CS440/ECE448 Fall 2023, Mp 3: A* Search

Due: Monday, September 25, 11:59pm

I. Overview

In this assignment you will be implementing the A* search algorithm for solving 2 different search problems - EightPuzzle and WordLadder. Your single implementation of the algorithm will work for both problems, by properly instantiating an AbstractState class for each of them. You will see both the power of A* as an algorithm that applies to arbitrary discrete state spaces, and the power of heuristics to speed up search.

II. Getting Started

To get started on this assignment, download the template code. The template contains the following files and directories:

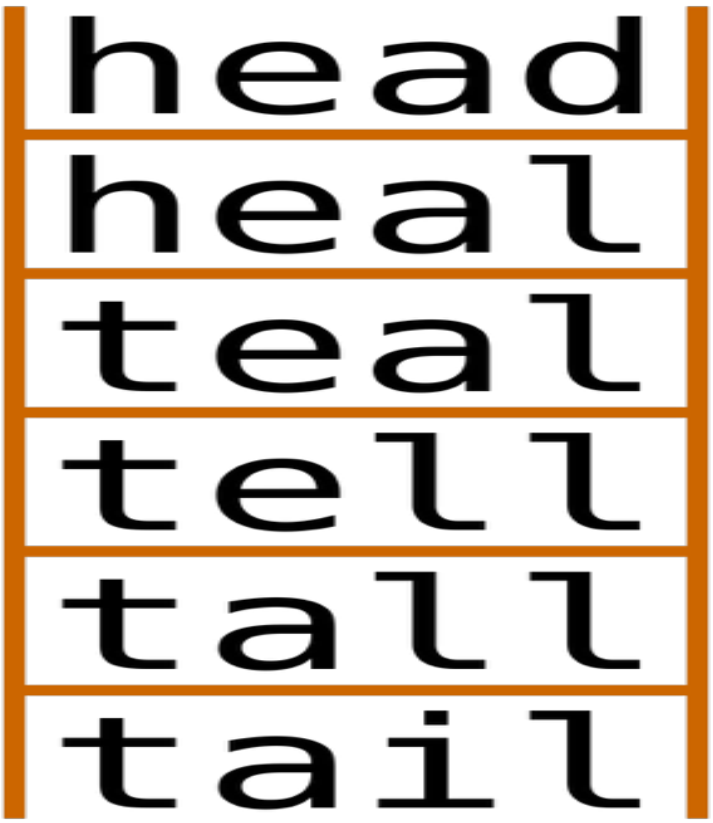
- `search.py`. You will edit and submit this - your implementation of A* goes here.
- `state.py`. You will edit and submit this - your implementation of each problem's State goes here.
- `utils.py`. Some utilities we provide.
- `main.py`. You will run this file to test your code.
- `data/eight_puzzle`. Text files containing example problems for the eight puzzle task

- `data/word_ladder`. Text file containing example problems for the word ladder task, along with a dictionary of english words

Please ONLY submit `search.py` and `state.py`.

For each of the remaining parts of the assignment you will find TODOs in `search.py` and `state.py` where you need to write your own code. For example, for part III you will find TODOs marked `# TODO(III)`. We've provided many comments and instructions in the code under those TODOs.

III. Implementing Best First Search (and Word-Ladder)



WordLadder: find a sequence of English words from some starting word (i.e., "head") to some goal word (i.e., "tail"), where consecutive words differ by only one letter

There are 2 "TODO(III)" in `search.py`.

Your first task is to implement a generic best first search algorithm in the method `best_first_search(starting_state)` in `search.py`. Your implementation should:

- use a priority queue (heapq) of states on the “frontier”
- use a dictionary that keeps track of the states which have been visited
- iteratively search through the neighbors of each state until you find the shortest path to the goal
- if you do not find the goal you should return an empty list

Notice that the input to `best_first_search` is just a starting state. You may be wondering:

- How do you find the neighbors of a state?
- How do you know if you’ve reached the goal?
- How can you hash state objects into a dictionary?
- How can you push state objects onto a sorted heap?

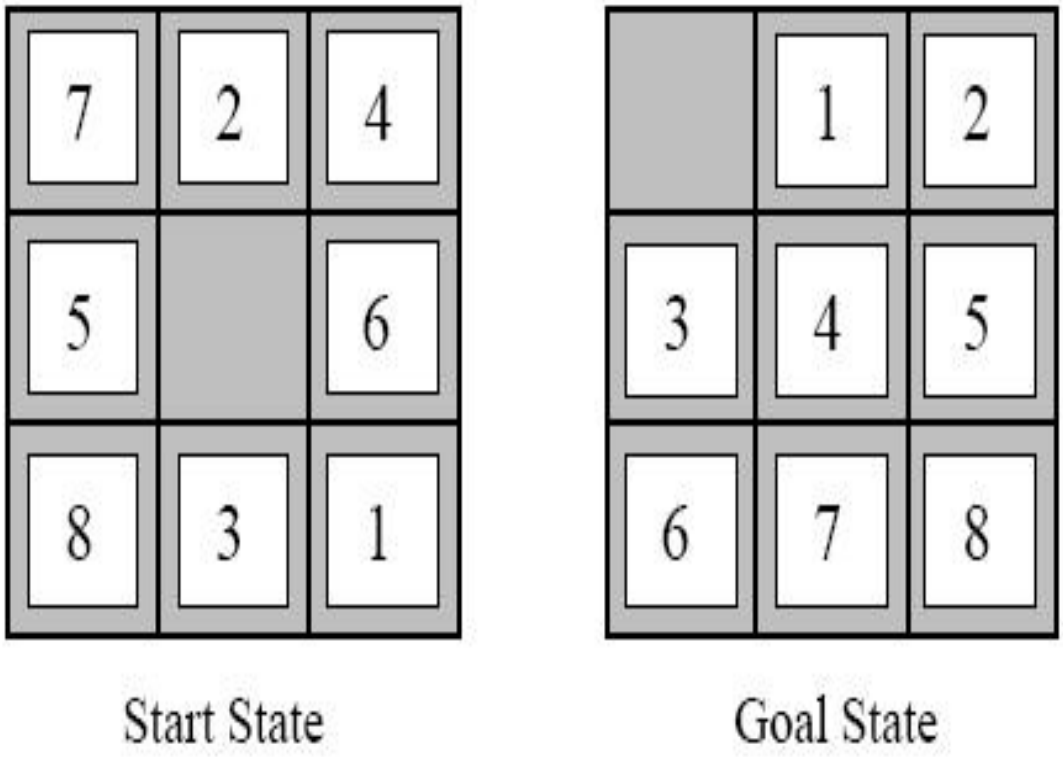
Now you should look at `state.py`, there are 3 “TODO(III)” in `state.py`. These questions should be answered by the comments in the code under those TODOs. You should first read through our `AbstractState` class, then look at an instantiation of this class called `WordLadderState`.

