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, Riverside 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:                            goal state:
[[1, 2, 4],                          [[1, 2, 3],
 [3, 0, 6],                           [4, 5, 6],
 [7, 8, 5]]                           [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 same example above, 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 (page 3) and Figure 2 (page 4) 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 Additional Examples

For the sake of comparison, I have a few made up puzzles, and run each of the algorithms on them. See Figures 3 (page 5) and 4 (page 6) for a comparison of the number of nodes expanded, and the maximum queue size reached.

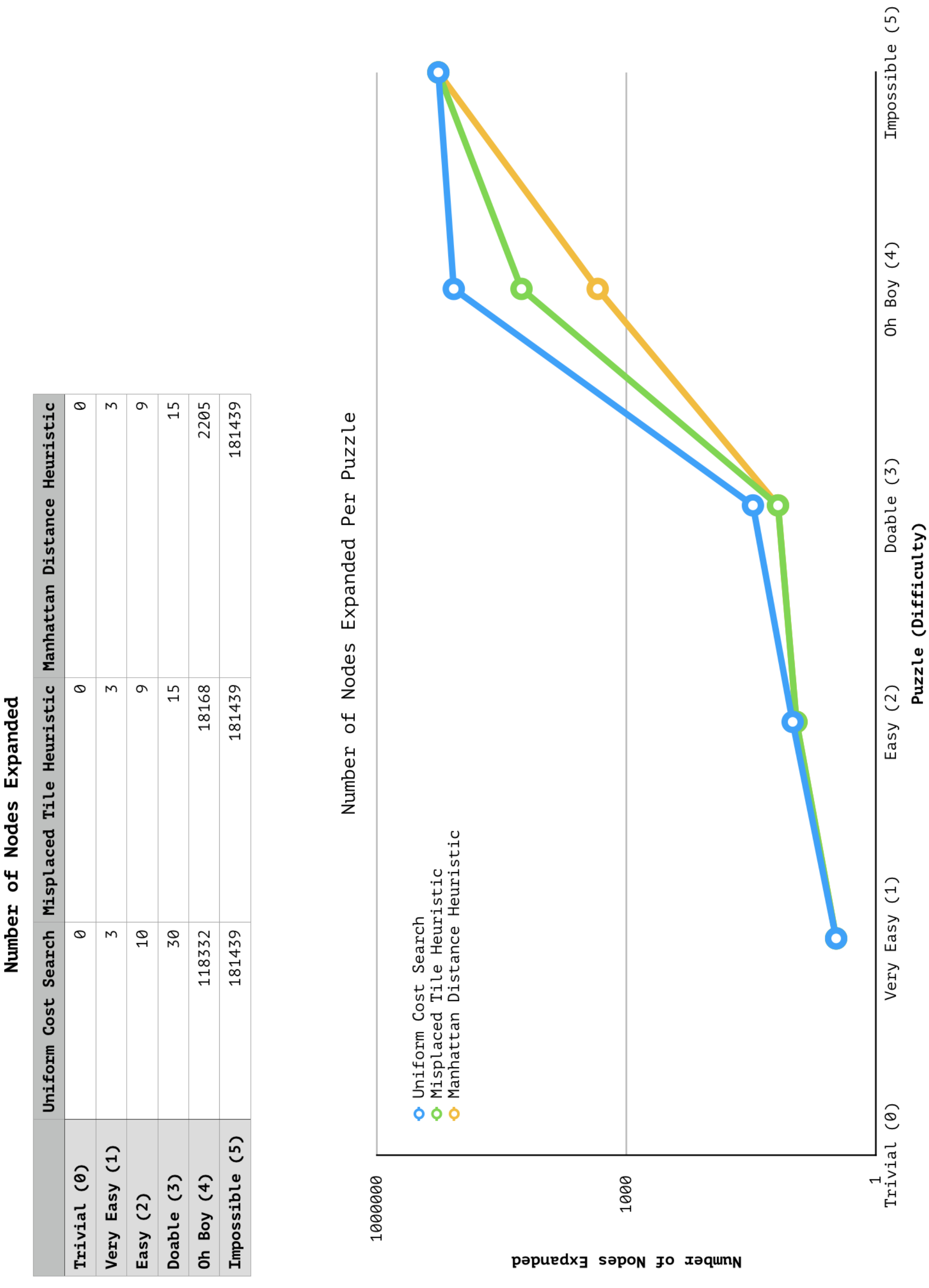
```
Puzzle 1:       Puzzle 2:       Puzzle 3:       Puzzle 4:       Puzzle 5:
[[5, 1, 3],     [[4, 8, 0],     [[3, 5, 8],     [[5, 1, 8],     [[5, 1, 3],
 [8, 6, 0],      [6, 5, 7],      [4, 2, 6],      [2, 4, 6],      [8, 6, 0],
 [2, 7, 4]]      [3, 2, 1]]      [0, 1, 7]]      [7, 3, 0]]      [2, 7,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

4 Conclusion

Considering the list of the three algorithms and the comparisons between them: Uniform Cost Search, Misplaced Tiles, and Manhattan Distance, it can be said that:

- It can be seen that out of the three algorithms, the Manhattan Distance Heuristic performed the best, followed by the Misplaced Tiles Heuristic, followed by Uniform Cost Search (or in this case, effectively also called Breadth-First Search).
