CSIT9000F: 2017 Fall Semester Final Exam

Name	
Student Number	

Instructions

1. The exam time is 180 minutes.
2. There are total 11 questions. The full mark is 100 points.
3. Write your answers in the exam paper only.

Problem	Marks
1 (6 pts)	
2 (6 pts)	
3 (6 pts)	
4 (15 pts)	
5 (10 pts)	
6 (10 pts)	
7 (10 pts)	
8 (7 pts)	
9 (10 pts)	
10 (12 pts)	
11 (8 pts)	
Total	

Problem 1 (6 pts) (*Boundary Following Robot and Production System*) Recall that our boundary-following robot has eight sensors s_1 - s_8 that detect if the eight surrounding cells are free for it to occupy: clockwisely, s_1 returns 1 iff the surrounding cell in the north-west direction is not free for it to occupy, s_2 returns 1 iff the surrounding cell in the north direction is not free for it to occupy, and so on. The robot has four actions: *north*, *east*, *south*, and *west*. We introduce four features x_i (for $s_{2i}+s_{2i+1}$, assuming s_9 is s_1), $i = 1, 2, 3, 4$, and under the assumption of no tight space, come up with the following production system to control the robot to follow the inside boundary of the room clockwisely and outsde boundary of an object counterclockwisely:

$$
\begin{aligned}
r_1: &\quad x_4\overline{x_1} \rightarrow north,\\
r_2: &\quad x_3\overline{x_4} \rightarrow west,\\
r_3: &\quad x_2\overline{x_3} \rightarrow south,\\
r_4: &\quad x_1\overline{x_2} \rightarrow east,\\
r_5: &\quad 1 \rightarrow north.
\end{aligned}
$$

Recall that the order of the rules may matter. Now if we swap r_1 and r_2, thus making r_2 the first rule, and r_1 the second, will the new system still achieve the goal? Explain your answer: give an informal proof if you think it still works but give a counterexample if you think it will not work anymore.

Problem 2 (6 pts) (*Simulus-Response Agents)* An artificial ant lives in a two-dimensional grid world and is supposed to follow a continuous pheromone trail (one cell wide) of marked cells. The ant occupies a single cell and faces either up, left, down, or right. It is capable of three actions, namely, move one cell ahead (m), turn to the left while remaining in the same cell (l), turn to the right while remaining in the same cell (r). The ant can sense whether or not there is a pheromone trace in the cell immediately ahead of it (in the direction it is facing).

Show that it is impossible to design a stimulus-response system to control the ant to follow the trail even under the assumption that it starts in a cell where it can sense a pheromone trace, there is no loop, and once it reaches the end of the trail, it has achieved the goal.

Problem 3 (6 pts) (*Perceptrons*) Again consider our robot example. The condition for the robot moving *north* is $\overline{x_1}\,\overline{x_2}\,\overline{x_3}\,\overline{x_4} + x_4\overline{x_1}$. Can this condition be represented by a perceptron (with inputs x_1, x_2, x_3, x_4)? If yes, give a perceptron for it. If not, explain why.

Problem 4 (15 pts) (*Perceptron Learning and GSCA*) Consider the following samples:

ID	x_1	x_2	x_3	OK
1	0	0	0	No
2	0	0	1	Yes
3	1	0	0	No
4	1	1	0	Yes

where x_1, x_2, and x_3 are some features that should not concern us here.

1. (6 pts) Use these four instances to train a single perceptron using the error-correction procedure. Use the learning rate = 1, and the initial weights all equal to 0. Recall that the threshold is considered to be a new input that always have value "1". Please give your answer by filling in the following table, where weight vector (w_1, w_2, w_3, t) means that w_i is the weight of input x_i, and t is the weight for the new input corresponding to the threshold. You can stop when the weight vector converges.

ID	Weight vector
Initial	(0, 0, 0, 0)
1	
2	
3	
4	
1	
2	
3	
4	
1	
2	
3	
4	
1	
2	
3	
4	

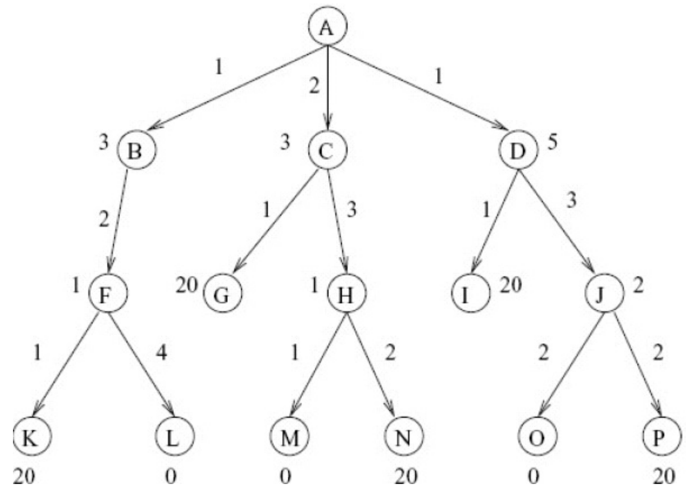
2. (3 pts) What is the Boolean function corresponding to your perceptron?

3. (6 pts) From the same training set, use the GSCA algorithm to learn a set of rules.

Problem 5 (10 pts) (*Game theory and auction*). Consider the single item first-price auction with three bidders B_i, $i = 1, 2, 3$, and assume that when there is a tie, the order to break the tie is $B_1 > B_2 > B_3$ (so for example, if B_1 and B_3 are tied, then B_1 wins). Suppose B_i values the item x_i, $i = 1, 2, 3$, and the information is common knowledge. Suppose further that each can bid with any value in the interval $[0, 1]$.

