Experimental Results & Report

The report discusses the search complexity, search time, and optimality of eleven algorithms (three uninformed and eight with heuristics) by presenting and analyzing the results of an experiment on four air cargo problems using these search algorithms. In the end, it discusses how to apply these results in designing planning systems.

ANALYSIS 1 – SEARCH COMPLEXITY

Table 1 displays the number of nodes expanded and the number of actions for all search and heuristic combinations for air cargo problems 1 and 2 and the relevant data for two uninformed search, four heuristics with greedy best first search, and two heuristics with A* search on air cargo problems 3 and 4.

From Table 1, we can see as the domain size grows from 20 in problem 1 to 104 in problem 4, the number of new node expansion increases exponentially for Breath-first Search and Uniform-first Search. Since Uniform-first Search would explore deeper lengths of small steps before exploring large and useful steps, the number of new nodes expansion grow more exponentially than that of Breath-first Search. Also, in A * Search, the number of new nodes expansions grow exponentially as the domain size increases in using heuristics unmet-goals, max-level and set-level, but with the level-sum heuristics the number of nodes expansions doesn't necessarily grow and expands the least nodes for each problem. Compared to A* Search and Uninformed Search, the growth of Greedy best-first search with different heuristics is largely reduced. Among heuristics with Greedy best-first search, max-level strategy doesn't necessarily expand more nodes as the domain size increases, and except problem 1, the Greedy-first search with level-sum heuristics expands the least nodes in each problem. Lastly, for Depth-first search, it matters more of where the goal lies, so the number of nodes expanded doesn't necessarily grow when the problem size gets bigger.

ANALYSIS 2 – SEARCH TIME

Table 2 displays the search time against the number of domain size for all search and heuristic combinations for air cargo problems 1 and 2 and the relevant data for two uninformed search, four heuristics with greedy best first search, and two heuristics with A* search on air cargo problems 3 and 4.

As indicated in Table 2, the search time grows exponentially for all eleven algorithms and heuristics combinations except Depth-first search, Greedy best-first Search with unmet goals strategy, and A* Search with unmet goals strategy. For Depth-first search, the search time doesn't necessarily increase as the domain size grows. It depends on at which depth the goal is. The Greedy best-first Search takes the least search time in each problem, but it overestimates the path cost, so it is not optimal as the problem size increases. Also, each A* search with same heuristics takes much more time than Greedy best-first search to complete the search.

ANALYSIS 3 - OPTIMALITY

Table 3 displays the number of actions and length of the plans for all search and heuristic combinations for air cargo problems 1 and 2 and the relevant data for two uninformed search, four heuristics with greedy best first search, and two heuristics with A* search on air cargo problems 3 and 4.

In general, Breadth-first search, Uniform-cost search, and A* search are optimal in terms of plan length.

RESULTS APPLIED IN PLANNING SYSTEMS

1. Which algorithm or algorithms would be most appropriate for planning in a very restricted domain (i.e., one that has only a few actions) and needs to operate in real time?
   - Greedy first-search with unmet goals would best fit these requirements. It is optimal when the domain size is small and is the most efficient among all algorithms to operate in real time.
2. Which algorithm or algorithms would be most appropriate for planning in very large domains (e.g., planning delivery routes for all UPS drivers in the U.S. on a given day)
   - Greedy best-first search algorithms with heuristics would be most appropriate for solving large domain size problem. They use least memory and take less time than A* star search on average.
3. Which algorithm or algorithms would be most appropriate for planning problems where it is important to find only optimal plans?
   - Uniform cost Search, Breadth-first Search, and A* Star search algorithms with admissible or consistent heuristics would be appropriate for planning problems that only need optimality. Breadth-first search is optimal when the steps costs are all identical.

Table 1

Algorithms	P 1 (20 actions) # Nodes expanded	P 2 (72 actions) # Nodes expanded	P 3 (88 actions) # Nodes expanded	P4 (104 actions) # Nodes expanded
Breadth-first Search	**178**	**30503**	**129625**	**944130**
Depth-first Search	**84**	**5602**	**3364**	**n/a**
Uniform-cost Search	**240**	**46618**	**161936**	**1066413**
Greedy best-first Search (unmet goals)	**29**	**170**	**230**	**280**
Greedy best-first Search (level sum)	**28**	**86**	**126**	**165**
Greedy best-first Search (max level)	**24**	**249**	**195**	**580**
Greedy best-first Search (set level)	**28**	**84**	**345**	**1164**
A Star Search (unmet goals)	**206**	**22522**	**65711**	**328509**
A Star Search (level sum)	**122**	**3426**	**3403**	**12210**
A Star Search (max level)	**180**	**26594**	**n/a**	**n/a**
A Star Search (set level)	**138**	**9605**	**n/a**	**n/a**

Table 2

Algorithms	P 1 (20 actions) Time in seconds	P 2 (72 actions) Time in seconds	P 3 (88 actions) Time in seconds	P 4 (104 actions) Time in seconds
Breadth-first Search	**0.0061**	**1.3564**	**11.2757**	**64.4467**
Depth-first Search	**0.0032**	**2.0176**	**0.9728**	**n/a**
Uniform-cost Search	**0.0099**	**2.2817**	**10.0336**	**85.9850**
Greedy best-first Search (unmet goals)	**0.0024**	**0.0129**	**0.03113**	**0.0530**
Greedy best-first Search (level sum)	**0.2984**	**6.2665**	**15.2661**	**27.1511**
Greedy best-first Search (max level)	**0.2103**	**12.6047**	**17.5703**	**63.4852**
Greedy best-first Search (set level)	**0.7870**	**17.2228**	**92.1180**	**477.32**
A Star Search (unmet goals)	**0.0064**	**1.5155**	**5.9060**	**39.9952**
A Star Search (level sum)	**0.7000**	**168.4863**	**268.3582**	**1416.9231**
A Star Search (max level)	**0.7324**	**948.3615**	**n/a**	**n/a**
A Star Search (set level)	**2.0267**	**1364.0545**	**n/a**	**n/a**

Table 3

Algorithms	P 1 (20 actions) Plan length	P 2 (72 actions) Plan length	P 3 (88 actions) Plan length	P 4 (104 actions) Plan length
Breadth-first Search	6	9	12	14
Depth-first Search	20	619	392	n/a
Uniform-cost Search	6	9	12	14
Greedy best-first Search (unmet goals)	6	9	15	18
Greedy best-first Search (level sum)	6	9	14	17
Greedy best-first Search (max level)	6	9	13	17
Greedy best-first Search (set level)	6	9	17	23
A Star Search (unmet goals)	6	9	12	14
A Star Search (level sum)	6	9	12	15
A Star Search (max level)	6	9	n/a	n/a
A Star Search (set level)	6	9	n/a	n/a