COMP 472 MP2

1. The length of the solutions across algorithms and heuristics. When do you have the lowest-cost solution?

In the 50 puzzle analysis, Uniform cost search , Algorithm A* (admissible heuristics: h1, h4) and Algorithm A with non-admissible heuristic h2, always found the shortest solution path.

The lowest cost solution is guaranteed to be found by Uniform cost search and Algorithm A* due to admissibility.

Algorithm A with heuristic h2 is only non-admissible in a specific case, therefore it frequently finds the lowest cost solution.

2. The admissibility of each heuristic and its influence on the optimally of the solution.

$h(n) \leq h^*(n)$ for all n

// ie. $h(n)$ never overestimates the true lowest cost from n to the goal

- h(n) is the **estimated** cost from node n to the goal state.
- h*(n) is the **actual** cost cost from node n to the goal state.

If h(n) never overestimates the true lowest cost from n to the goal, i.e. $h(n) \leq h^*(n)$ for all n, the heuristic function h(n) is admissible.

If Algorithm A uses an admissible heuristic in its calculation of f(n) it is considered to be admissible and called Algorithm A*. The admissible property means it guarantees to find the lowest cost solution path.

Algorithm A* is a compromise between Uniform cost search and Greedy best first search:

- Like UCS, Algorithm A* is able to find the lowest cost solution path.
- Like GBFS, Algorithm A* is able to leverage the knowledge of a heuristic, making it an informed search.

2.1. Heuristic 1: The number of blocking vehicles

Heuristic 1: The number of blocking vehicles (between the A car and the exit).

H1 is admissible. Given a board with X blocking cars, at least one move must be used by each car to clear A's path to the goal state.

In the best case, the rightmost car between the AA and the solution position lies on the exit of the parking and is removed by the complimentary valet service free of charge. Then each remaining blocking car can be removed from A's path in one move and add another move to move A itself. Essentially in the best case scenario, $h^*(n) = h(n)$, since we consider m - 1 moves for m blocking vehicles +1 move for A to go to the goal.

2.2 Heuristic 2: The number of blocked positions

Heuristic 2: The number of blocked positions (between the A car and the exit).

H2 is not admissible. It is possible for the number of blocked positions between the A car and the goal state to be greater than the number of moves needed to reach the goal state.

Example:

Given the game board and heuristic above,

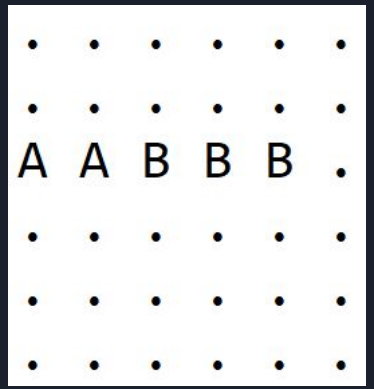
h(n) = the number of blocked positions = 3

h*(n) = the cost from n to the goal state = 2

h(n) > h*(n)

Therefore,

h(n) is not admissible.



2.3 Heuristic 3: The number of blocking vehicles * 5

Heuristic 3: The number of blocking vehicles (between the A car and the exit) * 5.

H3 is not admissible, there is no guarantee that the number of moves required to reach the goal state will always be greater than the number of blocking vehicles * 5. (This is proven in the below example where Algorithm A-h3 does not find the lowest cost solution)

Multiplying the heuristic by a relatively large (all moves only have a cost of 1) constant of 5 means g(n) has a much lower weight in the calculation of Algorithms A's f(n). This essentially transforms Algorithm A it into Greedy best first search, only considering the value of the heuristic (this is shown consistently in the 50 puzzle analysis).

Example : A-h3 performs similarly to all GBFS

Puzzle Number	Algorithm	Heuristic	Length of the Solution	Length of the Search Path	Execution Time (in seconds)
29	ucs	NA	16	5729	26.25
29	gbfs	h1	19	1933	4.16
29	gbfs	h2	19	1933	4.06
29	gbfs	h3	19	1933	4.13
29	gbfs	h4	17	1385	2.68
29	a	h1	16	3920	13.93
29	a	h2	16	3920	14.02
29	a	h3	18	1944	4.62
29	a	h4	16	3002	8.97

2.4 Heuristic 4: Modified - The number of blocking vehicles

Heuristic 4: If one of the blocking vehicles is vertical and has no available moves (trapped), H4 = the number of blocking vehicles + 1. Else, h4 = the number of blocking vehicles.

H4 is admissible, if a board contains one vertical blocking vehicle that has no available moves, it will cost at least one additional move plus h1 to remove all blocking cars from the A car's path.

H4 provides additional information to h1 while remaining admissible. This gained information is more valuable than the additional calculation cost, improving overall runtimes.

Example: H4 performs better for all gbfs and for all of Algorithm A's admissible heuristics (A*).

Puzzle Number	Algorithm	Heuristic	Length of the Solution	Length of the Search Path	Execution Time (in seconds)
32	ucs	NA	12	5891	33.27
32	gbfs	h1	16	798	1.24
32	gbfs	h2	16	798	1.25
32	gbfs	h3	16	798	1.24
32	gbfs	h4	16	700	1.08
32	a	h1	12	2372	7.81
32	a	h2	12	2372	7.88
32	a	h3	15	1026	1.95
32	a	h4	12	1916	5.77

3. The execution time across algorithms and heuristics. Is an informed search always faster?

Informed search is almost always faster than uninformed search because of the ability to leverage the information gained by a heuristic when picking the next node to visit.

However, if the heuristic function is costly to compute, it is possible that the information gained by the heuristic is not worth the cost of calculating it. In our case, since the heuristic functions are relatively easy to compute, informed search always outperformed uninformed.

Example : UCS (uninformed search) has the longest execution time.

Puzzle Number	Algorithm	Heuristic	Length of the Solution	Length of the Search Path	Execution Time (in seconds)
37	ucs	NA	20	5223	22.45
37	gbfs	h1	20	4237	15.31
37	gbfs	h2	20	4237	15.44
37	gbfs	h3	20	4237	15.48
37	gbfs	h4	21	4184	14.77
37	a	h1	20	4893	20.72
37	a	h2	20	4893	20.83
37	a	h3	20	4303	17.84
37	a	h4	20	4566	18.91

4. Other interesting facts that you deem worthy of describing.

- Greedy best first search always has the shortest search path but the longest solution path.
- Even though heuristic 3 (the number of blocked positions) is not admissible, it found the lowest cost solution path in all 50 puzzles.
- The small modification of heuristic 1 (the number of blocking cars) to heuristic 4 noticeably reduced execution times.