COMP4200 / COMP 5430: Artificial Intelligence
SUMPLEMENTARY Final Examination
FALL 2019

UMASS - LOWELL

Name: ________________________________

Student ID: ________________________________

No.	Topic	Points	Scores
1	Short Answer	30	
2	Adversarial	10	
	Pool A		
3	Genetic Algorithms	20	
4	Bayes Network	20	
	Pool B		
5	MDP & RL	20	
6	CSP	20	
Total		80	

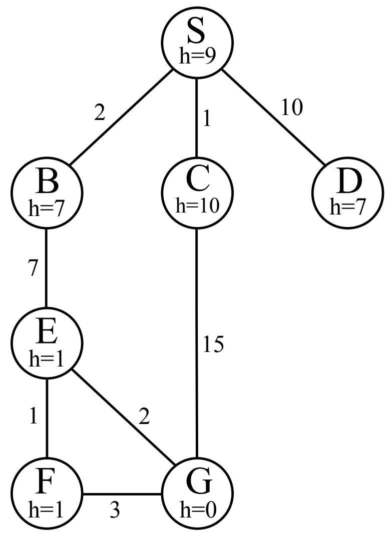
Instructions:

1. This examination contains 14 pages, including this page.
2. Questions [1 & 2] are compulsory; then choose one question from Pool A and Pool B. Please **CIRCLE** your choice.
3. Write your answers in this booklet. If you must write on the back page, please indicate **very** clearly on the front of the page that you have written on the back of the page.
4. One sided, handwritten A4 paper is allowed as a cheat sheet. Typed notes and any other resources, including lecture notes, books, conferring with other students/engineers are not allowed.
5. You may use a calculator. You may not share a calculator with anyone.

Question 1: Question Menagerie

[30 pts]

Consider the search graph shown below. S is the start state and G is the goal state. All edges are bidirectional.



For each of the following search strategies, give the path that would be returned, or write *none* if no path will be returned. If there are any ties, assume alphabetical tiebreaking (i.e., nodes for states earlier in the alphabet are expanded first in the case of ties).

(a) (1 point) Depth-first graph search

S-B-E-F-G

(b) (1 point) Breadth-first graph search

S-C-G

(c) (1 point) Uniform cost graph search

S-B-E-G

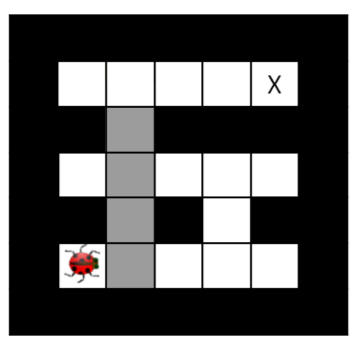
(d) (1 point) Greedy graph search

S-B-E-G

(e) (1 point) A* graph search

S-B-E-G

Parts (f) and (g) The hive of insects needs your help. 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.

(f) (2 points) 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.

A tuple of location coordinates m {1, . . . , M} and n {1, . . . , N} and the remaining air supply a {1, . . . , A}.

(g) (1 points) Give the size of your state space.

M * N * A

Parts (h), (i), and (j) 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.

(h) (2 points) Circle all of the following that are true (if any).

(a) h is admissible. h* is admissible and h <= h*.

(b) h is consistent. h* is consistent and subtracting a constant from both sides does not change the underlying inequality

(c) A* tree search (no closed list) with h will be optimal. Tree search requires admissibility.

(d) A* graph search (with closed list) with h will be optimal. Graph search requires admissibility and consistency

(i) (2 point) 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?

(a) Constant in k

(b) Linear in k

(c) Exponential in k

(d) 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.

(j) (2 points) Circle all of the following that are true (if any).

(a) h' is admissible.

(b) h' is consistent.

(c) A* tree search (no closed list) with h' will be optimal.

(d) A* graph search (with closed list) with h' will be optimal.

(k) (4 points) Answer **True or False** to contrast between genetic algorithms and simulated annealing?

F (a) Genetic algorithms are used for minimization problems while simulated annealing is used for maximization problems

T (b) Genetic algorithms maintain several possible solutions, whereas simulated annealing works with one solution.

F (c) Genetic algorithms maintain one solution, whereas simulated annealing maintains several possible solutions.

T (d) Simulated annealing is guaranteed to produce the best solution, while genetic algorithms do not have such a guarantee.

https://www.cs.mcgill.ca/~dprecup/courses/AI/Exams/sample_questions_answers.pdf

(l) (2 points) You are running minimax in a large game tree. However, you know that the minimax value is between $x - \epsilon$ and $x + \epsilon$, where x is a real number and ϵ is a small real number. You know nothing about the minimax values at the other nodes. Describe briefly but precisely how to modify the alpha-beta pruning algorithm to take advantage of this information.

Initialize the alpha and beta values at the root to α = (x − epsilon) and β = (x + epsilon) then run alpha-beta as normal. This will prune all of the game tree out of our known minimax bounds.

(m) (2 points) An agent prefers chocolate ice cream over strawberry and prefers strawberry over vanilla. Moreover, the agent is indifferent between deterministically getting strawberry and a lottery with a 90% chance of chocolate and a 10% chance of vanilla. Which of the following utilities can capture the agent's preferences?

(a) Chocolate 2, Strawberry 1, Vanilla 0

(b) Chocolate 10, Strawberry 9, Vanilla 0

(c) Chocolate 21, Strawberry 19, Vanilla 1

(d) No utility function can capture these preferences.

(n) (4 points) Consider a system with two states and two actions. You perform actions and observe the rewards and transitions listed below. Each step lists the current state, reward, action and resulting transition as S_i;R = r; a_k : $S_i \rightarrow S_j$. Perform Q-learning using a learning rate of $\alpha = 0.5$ and a discount factor of $\gamma = 0.5$ for each step. The Q-table entries are initialized to zero.

S_1;R = 10; a_1 : $S_1 \rightarrow S_1$

Q	S_1	S_2
a_1	-5	0
a_2	0	0

S_1;R = -10; a_2 : $S_1 \rightarrow S_2$

	S_1	S_2
a_1	-5	0
a_2	-5	0

(o) (4 points) Fill in the joint probability table so that the binary variables X and Y are independent.

X	Y	$P(X,Y)$
$+$	$+$	$3/5$
$+$	$-$	$1/5$
$-$	$+$	
$-$	$-$	

Question 2: Games: Multiple Choice

[10 pts]

In the following problems please choose **all** the answers that apply. You may circle more than one answer. You may also circle no answers, if none apply.

1. (3 points) In the context of adversarial search, α-β pruning

   (a) can reduce computation time by pruning portions of the game tree

   (b) is generally faster than minimax, but loses the guarantee of optimality

   (c) always returns the same value as minimax for the root of the tree

   (d) always returns the same value as minimax for all nodes on the leftmost edge of the tree, assuming successor game states are expanded from left to right

   (e) always returns the same value as minimax for all nodes of the tree

2. (2 points) Consider an adversarial game in which each state s has minimax value $v(s)$. Assume that the maximizer plays according to the optimal minimax policy π, but the opponent (the minimizer) plays according to an unknown, possibly suboptimal policy π'. Which of the following statements are true?

   (a) The score for the maximizer from a state s under the maximizer's control could be greater than $v(s)$.

   (b) The score for the maximizer from a state s under the maximizer's control could be less than $v(s)$.

   (c) Even if the opponent's strategy π' were known, the maximizer should play according to π.

   (d) If π' is optimal and known, the outcome from any s under the maximizer's control will be $v(s)$.

3. (5 points) Consider a very deep game tree where the root node is a maximizer, and the complete-depth minimax value of the game is known to be v_∞. Similarly, let π_∞ be the minimax-optimal policy. Also consider a depth-limited version of the game tree where an evaluation function replaces any tree regions deeper than depth 10. Let the minimax value of the depth-limited game tree be v_{10} for the current root node, and let π_{10} be the policy which results from acting according to a depth 10 minimax search at every move. Which of the following statements are true?

   (a) v_∞ may be greater than or equal to v_{10}.

   (b) v_∞ may be less than or equal to v_{10}.

   (c) Against a perfect opponent, the actual outcome from following π_{10} may be greater than v_∞.

   (d) Against a perfect opponent, the actual outcome from following π_{10} may be less than v_∞.

Question 3: Question Menagerie

[30 pts]

Suppose a genetic algorithm uses chromosomes of the form x = abcdefgh with a fixed length of eight genes. Each gene can be any digit between 0 and 9. Let the fitness of individual x be calculated as:

$$f(x) = (a + b) - (c + d) + (e + f) - (g + h) \tag{1}$$

and let the initial population consist of four individuals with the following chromosomes:

$$x_1 = 65413532 \tag{2}$$
$$x_2 = 87126601 \tag{3}$$
$$x_3 = 23921285 \tag{4}$$
$$x_4 = 41852094 \tag{5}$$

(a) (3 points) By looking at the fitness function and considering that genes can only be digits between 0 and 9 find the chromosome representing the optimal solution (i.e. with the maximum fitness). Find the value of the maximum fitness.

f(x1) = (6 + 5) − (4 + 1) + (3 + 5) − (3 + 2) = 9
f(x2) = (8 + 7) − (1 + 2) + (6 + 6) − (0 + 1) = 23
f(x3) = (2 + 3) − (9 + 2) + (1 + 2) − (8 + 5) = −16
f(x4) = (4 + 1) − (8 + 5) + (2 + 0) − (9 + 4) = −19

The order is x2, x1, x3 and x4.

(b) (5 points) Evaluate the fitness of each individual, showing all your workings, and arrange them in order with the fittest first and the least fit last.

(c) (Perform the following crossover operations:

ii. (2 points) Cross the second and third fittest individuals using a two–point crossover (*points b and f*).

Answer: Two – point crossover on x1 and x3
x1 = 6 5 | 4 1 3 5 | 3 2
x3 = 2 3 | 9 2 1 2 | 8 5
=> O3 = 6 5 | 9 2 1 2 | 3 2
O4 = 2 3 | 4 1 3 5 | 8 5

iii. (3 points) Cross the first and third fittest individuals (ranked 1st and 3rd) using a uniform crossover.

Answer: In the simplest case uniform crossover means just a random exchange of genes between two parents. For example, we may swap genes at positions a, d and f of parents x2 and x3:
x2 = 8 7 1 2 6 6 0 1
x3 = 2 3 9 2 1 2 8 5
=> O5 = 2 7 1 2 6 2 0 1
O6 = 8 3 9 2 1 6 8 5

(d) (7 points) Suppose the new population consists of the six offspring individuals received by the crossover operations in the above question. Evaluate the fitness of the new population, showing all your workings. Has the overall fitness improved?

Answer: The new population is:
O1 = 8 7 1 2 3 5 3 2
O2 = 6 5 4 1 6 6 0 1
O3 = 6 5 9 2 1 2 3 2
O4 = 2 3 4 1 3 5 8 5
O5 = 2 7 1 2 6 2 0 1
O6 = 8 3 9 2 1 6 8 5
Now apply the fitness function f(x) = (a+b)−(c+d)+(e+f)−(g+h):
f(O1) = (8 + 7) − (1 + 2) + (3 + 5) − (3 + 2) = 15
f(O2) = (6 + 5) − (4 + 1) + (6 + 6) − (0 + 1) = 17
f(O3) = (6 + 5) − (9 + 2) + (1 + 2) − (3 + 2) = −2
f(O4) = (2 + 3) − (4 + 1) + (3 + 5) − (8 + 5) = −5
f(O5) = (2 + 7) − (1 + 2) + (6 + 2) − (0 + 1) = 13
f(O6) = (8 + 3) − (9 + 2) + (1 + 6) − (8 + 5) = −6
The overall fitness has improved.

Question 4: Bayesian Networks:Mumps Outbreak

[15 pts] There has been a mumps outbreak in Lowell. You feel fine, but you're worried that you might already be infected and therefore won't be able to enjoy the holidays. You decide to use Bayes nets to analyze the probability that you've contracted mumps.

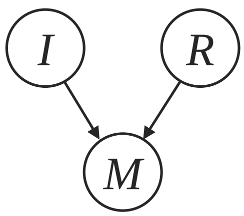
You first think about the following two factors:

- You think you have immunity from mumps ($+i$) due to being vaccinated recently, but the vaccine is not completely effective, so you might not be immune ($-i$).
- Your roommate didn't feel well yesterday, and though you aren't sure yet, you suspect they might have mumps ($+r$).

Denote these random variables by I and R. Let the random variable M take the value $+m$ if you have mumps, and $-m$ if you do not. You write down the following Bayes net to describe your chances of being sick:

I	P(I)
+i	0.8
-i	0.2

R	P(R)
+r	0.4
-r	0.6



I	R	M	P(M|I,R)
+i	+r	+m	0
+i	+r	-m	1.0
+i	-r	+m	0
+i	-r	-m	1.0
-i	+r	+m	0.7
-i	+r	-m	0.3
-i	-r	+m	0.2
-i	-r	-m	0.8

(a) (4 points) Fill in the following table with the joint distribution over I, M, and R, $P(I, M, R)$.

I	R	M	$P(I, R, M)$
$+i$	$+r$	$+m$	0
$+i$	$+r$	$-m$	.32
$+i$	$-r$	$+m$	0
$+i$	$-r$	$-m$	.48
$-i$	$+r$	$+m$	0.056
$-i$	$+r$	$-m$	.024
$-i$	$-r$	$+m$	0.024
$-i$	$-r$	$-m$	.096

https://s3-us-west-2.amazonaws.com/cs188websitecontent/exams/fa11_midterm_solutions.pdf

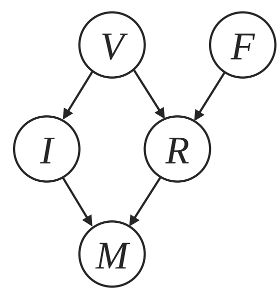
(b) (5 points) What is the marginal probability $P(+m)$ that you have the mumps?

https://s3-us-west-2.amazonaws.com/cs188websitecontent/exams/fa11_midterm_solutions.pdf

(c) (5 points) Assuming you do have the mumps, you're concerned that your roommate may have the disease as well. What is the probability $P(+r \mid +m)$ that your roommate has the mumps given that you have the mumps? Note that you still don't know whether or not you have immunity.

https://s3-us-west-2.amazonaws.com/cs188websitecontent/exams/fa11_midterm_solutions.pdf

You're still not sure if you have enough information about your chances of having the mumps, so you decide to include two new variables in the Bayes net. Your roommate went to a frat party over the weekend, and there's some chance another person at the party had the mumps ($+f$). Furthermore, both you and your roommate were vaccinated at a clinic that reported a vaccine mix-up. Whether or not you got the right vaccine ($+v$ or $-v$) has ramifications for both your immunity (I) and the probability that your roommate has since contracted the disease (R). Accounting for these, you draw the modified Bayes net shown on the right.



(d) (6 points) Indicate, *True / False*, for all the following statements based on the Bayes net shown above:

(i) $V \perp M \mid I,\ R$

(ii) $V \perp M \mid R$

(iii) $M \perp F \mid R$

(iv) $V \perp F$

(v) $V \perp F \mid M$

(vi) $V \perp F \mid I$

Question 5: MDPs and RL: Wandering Merchant

[20 pts] There are N cities along a major highway numbered 1 through N. You are a merchant from city 1 (that's where you start). Each day, you can either travel to a neighboring city (actions *East* or *West*) or stay and do business in the current city (action *Stay*). If you choose to travel from city i, you successfully reach the next city with probability p_i, but there is probability *1* - p_i that you hit a storm, in which case you waste the day and do not go anywhere. If you stay to do business in city i, you get $r_i > 0$ in reward; a travel day has reward 0 regardless of whether or not you succeed in changing cities. The diagram below shows the actions and transitions from city i. Solid arrows are actions; dashed arrows are resulting transitions labeled with their probability and reward, in that order.

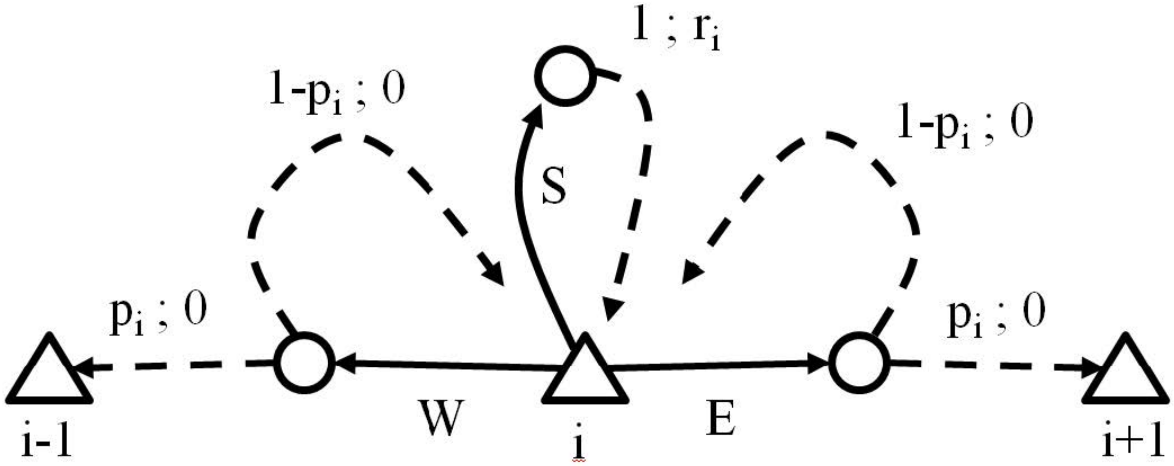


Figure 1: RL: Wandering Problem

(a) (3 points)If for $\forall i$, $r_i = 1$, $p_i = 1$, and there is a discount $\gamma = 0{:}5$, what is the value $V^{stay}(1)$ of being in city 1 under the policy that always chooses stay? Your answer should be a real number.

https://inst.eecs.berkeley.edu/~cs188/sp11/exams/midterm-fa08-solution.pdf

(b) (3 points)If for $\forall i$, $r_i = 1$, $p_i = 1$, and there is a discount $\gamma = 0{:}5$, what is the optimal value $V^*(1)$ of being in city 1?

https://inst.eecs.berkeley.edu/~cs188/sp11/exams/midterm-fa08-solution.pdf

(c) (3 points) If the r_i's and p_i's are known positive numbers and there is almost no discount, i.e. $\gamma = 1$, describe the optimal policy. You may define it formally or in words, e.g. "always go east", but your answer should precisely define how an agent should act in any given state. Hint: You should not need to do any computation to answer this question.

https://inst.eecs.berkeley.edu/~cs188/sp11/exams/midterm-fa08-solution.pdf

(d) (3 points) If the optimal value of being in city 1 is positive, i.e. $V^* > 0$, what is the largest k for which $V_k(1)$ could still be zero? Be careful of off-by-one errors.

https://inst.eecs.berkeley.edu/~cs188/sp11/exams/midterm-fa08-solution.pdf

(e) (3 points) If all of the r_i and p_i are positive, what is the largest k for which V_k(s) could still be zero for some state s? Be careful of off-by-one errors.

https://inst.eecs.berkeley.edu/~cs188/sp11/exams/midterm-fa08-solution.pdf

(f) (5 points)Suppose we experience the following sequence of states, actions, and rewards: (s=1, a=stay, r=4), (s=1, a=east, r=0), (s=2, a=stay, r=6), (s=2, a=west, r=0), (s=1, a=stay, r=4, s=1). What are the resulting Q(s, a) values if the learning rate is 0.5, the discount is 1, and we start with all Q(s, a) = 0? Fill in the table below; each row should hold the q-values after the transition specified in its first column. You may leave unchanged values blank.

