

Heuristic Analysis

1. OPTIMAL PLANS:

Let us take best case as base line for comparison to find the optimal search. The results below are taken with Breath-first search.

Air Cargo Problem 1

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

Air Cargo Problem 2

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

Air Cargo Problem 3

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

2. NON-HEURISTIC ANALYSIS:

Air Cargo Problem 1

	Expansions:	Goal Tests:	Plan length:	Time elapsed: (seconds)	Optimal:
BFS	43	56	6	0.068977395	Yes
BFTS	1458	1459	6	1.919167265	No
DFS	21	22	20	0.041281367	No
DLS	101	271	50	0.146947323	No
UCS	55	57	6	0.061265202	Yes

In the non-heuristic search algorithms , it took less than a second except BFTS. The fastest algorithm is DFS but has a long plan length, thus it is not optimal. We can learn from these results that DFS will find the plan to reach the goal but this plan would not be as good as optimal plan. BFTS has same plan length with the optimal plans but take long time, so BFTS does not give us optimal plan. BFS and UCS reach goals in optimal number of expansions and plan lengths. UCS manifests the best performance from non-heuristic searches. BFS shows the second best performance after UCS.

Air Cargo Problem 2

	Expansions:	Goal Tests:	Plan length:	Time elapsed: (seconds)	Optimal:
BFS	3401	4672	9	29.225824908	Yes
BFTS	-	-	-	-	-
DFS	1192	1193	1138	17.260999640	No
DLS	253158	2336904	50	2522.8568378	No
UCS	4761	4763	9	24.900485580	Yes

In this problem UCS has the best performance. UCS reached the goal in the optimal number of moves and has a better runtime than BFS. DFS reached the goal shortest amount of time but not the optimal number of moves. BFTS and DLS run for more than 20 minutes and DLS have a big plan length. UCS has the best in time and optimal in number of actions taken to the goal. BFS has optimal move but a bit slower than UCS.

Air Cargo Problem 3

	Expansions:	Goal Tests:	Plan length:	Time elapsed: (seconds)	Optimal:
BFS	14491	17947	12	230.23098989	Yes
BFTS	-	-	-	-	-
DFS	2014	2100	2014	45.266282649	No
DLS	-	-	-	-	-
UCS	17783	17785	12	106.91565659	Yes

In the Problem 3 results for algorithms show some similarity. UCS is faster than BFS with optimal number of actions. BFS is better than UCS again in number of Expansions. BFTS and DLS run for more than 20 minutes with no result. Final thoughts and non-heuristic metrics As Mr. Peter Norvig said in his video on Depth First Search, it will run to the deepest part of the tree first and then run back and start over again. In the example that we have seen in the class, it will surely find the goal but in most cases that route would not be optimal. We saw that same thing in these AirCargo problems as well. Despite of its fastest time, it finds a plan that is not optimized.

The best algorithm is UCS. It always finds an optimal solution for a problem, runs faster than BFS, but the number of nodes that it expends is larger than BFS.

3. HEURISTIC ANALYSIS:

Air Cargo Problem 1

	Expansions:	Goal Tests:	Plan length:	Time elapsed: (seconds)	Optimal:
RBFS	4229	4230	6	5.69401395	Yes
GBFGS	7	9	6	0.00861471	Yes
A*	55	57	6	0.08531007	Yes
A* h_ignore	41	43	6	0.06103492	Yes
A* h_levelsum	55	57	6	3.13158002	Yes

At this problem set, all heuristic searches reached goals in optimal number of actions. GBFGS is the fastest one and the number of nodes it has expended is the lowest. A* h_ignore search is the second best heuristic by its performance. This one is second fastest and also this 'version' of A* search has the best performance if we look just at A* variations results. GBFGS has the best performance for problem 1.

Air Cargo Problem 2

	Expansions:	Goal Tests:	Plan length:	Time elapsed: (seconds)	Optimal:
RBFS	-	-	-	-	-
GBFGS	550	552	9	2.6865089546	Yes
A*	4761	4763	9	26.274506080	Yes
A* h_ignore	1450	1452	9	9.4878951352	Yes
A* h_levelsum	-	-	-	-	-

In the case of the Problem 2, we didn't have many changes on the best result heuristics. GBFGS has the best performance in time, optimality of search and number of nodes expended. Also, at the second place we have A* h_ignore and also it is the best of A* searches in this Problem as well. A* h_levelsum run for 1303.65 seconds and reached optimal number of nodes. RBFS and A* h_levelsum run for more than 1 hour without any results. GBFGS has the best performance for problem 2.

Air Cargo Problem 3

	Expansions:	Goal Tests:	Plan length:	Time elapsed: (seconds)	Optimal:
RBFS	-	-	-	-	-
GBFGS	4031	4033	12	24.031957202	Yes
A*	17783	17785	12	114.04543092	Yes
A* h_ignore	5003	5005	12	35.281825062	Yes
A* h_levelsum	-	-	-	-	-

In the case of the Problem 3 heuristics does not act any differently for the comparison, if we compare with Problem 2. GBFGS shows the best performance for Problem 3.

In Summary, GBFGS algorithm in all 3 problems expended the least nodes, always found the optimal plan (with the optimal number of actions) and has the fastest run time. Therefore, the best algorithm to use according to all parameters is GBFGS. As we used A* search with three different heuristics, h_ignore_preconditions is the best A* heuristic manifesting the best performance.

A* Search Algorithms Comparison

A* search with llevelsum heuristic is the slowest of all informed searches, because it needs to traverse the graph and check where the goal is (on which layer/level). Their performance on the node expansion is also different. The A* search with ignore_preconditions heuristic expended the least number of nodes in three problems. Based on A* searches, A* search with ignore_preconditions is the best heuristic.

Non-heuristic Planning and Heuristic Planning Comparison

Greedy Best First Search (GBFS) has the best performance overall in the category of heuristic search functions. GBFS runs with the lowest time compared to UCS and BFS which have the best performance in the category of non-heuristic planning. Also, GBFS expanded less nodes than UCS and BFS and every time it reached goal with optimum number of actions. Overall GBFS has better results which gives the idea that it's is much better to use informed (heuristic) search functions then uninformed.