Heuristic Analysis

Manual Solutions to Planning Problems

Problem 1:

Init(At(C1, SFO) ∧ At(C2, JFK)
∧ At(P1, SFO) ∧ At(P2, JFK)
∧ Cargo(C1) ∧ Cargo(C2)
∧ Plane(P1) ∧ Plane(P2)
∧ Airport(JFK) ∧ Airport(SFO))
Goal(At(C1, JFK) ∧ At(C2, SFO))

Optimal Solution:

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

The optimal plan length is 6.

Problem 2:

Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL)
∧ At(P1, SFO) ∧ At(P2, JFK) ∧ At(P3, ATL)
∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3)
∧ Plane(P1) ∧ Plane(P2) ∧ Plane(P3)
∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL))
Goal(At(C1, JFK) ∧ At(C2, SFO) ∧ At(C3, SFO))

Optimal Solution:

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)

The optimal plan length is 9.

Problem 3:

Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL) ∧ At(C4, ORD)
∧ At(P1, SFO) ∧ At(P2, JFK)
∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3) ∧ Cargo(C4)
∧ Plane(P1) ∧ Plane(P2)
∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL) ∧ Airport(ORD))
Goal(At(C1, JFK) ∧ At(C3, JFK) ∧ At(C2, SFO) ∧ At(C4, SFO))

Optimal Solution:

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

The optimal plan length is 12.

Results from running uninformed search:

Problem 1:

A* Variation	Optimal	Expansions	Goal Tests	New Nodes	Plan Length	Time (ms)
BFS	YES	43	56	180	6	32
DFS	NO	12	13	48	12	9
Uniform Cost	YES	55	57	224	6	34

Problem 2:

A* Variation	Optimal	Expansions	Goal Tests	New Nodes	Plan Length	Time (ms)
BFS	YES	3346	4612	30534	9	13253
DFS	NO	1124	1125	10017	1085	7778
Uniform Cost	YES	4853	4855	44041	9	11898

Problem 3:

A* Variation	Optimal	Expansions	Goal Tests	New Nodes	Plan Length	Time (ms)
BFS	YES	14663	18098	129631	12	98434
DFS	NO	627	628	5176	596	3189
Uniform Cost	YES	18235	18237	159716	12	52206

As stated in Peter Norvig's tutorial videos, DFS is not always guaranteed to find an optimal solution, while BFS always does so. We see this being reflected in these results. DFS never obtained an optimal solution, while BFS was always right.

Results from running informed search:

Problem 1:

	Optimal	Expansions	Goal Tests	New Nodes	Plan Length	Time (ms)
H1	YES	55	57	224	6	35
Ignore Preconditions	YES	41	43	170	6	35
Levelsum	YES	11	13	50	6	49

Problem 2:

	Optimal	Expansions	Goal Tests	New Nodes	Plan Length	Time (ms)
H1	YES	4853	4855	44041	9	11835
Ignore Preconditions	YES	1450	1452	13303	9	4162
Levelsum	YES	86	88	841	9	39462

Problem 3:

	Optimal	Expansions	Goal Tests	New Nodes	Plan Length	Time (ms)
H1	YES	18235	18237	159716	12	53519
Ignore Preconditions	YES	5040	5042	44944	12	16255
Levelsum	YES	315	317	2902	12	192581

As stated in the tutorial videos, a* finds the optimal solution as long as the heuristic is admissible. When running a* search with different heuristics we always got the optimal path, although the efficiency of the algorithms differs significantly. The levelsum heuristic achieves great results memory-wise but takes a lot more time to compute than the other two. Ignore preconditions takes the least time to compute but uses way more memory than levelsum. So the ideal heuristic depends on the specific use case.

The best overall strategy to solve these specific problems depends on whether time or memory is the critical factor. If execution time is essential, the overall winner is a* search with ignoring preconditions. If memory is essential then a* search with the levelsum heuristic is the best choice. The performance of the algorithms is summarized in the charts below: