CS 188 Fall 2014

Introduction to Artificial Intelligence

Midterm

INSTRUCTIONS

- You have 80 minutes.
- The exam is closed book, closed notes except a one-page crib sheet.
- Please use non-programmable calculators only. Laptops, phones, etc., may not be used. If you have one in your bag please switch it off.
- Mark your answers ON THE EXAM ITSELF. If you are not sure of your answer you may wish to provide a *brief* explanation. All short answer sections can be successfully answered in a few sentences at most.
- Questions are not sequenced in order of difficulty. Make sure to look ahead if stuck on a particular question.

Last Name	
First Name	
SID	
Email	
First and last name of person on left	
First and last name of person on right	
All the work on this exam is my own. **(please sign)**	

For staff use only

Q. 1	Q. 2	Q. 3	Q. 4	Q. 5	Total
/10	/30	/ 20	/ 20	/20	/100

1. (10 points) Agents

Here is pseudocode for three agent programs A, B, C:

```
function A(percept)
return f_A()
```

```
function B(percept)
return f_B(percept)
```

```
function C(percept)
persistent: percepts, initially []
percepts ← push(percept,percepts)
return f_C(percepts)
```

In each of these agents, the function f is some arbitrary, possibly randomized, function of its inputs with no internal state of its own; the agent program runs on computer with unbounded memory but finite clock speed. We'll assume also that the environment and its performance measure are computable.

(a) (3 pt) Suppose the environment is fully observable, deterministic, discrete, single-agent, and static. For which agents, if any, is it the case that, for *every* such environment, there is *some* way to choose f such that the agent is perfectly rational?

A **B** **C**

(b) (3 pt) Suppose the environment is *partially* observable, deterministic, discrete, single-agent, and static. For which agents, if any, is it the case that, for *every* such environment, there is *some* way to choose f such that the agent is perfectly rational?

A **B** **C**

(c) (3 pt) Suppose the environment is partially observable, *stochastic*, discrete, single-agent, and *dynamic*. For which agents, if any, is it the case that, for *every* such environment, there is *some* way to choose f such that the agent is perfectly rational?

A **B** **C**

(d) (1 pt) *True/False*: There is *some* environment such that *every* agent is perfectly rational in that environment.

2. (30 points) Search problems

It is training day for Pacbabies, also known as Hungry Running Maze Games day. Each of k Pacbabies starts in its own assigned start location s_i in a large maze of size MxN and must return to its own Pacdad who is waiting patiently but proudly at g_i; along the way, the Pacbabies must, between them, eat all the dots in the maze.

At each step, all k Pacbabies move one unit to any open adjacent square. The only legal actions are Up, Down, Left, or Right. It is illegal for a Pacbaby to wait in a square, attempt to move into a wall, or attempt to occupy the same square as another Pacbaby. To set a record, the Pacbabies must find an optimal collective solution.

(a) (5 pt) Define a minimal state space representation for this problem.

(b) (2 pt) How large is the state space?

(c) (3 pt) What is the maximum branching factor for this problem?

(A) 4^k (B) 8^k (C) $4^k 2^{MN}$ (D) $4^k 2^4$

(d) (6 pt) Let $MH(p, q)$ be the Manhattan distance between positions p and q
and F be the set of all positions of remaining food pellets
and p_i be the current position of Pacbaby i.
Which of the following are admissible heuristics?

h_A: $\frac{\sum_{i=1}^{k} MH(p_i,g_i)}{k}$
h_B: $\max_{1\leq i\leq k} MH(p_i, g_i)$
h_C: $\max_{1\leq i\leq k}[\max_{f\in F} MH(p_i, f)]$
h_D: $\max_{1\leq i\leq k}[\min_{f\in F} MH(p_i, f)]$
h_E: $\min_{1\leq i\leq k}[\min_{f\in F} MH(p_i, f)]$
h_F: $\min_{f\in F}[\max_{1\leq i\leq k} MH(p_i, f)]$

(e) (2 pt) Give one pair of heuristics h_i, h_j from part (d) such that their *maximum* — $h(n) = max(h_i(n), h_j(n))$ — is an admissible heuristic.

(f) (2 pt) Is there a pair of heuristics h_i, h_j from part (d) such that their *convex combination* — $h(n) = \alpha h_i(n) + (1 - \alpha)h_j(n))$ — is an admissible heuristic for any value of α between 0 and 1? Briefly explain your answer.

Now suppose that some of the squares are flooded with water. In the flooded squares, it takes two timesteps to travel through the square, rather than one. However, the Pacbabies don't know which squares are flooded and which aren't, until they enter them. After a Pacbaby enters a flooded square, its howls of despair instantly inform all the other Pacbabies of this fact.

(g) (4 pt) Define a minimal space of belief states for this problem.

(h) (2 pt) How many possible environmental configurations are there in the initial belief state, before the Pacbabies receive any wetness percepts?

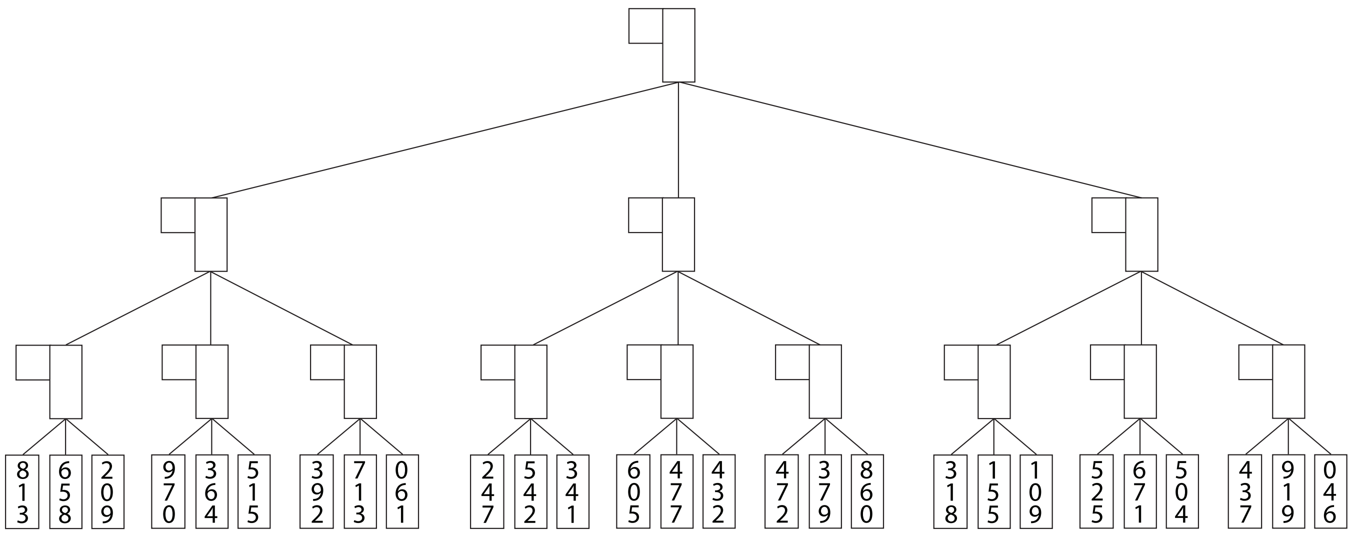
(i) (4 pt) Given the current belief state, how many different belief states can be reached in a single step?

(A) 4^k (B) 8^k (C) $4^k 2^{MN}$ (D) $4^k 2^4$

3. (20 points) Adversarial search Consider a game with three players (A, B, and C) in which, *before every move*, a fair 3-sided die is rolled to determine which player gets to make a move. (The sides of the die are marked A, B, and C.) The first die has been rolled, and it is A's turn to start the game. In every nonterminal state, the player whose turn it is has a choice of three moves. In a terminal state s, each player receives their own payoff from a payoff tuple $[U_A(s), U_B(s), U_C(s)]$; the aim of each player is to maximize the expected payoff he or she receives.

(a) (8 pt) The skeleton of the game tree below corresponds to two turns of the game, after which the game ends and the values shown are attained.

First, label each nonterminal node of the tree with A, B, C, or D. A, B, or C correspond to the respective player making a move, and D corresponds to a die roll. For any die roll node, label the outgoing branches A, B, C in that order. Then, propagate the values up the tree, assuming each player plays optimally and the die is fair.



(b) (6 pt) Suppose you know in advance that each value must be in the range 0-9, as shown. Using this knowledge, circle the *first* leaf node that need not be evaluated, if the tree is explored left-to-right. [Hint: you may find it helpful to keep track of bounds on the values of the internal nodes as the search progresses.]

