Midterm Examination

CS540: Introduction to Artificial Intelligence

October 22, 2008

LAST NAME: ____

FIRST NAME: ____

Problem	Score	Max Score
1	________	19
2	________	18
3	________	16
4	________	15
5	________	14
6	________	18
Total	________	100

Question 1. Decision Trees

Consider the following set of 8 training examples, each containing two attributes, A and B, and a desired binary classification, + or −. You may leave your answers in (a) – (c) as expressions containing logs of fractions.

A	B	Class
0	10	+
0	100	+
1	100	+
1	10	+
1	100	−
1	100	−
1	10	−
1	10	−

(a) [3] What is the entropy (information content) of the "Class"?

(b) [3] What is the information gain (mutual information) of attribute "A" in predicting the "Class"?

(c) [3] What is the information gain (mutual information) of attribute "B" in predicting the "Class"?

(d) [6] Draw the final decision tree trained from the above data. Indicate the number of "+" and "−" training examples at each leaf node, and the class prediction at each leaf.

(e) [2] True or False: Two different decision trees that both correctly classify a set of training examples, will also classify any other testing example in the same way (i.e., both trees will output the same class for any other example).

(f) [2] True or False: Given an arbitrary decision tree containing only binary attributes to predict a binary classification, there is an equivalent sentence in Propositional Logic that represents the same information described by the decision tree.

Question 2. Search

Consider the 3-puzzle problem, which is a simpler version of the 8-puzzle where the board is 2×2 and there are three tiles, numbered 1, 2, and 3. There are four moves: move the *blank* up, right, down, and left. These moves are applied, when possible, in this order for all uninformed searches and in case of sibling ties for other searches. Break other ties by increasing time on OPEN (i.e., first attempt the one which has been on OPEN the longest). The cost of each move is 1. The start and goal states are

Start

2	
1	3

Goal

1	2
3	

(a) [6] Draw the entire state space for this problem, labeling nodes and arcs clearly.

(b) Assuming there is no checking for repeated states of any kind, draw the search tree produced by each of the following search methods. For each node in a tree, label it with a number indicating when it was removed from the OPEN list (and expanded or detected as a goal node). If a method does not find a solution, show the part of the search tree and then explain why no solution is found.

(i) [6] Depth-First search.

(ii) [6] A* search with the heuristic equal to the number of misplaced tiles (do not count the blank as a tile).

Question 3. A* Heuristics

In standard A* search the objective function at each node n is $f(n) = g(n) + h(n)$, where $g(n)$ is the cost from start to this node, and $h(n)$ is an **admissible** heuristic estimating the cost from n to a goal. Now let us use a different objective function:

$$f(n) = w * g(n) + (100 - w) * h(n)$$

where $0 \leq w \leq 100$.

(a) [4] What search algorithm do you get when $w = 0$?

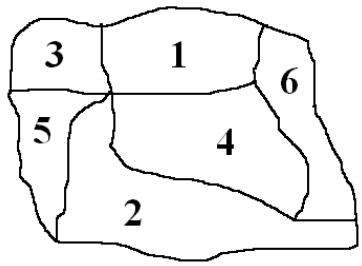
(b) [4] What about when $w = 50$?

(c) [4] What about when $w = 100$?

(d) [4] For what values of w is this algorithm guaranteed to be optimal? Explain briefly.

Question 4. Constraint Satisfaction

Consider the problem of coloring the six areas (numbered 1…6) in the following map using three colors: R, G, and B, so that no adjacent areas have the same color. Two areas are adjacent if they <u>share part of an edge</u> (note: they are NOT adjacent if they only share a corner).