In order to test your search code we’ve provided almost all of `WordLadderState`. Once you’ve filled in the missing code, and implemented the search code, you should be able to test your algorithm. Make sure your algorithm works on all the provided tests before moving on to the next parts. If it works you will not have to touch it again!

Run best_first_search on all WordLadder problems:

```
python3 main.py --problem_type=WordLadder
```

IV. EightPuzzle



EightPuzzle: find a sequence of tile moves that put each number in its final position (right) from some example starting position (left). You can only move a tile that is adjacent to the empty square into the empty square.

Now move on to EightPuzzleState, we've provided some but not all of the code you'll need here. There are 4 "TODO(IV)" in `state.py`.

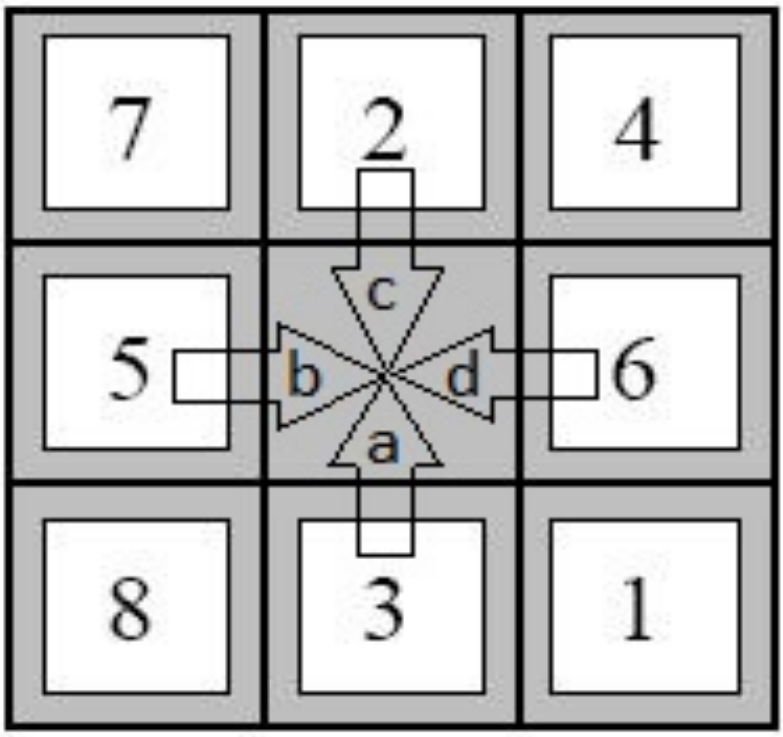
- Implement `manhattan(a,b)`
  - you will need this for computing the heuristic, you will also need this for parts V and VI
- Implement `EightPuzzleState.get_neighbors(self)`
  - In EightPuzzle the possible actions are to move an adjacent tile into the empty square (indicated by a zero)
  - There are up to 4 possible neighbors for each state, though if the empty tile is on the edge there are fewer
  - The order you add states onto the frontier matters for tiebreaking
    - You should add them in the order [below, left, above, right], where for example "below" corresponds to moving the empty tile down (moving the tile below the empty tile up). See the figure below for details.
- Implement `EightPuzzleState.compute_heuristic(self)`

    - There is more than one valid heuristic for this problem, the one we ask you to implement is Manhattan
        - Manhattan heuristic for Eight Puzzle is the sum of the manhattan distances from each tile to its goal location (not counting the empty tile)
        - This is a valid heuristic because each tile must move at least its manhattan distance times to reach its goal, and you can only move one tile at a time.
- Implement `EightPuzzleState.__lt__(self, other)`

Run best_first_search on EightPuzzle problems (all puzzles with puzzle_len=N can be solved in N steps):

```
python3 main.py --problem_type=EightPuzzle --puzzle_len=5
```

You can choose any puzzle length among [5, 10, 27].



Please add neighbors in this move order (a,b,c,d) to be consistent with our implementation. The manhattan heuristic for this example is: 3 (number of moves 1 is away from its goal location) + 1 + 2 + 2 + 2 + 3 + 3 + 2 (number of moves 8 is away from its goal location) = 18. This means this puzzle takes at least 18 moves to solve.

V Submission Instructions

Submit the main part of this assignment by uploading `search.py` and `state.py` to Gradescope.

Policies

You are expected to be familiar with the general policies on the course syllabus (e.g. academic integrity) and on the top-level MP page (e.g. code style). In particular, notice that this is an individual assignment.