$< s, a, r, s' >$	Q(1,S)	Q(1, E)	Q(2,W)	Q(2,S)
Initial	0	0	0	0
$< 1, S, 4, 1 >$				
$< 1, E, 0, 2 >$				
$< 2, S, 6, 2 >$				
$< 2, W, 0, 2 >$				
$< 1, S, 4, 1 >$				

After (1, S, 4, 1), we update Q(1, S) 0.5[4 + 1 · 0] + 0.5(0) = 2.
After (1, E, 0, 2), we update Q(1, E) 0.5[0 + 1 · 0] + 0.5(0) = 0.
After (2, S, 6, 2), we update Q(2, S) 0.5[6 + 1 · 0] + 0.5(0) = 3.
After (2, W, 0, 1), we update Q(2, W) 0.5[0 + 1 · 2] + 0.5(0) = 1.
After (1, S, 4, 1), we update Q(1, S) 0.5[4 + 1 · 2] + 0.5(2) = 4.

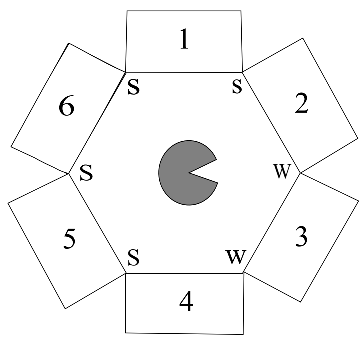
Question 6: CSPs: Trapped Pacman

[20 pts]

Pacman is trapped! He is surrounded by mysterious corridors, each of which leads to either a pit (P), a ghost (G), or an exit (E). In order to escape, he needs to figure out which corridors, if any, lead to an exit and freedom, rather than the certain doom of a pit or a ghost.

The one sign of what lies behind the corridors is the wind: a pit produces a strong breeze (S) and an exit produces a weak breeze (W), while a ghost doesn't produce any breeze at all. Unfortuantely, Pacman cannot measure the the strength of the breeze at a specific corridor. Instead, he can stand *between* two adjacent corridors and feel the max of the two breezes. For example, if he stands between a pit and an exit he will sense a strong (S) breeze, while if he stands between an exit and a ghost, he will sense a weak (W) breeze. The measurements for all intersections are shown in the figure below.

Also, while the total number of exits might be zero, one, or more, Pacman knows that two neighboring squares will *not* both be exits.



Pacman models this problem using variables X_i for each corridor i and domains P, G, and E.

(a) (9 points) State the binary **AND** unary constraints for this CSP (either implicitly or explicitly).
hint: There are atleast six binary and three unary constraints hence the points allocation

Binary:
X1 = P or X2 = P, X2 = E or X3 = E,
X3 = E or X4 = E, X4 = P or X5 = P,
X5 = P or X6 = P, X1 = P or X6 = P,
i, j, Adj(i, j)and¬(Xi = EandXj = E)

Unary:
X2 /= P,
X3 /= P,
X4 /= P

https://inst.eecs.berkeley.edu/~cs188/fa11/midterm_solutions.pdf

(b) (6 points) Cross out the values from the domains of the variables that will be deleted in enforcing arc consistency.

X_1	P	~~G~~	~~E~~
X_2	~~P~~	G	E
X_3	~~P~~	G	E
X_4	~~P~~	G	E
X_5	P	~~G~~	~~E~~
X_6	P	G	E

(c) (2 points) According to MRV, which variable or variables could the solver assign first?

X1 or X5 (tie breaking)

(d) (3 points) Assume that Pacman knows that $X_6 = G$. List all the solutions of this CSP or write *none* if no solutions exist.

(P,E,G,E,P,G)
(P,G,E,G,P,G)