CS-171, Intro to A.I. — Mid-term Exam — Winter Quarter, 2020

NAME:______________________________________ UCI NetID: _____________________

YOUR ID#: ______________

The Midterm Exam is take-home, open-book, open notes. Since you will not be able to ask for clarifications about any problems, if you have questions or confusions about any problem please write out your interpretation of the problem and we will take that statement into account when grading.

You are charged on your faithful personal honor, as someone of honesty, decency, and high personal integrity, not to discuss the exam with your fellow students nor to make any post about it on any social media platform. This exam is your own personal work, entirely alone, completely solo. Please do not degrade yourself by cheating.

<u>This page summarizes the points for each question, so you can plan your time.</u>

1. (18 pts total, 3 pts each) FOL for Wumpus World.

2. (16 pts total, 4 pts each) Question on local search, hill climbing

3. (20 pts total, 4 pts each) Question for Heuristic Search.

4. (14 pts total) Propositional Logic

5. (20 pts total) State Space Search

6. (12 pts total) Probability

<u>The Exam is printed on both sides to save trees! Work both sides of each page!</u>

1. (18 pts total, 3 pts each) FOL for Wumpus World.
The following two questions ask you to find the best FOL sentence encoding given English sentence. The predicates follow the intuitive interpretation, e.g. Pit(x) is True if there is a pit at x, Adjacent (x, y) is True if two squares x and y are adjacent, and Breezy(y) is True if square y is Breezy.

1.a. (3 pts) ___C_____ "A pit causes all adjacent squares to be breezy"

A. $\exists$ x Pit(x) $\Rightarrow$ [$\forall$ y Adjacent (x, y) $\Rightarrow$ Breezy(y)]
B. $\exists$ x Pit(x) $\wedge$ [$\exists$ y Adjacent (x, y) $\wedge$ Breezy(y)]
C. $\forall$ x Pit(x) $\Rightarrow$ [$\forall$ y Adjacent (x, y) $\Rightarrow$ Breezy(y)]
D. $\forall$ x Pit(x) $\Rightarrow$ [$\exists$ y Adjacent (x, y) $\wedge$ Breezy(y)]

1.b. (3 pts) ___B_____ "If all squares adjacent to a given square are not pit, the square is not breezy."

A. $\forall$ x [$\forall$ y Adjacent (y, x) $\Rightarrow$ Pit(y)] $\Rightarrow$ $\neg$ Breezy(x)
B. $\forall$ x [$\forall$ y Adjacent (y, x) $\Rightarrow$ $\neg$ Pit(y)] $\Rightarrow$ $\neg$ Breezy(x)
C. $\exists$ x [$\forall$ y Adjacent (y, x) $\Rightarrow$ $\neg$ Pit(y)] $\wedge$ $\neg$ Breezy(x)
D. $\exists$ x [$\forall$ y Adjacent (y, x) $\wedge$ $\neg$ Pit(y)] $\Rightarrow$ $\neg$ Breezy(x)

The following two questions ask you to convert FOL sentence to CNF. The sentences are part of the axioms for modeling the situation that a square is Smelly when there is only one Wumpus adjacent to that square.

1.c. (3 pts) $\forall$ x Smelly(x) $\Rightarrow$ $\exists$ y [Adjacent (x, y) $\wedge$ In (Wumpus, y)]

$\forall$ x $\neg$ Smelly(x) $\vee$ $\exists$ y [Adjacent (x, y) $\wedge$ In (Wumpus, y)]
$\forall$ x $\neg$ Smelly(x) $\vee$ [Adjacent (x, F(x)) $\wedge$ In (Wumpus, F(x))]
$\forall$ x [$\neg$ Smelly(x) $\vee$ Adjacent (x, F(x))] $\wedge$ [$\neg$ Smelly(x) $\vee$ In (Wumpus, F(x))]
[$\neg$ Smelly(x) $\vee$ Adjacent (x, F(x))] $\wedge$ [$\neg$ Smelly(x) $\vee$ In (Wumpus, F(x))]

1.d. (3 pts) $\exists$ x In(Wumpus, x) $\wedge$ $\forall$ y [Adjacent (x, y) $\Rightarrow$ $\neg$ In (Wumpus, y)]

$\exists$ x $\forall$ y In(Wumpus, x) $\wedge$ [Adjacent (x, y) $\Rightarrow$ $\neg$ In (Wumpus, y)]
$\exists$ x $\forall$ y In(Wumpus, x) $\wedge$ [$\neg$ Adjacent (x, y) $\vee$ $\neg$ In (Wumpus, y)]
$\forall$ y In(Wumpus, F()) $\wedge$ [$\neg$ Adjacent (F(), y) $\vee$ $\neg$ In (Wumpus, y)]
In(Wumpus, F()) $\wedge$ [$\neg$ Adjacent (F(), y) $\vee$ $\neg$ In (Wumpus, y)]

Also OK:
$\exists$ x $\forall$ y In(Wumpus, x) $\wedge$ [Adjacent (x, y) $\Rightarrow$ $\neg$ In (Wumpus, y)]
$\exists$ x $\forall$ y In(Wumpus, x) $\wedge$ [$\neg$ Adjacent (x, y) $\vee$ $\neg$ In (Wumpus, y)]
$\forall$ y In(Wumpus, C) $\wedge$ [$\neg$ Adjacent (C, y) $\vee$ $\neg$ In (Wumpus, y)]
In(Wumpus, C) $\wedge$ [$\neg$ Adjacent (C, y) $\vee$ $\neg$ In (Wumpus, y)]

The following two questions ask you to apply unification to two predicates and write down the most general unifier. Here, we introduce additional predicates, At (x, t) is True if agent is located at square x at time t. We use lower case symbols (x, y, t, and z) for variables and upper-case symbols (S1 and T1) for ground objects.

1.e. (3 pts) Unify (At (x, t), At (S1, T1))
{x/S1, t/T1}

1.f. (3 pts) Unify (Adjacent (x, y), Adjacent (S1, z))
{x/S1, y/z}
Also OK: {x/S1, z/y}

2. (16 pts total, 4 pts each) Question on local search, hill climbing:

Using the hill-climbing algorithm, we want to find the maximum value of $F(x)$. The function of *F(x)* is given in the histogram below. For example, $F(x = 1) = 1$ or $F(x = 10) = 8$.

2.a. (4 pts) Starting from the value $x = 3$, what is the output of the hill-climbing search for the maximum value of $F(x)$? (Show your work step by step)

(x = 3) -> (x = 4) -> (x = 5); F(x = 5) = 6

2.b. (4 pts) Starting from the value $x = 17$, what is the output of the hill-climbing search for the maximum value of $F(x)$? (Show your work step by step)

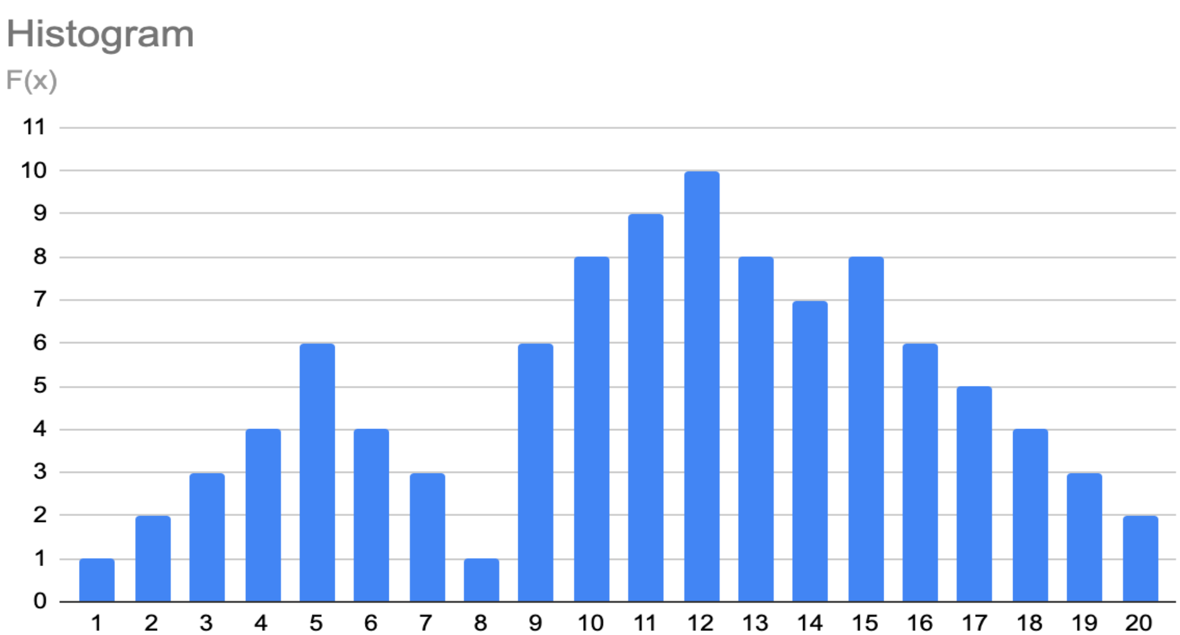
(x = 17) -> (x = 16) -> (x = 15); F(x = 15) = 8

2.c. (4 pts) What should be our starting point (value of x) to find the global maximum using the hill-climbing search algorithm? (One correct starting point is enough.)

