

**INSTRUCTIONS**

- **Written HW Due:** Friday 6/28/2019 at 11:59 PM (submit via Gradescope).
- **Corresponding self-grade due:** Tuesday 7/2/2019 at 11:59 PM (submit via Gradescope).
- **Policy:** Can be solved in groups (acknowledge collaborators) but must be written up individually.
- **Submissions:** Your submission should be a PDF that matches this template. Each page of the PDF should align with the corresponding page of the template (page 1 has name/collaborators, question 1 begins on page 2, etc.). Do not reorder, split, combine, or add extra pages. The intention is that you print out the template, write on the page in pen/pencil, and then scan or take pictures of the pages to make your submission. You may also fill out this template digitally (e.g. using a tablet.)

**Don't forget to fill up the self-grade assignment corresponding to this homework on Gradescope after the deadline of this assignment when the solution is released. You will have until the due date of the next homework to complete your self-grade. For more information, please visit the homework policy post on Piazza.**

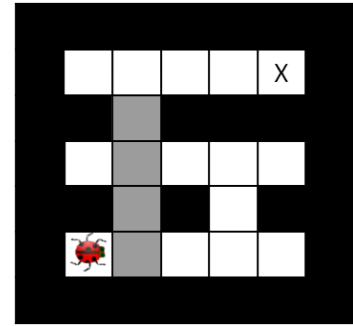
First Name	
Last Name	
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Collaborators	

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Q. 1	Q. 2	Total
/15	/15	/30

1. (15 points) **Question Menagerie**

**Parts (a) and (b)** The hive of insects needs your help again. As before, you control an insect in a rectangular maze-like environment with dimensions  $M \times N$ , as shown to the right. At each time step, the insect can move into a free adjacent square or stay in its current location. All actions have cost 1.



In this particular case, the insect must pass through a series of partially flooded tunnels. Flooded squares are lightly shaded in the example map shown. The insect can hold its breath for  $A$  time steps in a row. Moving into a flooded square requires your insect to expend 1 unit of air, while moving into a free square refills its air supply.

- (a) (4 pt) Give a minimal state space for this problem (i.e. do not include extra information). You should answer for a general instance of the problem, not the specific map shown.

- (b) (4 pt) Give the size of your state space.

**Parts (c), (d), and (e)** Consider a search problem where all edges have cost 1 and the optimal solution has cost  $C$ . Let  $h$  be a heuristic which is  $\max\{h^* - k, 0\}$ , where  $h^*$  is the actual cost to the closest goal and  $k$  is a nonnegative constant.

(c) (3 pt) Which of the following statements are true?

- (i)  $h$  is admissible.
- (ii)  $h$  is consistent.
- (iii) A\* tree search (no closed list) with  $h$  will be optimal.
- (iv) A\* graph search (with closed list) with  $h$  will be optimal.

(d) (2 pt) Which of the following is the most reasonable description of how much more work will be done (= how many more nodes will be expanded) with heuristic  $h$  compared to  $h^*$ , as a function of  $k$ ?

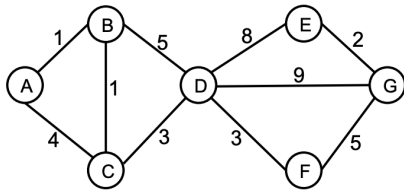
- (i) Constant in  $k$
- (ii) Linear in  $k$
- (iii) Exponential in  $k$
- (iv) Unbounded

Now consider the same search problem, but with a heuristic  $h'$  which is 0 at all states that lie along an optimal path to a goal and  $h^*$  elsewhere.

(e) (3 pt) Which of the following statements are true?

- (i)  $h'$  is admissible.
- (ii)  $h'$  is consistent.
- (iii) A\* tree search (no closed list) with  $h'$  will be optimal.
- (iv) A\* graph search (with closed list) with  $h'$  will be optimal.

## 2. (15 points) Search



Node	$h_1$	$h_2$
A	9.5	10
B	9	12
C	8	10
D	7	8
E	1.5	1
F	4	4.5
G	0	0

Consider the state space graph shown above. A is the start state and G is the goal state. The costs for each edge are shown on the graph. Each edge can be traversed in both directions. Note that the heuristic  $h_1$  is consistent but the heuristic  $h_2$  is not consistent.

- (a) [6 pts] **Possible paths returned** For each of the following graph search strategies (*do not answer for tree search*), mark which, if any, of the listed paths it could return. Note that for some search strategies the specific path returned might depend on tie-breaking behavior. In any such cases, make sure to mark *all* paths that could be returned under some tie-breaking scheme.

Search Algorithm	A-B-D-G	A-C-D-G	A-B-C-D-F-G
Depth first search	(i)	(ii)	(iii)
Breadth first search	(iv)	(v)	(vi)
Uniform cost search	(vii)	(viii)	(ix)
A* search with heuristic $h_1$	(x)	(xi)	(xii)
A* search with heuristic $h_2$	(xiii)	(xiv)	(xv)

- (b) [9 pts] **Heuristic function properties**

Suppose you are completing the new heuristic function  $h_3$  shown below. All the values are fixed except  $h_3(B)$ .

Node	A	B	C	D	E	F	G
$h_3$	10	?	9	7	1.5	4.5	0

For each of the following conditions, write the set of values that are possible for  $h_3(B)$ . For example, to denote all non-negative numbers, write  $[0, \infty]$ , to denote the empty set, write  $\emptyset$ , and so on.

- (i) [2 pts] **What values of  $h_3(B)$  make  $h_3$  admissible?**

- (ii) [3 pts] **What values of  $h_3(B)$  make  $h_3$  consistent?**

- (iii) [4 pts] **What values of  $h_3(B)$  will cause A\* graph search to expand node A, then node C, then node B, then node D in order?**