Artificial Intelligence

Spring 2018: Practice Midterm

Instructions: This exam is governed by the **Emory Honor Code**. This exam is closed book and closed notes. However, you may use 1 sheet of notes. You may also use an ancient calculator (not an app but the actual device). You will have 75 minutes for this exam. The point values are indicated beside each problem.

Name (print): ___Solution________________________________

This table is for grading, please leave it blank.

Problem	***Points***	***Score***
1: Search	15	
2: Games	10	
3: Bayesian Reasoning	10	
4: (Hidden) Markov Models	15	
5: Various	18	
Total		

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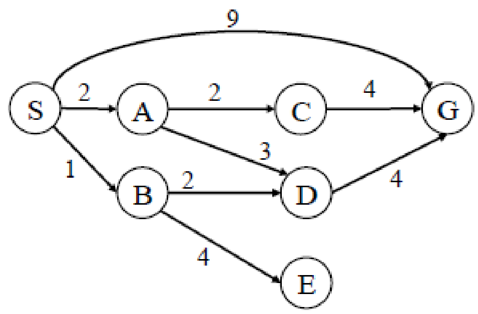
Problem 1: Search (15pts)



Heuristic

S	A	B	C	D	E	G
6	0	6	4	1	10	0

Consider the following search problem, represented as a graph. The start state is S and the only goal state is G. Note that the following problems variously reference both tree search and graph search. For questions which require a heuristic, use the one given below.

(a) **(2 pts)** What path **would breadth-first graph search** (BFS) return for this search problem?

S-G (BFS finds the path to the goal with the fewest edges.)

(b) **(2 pt)** What path would **uniform cost graph search** (UCS) return for this search problem?

S-B-D-G (UCS graph search always finds the optimal path.)

(c) **(2 pt)** What path would **greedy graph search** with *provided heuristic* return for this search problem?

S-G

Algorithm progression:

Path expanded	Fringe (ordered by heuristic alone)
S	S-A(0) S-G(0) S-B(6)
S-A	S-G(0) S-A-D(1) S-A-C(4) S-B(6)
S-G	S-A-D(1) S-A-C(4) S-B(6)

(d) **(3 pt)** What path would **A* graph search**, using the *provided heuristic***,** return for this search problem?

S-B-D-G

Solution (on board in review session).
Gist : maintain Fringe as priority queue, insert nodes n with f(n)=g(n) + h(n)
Assume PQ does the right thing when inserting duplicate nodes (if f(n) is smaller than previous, than updates it; otherwise ignored).

(e) **(2 pt)** Name a path that UCS expands (pops of the queue) but A* does not.

S-B-E or S-A-C (both will be expanded by UCS but not by A*)

(f) **(2pts)** Is the provided heuristic *admissible*? Explain concretely why or why not (give example)

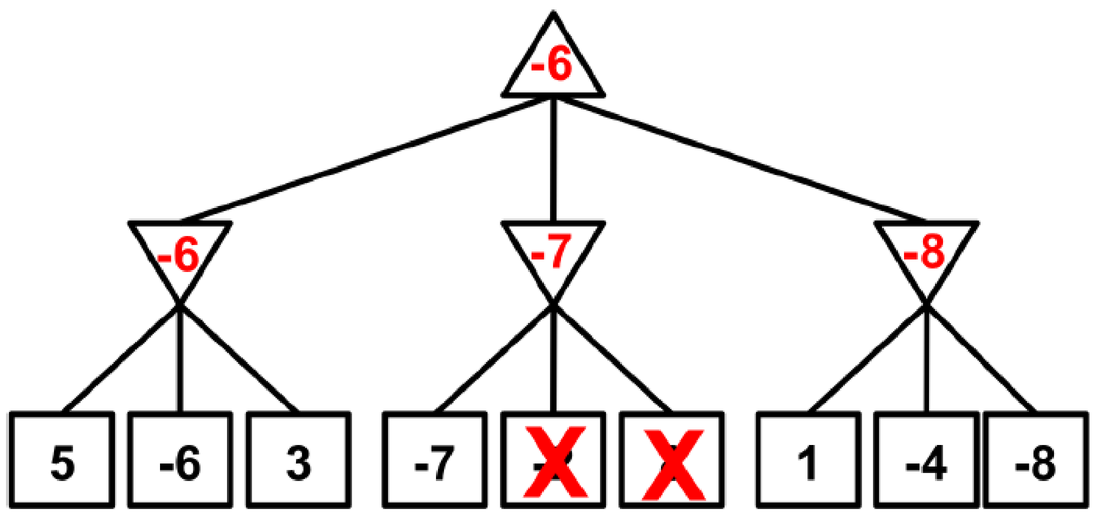
Yes (every h value <= true optimal cost)

(g) **(2pts)** Is the provided heuristic *consistent*? Explain concretely why or why not (give example)

No: h(S) > 2 + h(A). Violates consistency def: at every edge, h(a) <= cost(a,b)+h(b)

Problem 2 (10 pts): Games

Consider the following zero-sum game, in which the utilities $U_A(s)$ are shown for the first player (A). Assume the second player (B) is a minimizer: B holds the opposite utilities to A, $U_B(s) = -U_A(s)$. In this case, B's maximization of U_B is equivalent to minimization of U_A (i.e. the computation is standard minimax).



