15-381	Artificial Intelligence	HW2

INSTRUCTIONS

- **Due: Monday, 28 January 2019 at 10:00 PM EDT.** Remember that you have NO slip days for Written Homework, but you may turn it in up to 24 hours late with 50% Penalty.
- **Format:** Submit the answer sheet pdf containing your answers. You should solve the questions on this handout (either through a pdf annotator, editing the tex files, or by printing and scanning). Make sure that your answers (typed or handwritten) are within the dedicated regions for each question/part. If you do not follow this format, you may lose points.
- **How to submit:** Submit a pdf with your answers on Gradescope.
- **Policy:** See the course website for homework policies and Academic Integrity.

Last Name	
First Name	
Andrew ID	

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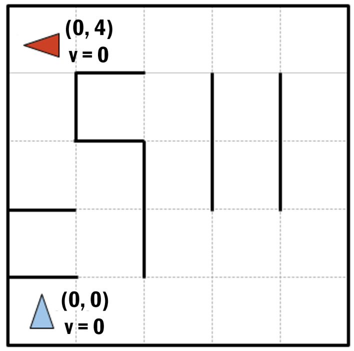
Q1	Q2	Q3	Total Score
/40	/30	/30	/100

Q1. [40 pts] Search and Heuristics



Imagine a car-like agent wishes to exit a maze like the one shown above. The agent is directional and at all times faces some direction $d \in (N, S, E, W)$. With a single action, the agent can *either* move forward at an adjustable velocity v or turn. The turning actions are *left* and *right*, which change the agent's direction by 90 degrees. Turning is only permitted when the velocity is zero (and leaves it at zero). The moving actions are *fast*, *maintain* and *slow*. *Fast* increments the velocity by 1 and *slow* decrements the velocity by 1; in both cases the agent then moves a number of squares equal to its NEW adjusted velocity. Maintaining velocity allows the agent to go just as many squares as last time. Any action that would result in a collision with a wall crashes the agent and is illegal. Any action that would reduce v below 0 or above a maximum speed V_{max} is also illegal. The agent's goal is to find a plan which parks it (stationary) on the exit square using as few actions (time steps) as possible.

(a) [5 pts] Suppose the agent wants to take the leftmost path from the start (0,0) facing north to the goal (0,4) facing west. Write down the sequence of actions for it to take.

Actions:

(b) [5 pts] If the grid is M by N, what is the size of the state space? You should assume that all configurations are reachable from the start state.

State Space Size:

(c) [5 pts] What is the maximum branching factor of this problem? Draw an example state (x, y, orientation, velocity, grid/walls) that has this branching factor, and list the set of available actions.

You may assume that illegal actions are simply not returned by the problem model. You do not necessarily have to use the example grid above. Make sure to label your drawing.

Maximum Branching Factor:

Maximum Branching Example State and Available Actions:

What is the minimum branching factor? Draw an example state (x, y, orientation, velocity, grid/walls) that has this branching factor, and list the set of available actions.

You may assume that illegal actions are simply not returned by the problem model. You do not necessarily have to use the example grid above. Make sure to label your drawing.

Minimum Branching Factor:

Minimum Branching Example State and Available Actions:

(d) [5 pts] Is the Manhattan distance from the agent's location to the exit's location admissible?

If not, draw an example state (x, y, orientation, velocity, grid/walls) where this heuristic overestimates at that state, and specify: 1) the heuristic value at that state and 2) the actual cost from that state to the goal.

You may assume that illegal actions are simply not returned by the problem model. You do not necessarily have to use the example grid above. Make sure to label your drawing, including the goal state.

Is it admissible?

Example State, Heuristic Value, Actual Cost:

(e) [5 pts] Is the following heuristic admissible? *The number of turns for the agent to take to face the goal.*

If not, draw an example state (x, y, orientation, velocity, grid/walls) where this heuristic overestimates at that state, and specify: 1) the heuristic value at that state and 2) the actual cost from that state to the goal.

You may assume that illegal actions are simply not returned by the problem model. You do not necessarily have to use the example grid above. Make sure to label your drawing, including the goal state.

Is it admissible?

Example State, Heuristic Value, Actual Cost:

(f) [5 pts] Is the following heuristic admissible? *Manhattan distance* / V_{max}.

If not, draw an example state (x, y, orientation, velocity, grid/walls) where this heuristic overestimates at that state, and specify: 1) the heuristic value at that state and 2) the actual cost from that state to the goal.

You may assume that illegal actions are simply not returned by the problem model. You do not necessarily have to use the example grid above. Make sure to label your drawing, including the goal state.

Is it admissible?

Example State, Heuristic Value, Actual Cost:

(g) [3 pts] If we used an inadmissible heuristic in A* search, could it change the completeness of the search?

Answer:

(h) [3 pts] If we used an inadmissible heuristic in A* search, could it change the optimality of the search?

Answer:

(i) [4 pts] Give a general advantage that an inadmissible heuristic might have over an admissible one.

Answer:

Q2. [30 pts] Search Nodes

Consider tree search (i.e. no explored set) on an arbitrary search problem with max branching factor b. Each search node n has a backward (cumulative) cost of $g(n)$, an admissible heuristic of $h(n)$, and a depth of $d(n)$. Let n_c be a minimum-cost goal node, and let n_s be a shallowest goal node.

For each of the following, give an expression that characterizes the set of nodes that are explored before the search terminates. For instance, if we asked for the set of nodes with positive heuristic value, you could say: for all n, such that $h(n) \geq 0$. Don't worry about ties (so you won't need to worry about $>$ versus $\geq$). If there are no nodes for which the expression is true, you must write "none."

(a) [10 pts] Give an inequality in terms of the functions defined above to describe the nodes n that are explored in a breadth-first search before terminating.

Inequality: All n, such that:

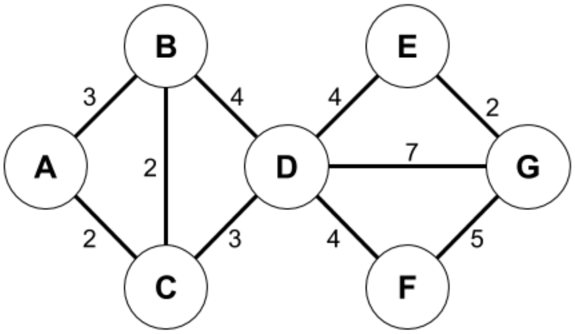
(b) [10 pts] Give an inequality in terms of the functions defined above to describe the nodes n that are explored in a uniform cost search before terminating.

Inequality: All n, such that:

(c) [10 pts] Give an inequality in terms of the functions defined above to describe the nodes n that are explored in an A* before terminating.

Inequality: All n, such that:

Q3. [30 pts] Searching a Graph



Node	h_1	h_2
A	12.5	11
B	12	10
C	11	9
D	5	6
E	1	2
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.

(a) [15 pts] For each of the following graph search strategies, mark with an X 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.

Algorithm	A-B-D-G	A-C-D-G	A-C-D-E-G
BFS	(i)	(ii)	(iii)
DFS	(iv)	(v)	(vi)
UCS	(vii)	(viii)	(ix)
A* with heuristic h_1	(x)	(xi)	(xii)
A* with heuristic h_2	(xiii)	(xiv)	(xv)

(b) [3 pts] What is the cost of the shortest uniform cost path from A to G

Answer:

(c) [6 pts] Is h_1 admissible? Is it consistent?

Admissible?

Consistent?

(d) [6 pts] Is h_2 admissible? Is it consistent?

Admissible?

Consistent?