Intro to AI (20071) - 4003-455-01, 4005-750-01 (Section 01)
Midterm Examination
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Duration: 110 minutes **Points:** This exam is out of 100 points.

Student Name: _____
Section (circle one): Undergraduate Graduate

Q1(16) Q2(12) Q3(20) Q4(12) Q5(22) [Q6(18) **OR** Q7(18)] :: Total

Instructions

- This exam is closed book and notes, and calculators or other electronic devices are not permitted. You may use a pen or pencil.
- Make sure to write your name on this question sheet, the examination booklet provided, and any other booklets or pages that you use during the exam. Put this page and any loose pages you have used in the back of the booklet before handing it in at the end of the exam.
- Remain in the examination room for the first 20 and the last 10 minutes of the exam. Please make sure that if you close the door to the room behind you during the exam, that you do so quietly.
- **If you do not understand a question, or need additional paper please raise your hand.**

Questions

1. (16 points) **Short Answer**
   (a) (4) Briefly define what it means for a logical statement A to be *entailed* by another statement B.
   (b) (4) Briefly describe how a *goal-based* agent differs from a *utility-based* agent.
   (c) (4) Briefly define what the *minimax value* of a game tree node is.
   (d) (4) We have seen that (well-defined) search problems can be specified by four components. Name these and describe each briefly.

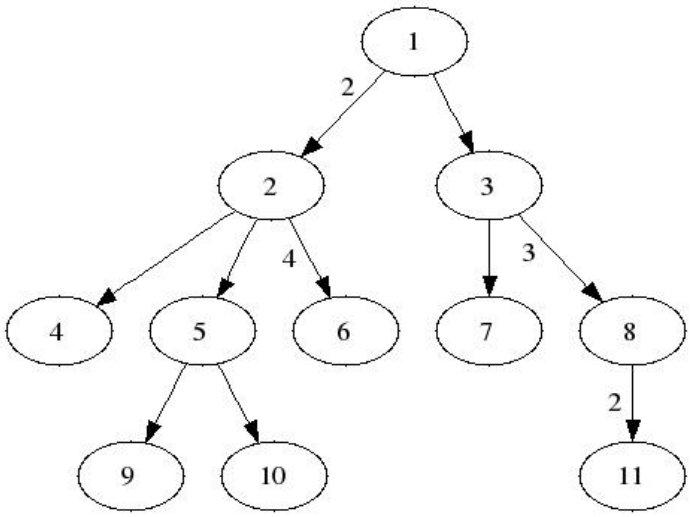
2. (12 points) **True/False**
   For each of the following, indicate whether the statement is true or false. If you are not sure, you may include a *brief* explanation with your answer.
   (a) (3) A rational agent outperforms all non-rational agents because it knows the actual outcome of its actions.
   (b) (3) Backtracking search for constraint satisfaction problems is a variation of depth-first search.
   (c) (3) In general, forward chaining is more efficient than backward chaining when trying to construct a proof for a query of a logical knowledge base.
   (d) (3) In a game of partial information such as poker, an optimal strategy is for a player to choose their next move based on the expected minimax value for all possible outcomes.
3. (20 points) **Uninformed and Informed Search**
   (a) (3) Circle each search algorithm that is *optimal* in the following list. *Assume that the bi-directional search makes use of a breadth-first search.

   1.Uniform-cost 2.Breadth-first 3.Iterative-deepening 4.Bi-directional* 5.Depth-first

   (b) (3) Circle each search algorithm that is *complete* in the following list. *Assume that the bi-directional search makes use of a breadth-first search.

   1.Uniform-cost 2.Breadth-first 3.Iterative-deepening 4.Bi-directional* 5.Depth-first

(c) (3) Give the run-time and space complexity for depth-first search. Define any symbols used.
(d) (3) Give the run-time and space complexity for iterative deepening search. Again, define symbols used.
(e) (2) Greedy, A*, and Uniform-cost are all instances of which type of search algorithm?
(f) (6) Below is a search tree, in which path costs between nodes are 1, except where indicated otherwise. List nodes from the tree below in the order that they are visited by the following algorithms when searching for the node marked 9:
   i. Iterative deepening
   ii. A* with *h(n) = 0* for all nodes *n*
   iii. Bi-directional search (using breath-first search)

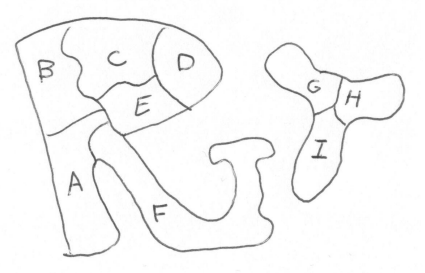


4. (12 points) **First-Order Logic**
(a) Consider a knowledge base containing the sentences: C(a), C(b), and $\exists x, y \;\; C(x) \rightarrow C(y)$.
(4) Does this knowledge base entail $\forall x \;\; C(x)$? Explain your answer in terms of models.
(b) (4) Is the following statement a correct representation of the statement:
Everyone's zip code within a state has the same first digit ? If not, state what the problem is.
$\forall x, s, z_1 \;\; [State(s) \wedge LivesIn(x, s) \wedge Zip(x) = z_1] \rightarrow$
$[\forall y, z_2 \;\; LivesIn(y, s) \wedge Zip(y) = z_2 \rightarrow Digit(1, z_1) = Digit(1, z_2)]$.
(c) (4) Provide a first-order sentence to represent the statement: All Canadians enjoy the same beverages.

5. (22 points) **Propositional Logic**
(a) (4) Rewrite the following knowledge base in conjunctive normal form:
$A \rightarrow B, \quad A \wedge B \rightarrow C, \quad A \wedge C \rightarrow D, \quad B \wedge C \wedge D \rightarrow E, \quad A$
(b) (6) Prove that E is entailed by the knowledge base in (a) using Modus Ponens with forward chaining.
(c) (8) Prove that E is entailed by the knowledge base in (a) using resolution.
(d) (4) For a vocabulary of four propositions (P, Q, R, and S), how many (satisfying) models are there for the statement: $P \Leftrightarrow Q \Leftrightarrow R?$

*** Answer *either* question 6 or 7 ***

6. (18 points) **Constraint Satisfaction**



Consider the problem of coloring a map using three colors (red, green, blue), such that no two adjacent regions are the same color. In particular, consider the map below:

(a) (4) Give an incremental definition for the map-coloring problem, and draw the constraint graph for this map.
(b) (6) Show the search tree for a backtracking search using

forward-checking to depth 3 for this map-coloring problem.

(c) (4) Using an example, illustrate how map coloring problem can be solved using *minimum conflicts* search (hill climbing, using the minimum-conflicts heuristic). Show the initial configuration for the search, and then two iterations of the algorithm.

(d) (4) Describe any properties of the map that would allow a solution to be produced more efficiently.

7. (18 points) **Adversarial Search**

Consider a version of tic-tac-toe where the board is size 2x2, each player may choose to pass during their turn (not marking any square), and X moves first.

(a) (6) Draw the game tree down to depth 2. You do not have to show leaves that are reflections or rotations of sibling nodes already shown (there should be five leaves).

(b) (4) Suppose the evaluation function being used is the number of Xs minus the number of Os. Mark the minimax value for all leaves and internal nodes in the game tree you drew for (a)

(c) (4) Circle any node that would not be evaluated by the alpha-beta pruning algorithm while doing a left-to-right search of the game tree.

(d) (4) What is meant by the *expectiminimax* value for a node?