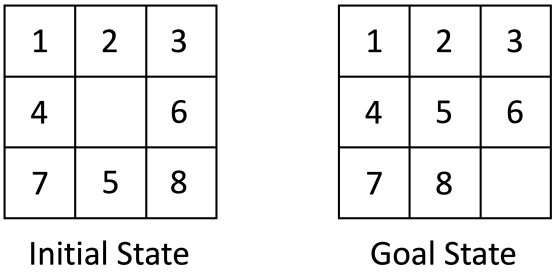
Washington State University
School of Electrical Engineering and Computer Science
Fall 2021

CptS 440/540 Artificial Intelligence
Homework 3 - Solution
Due: September 16, 2021 (11:59pm pacific time)

General Instructions: Put your answers to problem 1 (and problem 3 for 540 students) into a PDF document and upload the document as your submission for Homework 3 for the course CptS 440 Pullman (all sections of CptS 440 and 540 are merged under the CptS 440 Pullman section) on the Canvas system by the above deadline. Note that you may submit multiple times, but we will only grade the most recent entry submitted before the deadline.

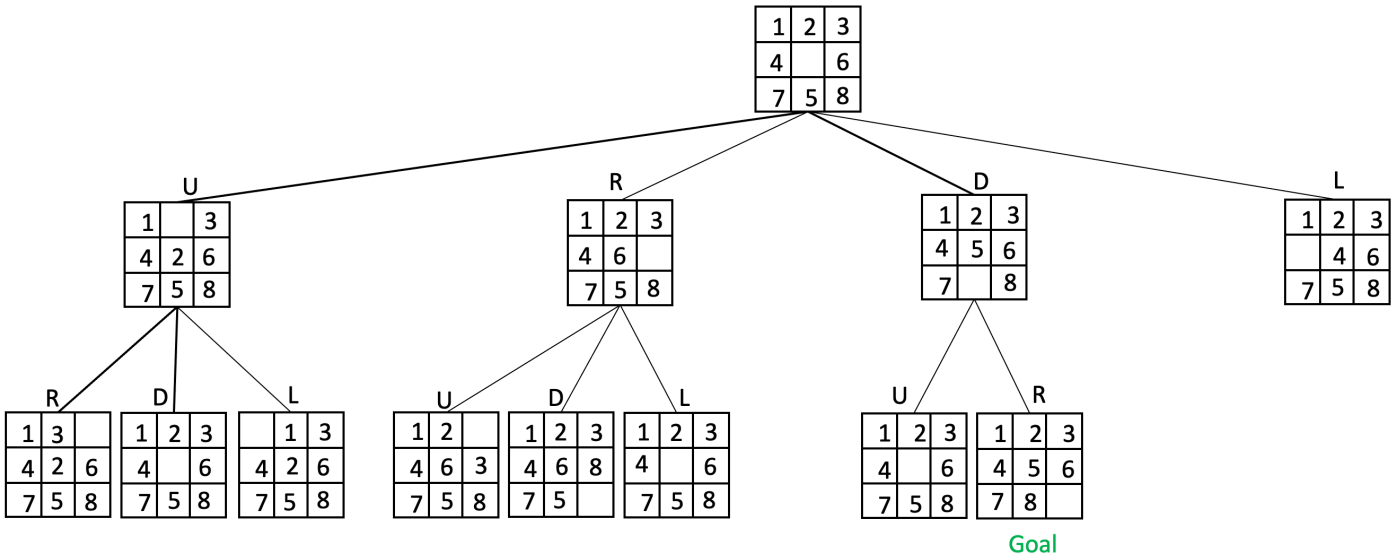
1. Consider the following initial and goal states for the 8-puzzle problem. In the search algorithms below, when iterating over possible actions (i.e., moving the blank tile), always consider the actions in the order: Up, Right, Down, Left. *Be sure to use the search algorithms as defined in the lecture notes*.