- The Misplaced Tile and Manhattan Distance heuristics improve the efficiency of algorithms. Uniform Cost Search, h(n) having been hardcoded to 0, became Breadth First Search, which has a time complexity of $O(b^d)$ and also a space complexity of $O(b^d)$, where b is the branching factor and d is the depth of the solution in the search tree.
- While both the Misplaced Tile Heuristic and Manhattan Distance Heuristic improved the run time and space cost of Uniform Cost Search, it is clear that the Manhattan Distance Heuristic performed better between the two. It can be concluded that while an relevant heuristic will perform better than a blind search, not all heuristics are made equal.

Figure 1: The Number of Nodes Expanded, Preset Puzzles

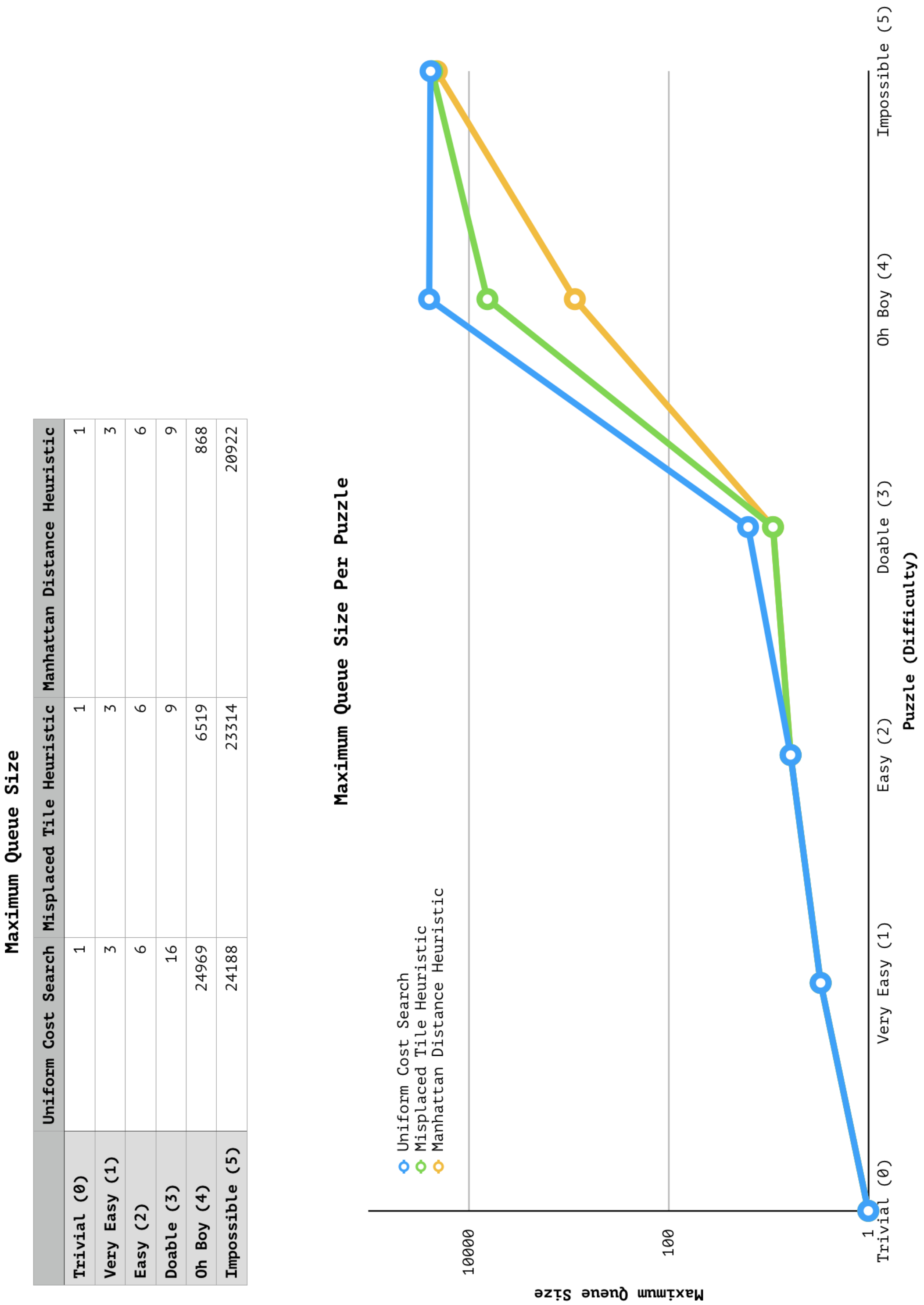


Number of Nodes Expanded

	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

Figure 2: The Maximum Queue Size, Preset Puzzles



Maximum Queue Size

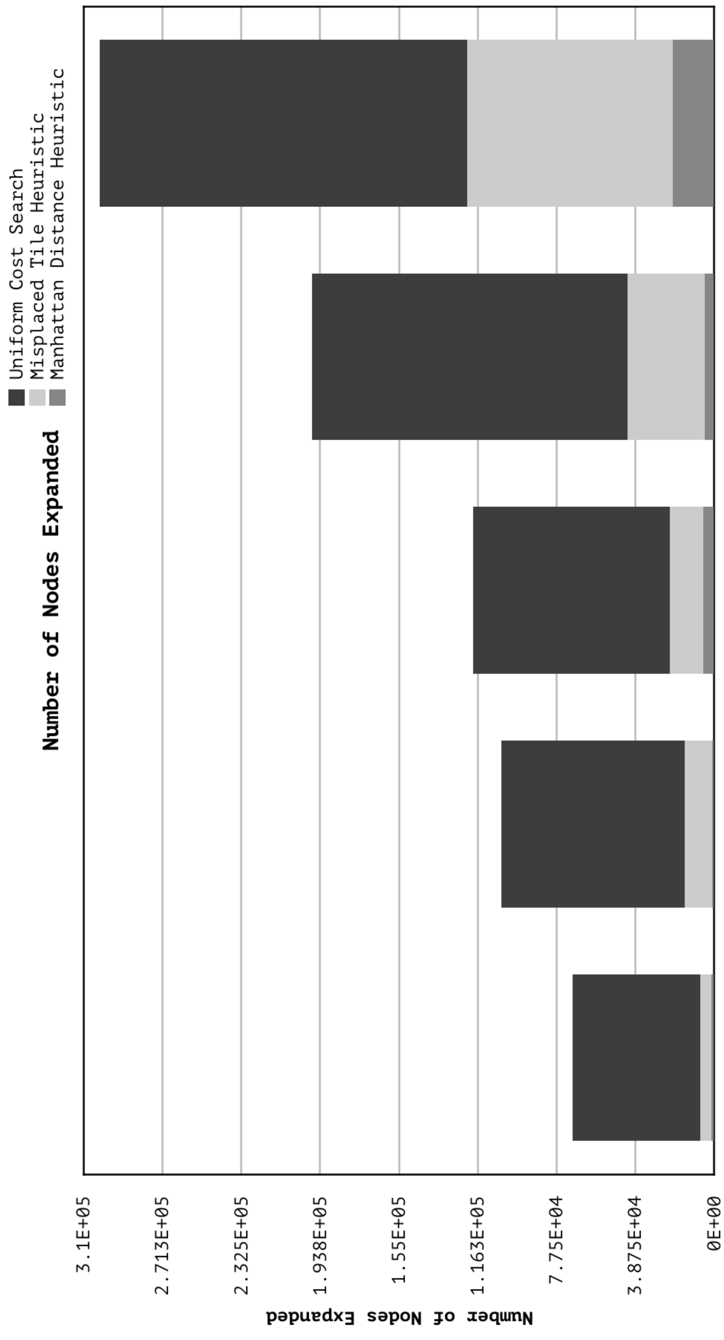
	Uniform Cost Search	Misplaced Tile Heuristic	Manhattan Distance Heuristic
Trivial (0)	1	1	1
Very Easy (1)	3	3	3
Easy (2)	6	6	6
Doable (3)	16	9	9
Oh Boy (4)	24969	6519	868
Impossible (5)	24188	23314	20922

Queue Size.png

Figure 3: The Number of Nodes Expanded, Randomly Generated Puzzles

