Homework #2: Search Algorithms
35 Points Total
Last Updated: 2/8/20 9:00pm

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Course Policy: Read all the instructions below carefully before you start working on the assignment, and before you make a submission.

- Please include your name and NetIDs on the first page. We recommend typesetting your submission in LATEX, and an Overleaf template is linked here.

- As part of the typesetting requirement, all (state) graphs must be computer-generated (no hand-drawn or stylus-drawn graphs will be accepted). We recommend using TikZ, this online tool, or Powerpoint/Google Slides/Keynote to draw any graphs.

- Homeworks must be submitted via Gradescope by the due date and time.

- Late homeworks are accepted until **2/19/20 at 11:59pm** for a 50% penalty per course policy.

- All sources of material outside the course must be cited. The University Academic Code of Conduct will be strictly enforced.

Problem 1: A* Search   (12 points)
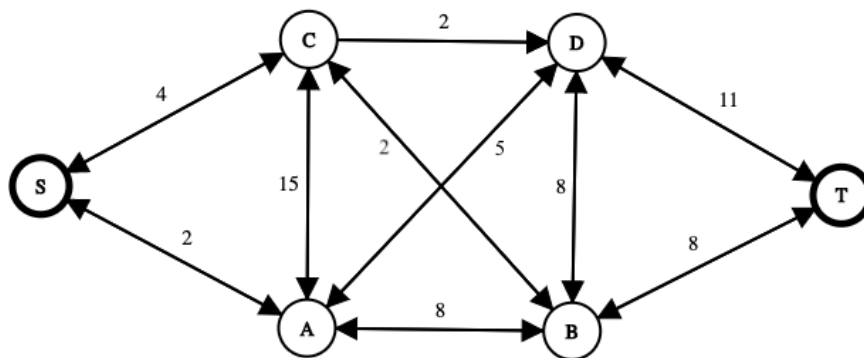
Consider the search space depicted above for a hypothetical search problem. S is the initial state and T is the goal state. The cost of each edge has been labeled on the graph.

A (4 points): Compute the shortest path and its cost using uniform cost search (Djikstra's algorithm).

[Your Solution Here]

B (4 points): Consider the following table representing $h(s)$ for each state s in the space. What path does A* search find using this $h(s)$, and what is its cost?

[Your Solution Here]

C (4 points): Compare your results for (a) and (b). If they are the same, explain why. If they are different,

State s	A	B	C	D
$h(s)$	10	16	9	9

provide a specific reason.

[Your Solution Here]

Problem 2: DFS, BFS, IDS (13 points)

Consider the following puzzle called "Moving Magic Square". It is played on a 3×3 table containing each of the numbers 1 to 9. The number 9 is the "movable number". You can move 9 in four directions (up/down/left/right), and swap 9 with the number in that direction. The initial state is shown in Table 1. As the player, we want to move 9 to reach a final state such that the sum of the three numbers on every row, column, and diagonal is 15. There are multiple states that satisfy this condition, and you can stop your answer when you find the first satisfied state. (Hint: You can define the operations in order of up/down/left/right, which might be helpful for fewer steps to reach the satisfied state.)

6	9	8
7	1	3
2	5	4

Table 1: Initial state

A (2 points): Formulate this as a search problem. What are the states, operators, initial state, and goal condition?

[Your Solution Here]

B (2 points): Is this state space a graph or a tree?

[Your Solution Here]

C (3 points): Draw the portion of the state space that would be generated by the Breadth-First Search (BFS) procedure and mark the order in which each state is expanded with the numbers 1, 2, 3... Do not create multiple copies of states that are identical, and identify the states that are goal states.

[Your Solution Here]

D (3 points): Draw the portion of the state space that would be generated by the Depth-First Search (DFS) procedure and mark the order in which each state is expanded with lower-case letters a, b, c... Do not create multiple copies of states that are identical, and identify the states that are goal states.

[Your Solution Here]

E (3 points): Draw the portion of the state space that would be generated by the Iterative Deepening Search (IDS) procedure and mark the order in which each state is expanded with upper-case letters A, B, C... Do not create multiple copies of states that are identical, and identify the states that are goal states.
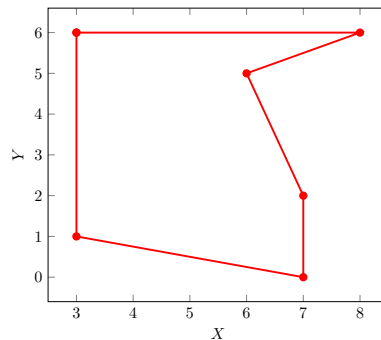
[Your Solution Here]

Problem 3: Hill Climbing Heuristics (10 points)

Hill-climbing methods have generated the best results obtained thus far for many very large Travelling Salesman Problems (TSPs). The TSP problem statement is the following: "Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city and returns to the origin city?". The

6 points in the diagram below define a hypothetical TSP comprised of 6 cities, and shows one sample path that is a possible solution to this TSP.

To solve such problems using hill climbing, states are an ordered list of cities specifying the order in which each city is visited. Thus, for example, in the diagram below the state is ((3,1), (3,6), (8,6), (6,5), (7,2), (7,0)). The last vertex in the list is then connected back to the first vertex in the list. The hill climbing operator we will consider here takes a state and swaps two of the cities in the list, thereby generating a new path that visits all the cities. The evaluation function $f(s)$ will simply be the length of the path given in s.

A (2 points): How many states would this operator generate for the sample solution above?
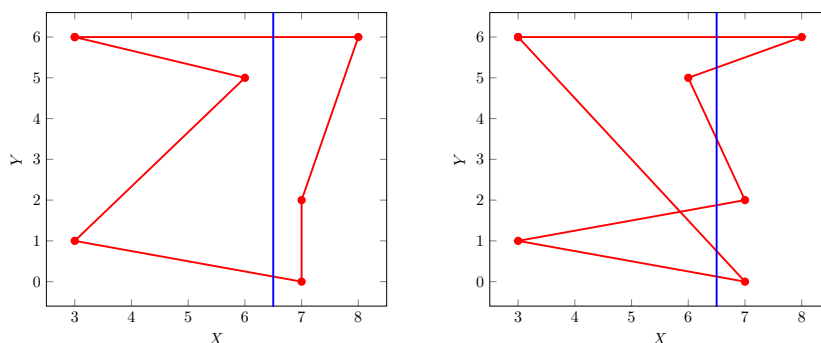
[Your Solution Here]

B (3 points): Consider the subset of these states that were created by swapping (8,6) with one of the other vertices. Draw all of these states, and give the value $f(s)$ for each such state.

We suggest copying and pasting the source TikZ (labelled with "copy here" in the LATEX source) from the starting state S and changing the coordinates to show all possible successor states.

[Your Solution Here]

C (5 points): Now lets say that we added a river at $X = 6.5$ and a cost, R, is added to the heuristic $f(s)$ every time the path crosses the river. Let n be the number of times a path crosses the river. What would the costs R_l and R_r (left and right, respectively) have to be in order for hill climbing to yield the following solutions? Note that R can be a negative value.

[Your Solution Here]