CIS 471/571: Introduction to Artificial Intelligence, Fall 2020

FINAL EXAM

- You have approximately 120 minutes.

- The exam is open book.

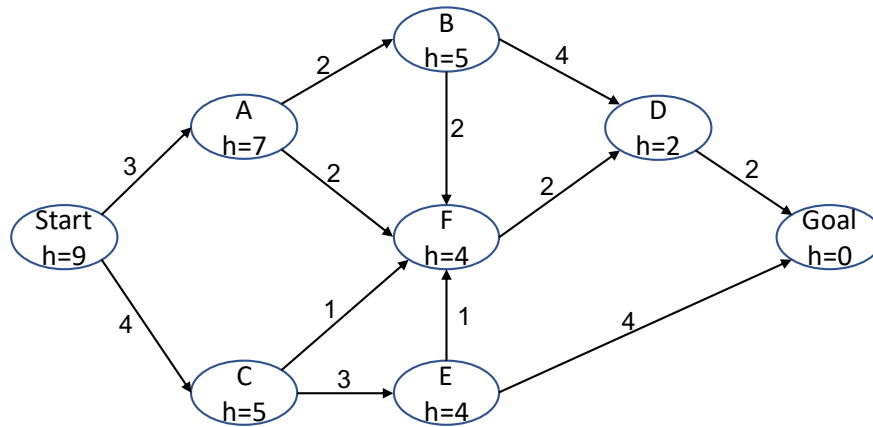| First Name	
Last Name	

Q1. Graph Search (15 points)

Q1.1. Search Algorithms. (7.5 points) Consider the following graph. For the following sub-questions, ties are broken in alphabetical order.

B
h=5
A
h=7
D
h=2
Start
h=9
F
h=4
Goal
h=0
C
h=5
E
h=4

2 4 2 3 2 2 2 1 1 4 4 3

1. (2.5 pts) What path would UCS return?

2. (2.5 pts) What path wo

3. (2.5 pts) What path wo

**Q1.2. Missing Heuristic Values. (7.5 points)** shown below in which some of the states are missing a heuristic value. Determine the po missing heuristic value so that the heuristic is admissible and consistent. If this isn't possible, write so.

B
h=5
A
h=?
D
h=?
Start
h=9
F
h=4
Goal
h=0
C
h=5
E
h=?

2 4 3 2 2 2 2 1 1 4 4 3
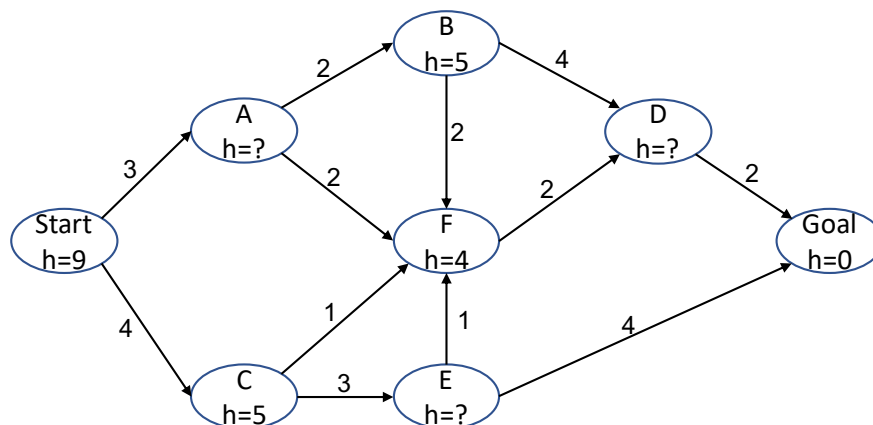
| State	Range for $h(s)$
A	$\leq h(A) \leq$
D	$\leq h(D) \leq$
E	$\leq h(E) \leq$

Q2. Adversarial Search (20 points)

Q2.1. Search Algorithms. (15 points) Consider the zero-sum game tree shown below. Triangles that point up, such as at the top node (root), represent choices for the maximizing player; triangles that point down represent choices for the minimizing player. Outcome values for the maximizing player are listed for each leaf node, represented by the values in circles at the bottom of the tree.
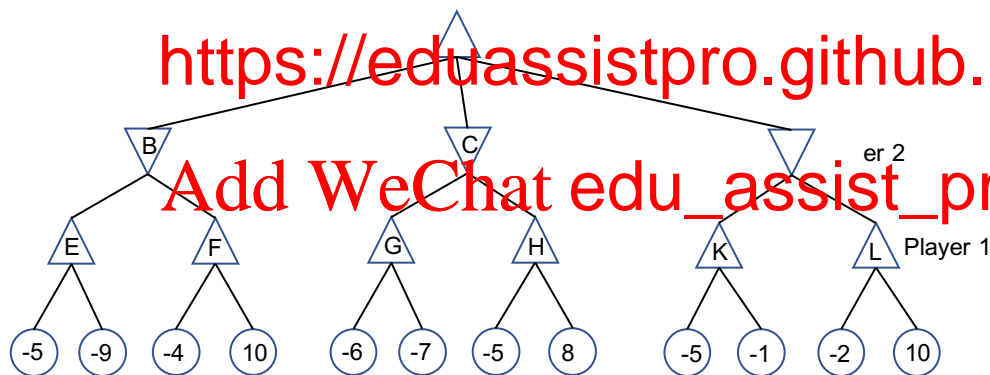
1. (5 points) Assuming both players act optimally, carry out the minimax search algorithm. Enter the values for the letter nodes.

2. (10 points) Assuming both players act optimally, use alpha-beta pruning to find the value of the root node. The search goes from left to right; when choosing which child to visit first, choose the left-most unvisited child.

   - Enter the values of the letter nodes.

- Select the leaf nodes that don't get visited due to pruning.

Q2.2. Unknown Leaf Nodes. (5 points) Consider the following game tree with the same setting as Q2.1 except the leaf has an unknown payoff, y.
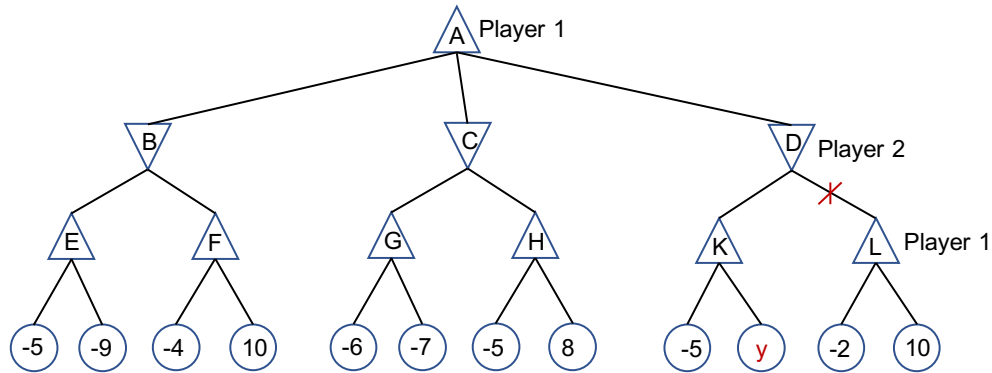

Similar to Q2.1.2, by using alpha-beta pruning, there are some pruning in the branches starting from nodes B and C. For what values of y such that the pruning shown in the figure will also be achieved? The search goes from left to right; when choosing which child to visit first, choose the left-most unvisited child

- Write All if y c

- Write None if y has no possible values

- Use an inequality in the form $y \geq value$, $y > value$, or $\{value1 < y < value2\}$ to specify an interval of values. As an example, if you think values larger than 16, you should enter $y > 16$.

Q3. Markov Decision Process (15 points)

Pacman is an agent in deterministic MDP with states A, B, C, D, E, F, G. He can deterministically choose to follow any edge pointing out of the state he is currently in. He cannot stay in place. $D, E,$ $F,$ and G are terminal states. Let the discount factor be $\gamma = 0.8$. Pacman receives the reward value labeled underneath a state upon entering that state. For example, $R(A, A \to C, C) = R(C) = +10$.
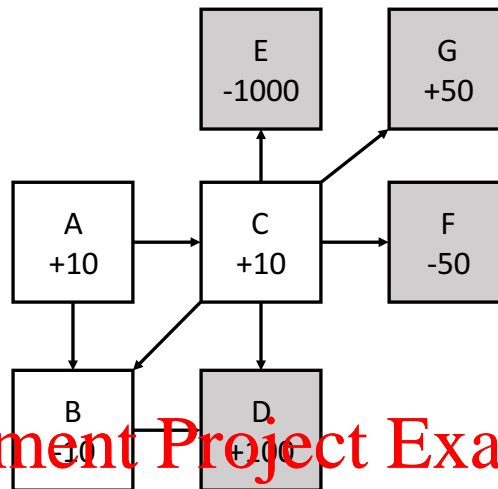

1. Write down the optim ... $s = A$ and $s = C$.

2. Pacman is now becomes indecisive if he enters state C. In state C, he finds the two best actions (among the four actions he can take from ... al probability, chooses between the two. Let $\bar{V}(s)$ be the ... according to $\pi^*(s)$ for all $s \neq C$, and follows the indecisive policy w ... hat are the values $\bar{V}(s)$ for $s = A$ and $s = C$?