Any of 8 <= x <= 14.

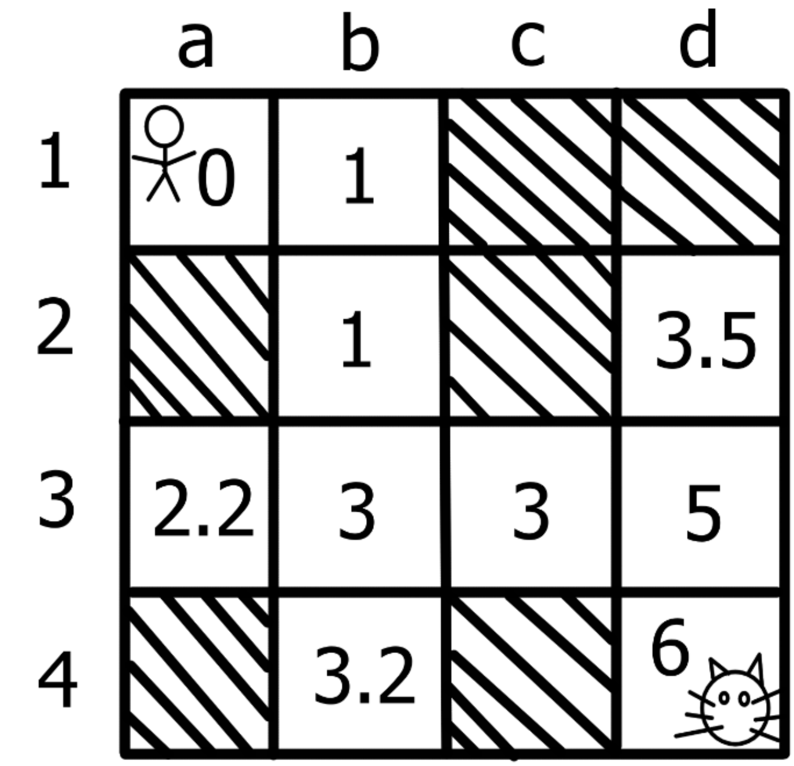
2.d. (4 pts) Can you suggest any strategies for the hill-climbing algorithm to avoid getting stuck at the local optimums?

See R&N section 4.1.2-4.



3. (20 pts total, 4 pts each) Question for Heuristic Search. You are making a video game during a hackathon. You are programming the AI for an enemy—the tiger, which will approach and kill players. You use the A* algorithm. When generating the path, assume the player (human) does not move.

Consider the following situation. The player is at a1, the tiger is at d4. Black tiles are obstacles. The tiger can move up, down, left, right, and each movement costs 1 step. The successors of a state are the adjacent tiles (up, down, left, right) into which the tiger can move with one step. The h(n) values of the walkable tiles are below inside each tile. You are doing tree search (do not remember nodes).



3.a. (4 pts) A* search will sort the frontier (= queue = fringe = open list) by ___C___
A. h(n)
B. g(n)
C. h(n) + g(n)
D. h(n) * g(n)

3.b. (4 pts) Is the heuristic above admissible? (Y = Yes/N = No) _____Y______
Justify your answer:

<u>None of the heuristic values overestimate the cost to reach the goal from that tile.</u>

3.c. (4 pts) Is the heuristic above consistent? (Y = Yes/N = No) ______N_____
Justify your answer:
<u>For example, from d3 to d2, h(d2) + 1 = 3.5 + 1 = 4.5 < 5 = h(d3), which violates the triangle inequality. Seen a different way, moving from d3 to d2 results in a decrease of f(), which violates the condition that f() be non-decreasing along any path.</u>

3.d. (4 pts, <u>no partial credit</u>) If A* algorithm is used to generate the path, fill in the following:

Order of node expansion: <u>d4 d3 c3 d2 b3 b2 b1 (a1)</u>

Path found: <u>d4 d3 c3 b3 b2 b1 a1</u> Cost of path found: <u>6</u>

3.e. (4 pts, <u>no partial credit</u>) You ran out of time during the hackathon. Instead of A* search, you decided to use Greedy Best First algorithm instead. If Greedy Best First algorithm is used to generate the path, fill in the following:

Order of node expansion: <u>d4 d3 c3 b3 b2 b1 (a1)</u>

Path found: <u>d4 d3 c3 b3 b2 b1 a1</u> Cost of path found: <u>6</u>

4. (14 pts total) Propositional Logic

4.a. (2 pts) Which of the following is an invalid proposition? (I.e., it cannot be assigned a truth-value?)