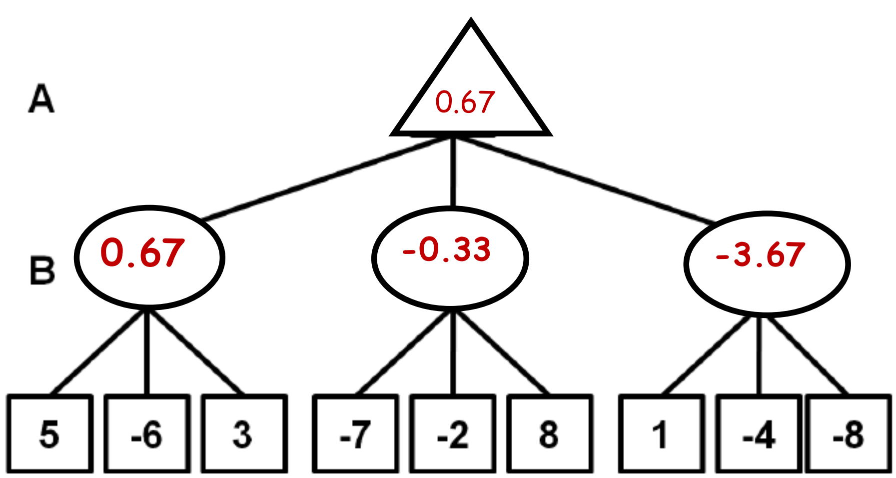
(a) **(3pts)** **I**n each node, write UA(s), the (minimax) utility of that state for player A, assuming that B is a minimizer.

above

(b) ((3 points) Cross out any nodes which will be skipped by alpha-beta pruning, assuming left-to-right ordering.

above

(c) (4 points) Suppose B is now a **Randomizer** node (for example, a randomly moving ghost), that chooses each of the available actions with equal probability.
Re-draw the game tree, and fill in the ExpectiMax utility of that state for player A.

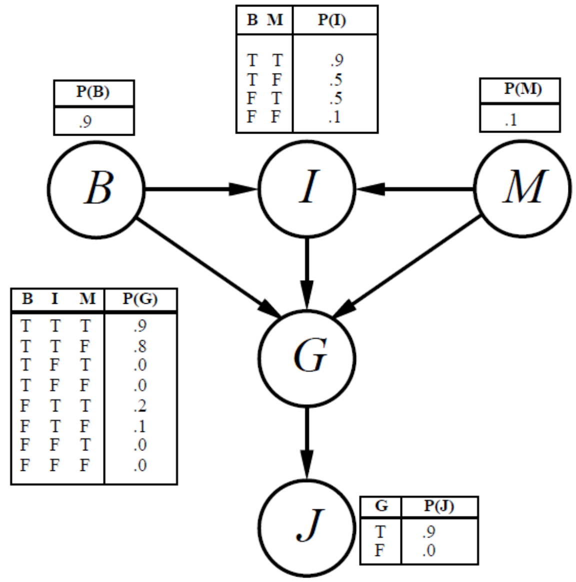


Problem 3 (10 pts): Bayesian Justice

In a galaxy far, far away, the law is enforced following the Bayes Net on the right. The Boolean variables are:

B: **B**roke the law
M: Politically **M**otivated prosecutor
I: is **I**ndicted (prosecuted)
G: found **G**uilty
J: goes to **J**ail

Note: if not explicitly stated, probability refers to True, so, P(B=True) is shortened to P(B).



P(B)
.9

P(M)
.1

B	M	P(I)
T	T	.9
T	F	.5
F	T	.5
F	F	.1

B	I	M	P(G)
T	T	T	.9
T	T	F	.8
T	F	T	.0
T	F	F	.0
F	T	T	.2
F	T	F	.1
F	F	T	.0
F	F	F	.0

G	P(J)
T	.9
F	.0

(a) (3 pts) Which, if any, of the following are asserted by the network structure? (ignoring CPTs for now). Circle all the correct answer(s).

