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CSE 415 HW3: Heuristics and A* Search

Item 8: Heuristics for the Eight Puzzle

Uniform Cost Search (No Heuristics)

Problem	Puzzle Permutation	Success	Aborted	Solution Length	Total Cost	States Expanded	Max OPEN Length
A	[3,0,1,6,4,2,7,8,5]	Y	N	7	7	166	101
B	[3,1,2,6,8,7,5,4,0]	Y	N	12	12	1490	898
C	[4,5,0,1,2,8,3,7,6]	Y	N	14	14	4070	2290
D	[0,8,2,1,7,4,3,6,5]	Y	N	16	16	7982	4700

A* Search With Hamming Heuristic

Problem	Puzzle Permutation	Success	Aborted	Solution Length	Total Cost	States Expanded	Max OPEN Length
A	[3,0,1,6,4,2,7,8,5]	Y	N	7	7	7	6
B	[3,1,2,6,8,7,5,4,0]	Y	N	12	12	94	72
C	[4,5,0,1,2,8,3,7,6]	Y	N	14	14	189	127
D	[0,8,2,1,7,4,3,6,5]	Y	N	16	16	589	368

A* Search With Manhattan Heuristic

Problem	Puzzle Permutation	Success	Aborted	Solution Length	Total Cost	States Expanded	Max OPEN Length
A	[3,0,1,6,4,2,7,8,5]	Y	N	7	7	7	6
B	[3,1,2,6,8,7,5,4,0]	Y	N	12	12	33	25
C	[4,5,0,1,2,8,3,7,6]	Y	N	14	14	56	39
D	[0,8,2,1,7,4,3,6,5]	Y	N	16	16	148	96

- All heuristic runs completed within a second or two

Evaluating my Custom Heuristic

My heuristic works by counting the total distance each face is from its desired face. For example, if a color is on the right face, its distance is zero. If it is on the completely opposite face, its distance is two. Else, its distance is one. This is pretty much just an extension to the Manhattan Heuristic to the Rubik2Cube problem. Below are some statistics surrounding its performance vs Hamming and UCS. In each trial, the solved cube was mixed up by 5 random moves before the program attempts to solve it. For consistency, the random moves were seeded by the same number for testing each heuristic so they all began from the same initial state.

Heuristic Type	Success?	Solution Length	Total Cost	State Expanded	Runtime	Max OPEN length
UCS	No	N/A	N/A	N/A	>5 minutes	N/A
Hamming	Yes	7	7	105	1.71 sec	1156
Custom	Yes	5	5	60	0.59 sec	661

Note that Hamming did NOT produce an optimal solution. This is because for this problem, 8 faces move at a time. Thus, counting the number of faces out of place is not an admissible heuristic: a cube one move away from being solved has 8 faces out of place. Even though my custom heuristic is also not admissible (consider the same case where the cube is one move away from being solved) it appears to greatly reduce the number of states required to solve the cube as well as the length of the OPEN list. I reran these tests several times to see if this holds up on different starting positions and this seems to be the case. Comparing the costs of the two heuristics, it is clear the Hamming heuristic is $O(n^2)$, where n is the side length of the cube: you have to check the color of $6*n^2$ faces. My custom heuristic is $O(n^2)$ as it also only traverses the set of faces a single time. So it gets improved performance at no extra computational cost. Of course, it is still a significant cost.