(a) [6] Fill in the table below with the domain of each area after each of the following steps of selecting an area and assigning a color followed by <u>forward checking</u> (FC):

	1	2	3	4	5	6
Initial domain	R,G,B	R,G,B	R,G,B	R,G,B	R,G,B	R,G,B
After 1=R and FC						
After 2=G and FC						
After 3=G and FC						

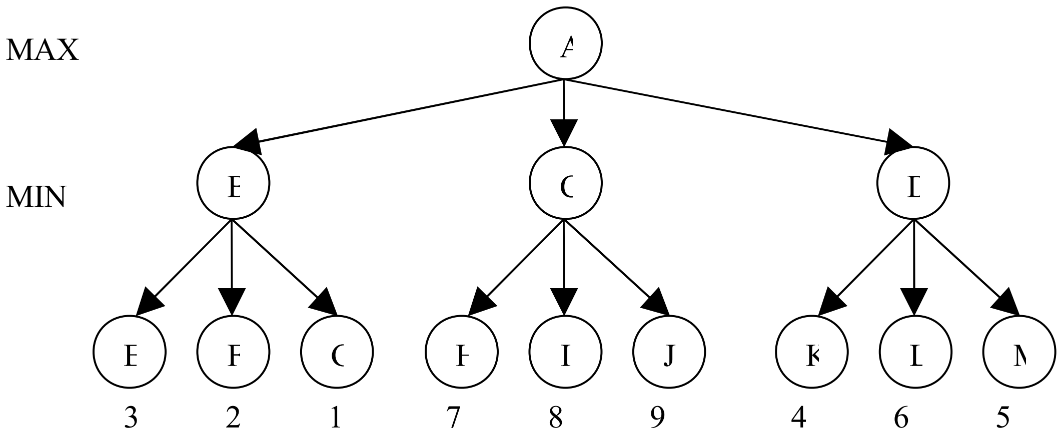
(b) [3] What general conditions in a table such as the one above would indicate a "<u>deadend</u>" in a backtracking search with forward checking and constitute a backtrack point when searching for a solution?

(c) [6] Fill in the table below with the domain of each area after each of the following steps of applying the arc consistency algorithm to the given initial domain (note: the initial domain is not related to (a)). Write below the resulting domains for each of the six areas after each of the following arcs are processed in this order. An arc "*x* → *y*" is consistent if for each value of *x* there is some value of *y* that is consistent with it.

	1	2	3	4	5	6
Initial domain	R,G,B	R,G	R,G,B	R	R,G,B	R
After 4 → 2						
After 2 → 6						
After 6 → 4						

Question 5. Game Playing

Consider the following game tree. The root is a maximizing node, and children are visited left to right.



(a) [4] Compute the minimax game value of nodes A, B, C, and D using the minimax algorithm.

(b) [4] Circle all the nodes, or state that none exist, that are not visited by alpha-beta pruning.

(c) [6] Draw a new game tree by re-ordering the children of each internal node, such that the new game tree is equivalent to the tree above, but alpha-beta pruning will prune as many nodes as possible.

Question 6. Logic

The propositional logic (PL) connective ☺ is defined as:

P	Q	P ☺ Q
T	T	F
T	F	T
F	T	T
F	F	T

(a) [5] Is the inference rule $\neg(\alpha ☺ \beta) \mid\!- \beta$ <u>sound</u> for PL? Justify your answer by showing an appropriate truth table.

(b) [5] You are given the following four sentences in PL defining a knowledge base:

P ☺ Q
$(P \vee Q) \wedge (P \vee R)$
$(S \vee Q) \wedge (S \vee \neg R)$
$\neg R$

Prove S using <u>resolution</u> (resolution refutation).

(c) [4] Express (P $\vee$ Q) using only ☺, P, and Q.
(Hints: You need 3 ☺s. What is P ☺ P?)

(d) [4] Is the sentence "Any basketball player from Wisconsin is better than some basketball player from Michigan" represented accurately in First-Order Logic by

$\forall x$ Bball-player(x) $\wedge$ From(x, Wisc) $\wedge$ ($\exists y$ (Bball-player(y) $\wedge$ From(y, Mich)) $\Rightarrow$ Better(x, y))

If yes, explain briefly why. If no, explain why not and correct it.