X (i) P(B, I, M) = P(B)P(I)P(M) would be true if B, I, and M were independent

(ii) P(J|G) = P(J|G, I) (J is conditionally independent on I given G; also on B, M)

X (iii) P(G|B,I,M) = P(G|B)*P(G|I)*P(G|M) Would be true if not for edges B→I, M→I

(b) (3 pts) Calculate the value of P(+b, +i, -m, +g, +j) using the CPTs provided. Show work.

P(+b, +i, -m, +g, +j) = P(+b)*p(-m)*p(+i|+b,-m)*p(+g|+b,+I,-m)*p(+j|+g) =
0.9 * 0.9 * 0.5 * 0.8 * 0.9 = 0.29

(c) (4 pts) Calculate the probability that someone goes to jail given that they broke the law (+b), have been indicted (+i), and face a politically motivated prosecutor (+m). First, set up the conditional probability formula, then solve by using chain and/or product rules. Show work.

P(+j | +b, +i, +m) = p(+j,g,+b,+i,+m)* p(+b,+i,+m) = p(+j,g,+b,+i,+m)
= p(+j|+g)*p(+g|+b,+i,+m)+ p(+j|-g)*p(-g|+b,+i,+m)
= 0.9 * 0.9 + 0 * 0.1 = 0.81

If wanted P(+j) (in general), would need to compute full distribution:
P(-j | +b, +i, +m) = p(-j|+g)*p(+g|+b,+i,+m)+ p(-j|-g)*p(-g|+b,+i,+m)
= 0.1 * 0.9 + 1 * 0.1 = 0.19

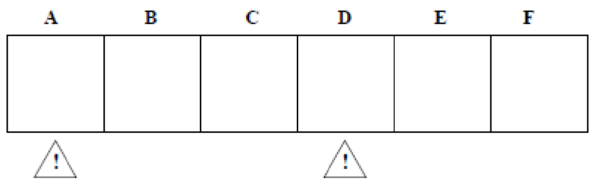
And then would normalize: p(+j|…)/(p(+j|…)+p(-j|…)) = 0.81 / (0.81+0.19) = 0.81

Problem 5 (15 pts): HMM Search and Rescue

Adapted from Pieter Abbeel

You are an interplanetary search and rescue expert who has just received an urgent message: a rover on Mercury has fallen and become trapped in Death Ravine, a deep, narrow gorge on the borders of enemy territory. You zoom over to Mercury to investigate the situation.

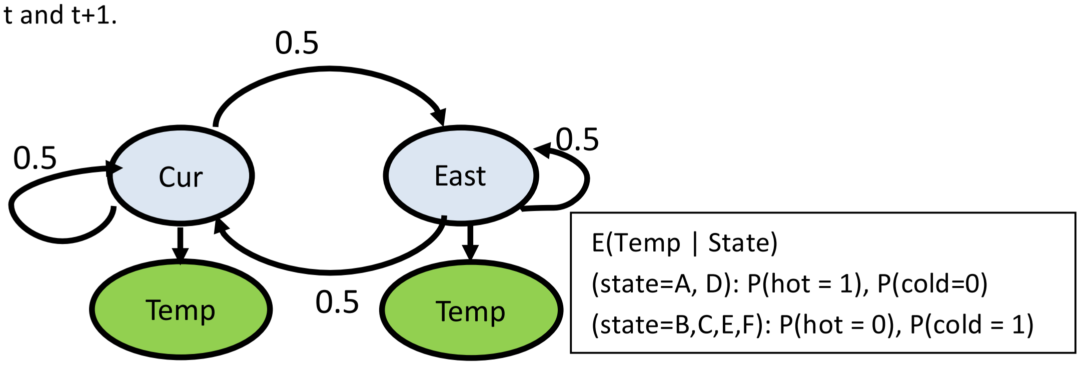
Death Ravine is a narrow gorge 6 miles long, as shown below. There are volcanic vents at locations A and D, indicated by the triangular symbols at those locations.



The rover was heavily damaged in the fall, and as a result, most of its sensors are broken. The only ones still functioning are its thermometers, which register only two levels , *hot* and *cold*. The rover sends back evidence $E = hot$ when it is at a volcanic vent (A and D), and $E = cold$ otherwise. There is no chance of a mistaken reading.

The rover fell into the gorge at position A on day 1, so $X_1 = A$. Let the rover's position on day t be $X_t \in \{A, B, C, D, E, F\}$. The rover is still executing its original programming, trying to move 1 mile east (i.e. right, towards F) every day. However, because of the damage, it only moves east with probability 0.5, and it stays in place with probability 0.5. Your job is to figure out where the rover is, so that you can dispatch your rescue-bot.

