Part 1 - Planning problems

Experiment and document metrics for non-heuristic planning solution searches

Problem 1 Results (uninformed)

Strategy	Optimal	Plan Length	Expansions	Goal Tests	New Nodes	Time elapsed
Breadth First Search	YES	6	43	56	180	0.13s
Breadth First Tree Search	YES	6	1458	1459	5960	3.54s
Depth First Graph Search	NO	12	12	13	48	0.028s
Depth Limited Search	NO	50	101	271	414	0.25s
Uniform Cost Search	YES	6	55	57	224	0.13s
Recursive Best First Search	YES	6	4229	4230	17029	9.9s
Greedy Best First Graph Search	YES	6	7	9	28	0.016s

Problem 2 Results (uninformed)

Strategy	Optimal	Plan Length	Expansions	Goal Tests	New Nodes	Time elapsed
Breadth First Search	YES	9	3401	4672	31049	36.5s
~~Breadth First Tree Search~~	~~———~~	~~———~~	~~———~~	~~———~~	~~———~~	>10m
Depth First Graph Search	NO	346	350	351	3142	3.78s
~~Depth Limited Search~~	~~———~~	~~———~~	~~———~~	~~———~~	~~———~~	>10m
Uniform Cost Search	YES	9	4761	4763	43206	43.48s
~~Recursive Best First Search~~	~~———~~	~~———~~	~~———~~	~~———~~	~~———~~	>10m
Greedy Best First Graph Search	YES	9	550	552	4950	4.8s

Problem 3 Results (uninformed)

Strategy	Optimal	Plan Length	Expansions	Goal Tests	New Nodes	Time elapsed
Breadth First Search	YES	12	14491	17947	128184	225.38s
~~Breadth First Tree Search~~	———	———	———	———	———	>10m
Depth First Graph Search	NO	1878	1948	1949	16253	35.25s
~~Depth Limited Search~~	———	———	———	———	———	>10m
Uniform Cost Search	YES	12	17783	17785	155920	197.2s
~~Recursive Best First Search~~	———	———	———	———	———	>10m
Greedy Best First Graph Search	NO	22	4031	4033	35794	44.65s

Part 2 - Domain-independent heuristics

Problem 1 Results (informed)

Strategy	Optimal	Plan Length	Expansions	Goal Tests	New Nodes	Time elapsed
A* Search with h1 heuristic	YES	6	55	57	224	0.17s
A* Search with Ignore Preconditions heuristic	YES	6	41	43	170	0.11s
A* Search with Level Sum heuristic	YES	6	11	13	50	1s

Problem 2 Results (informed)

Strategy	Optimal	Plan Length	Expansions	Goal Tests	New Nodes	Time elapsed

A* Search with h1 heuristic	YES	9	4761	4763	43206	43.96s
A* Search with Ignore Preconditions heuristic	YES	9	1450	1452	13303	14.1s
A* Search with Level Sum heuristic	YES	9	86	88	841	155s

Problem 2 Results (informed)

Strategy	Optimal	Plan Length	Expansions	Goal Tests	New Nodes	Time elapsed
A* Search with h1 heuristic	YES	12	17783	17785	155920	191s
A* Search with Ignore Preconditions heuristic	YES	12	5003	5005	44586	55.5s
A* Search with Level Sum heuristic	YES	12	311	313	2863	944.8s

Part 3: Written Analysis

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

Problem 1 Optimal Plan	Problem 2 Optimal Plan	Problem 3 Optimal Plan
Load(C2, P2, JFK) Load(C1, P1, SFO) Fly(P2, JFK, SFO) Unload(C2, P2, SFO) Fly(P1, SFO, JFK) Unload(C1, P1, JFK)	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, JFK)	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)

•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.

•Depth first graph search was by far the fastest non-heuristic search method, however it was not optimal for any of the 3 problems evaluated. The only search methods that were optimal for all 3 problems were Breadth first search and uniform cost search. With that in mind, breath first search should be the method used if finding the optimal path length is critical, since it is the fastest amongst the optimal search methods.

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

• All heuristic search methods yielded optimal plans. There were however some large discrepancies in execution time and nodes expanded. A* search with h1 heuristic expanded 3 times as many nodes as A* with ignore preconditions and 50 times more than A* with level sum. A* with ignore preconditions was by far the fastest of all 3, but still expanded more nodes than A* Search with Level Sum heuristic, which means that the calculation of the level sum heuristic was probably too expansive compared to the preconditions heuristic.

•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?

• Search strategies that are deemed uninformed have no additional information about states beyond the current one. They can only arbitrarily select the next node given the current one, and differentiate a state from a goal state [1]. This is in contrast with informed search methods which use problem specific knowledge during node expansion[1]. This is why all the informed search methods yield better results overall, they reduced the number of node expansions by making use of information about the problem specific knowledge. The Ignore Preconditions heuristic was by far the best since it yielded the fastest optimal plan. It seemed to perform much faster than the Levelsum, despite having more nodes. The level sum returns the sum of level costs of the goal, whereas the ignore preconditions drops all preconditions from actions.[1] Given this problem definition, it is much less costly to list all possible action in a given state that to go through all levels of the problem calculating the sum. The Ignore

Preconditions heuristic was also better than the non-heuristic planning methods as well since the heuristic used drastically reduced the number of irrelevant nodes expanded.

•[1] Artificial Intelligence: A Modern Approach ,S. Russell & P. Norvig (2010, 3rd Ed.)