CS170: Assignment 1 Write Up

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1 Introduction

This assignment is the first project in Dr. Eamonn Keogh's Introduction to AI course at the University of California, Riveside during the quarter of Fall 2017. The following write up is to detail my findings through the course of project completion.

It explores Uniform Cost Search, and the Misplaced Tile and Manhattan Distance heursitics applied to A*. My lanugage of choice was Python (version 3), and the full code for the project is included.

2 Comparison of Algorithms

The three algorithms implemented are as follows: Uniform Cost Search, A* using the Misplaced Tile heuristic, and A* using the Manhattan Distance heuristic.

2.1 Uniform Cost Search

As noted in the initial assignment prompt, **Uniform Cost Search** is simply A* with h(n) hard-coded to 0, and it will only expand the cheapest node, whose cost is in g(n). In the case of this assignment, there are no weights to the expansions, and each expanded node will have a cost of 1.

2.2 The Misplaced Tile Heuristic

The second algorithm implemented is A* with the **Misplaced Tile Heuristic**. The heuristic looks to the number of "misplaced" tiles in a puzzle. For example:

```
A puzzle:
[[1, 2, 4],
 [3, 0, 6],
 [7, 8, 5]]
```

...and it's goal state:

```
goal state:
[[1, 2, 3],
 [4, 5, 6],
 [7, 8, 0]]
```

Not counting 0 (the placeholder for the blank/missing tile), g(n) is set to the number of tiles not in their current goal state position are counted; in this example, g(n) = 3. This assigns a number, where lower is better, to node expansion based on how many misplaced tiles there are after any given position change of the space. When applied to the n-puzzle, queue will expand the node with the cheapest cost, rather than expanding each of the child nodes as Uniform Cost Search would.

2.3 The Manhattan Distance Heuristic

The **Manhattan Distance Heuristic** is similar to the Misplaced Tile Heuristic such that it considers the cost of future expansions and looks at misplaced tiles, but has a different rationale to it. The heuristic considers all of the misplaced tiles *and* the number of tiles away from its goal state position would be. The resulting g(n) is the sum of all the cost of all misplaced tile distances. Using the example above:

```
A puzzle:
[[1, 2, 4],
 [3, 0, 6],
 [7, 8, 5]]

goal state:
[[1, 2, 3],
 [4, 5, 6],
 [7, 8, 0]]
```

Not counting the position of 0, it can be seen that tiles 4, 3, and 5 are out of place. Based on their positions in the puzzle and their goal state positions, g(n) = 8.

2.4 Comparison of Algorithms on Sample Puzzles

There were six puzzles of varying difficulty given to implement. The easiest of the six is a trivial puzzle (the puzzle being the goal state) and the hardest puzzle is impossible to solve (the goal state, but the position of tiles 7 and 8 swapped). The puzzle configurations themselves can be seen in nPuzzle.py. See Figure 1 and Figure 2 for a visual representation of the number of nodes expanded and the maximum queue size, respectively.

It was found that the difference between the three algorithms was relatively negligible when given easier puzzles, but the heuristics (and how good the heuristic was) made a significant difference in the space complexity when solving more difficult but still solvable puzzles.