(c) (6 pt) Now consider a version of the above game in which the moves are moves in an 8-puzzle, and a player receives +1 for making the final move that solves the puzzle, –1 if another player does so. If the same state is repeated 3 times, the game ends with everyone receiving 0. In the initial state it is A's turn to move and the puzzle is two steps from being solved. To keep things simple, remember that in an 8-puzzle every move takes you either one step closer or one step further away from the goal, so each player has essentially two choices and (to make this choice) we can use number-of-steps-from-goal as the state variable. Should A move towards the goal or away from it? Justify your answer *quantitatively*.

4. (20 points) Constraint satisfaction

Suppose you have a search problem defined by more or less the usual stuff:

- a set of states S;
- an initial state s_0;
- a set of actions A including the $NoOp$ action that has no effect;
- a transition model $Result(s, a)$;
- a set of goal states G.

Unfortunately, you have no search algorithms! All you have is a CSP solver.

(a) **(10 pt)** Given some time horizon T, explain how to formulate a CSP such that (1) the CSP has a solution exactly when the problem has a solution of length T steps; (2) the solution to the original problem can be "read off" from the variables assigned in CSP solution. Your formulation must give the variables, their domains, and all applicable constraints expressed as precisely as possible. You should have at least one variable per time step, and the constraints should constrain the initial state, the final state, and consecutive states along the way.

(b) **(2 pt)** Explain how to modify your CSP formulation so that the CSP has a solution when the problem has a solution of length $\leq T$ steps, rather than exactly T steps.

(c) **(8 pt)** Suppose you also know the step cost function $c(s, a, s')$ and you have a local-search CSP solver. What heuristic can you give the solver, and what local-search algorithm should it run, such that a globally optimal solution is returned (if one exists) of length $\leq T$?

5. (20 points) Propositional logic

(a) (6 pt) Consider a vocabulary with only four symbols, A, B, C, and D. For each of the following sentences, how many possible worlds make it true?

i. $(A \wedge B) \vee (C \wedge D)$

ii. $\neg(A \wedge B \wedge C \wedge D)$

iii. $B \Rightarrow (A \wedge B)$

(b) (8 pt) A certain procedure to convert a sentence to CNF contains four steps (1-4 below); each step is based on a logical equivalence. Circle ALL of the valid equivalences for each step.

i. Step 1: drop biconditionals

a) $(\alpha \Leftrightarrow \beta) \equiv ((\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha))$

b) $(\alpha \Leftrightarrow \beta) \equiv ((\alpha \Rightarrow \beta) \vee (\beta \Rightarrow \alpha))$

c) $(\alpha \Leftrightarrow \beta) \equiv (\alpha \wedge \beta)$

ii. Step 2: drop implications

a) $(\alpha \Rightarrow \beta) \equiv (\alpha \vee \neg\beta)$

b) $(\alpha \Rightarrow \beta) \equiv (\neg\alpha \vee \beta)$

c) $(\alpha \Rightarrow \beta) \equiv (\neg\alpha \wedge \beta)$

iii. Step 3: move not inwards

a) $\neg(\alpha \vee \beta) \equiv (\neg\alpha \wedge \neg\beta)$

b) $\neg(\alpha \vee \beta) \equiv (\neg\alpha \vee \neg\beta)$

c) $\neg(\alpha \wedge \beta) \equiv (\neg\alpha \vee \neg\beta)$

iv. Step 4: move "or" inwards and "and" outwards

a) $(\alpha \vee (\beta \wedge \gamma)) \equiv (\alpha \vee \beta \vee \gamma)$

b) $(\alpha \vee (\beta \wedge \gamma)) \equiv ((\alpha \vee \beta) \wedge (\alpha \vee \gamma))$

c) $(\alpha \vee (\beta \wedge \gamma)) \equiv ((\alpha \wedge \beta) \vee (\alpha \wedge \gamma))$

(c) **(4 pt)** A group of Stanford students write a Convert-to-CNF-ish procedure. In their implementation, they simply apply the *first* equivalence (the one labeled "a)") from each of the four steps in part (b). Show the transformed sentence generated by Convert-to-CNF-ish at each stage, when applied to the input sentence $A \Leftrightarrow (C \vee D)$.

(d) **(2 pt)** Is the final output of the Convert-to-CNF-ish equivalent to the input sentence in part (c)? If not, give a possible world where the input and output sentences have different values.