# **Project 3 - Implement a Planning Search**

## I. Optimal plan for Air Cargo Problems 1, 2, and 3.

### a. Air Cargo Problem 1

#### Optimal plan length for problem 1 is = 6

Here are the 6 actions:

- 1. Load(C1, P1, SFO)
- 2. Load(C2, P2, JFK)
- 3. Fly(P1, SF0, JFK)
- 4. Fly(P2, JFK, SFO)
- 5. Unload(C1, P1, JFK)
- 6. Unload(C2, P2, SFO)

#### b. Air Cargo Problem 2

## Optimal plan length for problem 2 is = 9

Here are the 9 actions:

- 1. Load(C1, P1, SFO)
- 2. Load(C2, P2, JFK)
- 3. Load(C3, P3, ATL)
- 4. Fly(P1, SF0, JFK)

- 5. Fly(P2, JFK, SFO)
- 6. Fly(P3, ATL, SFO)
- 7. Unload(C2, P2, SFO)
- 8. Unload(C1, P1, JFK)
- 9. Unload(C3, P3, SF0)

#### c. Air Cargo Problem 3

#### Optimal plan length for problem 3 is= 12

Here are the 12 actions:

- 1. Load(C1, P1, SFO)
- 2. Load(C2, P2, JFK)
- 3. Load(C3, P1, ATL)
- 4. Load(C4, P2, ORD)
- 5. Fly(P1, SFO, ATL)
- 6. Fly(P2, JFK, ORD)
- 7. Fly(P2, ORD, SFO)
- 8. Fly(P1, ATL, JFK)
- 9. Unload(C4, P2, SFO)
- 10. Unload(C3, P1, JFK)
- 11. Unload(C2, P2, SFO)
- 12. Unload(C1, P1, JFK)

## II Uninformed Non-heuristic search result metrics

Air Cargo Problem 1								
						Optimal		
						Plan		
	Node	Goal	New	Time	Plan	Len?		
Search algo	Expansions	Tests	nodes	elapsed(seconds)	length	Y/N		
Breadth First Search	43	56	180	0.033	6	Υ		
Depth First Graph Search	21	22	84	0.015	20	N		
<pre>greedy_best_first_graph_search</pre>								
h_1	7	9	28	0.006	6	Υ		
uniform_cost_search	55	57	224	0.036	6	Υ		

Air Cargo Problem 2								
						Optimal		
						Plan		
	Node	Goal	New	Time	Plan	Len?		
Search algo	Expansions	Tests	nodes	elapsed(seconds)	length	Y/N		
Breadth First Search	3343	4609	30509	14.18	9	Υ		
Depth First Graph Search	624	625	5602	3.18	619	N		
<pre>greedy_best_first_graph_search</pre>								
h_1	998	1000	8982	6.59	13	N		
uniform_cost_search	4853	4855	44041	49.024	9	Υ		

Air Cargo Problem 3								
						Optimal		
						Plan		
	Node	Goal	New	Time	Plan	Len?		
Search algo	Expansions	Tests	nodes	elapsed(seconds)	length	Y/N		
Breadth First Search	14663	18098	129631	100.793	12	Υ		
Depth First Graph Search	408	409	3364	1.63	392	N		
<pre>greedy_best_first_graph_search</pre>								
h_1	5578	5580	49150	116.48	22	N		
uniform_cost_search	18223	18225	159618	417.16	12	Υ		

**Breadth First search** always results in an optimal plan length for all three problems. However it is not computationally efficient because it expands more nodes and takes a lot longer to complete. Depth First search in all three problems expands fewer nodes, uses less memory and is significantly faster as seen in problem #3. Greedy best first graph search is a good option as well. While it is not as fast as Depth FirstGraph Search it still has fewer node expansions than Breadth First Search.

## III Informed heuristic search result metrics

Air Cargo Problem 1								
Search algo	Node Expansions	Goal Tests	New nodes	Time elapsed(seconds)	Plan length	Optimal Plan Len? Y/N		
Breadth First Search	43	56	180	0.033	6	Υ		
Depth First Graph Search	21	22	84	0.015	20	N		
<pre>greedy_best_first_graph_search h_1</pre>	7	9	28	0.006	6	Υ		
uniform_cost_search	55	57	224	0.036	6	Υ		
astar_search h_1	55	57	224	0.039	6	Υ		
<pre>astar_search h_ignore_preconditions</pre>	41	43	170	0.034	6	Y		
astar_search h_pg_levelsum	11	13	50	1.44	6	Υ		

Air Cargo Problem 2								
Search algo	Node Expansions	Goal Tests	New nodes	Time elapsed(seconds)	Plan length	Optimal Plan Len? Y/N		
Breadth First Search	3343	4609	30509	14.18	9	Υ		
Depth First Graph Search	624	625	5602	3.18	619	N		
<pre>greedy_best_first_graph_search h_1</pre>	998	1000	8982	6.59	13	N		
uniform_cost_search	4853	4855	44041	49.024	9	Υ		
astar_search h_1	4853	4855	44041	45.946	9	Υ		

astar_search						
h_ignore_preconditions	1506	<b>1508</b>	13820	13.3897	9	Y
astar_search h_pg_levelsum	86	88	839	155.179	9	Υ

Air Cargo Problem 3								
Search algo	Node Expansions	Goal Tests	New nodes	Time elapsed(seconds)	Plan length	Optimal Plan Len? Y/N		
Breadth First Search	14663	18098	129631	100.793	12	Υ		
Depth First Graph Search	408	409	3364	1.71	392	N		
<pre>greedy_best_first_graph_search h_1</pre>	5578	5580	49150	116.48	22	N		
uniform_cost_search	18223	18225	159618	417.16	12	Υ		
astar_search h_1	18223	18225	159618	385.649	12	Υ		
astar_search h_ignore_preconditions	5118	5120	45650	87.03	12	Υ		
astar_search h_pg_levelsum	404	406	3718	1068.75	12	Y		

All three A\* searches reach the optimal plan length 6, 9, and 12 for problems 1, 2 and 3 respectively.

A\* search that ignores preconditions does best for all three air cargo problems. It is the fastest but it also expands more nodes.

**A\* search that ignores preconditons** performs better than Breadth First Search in that it reaches optimal plan length faster and expands fewer nodes.

A\* search with level sum heuristic uses the least memory expanding fewer nodes, but performs poorly compared to search that ignores preconditions.