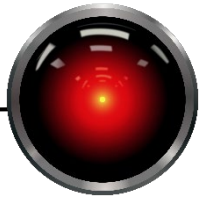


Assignment 02

Part I; 20 points each

1. Explain the difference between a problem state and a search state.

2. Sometimes search spaces can be reduced by constraining the list of available actions in a way that does not change the problem. Suggest a constraint that would make searching a crossword puzzle faster.

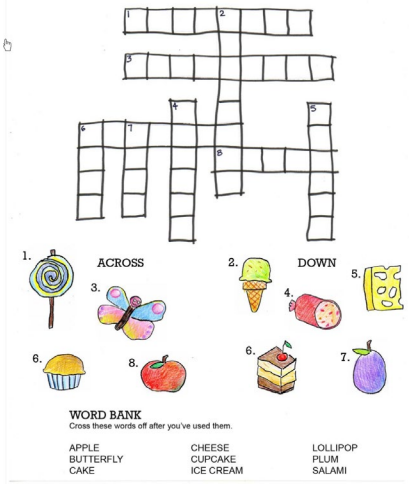


Figure 1 – Sample crossword puzzle for kids from www.articulation360.wordpress.com

3. An A* algorithm finds an optimal solution at depth 15 after expanding 10,000 nodes. What is the effective branching factor? (Hint: For high-order polynomials, using a root finder is usually a good way to find the roots of the polynomial. numpy has a polynomial root finder numpy.roots. If you use it, show your arguments to the function). Suppose that the actual branching factor is 4. The A* algorithm expanded what percentage of the nodes that would have needed to be expanded in a breadth-first search?

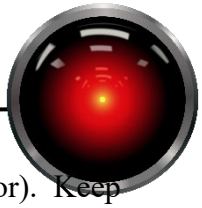
4. Prove that the number of misplaced titles heuristic for the 8-puzzle is consistent. Assume a cost of 1 per tile move.

Part II: N-Puzzle Search (120 points)

In this assignment, you will write a generic graph search routine that can be used to conduct breadth-first, depth-first, and A* search by varying the parameters given to it. Several classes are provided to you in package basicsearch_lib02 to help you in this endeavor and you are required to use them.

Skeleton code is provided in the following files that can be accessed from Blackboard:

driver02.py – The driver module will create 31 different tile board puzzles. For each of these, a solution will be searched using breadth first, depth first, and A* search using a Manhattan distance heuristic. An easy strategy to make sure that all three search types use the same puzzle is to generate one NPuzzle, get its state, and construct new instances



of the board passing in the state (see the force_state argument in the constructor). Keep track of the number of nodes expanded and the amount of time used for each of these. Upon completion, print a table summary that indicates the mean (average) and standard deviation of the following measurements:

- length of plan (number of steps to solution)
- number of nodes expanded
- elapsed time in seconds

Example table with first row filled in. Your answers will vary depending upon the initial puzzle state:

Method	PlanLen	# Nodes	Elapsed (sec)
Breadth first	23± 3.4	97636± 57773	22.3±14.3
Depth first	TBD	TBD	TBD
Manhattan	TBD	TBD	TBD

Running the 31 trials will take a little bit of time, so use a much smaller number when debugging. One execution of the 31 trials on one core of an Intel i7-11700K took about 25 minutes (duration depends on the difficulty of the randomly generated puzzles) and it is recommended that you make sure that each search type is working before you try to start looping on solutions.

npuzzle.py – Implement class NPuzzle. It is subclassed from the Problem class in basicsearch_lib02.searchrep. Begin by reading the NPuzzle code to understand what the parent class does. NPuzzle will use an instance of class TileBoard as a Problem state. You will need to provide an implementation that allows you to pass in functions g and h to provide the search strategy as well as support TileBoard constructors. The TileBoard class is used to track the puzzle and should be created at initialization and passed to NPuzzle's parent constructor (read about Python super() method if you are unfamiliar with calling a parent method). Some methods will need to be overridden. For example, the actions(state) method will need to invoke the appropriate method associated with a TileBoard.

problemsearch.py – Implement function graph_search. It takes an instance of NPuzzle and flags for controlling verbosity and debugging (see file for details) and conducts a search. When instantiating the NPuzzle, be sure to use parent class's g and h arguments to set the path cost and heuristic functions which will govern the type of search that is conducted. It returns a tuple consisting of a plan (list of actions) and the number of nodes that were expanded. You will need to use a priority queue and search nodes (see below)

explored.py – Implement class Explored. Apart from the no argument constructor, it has two methods: exists(state) and add(state). Both of these expect state tuples from a TileBoard and use a hash table to determine whether a state has been seen before (exists) and to add new states as they are removed from the frontier set (add). The Python builtin hash will generate a hash key from any hashable value. Handle hash key collisions as a bucket list.

searchstrategies.py – Implement classes BreadthFirst, DepthFirst, and Manhattan. These are classes that provide implementations for the cost to node (g) and cost from node to goal heuristic (h) functions. Note g and h are class methods (see details on class methods in the comments of the code provide) and that when you pass them to the NPuzzle constructor, you need to pass the function handles to the constructor rather than invoking the function. Concretely, if you wanted to pass BreadthFirst's function handle for g to NPuzzle, you would call NPuzzle(num_tiles, g=BreadthFirst.g, …). NPuzzle's parent class stores g in a publicly accessible instance variable and other code (e.g. the Node class discussed below) will invoke the functions to evaluate search nodes. Note that we defined DepthFirst's g as a constant and h as the negative depth. The structure of the Node implementation expects h to be called with a single argument: state. As the depth is captured in the Node, and not the state, reverse the roles of g and h when implementing DepthFirst. The depth can be accessed from the g function which expects a parent, action, and the search node itself.

There are several helper classes that you should use from modules in the basicsearch_lib02: queues.py and searchrep.py

From queues.py use class PriorityQueue to maintain the order of the queue. Remember, we defined g and h in a way that priority queues can be used all search types and f is the sum of these. You do not need to use the other queues in the module.

From searchrep.py, in addition to the previously mentioned Problem class, class Node should be used to construct a node in the search space, and these are the objects that should be generated in your search. To create the first node, call the constructor with instances of the problem representation, NPuzzle, and the initial state (a TileBoard). To obtain the list of new search states obtainable from a search node, call expand with an instance of the problem. It will use the problem's actions method to determine the possible actions that can be generated and derive new child nodes. Node's get_f function will be useful for maintaining the order of your priority queue. While you need not modify anything in the library, be sure that you understand how this is working. Step through the code with a debugger if you cannot follow it by reading. Finally, searchrep provides function print_nodes that takes a list of search nodes and prints out their puzzle representations on a single line. You may find this useful for debugging, but otherwise the function provides no purpose.

What to turn in:

As always, parts I and II are submitted separately. When submitting your code:

1. Do not submit the provided library module.
2. Include the generated table from your 31 trials in file results.txt.
3. Remember that an affidavit must accompany part II in your driver code.
4. If you are pair programming, be sure that you submit for both students on gradescope.