3 Mathematic Verification

4 Example Traceback

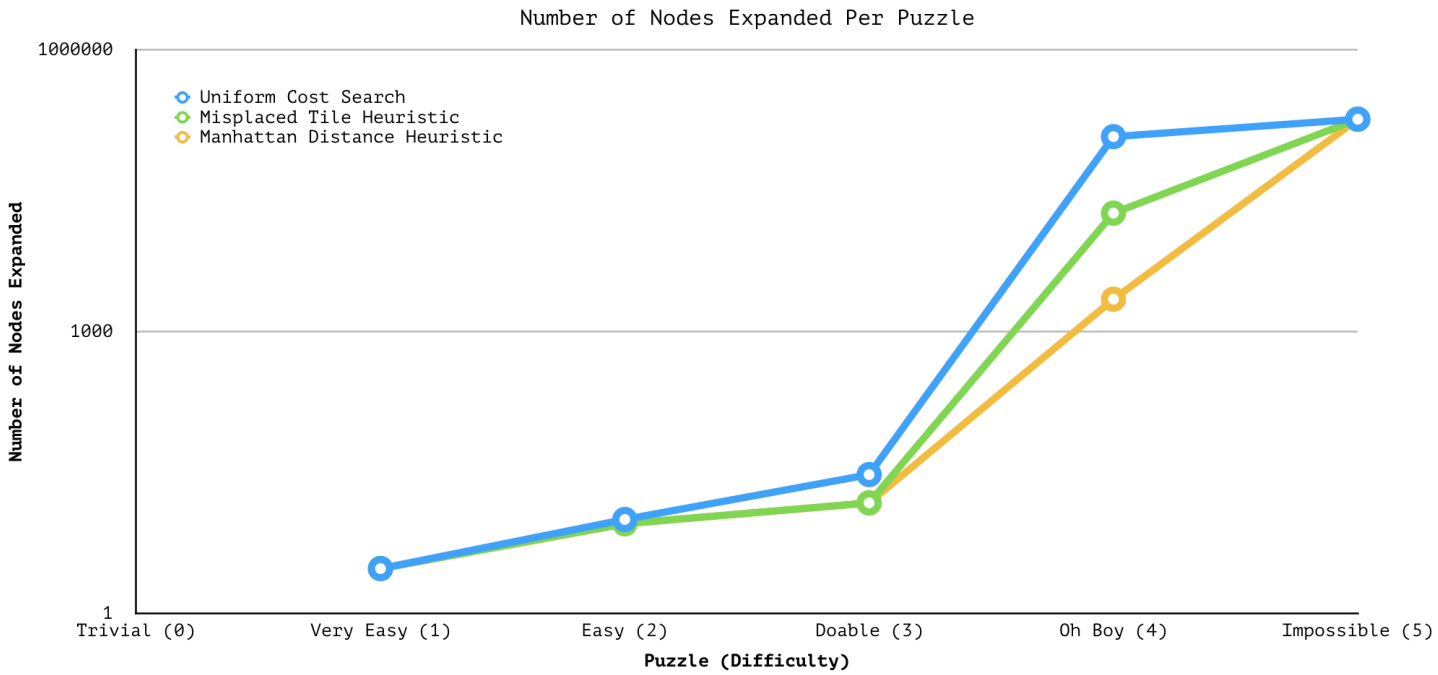
This section is the output (in three columns) from the assignment on puzzle 3, Doable, for Uniform Cost Search and the Misplaced Tile heuristic.

Algorithm: Uniform Cost Search, Puzzle: Doable Nodes expanded: 30, Max queue size: 16

```
[4, 1, 2]                [1, 5, 2]                [1, 5, 2]
[5, 3, 0]                [4, 8, 3]                [4, 0, 3]
[7, 8, 6]                [7, 0, 6]                [7, 8, 6]

[4, 0, 2]                [1, 5, 2]                [4, 1, 2]
[5, 1, 3]                [0, 4, 3]                [7, 5, 3]
[7, 8, 6]                [7, 8, 6]                [0, 8, 6]

[4, 1, 2]                [4, 1, 2]                [4, 1, 2]
[5, 8, 3]                [7, 5, 3]                [5, 0, 3]
[7, 0, 6]                [8, 0, 6]                [7, 8, 6]

[1, 5, 2]                [1, 2, 3]                [1, 2, 0]
[4, 3, 0]                [4, 5, 0]                [4, 5, 3]
[7, 8, 6]                [7, 8, 6]                [7, 8, 6]
```