A. The wumpus is scary.
B. I said hello to the wumpus.
C. Hello, wumpus.
D. The wumpus is scared of glitter.

_____C_____

4.b. (8 pts total, 2 pts each) Let all three KB statements below be true:

I. Those who like the ocean (O), like swimming (S). ($O \Rightarrow S$)
II. Those who like running (R), like hiking (H). ($R \Rightarrow H$)
III. Those who do not like hiking (H), do not like swimming (S). ($\neg H \Rightarrow \neg S$)

Which of the following statements are entailed by KB (= must be true)? (Write Y=Yes, N=No)

4.b.i. (2 pts) Those who like running, like swimming. _____N_____

4.b.ii. (2 pts) Those who like the ocean, like hiking. _Y_____

4.b.iii. (2 pts) Those who like swimming, do not like running. _____N_____

4.b.iv. (2 pts) Those who like running, do not like the ocean. _____N_____

4.c. (2 pts total) Let all three KB statements below be true:

I. If Eddie (E) goes to office hours, then Kyle (K) goes to office hours. ($E \Rightarrow K$)
II. If Kyle (K) goes to office hours, then Jerry (J) does not go to office hours. ($K \Rightarrow \neg J$)
III. Neither Jerry (J) nor Kyle (K) went to office hours. ($\neg J \wedge \neg K$)

Is the following statement entailed by KB (= must be true)? (Write Y=Yes, N=No)

Eddie went to office hours. _____N_____

4.d. (2 pts total, 1 pt each) Let all three KB statements below be true:

I. If Ann (A) goes to class, then James (J) also goes to class. ($A \Rightarrow J$)
II. If James (J) goes to class, then Davis (D) also goes to class. ($J \Rightarrow D$)
III. James (J) did not go to class. $\neg J$

Which of the following statements are entailed by KB (= must be true)? (Write Y=Yes, N=No)

4.d.i. (1 pt) _____Y_____Ann did not go to class

4.d.ii. (1 pt) _____N_____Davis did not go to class

5. (20 pts total) State Space Search.

5.a. (4 pts) Which of the following search algorithms has a FIFO (first in, first out) queue?

______B__________

A. Depth-First Search
B. Breadth-First Search
C. Uniform Cost Search
D. Iterative Deepening Search

5.b. (4 pts) Which of the following search algorithms has a priority queue?

______C__________

A. Depth-First Search
B. Breadth-First Search
C. Uniform Cost Search
D. Iterative Deepening Search

5.c. (4 pts) Which of the following search algorithms is not optimal when all the step costs are identical?

______A__________

A. Depth-First Search
B. Breadth-First Search
C. Uniform Cost Search
D. Iterative Deepening Search

5.d. (8 pts total, 2 pts each) Answer T (= True) or F (= False)

______T_____ : In general, tree search requires more time than graph search

______F_____ : Redundant paths to the same state (node) are not pruned in graph search.

______T_____ : When there are many loops in a graph, search strategy that utilize IDS is preferred.

______T_____ : In BFS, goal test happens before the node is inserted into the frontier.

6. (12 pts total, 3 pts each) Probability. In the full joint distribution below, each row shows the probability of the indicated joint occurrence of values assigned to random variables X and Y. X is a Boolean variable taking values in *{t, f}*. Y is a categorical variable taking values in *{a, b, c}*.

X	Y	P(X, Y)
t	*a*	0.1
t	*b*	0.3
t	*c*	0.2
f	*a*	0.1
f	*b*	0.1
f	*c*	0.2

For the following questions, you need only produce an arithmetic expression that would evaluate to the correct answer. An arithmetic expression involves only numbers, parentheses, and the arithmetic operators +, −, *, /. You do not need to produce a final number, only a correct arithmetic expression. An example of an arithmetic expression is P(X=t) = 0.1+0.3+0.2.

6.a. (3 pts) Write an arithmetic expression that would evaluate to $P(X = f \wedge Y \neq c)$.

0.1 + 0.1

6.b. (3 pts) Write an arithmetic expression that would evaluate to $P(X = t \mid Y = b)$.

0.3 / (0.3 + 0.1)

6.c. (3 pts) Write an arithmetic expression that would evaluate to $P(X = t \vee Y \neq b)$.

0.1 + 0.3 + 0.2 + 0.1 + 0.2 Also OK: 1.0 – 0.1

6.d. (3 pts) Write an arithmetic expression that would evaluate to $P(X = f \wedge Y \neq c \mid Y = a)$.

0.1 / (0.1 + 0.1)

****** THIS IS THE END OF THE MID-TERM EXAM ******