025523399988742

astar_search with h_pg_levelsum

Expansions Goal Tests New Nodes

11 13 50

Plan length: 6 Time elapsed in seconds: 2.2587175180005943

- Problem 2

A* search with “ignore preconditions” and “planning graph level sum” heuristics were applied on Problem 2. Optimality of plans were equal since plan lengths of results of heuristics were equal. Node expansion of PG level sum was better than ignore preconditions heuristic however PG heuristic consumed more time.

astar_search with h_ignore_preconditions

Expansions Goal Tests New Nodes

1506 1508 13820

Plan length: 9 Time elapsed in seconds: 24.999252304999573

astar_search with h_pg_levelsum

Expansions Goal Tests New Nodes

86 88 841

Plan length: 9 Time elapsed in seconds: 166.541025727504

- Problem 3

A* search with “ignore preconditions” and “planning graph level sum” heuristics were applied on Problem 3. Optimality of plans were equal since plan lengths of results of heuristics were equal. Node expansion of PG level sum was better than ignore preconditions heuristic however PG heuristic consumed more time.

h_ignore_preconditions

Expansions Goal Tests New Nodes

5118 5120 45650

Plan length: 12 Time elapsed in seconds: 152.69516910499988

astar_search with h_pg_levelsum

Expansions Goal Tests New Nodes

404 406 3718

Plan length: 12 Time elapsed in seconds: 1154.4969627028177

4. Comparison of Heuristic and Non-heuristic Search Results

Planning Graph Level Sum heuristic is the optimal one in terms of node expansion, goal test and new node creation counts. Ignore preconditions heuristic gives result in equal optimality with planning graph but node expansion, goal test and new node creation counts are much larger than planning graph. PG Level Sum heuristic method gave consistently optimal results for all three problems. However, depth first non-heuristic search gives nonoptimal results for all three problems. Other non-heuristic methods like breadth first search gives optimal plans but it is not as efficient as planning graph in terms of node expansion and goal test counts.