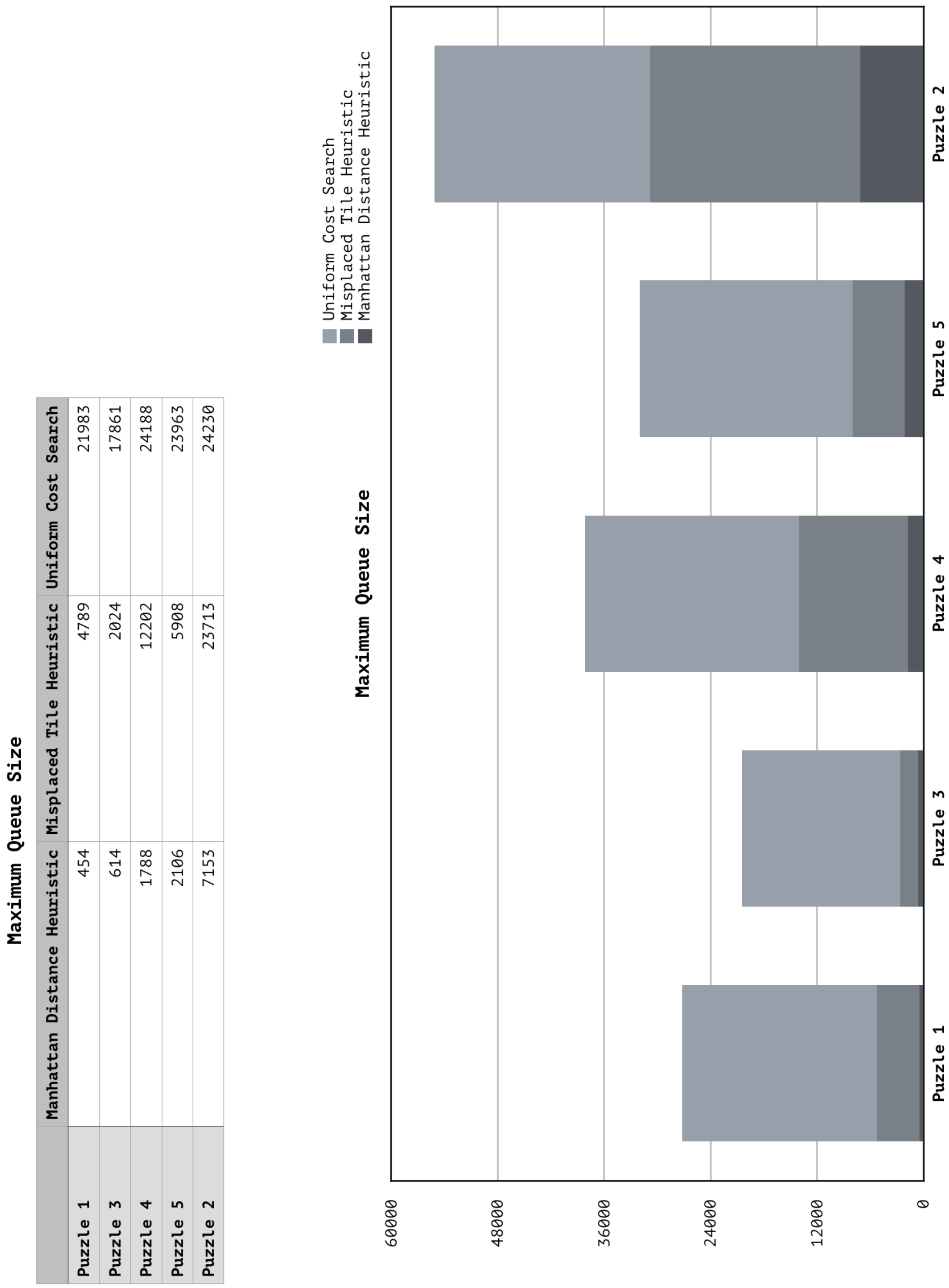
Number of Nodes Expanded

	Manhattan Distance Heuristic	Misplaced Tile Heuristic	Uniform Cost Search
Puzzle 3	1507	5340	62698
Puzzle 1	1144	13307	90374
Puzzle 5	5553	16166	96901
Puzzle 4	4608	38054	154909
Puzzle 2	20317	100978	180949



Number Nodes Expanded.png

Figure 4: The Maximum Queue Size, Randomly Generated Puzzles


Maximum Queue Size

	Manhattan Distance Heuristic	Misplaced Tile Heuristic	Uniform Cost Search
Puzzle 1	454	4789	21983
Puzzle 3	614	2024	17861
Puzzle 4	1788	12202	24188
Puzzle 5	2106	5908	23963
Puzzle 2	7153	23713	24230

Maximum Queue Size.png