**CS4750-HW2**

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**References:** For *depth\_first\_graph\_search.py, interative\_deepening\_tree\_search.py, node.py, problem.py*, we implemented using the code from <https://github.com/aimacode/aima-python/blob/master/search.py> and modified it a bit to fit with the assignment requirement. For the A\* tree search using Manhattan distance heuristic (*a\_star-python.py*), we implemented our code based on the pseudo code from [https://en.wikipedia.org/wiki/A\*\_search\_algorithm](https://en.wikipedia.org/wiki/A*_search_algorithm).

**Description**: Iterative deepening tree search and depth first graph search are implemented using the Node and Problem class. The node class handles keeping track of parent, child and expanding itself, basically it handles the tree/graph structure so our search doesn't have to worry about that. The problem class handles goal testing and managing the 4x4 square, again so that our search algorithm doesn't have these details to worry about. Iterative deepening tree search uses a counter and depth first limited search. This is so that depth first search acts more like breadth first search without the memory issues. Depth first graph search is just depth first search, that doesn't expand the same node twice. These were both developed on a windows laptop using VS Code, python extension, to run and debug.

**Result:**

**Test case 1:**

1. Iterative deepening tree search (IDS)
2. First 5 search nodes that expanded (order left to right):

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 | 12 |  |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 | 12 |  |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 |  |
| 13 | 14 | 12 | 8 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 |  | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 | 12 |  |

1. Solution Sequence
   * 1. 8 steps
     2. ['LEFT', 'UP', 'UP', 'UP', 'RIGHT', 'DOWN', 'DOWN', 'DOWN']
2. Nodes Expanded
   * 1. 2705 Nodes
3. Time Taken
   * 1. 37.142 ms
4. Depth-first graph search (DFGS)
5. First 5 search nodes that expanded (order left to right):

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 | 12 |  |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 |  |
| 13 | 14 | 12 | 8 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 |  | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 |  |
| 9 | 10 | 15 | 4 |
| 13 | 14 | 12 | 8 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 |  | 11 |
| 9 | 10 | 15 | 4 |
| 13 | 14 | 12 | 8 |

1. Solution Sequence
   1. No solution found
2. Nodes Expanded
   1. 1,000,000 Nodes
3. Time Taken
   1. 18571.336 ms
4. A\* tree search

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 |  | 8 |
| 13 | 14 | 15 | 12 |

1. First 5 search nodes that expanded (order left to right):

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 | 12 |  |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 | 11 | 4 |
| 9 | 10 | 15 | 8 |
| 13 | 14 |  | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 | 7 | 3 |
| 5 | 6 |  | 4 |
| 9 | 10 | 11 | 8 |
| 13 | 14 | 15 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 | 2 |  | 3 |
| 5 | 6 | 7 | 4 |
| 9 | 10 | 11 | 8 |
| 13 | 14 | 15 | 12 |

1. Solution and total number of moves to reach the solution:
2. Number of node expanded:
3. CPU execution time:

**Test case 2:**

1. Iterative deepening tree search (IDS)

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
|  | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

* 1. First 5 search nodes that expanded (order left to right):

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
|  | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
|  | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
| 10 |  | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
|  | 10 | 14 | 12 |

* 1. Solution Sequence
     1. No solution found
  2. Nodes Expanded
     1. 1,000,000 Nodes
  3. Time Taken
     1. 12948.824 ms

1. Depth-first graph search (DFGS)
   1. First 5 search nodes that expanded (order left to right):

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
|  | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
|  | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
| 10 |  | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
|  | 2 | 11 | 4 |
| 9 | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 6 |  | 15 | 8 |
| 13 | 10 | 14 | 12 |

* 1. Solution Sequence
     1. No solution found
  2. Nodes Expanded
     1. 1,000,000 Nodes
  3. Time Taken
     1. 18714.244 ms

1. A\* tree search
   1. First 5 search nodes that expanded (order left to right):

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 4 |
| 13 | 6 | 15 | 8 |
|  | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
| 9 | 2 | 11 | 14 |
|  | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 5 | 1 | 7 | 3 |
|  | 2 | 11 | 14 |
| 9 | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1 | 7 | 3 |
| 5 | 2 | 11 | 4 |
| 9 | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

|  |  |  |  |
| --- | --- | --- | --- |
| 1 |  | 7 | 3 |
| 5 | 2 | 11 | 4 |
| 9 | 6 | 15 | 8 |
| 13 | 10 | 14 | 12 |

* 1. Solution and total number of moves to reach the solution:
  2. Number of node expanded:
  3. CPU execution time: