UNIVERSITY OF TORONTO
Faculty of Arts and Science

DECEMBER 2008 EXAMINATIONS

PLEASE HAND IN

CSC384H1F

Duration - 3 hours

Examination Aids: the text book, class notes and/or a calculator

You have 180 minutes to work on this exam. You will not necessarily finish all questions, so do your best ones first.

The exam has 12 pages in total.

Don't panic!

STUDENT ID: ______________________________

NAME: ______________________________

| Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Total |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 12 max | 8 max | 12 max | 20 max | 21 max | 15 pts | 12 pts | 100 max |

**Q1. True/False and Short Answer (12 pts total)**

**(a) True/False (2 pts):** There is some single Bayes' net structure over three variables which can represent any probability distribution over those variables.

**(b)True/False (2 pts):** A search problem must name exactly one state as being the goal.

**(c) True/False (2 pts):** Suppose that variables $X_1, X_s, \ldots, X_k$ have no parents in a Bayes net with *n* variables in total, where $n > k$. This Bayes net asserts that $P(X_1, X_s, \ldots, X_k) = P(X_1)P(X_2) \ldots P(X_k)$.

**(d) True/False (2 pts):** "There is a tortoise that is older than any human being" is a good translation of:

> ∃(t) Tortoise(t) => (∀(h) Human(h) ^ LessThan(Age(t),Age(h))), where LessThan(Age(t),Age(h)) is a predicate that is true when Age(t) > Age(h).

**(e) (1 pt each).** For each pair of sentences in first order logic below, state the *most-general unifier* (MGU) or say none exists. State MGUs as substitution lists (i.e. {X = Q(Y), Z=B..}).

a. P(X, 2) and P(1, 2, 3)

b. P(X,Y,Z) and P(1, f(2), f(g(a, b)))

c. P(X, f(3), X) and P(g(1,2), Z, g(Z, 2))

d. P(X) and Q(1)

**Q2. Basic Probability (4 pts each, 8 pts total)**

(a) Suppose we want to calculate P(H|E,F) and we don't have any conditional independence information. Which of the following sets of numbers are sufficient for the calculation? Assume that P(X|Y) means the conditional probabilities for all possible values of X and Y.

(i) P(E,F), P(H), P(E|H) , P(F|H)
(ii) P(E,F), P(H), P(E,F|H)
(iii) P(E|H), P(H), P(F|H)

(b) Suppose we know that P(E|H,F) = P(E|H) for all values of E,H and F. Now which of the above sets are sufficient?

## Q3. Classical Planning (4 pts each, 12 pts total)

Consider the set of STRIPS actions:

| Action | Preconditions | Adds | Deletes |
|---|---|---|---|
| T | c | b | c |
| S | b | a | b |
| R | a | b | c |

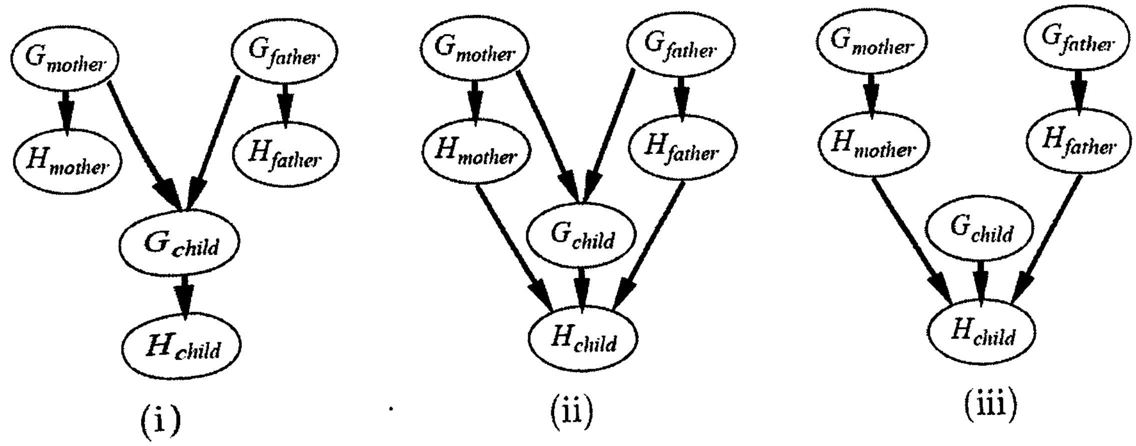
Assume your start state is $S_0 = \{c\}$, and your goal is $G = \{a, b, c\}$.

**(a)** Show the GraphPlan leveled graph from $S_0$ grown until the final state layer includes the goal $G$.

**(b)** Assume you are using the GraphPlan leveled graph to estimate the number of actions required to get from the start state to the goal state, $G$. Use the CountActions heuristic that we covered in class. What is the heuristic value of $S_0$? That is, what is CountActions($G$, $S_{final}$) given the graph you just built, where $S_{final}$ is the final state layer?

**(c)** If two facts in your graph, $a$ and $b$, are mutex free at state level $i$, can they ever become mutex at some level $k > i$?

**Q4. Bayesian Nets (4 pts each, 20 pts total)**




Let $H_x$ be a random variable denoting the handedness of an individual $x$, with possible values *left* or *right*. A common hypothesis is that left or right handedness is inherited. The hypothesis states that each person possesses a gene, $G_x$, with values *left* or *right*, and that each person's actual handedness is the same as their gene with a certain probability $s$. Furthermore, the gene may be inherited from either of an individual's parents with equal likelihood, but there is a small non-zero probability, $m$, that a random mutation may flip the handedness of the gene that is passed on.

(a) Which of the network structures in Fig. 1 claim that:

$$P(G_{father}, G_{mother}, G_{child}) = P(G_{father})P(G_{mother})P(G_{child})?$$

(b) Which of the networks make independence claims that are consistent with the hypothesis?

(c) Which of the three networks is the best description of the hypothesis?

**Q4 Continued.**

(d) Draw Conditional Probability Tables (CPTs) for the $G_{child}$ node in networks (i) or (ii) and fill in the values.

(e) Suppose that $P(G_{father} = left) = P(G_{mother} = left) = x$. In network (i) or (ii), derive an expression for $P(G_{child} = left)$ in terms of $m$ and $x$ only, by conditioning on its parent nodes.

**Q5. Search (21 pts total)**

Two automated movie critics (Siskel and Ebert) are in a movie theater and must meet to review a new Hollywood blockbuster. The movie theater is represented by an $M x M$ grid. At every time step Siskel and Ebert can move, simultaneously, in one of four directions: *East, North, South and West*. They can also stay put at a given time step by executing a "*Rest*" command.

You must devise a plan which allows Siskel and Ebert to meet in the theater, somewhere, in as few time steps as possible. Passing each other doesn't count as meeting; they must be in the same square of the theater at the same time.

**(a) (12 pts)** What:

are *states* in this search problem?

is the *maximum size* of the search space?

is the *maximum branching factor* of the search tree?

is the *goal state* for this search?

**(b) (3 pts)** Provide a non-trivial and ADMISSIBLE heuristic for this problem.

**(c) (3 pts)** Circle all the search methods which are guaranteed to find optimal solutions to this problem:

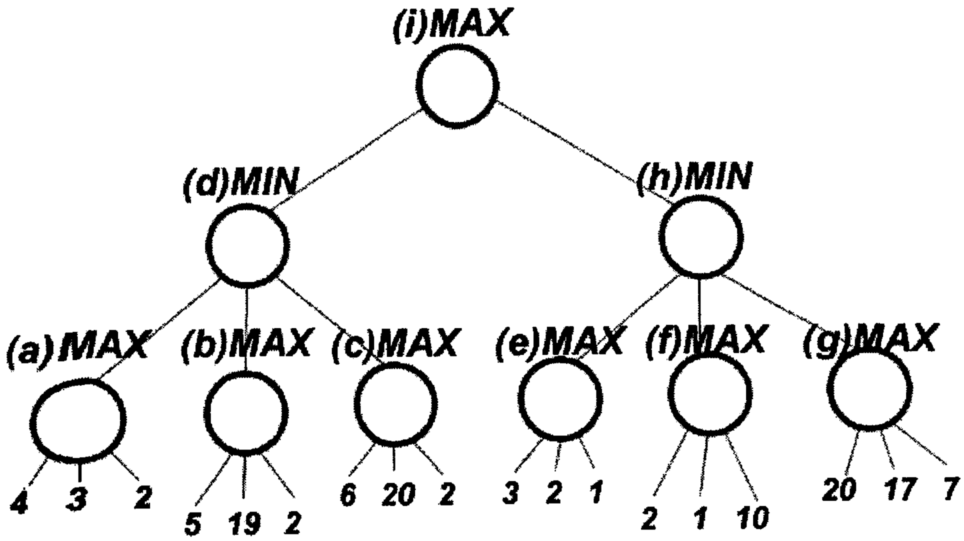
(i) DFS
(ii) BFS
(iii) UCS
(iv) A* (with an admissible heuristic)
(v) A* (with heuristic that returns zero for each state)
(vi) Greedy search (with an admissible heuristic)

**Q5 Continued.**

**(d) (3 pts)** If you had two admissible heuristics for this search, h1 and h2, which of the following would also be guaranteed to be admissible? Circle all that apply:

(i) h1 + h2
(ii) h1 * h2
(iii) max(h1, h2)
(iv) min(h1, h2)
(v) ($\alpha$)h1 + (1 - $\alpha$)h2, where $\alpha$ is either 0 or 1.

**Q6. Game Tree Search (15 pts total)**



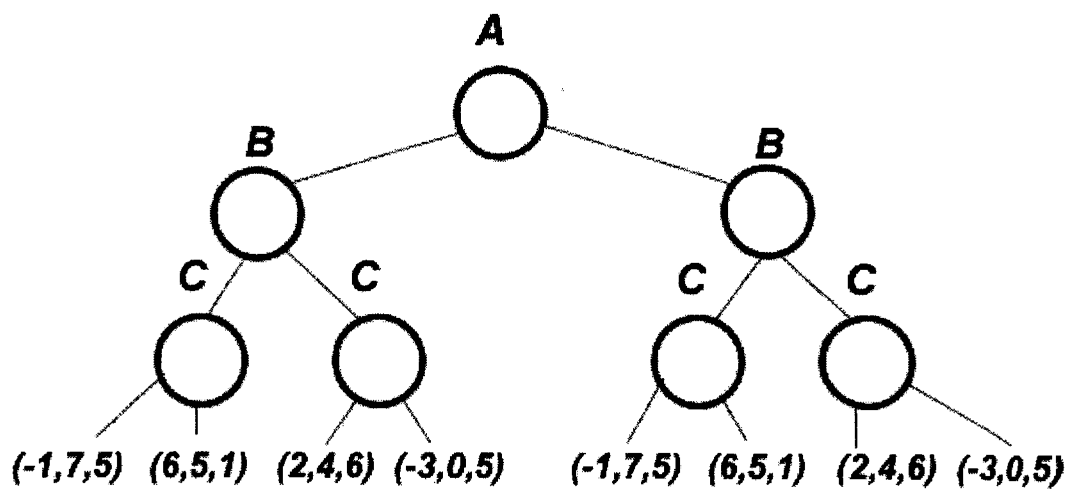

**(a) (4 pts)** Place the minimax values for each node in the circles.

**(b) (4 pts)** Mark nodes with an asterisk (*) that will be visited during a minimax depth-first search that uses *alpha-beta* pruning. Also draw a circle around any terminal node that will be visited. Draw a line across each edge that leads to a sub-tree that would be pruned during the search.

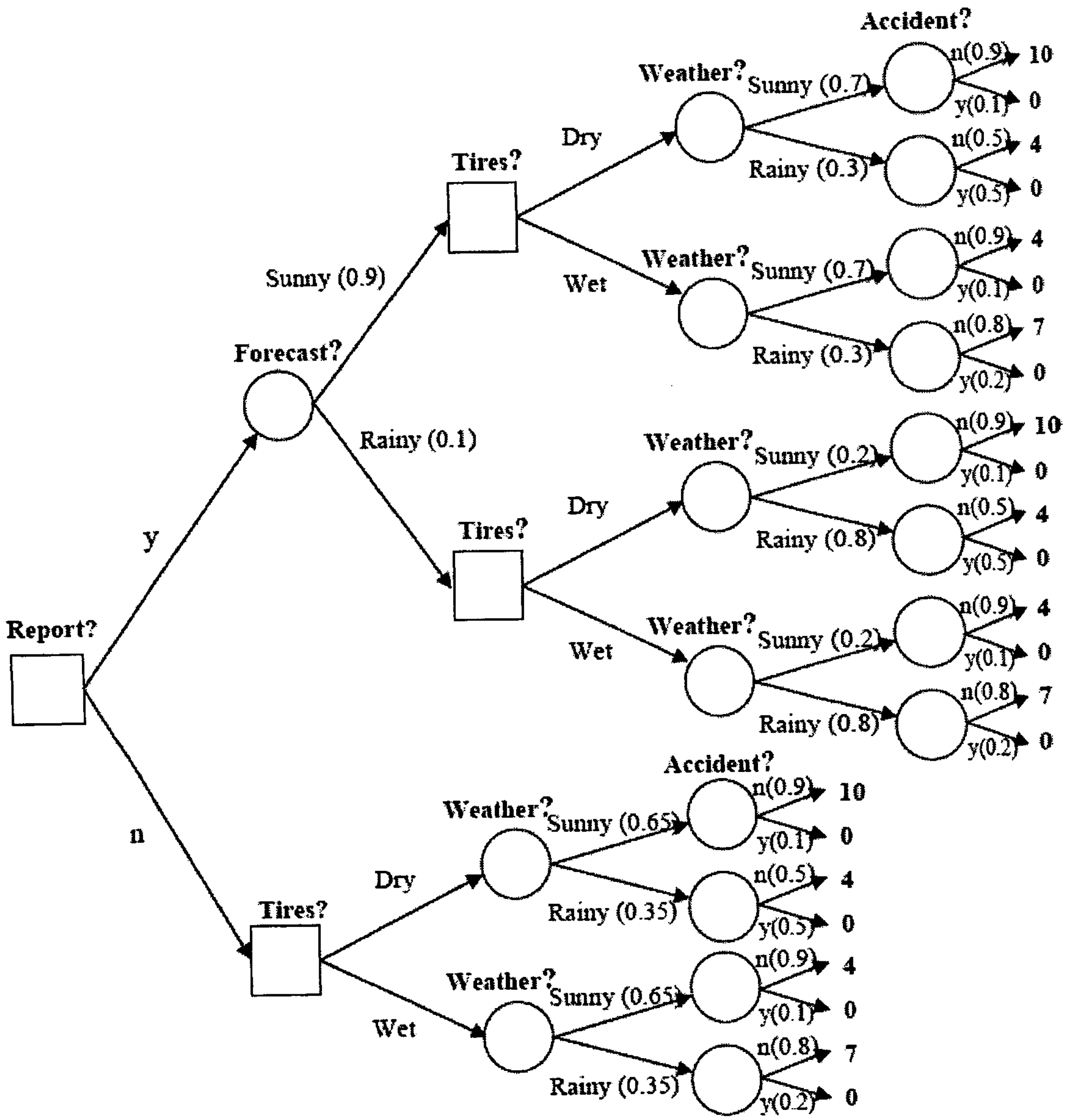
**(c) (2 pts)** In the first move will player MAX move to node (D) or (H)?

**Q6 Continued.**

**(d) (5 pts)** Suppose we want to modify our game so that it is a 3-person, perfect information game in which players A, B and C take turns. To do this, we will assume there are independent evaluation functions associated with players A, B, and C; these will be called $f_A$, $f_B$ and $f_C$. Each function will return the estimated value of a game position for a particular player. For example, $f_A(n) = -5$ means that node $n$ has a low value for player A, while $f_A(n) = 100$ means it has a high value for player A. Now, let's modify the minimax algorithm to work for this game. At each leaf node below, $n$, you have been given the values for $(f_A(n), f_B(n), f_C(n))$ in that format. Place **backed-up minimax values** for nodes at each level in the circles of the game tree. The root node corresponds to player A's turn, nodes at depth 1 corresponds to B's turn, etcetera.



**Q7. Decision Networks (4 pts each, 12 pts total).** You are planning a trip, and according to the weather you want to use tires for wet or dry roads. If you go for a dry road tire and the road is wet your chances of an accident are higher, but if you pick a wet road tire and the road is dry, your fuel consumption will rise. Before leaving on your trip, you can consult a weather report to help you make your decision, however this report may not be accurate. In order to maximize the utility of your trip (i.e., the safety and fuel efficiency of your trip) you decide to use the decision tree below. Squares are choice nodes and circles are chance nodes. Arcs going out of a chance node are labeled with a probability and the numbers in bold at the leaves are utility values.



**Q7 Continued.**

**(a)** Fill in the choice and chance nodes with their expected utility values.

**(b)** What is the policy that maximizes expected utility?

**(c)** What is the accuracy of the weather report? That is, what is the probability that the forecast is accurate?