This project implements a planning search agent that solves deterministic logistics planning problems, our agent in this case is restricted to the Air Cargo transport system. We use a **planning graph** and **automatic domain-independent heuristics with A* search** and compare their results/performance against several **uninformed non- heuristic search methods** (breadth-first, depth-first, etc.).

optimal plan lengths for problems 1,2, and 3 are **6, 9, and 12 actions**, respectively. Below are the optimal plans:

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)
```

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(C2, P2, SFO)
Unload(C1, P1, JF)
```

Problem 3:

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

Part 1

Uninformed search algorithms (blind search) have no additional information about states beyond that provided in the problem definition. The process in general is about generating successors nodes and testing each one of them to see if it’s a goal state or not. This section compares the performance of 3 Algorithms in terms of **speed** (execution time, measured in seconds), **memory usage** (measured in search node expansions) and **optimality** (Yes, if a solution of optimal length is found; No, otherwise).

Solving Air Cargo Problem 1

Time Algorithm	Plan length	Time elapsed	Expansions	Goal Tests	New Nodes	Optimality
Breadth first search	6	0.03965075299493037	43	56	180	Yes
Depth first graph search	12	0.008823884010780603	12	13	48	No
Uniform cost search	6	0.04654892301186919	55	57	224	Yes

Solving Air Cargo Problem 2

Time Algorithm	Plan length	Time elapsed	Expansions	Goal Tests	New Nodes	Optimality
Breadth first search	9	19.28290374201606	3343	4609	30509	Yes
Depth first graph search	575	4.847420024016174	582	583	5211	No
Uniform cost search	9	17.18141491501592	4853	4855	44041	Yes

Solving Air Cargo Problem 3

Time Algorithm	Plan length	Time elapsed	Expansions	Goal Tests	New Nodes	Optimality
Breadth first search	12	110.0157	14663	18098	129631	Yes
Depth first graph search	596	3.4469	627	628	5176	No

Uniform cost search	12	55.8357	18222	18224	159608	Yes

Analysis

Breadth First Search (BFS) and **Uniform Cost Search** are the only two uninformed search strategies that **yield an optimal action plan** under the 10mn time limit. When it comes to execution speed and memory usage, **Depth First Graph Search** is the **fastest and uses the least memory**. [3]However, it does not generate an optimal action plan (problem 1: plan length of 12 instead of 6, problem 2: plan length of 346 instead of 9, problem 3: plan length of 1878 instead of 12).

If finding the optimal path length is critical, what strategy should we use?
BFS is **faster and uses less memory** than Uniform Cost Search, BFS is the recommended search strategy. BFS is complete and optimal. Its only downside is memory usage, if the problem's branching factor is high.

Part 2

Informed Search Algorithm's utilizes problem-specific knowledge beyond the definition of the problem itself, those algorithms are capable of finding solutions in an efficient manner compared to uninformed approaches. This section, we compare the performance of **A* Search using three different heuristics**. Evaluation is measured in terms of **speed**, **memory usage** and **optimality**.

Solving Air Cargo Problem 1

Time Algorithm	Plan length	Time elapsed	Expansions	Goal Tests	New Nodes	Optimality
Astar search with h_1	6	0.06032128199876752	55	57	224	Yes
Astar search with h ignore precondition	6	0.05123359199933475	41	43	170	Yes
Astar search with h_pg_levelsum	6	1.4700912830012385	32	34	138	Yes

Solving Air Cargo Problem 2

Time Algorithm	Plan length	Time elapsed	Expansions	Goal Tests	New Nodes	Optimality
Astar search with h_1	9	14.420077874005074	4853	4855	44041	Yes
Astar search with h ignore precondition	9	5.147074280997913	1445	1447	13257	Yes
Astar search with h_pg_levelsum	9	124.49547548699775	167	169	1608	Yes

Solving Air Cargo Problem 3

Time Algorithm	Plan length	Time elapsed	Expansions	Goal Tests	New Nodes	Optimality
Astar search with h_1	12	62.22524076500122	18222	18224	159608	Yes
Astar search with h ignore precondition	12	19.924693720000505	5040	5042	44944	Yes
Astar search with h_pg_levelsum	12	975.0174945339968	1021	1023	9577	Yes

Analysis

While all heuristics yield an optimal action plan, only the h1 and Ignore Preconditions heuristics return results within the 10mn max execution time set by the Udacity staff. A* algorithms are optimal provided that heuristics are admissible [1]

Which heuristic should we use?

Of the two strategies mentioned above, **A* Search with Ignore Preconditions heuristic is the fastest**. If we let search run to completion on our machine, **A* Search with Level Sum heuristic uses the least memory**, but its execution time is much slower.

Informed vs Uninformed Search Strategies

The search strategies that generate optimal plans are Breadth First Search, Uniform Cost Search, and A* Search with all three heuristics.

When it comes to execution speed and memory usage of uninformed search strategies, **Depth First Graph Search** is faster and uses less memory than Uniform Cost Search. As for informed search strategies, **A* Search with Ignore Preconditions heuristic** is the fastest and uses the least memory. [2]

Conclusion

The results are in favour of informed search strategies with custom heuristics over uninformed search algorithms when searching for an optimal plan. The benefits are significant both in terms of speed and memory usage. Another, more subtle, benefit is that one can customize the trade-off between speed and memory usage by using different heuristics, which is simply not possible with uninformed search strategies.

References

References:
[1] Artificial Intelligence A modern Approach, Russell and Norvig (International edition)
[2] Wikipedia page about Search Algorthims , https://en.wikipedia.org/wiki/Search_algorithm - Visted on 20th of August 2017
[3] Udacity Forums answer, https://discussions.udacity.com/t/uniform-cost-vs-breath-first/227342/2 - Visited on 20th of August 2017