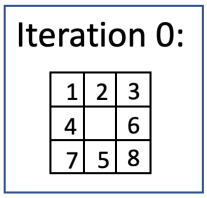
   a. Draw the search tree showing all nodes generated by the Breadth-First Search algorithm to solve this problem.
   b. Draw the search trees showing all nodes generated for each iteration of the Iterative-Deepening Search algorithm to solve this problem.
   c. Draw the search tree generated by the A* search algorithm to solve this problem using the city-block distance for the heuristic *h*. The city-block distance for an 8-puzzle state is the sum of the city-block distances of each tile in the puzzle (excluding the blank tile). Next to every node, show the values of *f*, *g* and *h*. If two nodes have the same *f* value, then prefer nodes farther to the left in the search tree.
   d. Draw the search tree generated by the Hill-Climbing search algorithm to solve this problem, where a state's Value = 1 / (*h* + 1), where *h* is the heuristic from part (c). Next to every node, show its Value. Finally, indicate which node is returned. Be careful; note that the Hill-Climbing algorithm does not employ the goal test, but stops only after none of the generated neighbor nodes has a strictly better Value.

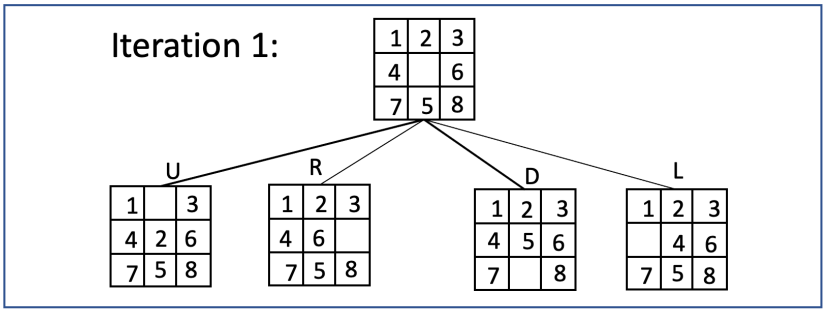
Solution:

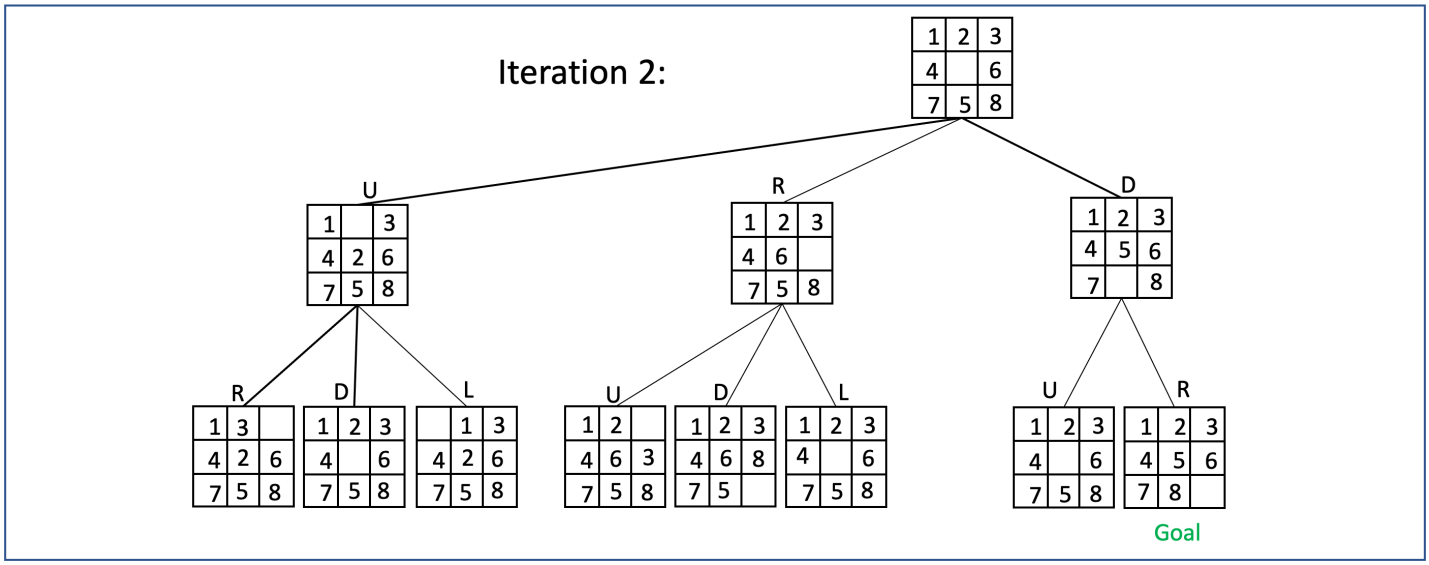
a. BFS search tree:



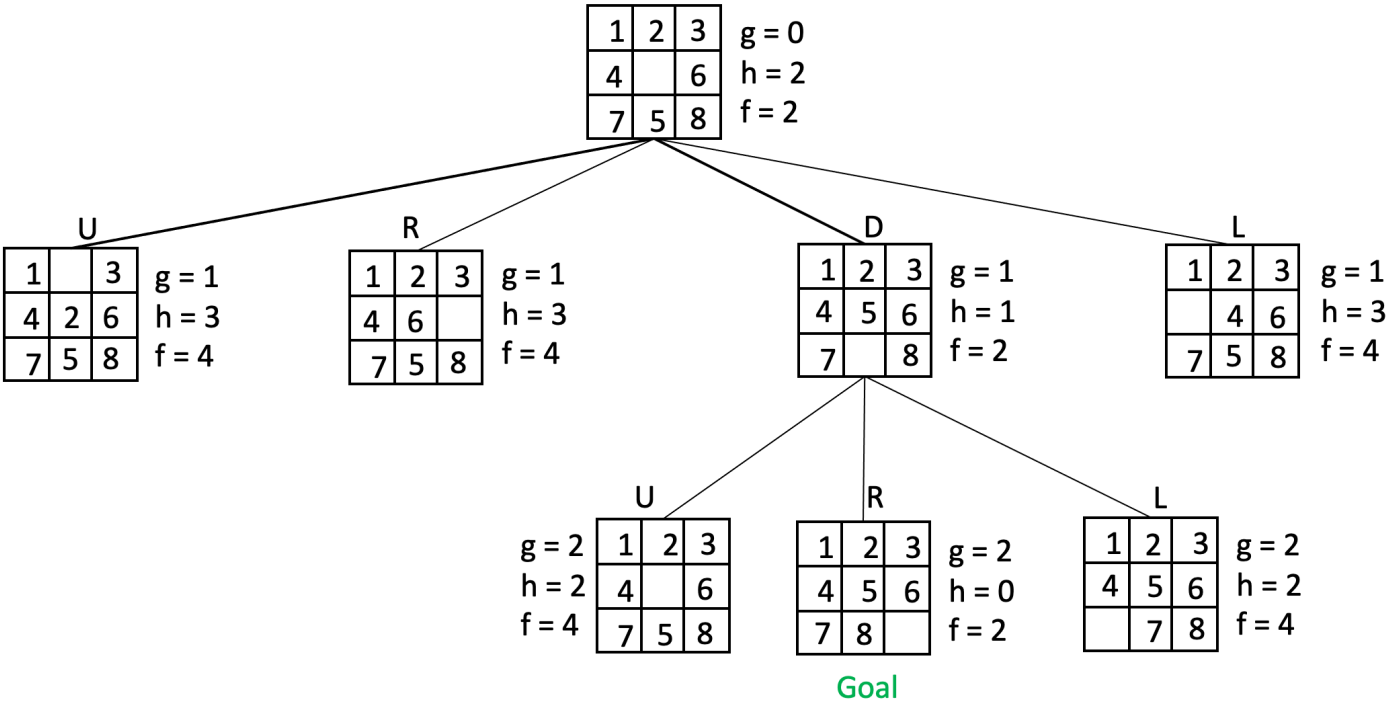
b. IDS search trees:



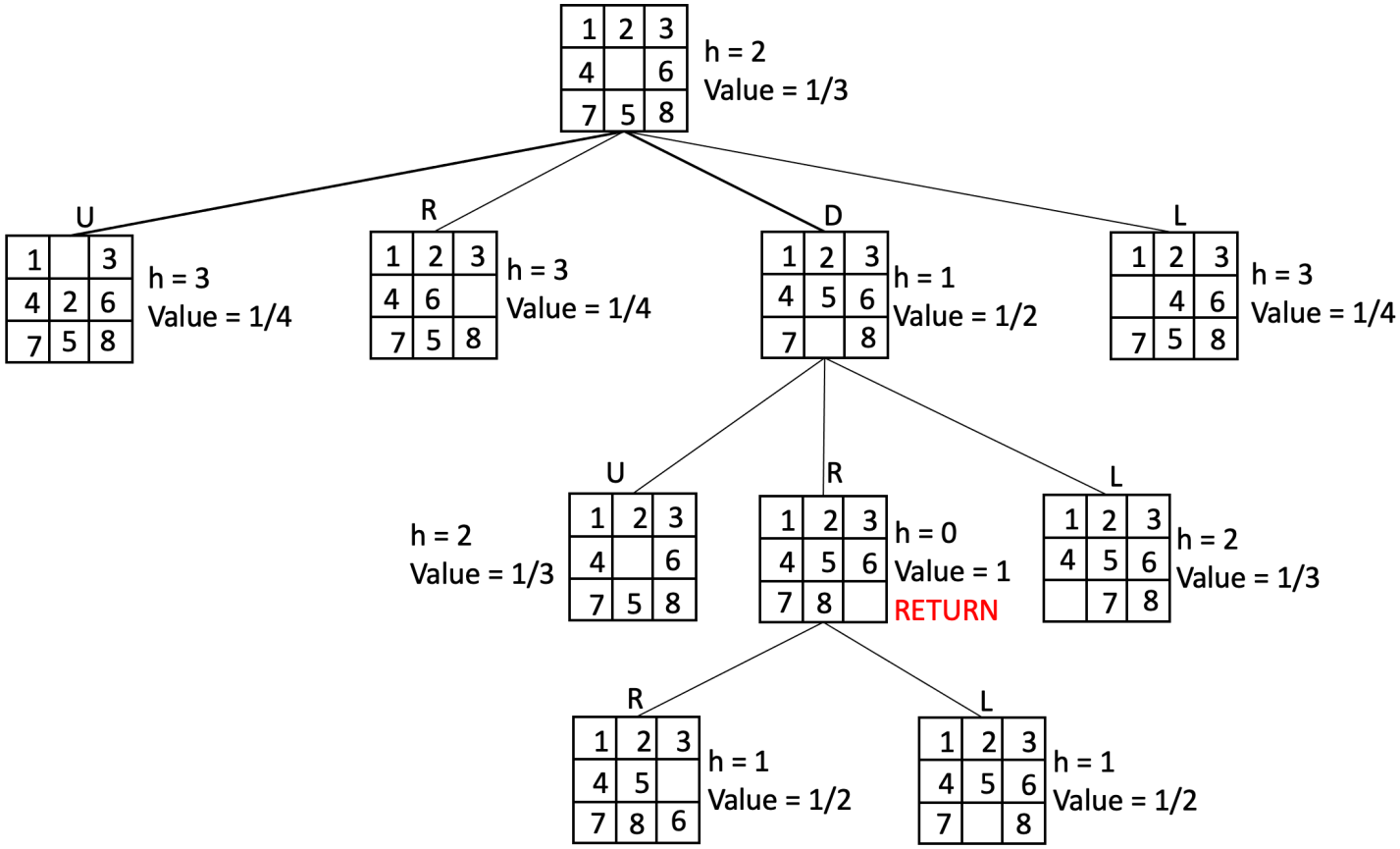




c. A* search tree:



d. Hill-climbing search tree:



2. Take Quiz 3 on Canvas. You have multiple attempts. Your answers will be graded, but the main point of this exercise is to make sure you are setup to take an exam via Canvas.

   Solution:
   - Q1: What is the worst-case time complexity of iterative-deepening search? $O(b^d)$
   - Q2: What is the worst-case time complexity of A* search? $O(b^d)$
   - Q3: What is the worst-case space complexity of iterative-deepening search? O(bd)
   - Q4: What is the worst-case space complexity of A* search? $O(b^d)$

3. *CPTS 540 Students Only*: Given that CityBlockDistance is an admissible heuristic for the 8-puzzle problem, answer the following:
   a. Is (CityBlockDistance – 1) an admissible heuristic for the 8-puzzle problem? Justify your answer.
   b. Is (CityBlockDistance + 1) an admissible heuristic for the 8-puzzle problem? Justify your answer.

   Solution:
   a. Yes. Since CityBlockDistance is admissible, and therefore never over-estimates the cost to the goal, then (CityBlockDistance – 1) will also never over-estimate the cost to the goal, and therefore is admissible.
   b. No. As a counterexample, consider the initial state in problem 1. The optimal solution has a cost of 2, but the cost according to the heuristic is (CityBlockDistance + 1) = 3. Therefore, the heuristic can overestimate the cost to the goal, and thus, is not admissible.