5

Q4. Reinforcement Learning (15 points)

Q4.1. True/False. (5 points) Which of the following statements are true?

1. In Direct Evaluation, you recalculate state values after each transition you experience.

2. The exploration function $f = R(s, a, s') + \ln(1 + \frac{1}{N(s,a)})$ (where $N(s, a)$ refers to the number of times that you have visited state s and taken action a in your samples) would encourage the agent to visit unseen states and actions.

3. In approximate Q-learning, different states always have different feature-representations.

Q4.2. Q-learning (10 points) Consider a non-deterministic MDP as shown in the following figure with five states $\{A, B, C, D, E\}$. The agent can choose to follow any edge pointing out of the state he is currently in. The transition and reward functions are unknown. When the agent takes
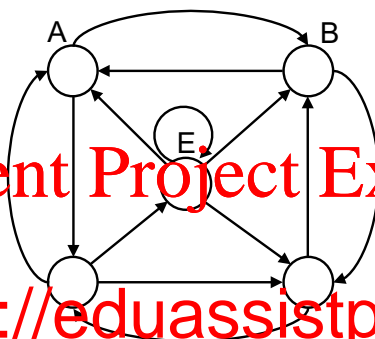
an action from a state, the agent may end up staying still or moving to one of n
that can be reached from that state. For example, if the agent is at state B and taking action
$B \rightarrow C$, the resulting state can be any state in $\{A, B$ ~~...~~ $\gamma = 0.5$. The
learning rate $\alpha = 0.5$

Suppose agent chooses actions according to some policy π and generates the following sequence of actions and rewards in the unknown game:

t	s_t	a_t	s_{t+1}	r_t
0	B	B→C	B	4
1	B	B→C	C	-3
2	C	C→E	E	3
3	E	E→A	A	1

Assume that all Q-values are initialized as 0. What are the Q-values learned by running Q-learning with the above experience sequence?

Q5. Bayes Nets (35 points)

Q5.1. Independence. (10 points) Consider the following Bayesian network with 6 variables $\{X_1, X_2, \ldots, X_6\}$.
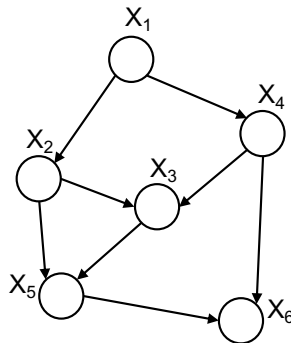
Which of the following statements are true:

1. $X_2 \perp\!\!\!\perp X_6 \mid X_1, X_5$

2. $X_4 \perp\!\!\!\perp X_5 \mid X_3$

Q5.2. Inference (15 points) Assume the following Bayes Net and corresponding CPTs.

A	P(A)
0	0.200
1	0.800

B	A	P(B|A)
0	0	0.400
1	0	0.600
0	1	0.200
1	1	0.800

C	B	P(C|B)
0	0	0.600
1	0	0.400
0	1	0.600
1	1	0.400

D	B	P(D|B)
0	0	0.800
1	0	0.200
0	1	0.600
1	1	0.400

E	C	D	P(E|C,D)
0	0	0	0.200
1	0	0	0.800
0	1	0	0.600
1	1	0	0.400
0	0	1	0.800
1	0	1	0.200
0	1	1	0.800
1	1	1	0.200

Compute the following conditional probabilities:

- $P(C = 1 \mid A = 1)$

- $P(E = 1 \mid A = 1, D = 1)$

Q4.3. Gibbs Sampling. (10 points)   We will work on the same Bayes net and its corresponding CPTs as in Q4.2. We observe the value of the variable $C = 0$. In this question, we will perform Gibbs sampling, using the random samples given in the table below.

0.320	0.037	0.303	0.318	0.032	0.969	0.018	0.058	0.908	0.249

When generating random samples, use as many values as needed from the table below, which we generated independently and uniformly at random from $[0, 1)$. Use numbers from left to right. To sample a binary variable W with probability $P(W = 0) = p$ and $P(W = 1) = 1 - p$ using a value a from the table, choose $W = 0$ if $a < p$ and $W = 1$ if $a \geq p$.

Our current sample is $(A = 1, B = 0, C = 0, D = 1, E = 1)$. We are going to generate 2 new samples using Gibbs sampling as follows:

1. To generate the first new sample, the non-evidence variable E is chosen.

   - Provide the conditional probability table based on which to sample a value of E?
   - What would be the value of each variable in the new sample?

2. To generate the second ⟨...⟩ chosen.

   - Provide the c ⟨...⟩ A?
   - What would be the value of each variable in the new samp ⟨...⟩

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