Part 1 - Planning problems

- Run uninformed planning searches for air_cargo_p1, air_cargo_p2, and air_cargo_p3; provide metrics on number of node expansions required, number of goal tests, time elapsed, and optimality of solution for each search algorithm. Include the result of at least three of these searches, including breadth-first and depth-first, in your write-up (breadth_first_search and depth_first_graph_search).

Problem 1:

a) Breadth_first_search...

Expansions	Goal Tests	New Nodes
43	56	180

Plan length: 6 Time elapsed in seconds: 0.0934912137194671

Optimal solution

b) Depth_first_graph_search..

Expansions	Goal Tests	New Nodes
12	13	48

Plan length: 12 Time elapsed in seconds: 0.022787541348643553

Not an *Optimal solution*

c) Uniform_cost_search...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.20902150526094268

Optimal solution

Problem 2:

a) breadth_first_search...

Expansions	Goal Tests	New Nodes
3343	4609	30509

Plan length: 9 Time elapsed in seconds: 33.36426982576758

Optimal solution

b) depth_first_graph_search...

Expansions Goal Tests New Nodes

559 560 5008

Plan length: 551 Time elapsed in seconds: 6.8981590317009776

Not an Optimal solution

c) uniform_cost_search...

Expansions Goal Tests New Nodes

4852 4854 44030

Plan length: 9 Time elapsed in seconds: 29.893151232095086

Optimal solution

Problem 3

a) breadth_first_search...

Expansions Goal Tests New Nodes

14663 18098 129631

Plan length: 12 Time elapsed in seconds: 253.2689354506203

Optimal solution

b) Depth_first_graph_search...

Expansions Goal Tests New Nodes

1501 1502 12519

Plan length: 1451 Time elapsed in seconds: 31.835781316129214

Not an Optimal solution

c) uniform_cost_search...

Expansions Goal Tests New Nodes

18236 18238 159726

Plan length: 12 Time elapsed in seconds: 132.09407775901434

Optimal solution

Part 2 - Domain-independent heuristics

- Run A* planning searches using the heuristics you have implemented on `air_cargo_p1`, `air_cargo_p2` and `air_cargo_p3`. Provide metrics on number of node expansions required, number of goal tests, time elapsed, and optimality of solution for each search algorithm and include the results in your report.

  Problem 1.

  Astar_search with h_ignore_preconditions...

  Expansions Goal Tests New Nodes

  41 43 170

  Plan length: 6 Time elapsed in seconds: 0.10034497449204571

  Optimal solution

  Astar_search with h_pg_levelsum...

  Expansions Goal Tests New Nodes

  11 13 50

  Plan length: 6 Time elapsed in seconds: 1.9393231257964674

  Optimal solution

  Problem 2

  Astar_search with h_ignore_preconditions...

  Expansions Goal Tests New Nodes

  1450 1452 13303

  Plan length: 9 Time elapsed in seconds: 9.152174673842087

  Optimal solution

Astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
86	88	841

Plan length: 9 Time elapsed in seconds: 136.32967111934028

Optimal solution

Problem 3

astar_search with h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
5040	5042	44944

Plan length: 12 Time elapsed in seconds: 36.96156005183249

Optimal solution

astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
318	320	2934

Plan length: 12 Time elapsed in seconds: 697.4321116983822

Optimal solution

Part 3: Written Analysis

- Provide an optimal plan for Problems 1, 2, and 3.

Problem 1

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Problem 2

Load(C2, P2, JFK)

Load(C1, P1, SFO)

Load(C3, P3, ATL)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

Fly(P3, ATL, SFO)

Unload(C3, P3, SFO)

Problem 3

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P2, JFK, ORD)

Load(C4, P2, ORD)

Fly(P1, SFO, ATL)

Load(C3, P1, ATL)

Fly(P2, ORD, SFO)

Fly(P1, ATL, JFK)

Unload(C4, P2, SFO)

Unload(C3, P1, JFK)

Unload(C1, P1, JFK)

Unload(C2, P2, SFO)

- Compare and contrast non-heuristic search result metrics (optimality, time elapsed, number of node expansions) for Problems 1,2, and 3. Include breadth-first, depth-first, and at least one other uninformed non-heuristic search in your comparison; Your third choice of non-heuristic search may be skipped for Problem 3 if it takes longer than 10 minutes to run, but a note in this case should be included.

  Breadth First Search:

Problem	Optimal	Time elapsed	No of Node Expansions
1	Yes	0.0934912137194671	43
2	Yes	33.36426982576758	3343
3	Yes	253.2689354506203	14663

  Depth First Graph Search

Problem	Optimal	Time elapsed	No of Node Expansions
1	No	0.022787541348643553	12
2	No	6.8981590317009776	559
3	No	31.835781316129214	1501

  Uniform_cost_search

Problem	Optimal	Time elapsed	No of Node Expansions
1	Yes	0.20902150526094268	55
2	Yes	29.893151232095086	4852
3	Yes	132.09407775901434	18236

- Compare and contrast heuristic search result metrics using A* with the "ignore preconditions" and "level-sum" heuristics for Problems 1, 2, and 3.

ignore preconditions

Problem	Optimality	Time elapsed	No of Node Expansions
1	Yes	0.10034497449204571	41
2	Yes	9.152174673842087	1450
3	Yes	36.96156005183249	5040

level-sum heuristics

Problem	Optimality	Time elapsed	No of Node Expansions
1	Yes	1.9393231257964674	11
2	Yes	136.32967111934028	86
3	Yes	697.4321116983822	318

- 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?

  Ignore preconditions is the best heuristics for all the problems. For problem 1 Breadth first search gave better result as it found the goal in little less time. But otherwise Ignore precondition heuristic A* search gave better results and it was able to find the goal in considerable less amount of time and the number of nodes expanded are also less than the non heuristic search planning methods.