Number of Nodes Expanded

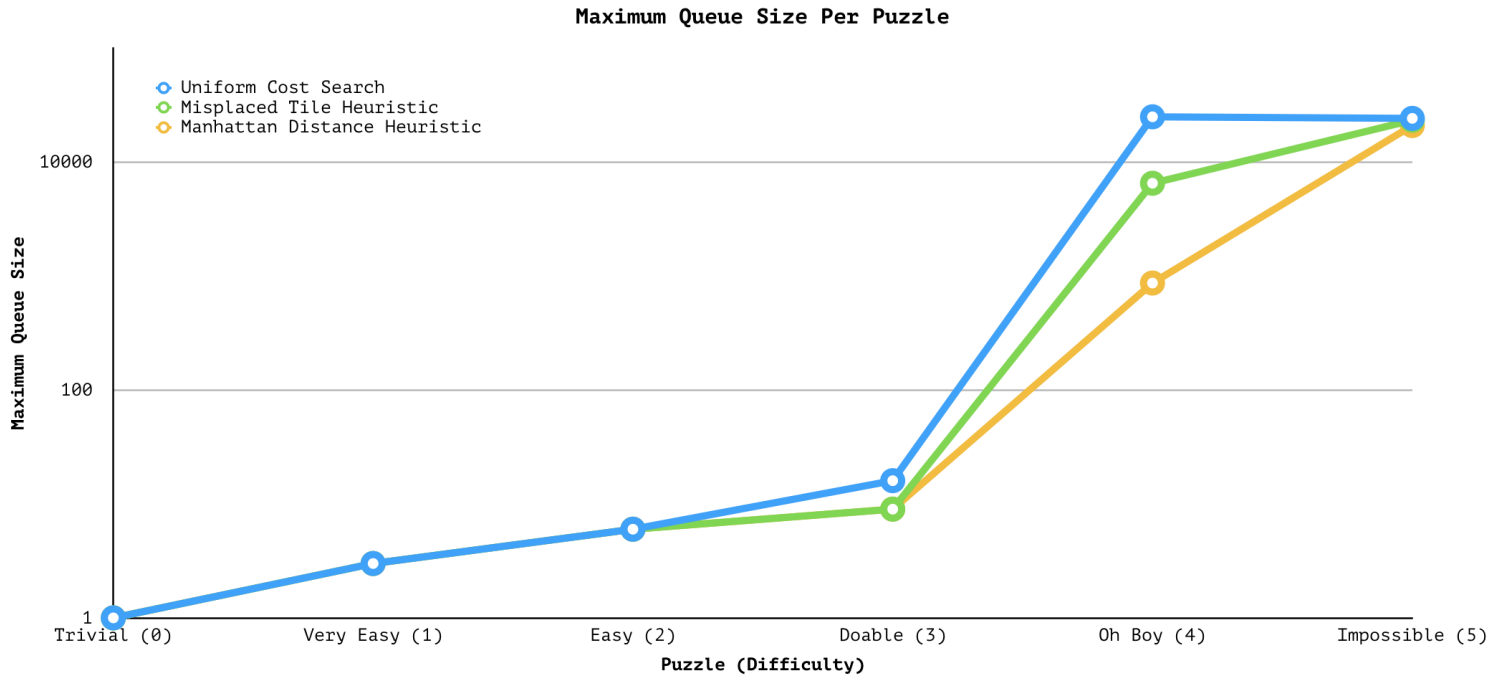
	Uniform Cost Search	Misplaced Tile Heuristic	Manhattan Distance Heuristic
Trivial (0)	0	0	0
Very Easy (1)	3	3	3
Easy (2)	10	9	9
Doable (3)	30	15	15
Oh Boy (4)	118332	18168	2205
Impossible (5)	181439	181439	181439



Nodes Expanded.png

Maximum Queue Size

	Uniform Cost Search	Misplaced Tile Heuristic	Manhattan Distance Heuristic
Trivial (0)	1	1	1
Very Easy (1)	3	3	3
Easy (2)	6	6	6
Doable (3)	16	9	9
Oh Boy (4)	24969	6519	868
Impossible (5)	24188	23314	20922



Queue Size.png

```
                        [1, 0, 2]                   [4, 5, 3]
[4, 1, 2]               [4, 5, 3]                   [7, 8, 6]
[0, 5, 3]               [7, 8, 6]
[7, 8, 6]
                        [0, 1, 2]
```

Algorithm: Misplaced Tile Heuristic, Puzzle: Doable Nodes expanded: 15, Max queue size: 9

```
                        [4, 0, 3]
[1, 2, 3]               [7, 8, 6]                   [1, 0, 2]
[4, 0, 5]                                           [4, 5, 3]
[7, 8, 6]               [1, 2, 0]                   [7, 8, 6]
                        [4, 5, 3]
[1, 2, 3]               [7, 8, 6]                   [0, 1, 2]
[4, 5, 0]                                           [4, 5, 3]
[7, 8, 6]               [4, 1, 2]                   [7, 8, 6]
                        [0, 5, 3]
[1, 5, 2]               [7, 8, 6]
```