(a) (4) Draw the HMM diagram clearly showing states, observations, and transition probabilities, illustrating the HMM for times t and t+1.



(b) (6 pts) Three days have passed since the rover fell into the ravine. The observations were *(E1 = hot, E2 = cold, E3 = cold)*. What is $P(X3|hot_1, cold_2, cold_3)$, i.e., the probability distribution over the rover's position on day 3, given the observations?

T=1: X_1={A,0,0,0,0); E_1 = hot)

T=2: passage of time only: X_2 ' = X_1*P = {A=0.5, B=0.5, C,D,E,F=0};
Apply evidence: X_2 = E_2 =cold, so using E(Temp|X), X_2' *E(cold| $X_{2)}$ =
P(X_2, $E_{2)}$ = {A=0, B=0.5, C,D,E,F=0}
Normalize: → X_2{A=1, B,C,D,E,F=0}

T=3: passage of time: X_3 ' = X_2*P = {A=0, B=0.5, C=0.5, D,E,F=0};
apply evidence E_3 : X_3 = $X_{3'}$*E_3={A=0,B=0.5,C=0.5, D,E,F=0}
normalize: → X_3{ A=0,B=0.5,C=0.5, D,E,F=0}

You decide to attempt to rescue the rover on day 4. However, the transmission of E4 seems to have been corrupted, and so it is not observed.

(c) (3 pt) What is rover's position distribution for <u>day 4</u> given the same evidence, *P(X4|hot$_1$, cold$_2$, cold$_3$)* ?

Use X3 to predict X4 using passage of time:

T4: X_4' = X_3*P . Use X_3{ A=0,B=0.5,C=0.5, D,E,F=0} (from part b)

P(A)=0;

P(B)=0.5*0.5=0.25; (stay in B with prob 0.5 * prob of being in B at time 3)

P(C) = 0.5*0.5 + 0.5*0.5 = 0.5; (two ways to get to C: stay in C or move East from B)

P(D)=0.5*0.5=0.25; (prob of moving East from C * prob of being in C at time 3)

P(E)=P(F)=0.

→ X_4: {A=0, B=0.25, C=0.5, D=0.25, E,F=0}

(d) (2 pt) The observation wasn't corrupted, it was just accidentally encrypted! You decrypt the message which states that E_4 = hot$_4$. What is the rover's position distribution for <u>day 4</u> given the updated evidence, *P(X4|hot$_1$, cold$_2$, cold$_3$, hot$_4$)* ? (hint: re-use work from (c)).

P(X4|E4) = p(X_4)*P(E_4|X_4)/Z = {A=0, B=0.25, C=0.5, D=0.25, E,F=0} * P(hot|X_4) =

X_4' = {A=0, B=0, C=0, D=0.25, E=0, F=0}

Z = 1/sum(X_4') = 1/4 → P(A,B,C,E,F=0), P(D)=1. (rover has to be in D with prob 1)

Problem 5, Various: True/False/Short Answer

Each T/F problem is worth 2 points. Incorrect answers give you 0 points. Skipped questions give you 1 point.

(a) **True False** An optimal solution path for a search problem with positive costs will never have repeated states.

True: will not expand closed (explored) states

(b) **True False** If two search heuristics h1(s) and h2(s) have the same average value, the heuristic h3(s) = max(h1(s), h2(s)) **could** give better A* efficiency than h1 or h2.

True: e.g., if h1 works better in the beginning, h2 works better in later stages

(c) **True False** If one search heuristic h1(s) is admissible, and another h2(s) is inadmissible, then a new heuristic h3(s) = min(h1(s), h2(s)) will be admissible.

True: by definition of admissibility

(d) **True False** In A* search, the first path to the goal which is added to the fringe will always be optimal.

False: the first goal removed from the fringe is optimal

(e) **True False** The minimax value of a state is always greater than or equal to the expectimax value of that state. Clarification: the *Min* node is replaced by *Random* node, *Max* remains *Maximizer*.

False: the opposite: ExpectiMax chance nodes always predict at least as high (and usually higher) than Min nodes.

(f) **True False** Alpha-beta pruning can change the final minimax value of the root of a game search tree.

False: by construction, same result as MiniMax, but fewer nodes expanded

(g) **True False** When doing alpha-beta pruning on a game tree which is traversed from left to right, the leftmost branch can be pruned.

False: no previously seen Alpha, Beta values to prune against

(h) **True False** Iterative deepening is a useful alternative to breadth first search because it uses less computation than BFS

False: uses more computation, but less space than BFS (only stores stack)