- Make this auction into a game in normal form $(\{B_1, B_2, B_3\}, R_1, R_2, R_3, u_1, u_2, u_3)$ by defining R_i (the set of pure strategies for player B_i) and u_i (player B_i's utility function). You can assume that all players are risk neutral.
- Suppose $0 \leq x_1 = x_2 = x_3 \leq 1$. Are there Nash equilibria? If yes, give all of them. If no, give a proof.

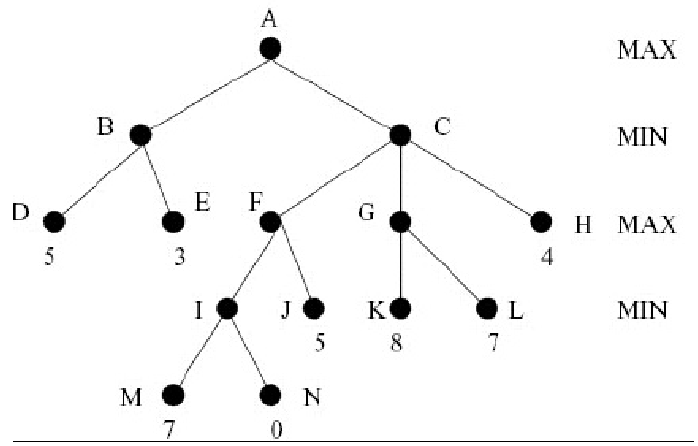
Problem 6 (10 pts) Consider the following state space. The number next to a state is the value of the heuristic function on the state, and the number next to an arc from state α to state β is the cost of the corresponding operator $\Pi_{\alpha\beta}$. If the number next to a state is 0, that means that the state is a goal state.



(2.1) Give the sequence of the states expanded by A^* algorithm, starting from the root A and terminating at a goal state. Notice that whenever there is a tie, we prefer nodes at deeper levels, and on the same level, left to right.

(2.2) Can you adjust the heuristic function so that the goal state O is returned? Notice that your heuristic function still needs to be admissible, and you don't need to do this question if O is already the terminating goal state in your solution to (2.1).

Problem 7 (10 pts) Consider the following minimax search tree.



- Perform a left to right apha-beta pruning on the tree, and list the nodes that are pruned. Notice that when a node is pruned, all of its decendents are pruned as well.
- Re-order the children of some of the nodes, so that left-to-right alpha-beta pruning will prune the most number of nodes.

Problem 8 (7 pts) Let x_{ij} be propositional symbols (variables), and A the following sentence:

$$(x_{11} \wedge x_{12}) \vee \cdots \vee (x_{n1} \wedge x_{n2}).$$

By introducing new variables if necessary, convert A into a set of clauses so that the number of clauses is polynomial in n.

Problem 9 (10 pts) Let $Fools(x, y, t)$ stands for "x fools y at time t". Represent the following statements in first-order logic:

1. Everyone can fool every other person sometimes.
2. There is exactly one time when someone fools everyone else.
3. At no time one can fool all other people.
4. One cannot fool another person all the time.
5. For any two people x and y, if x can fool y some time, then y can also fool x some other time.

Problem 10 (12 pts) We are given the following facts:

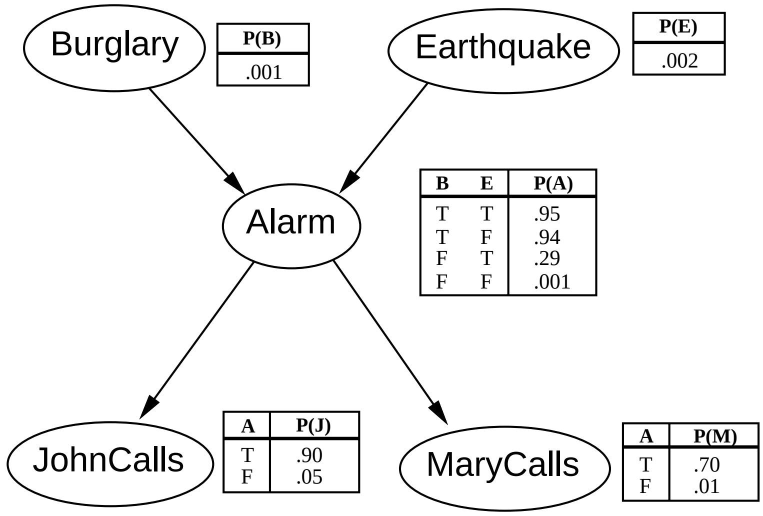
> Tony, Mike, and John are members of the Alpine Club. Every member of the Alpine Club is either a skier or a mountain climber or both. No mountain climber likes rain, and all skiers like snow. Mike dislikes whatever Tony likes and likes whatever Tony dislikes. Tony likes rain and snow.

1. Represent these facts by first-order logic sentences using the following language:
   - $AC(x)$: x is a member of the Alpine Club.
   - $CL(x)$: x is a mountain climber.
   - $SK(x)$: x is a skier.
   - $R(x)$: x likes rain.
   - $SN(x)$: x likes snow.
   - Constants: t (Tony), j (John), and m (Mike).
2. Convert your sentences into clauses and prove by resolution refutation the following assertion: there is a member of the Alpine Club who is a mountain climber but not a skier, i.e.

$$\exists x. AC(x) \land CL(x) \land \neg SK(x).$$

3. Who is that member?

Problem 11 (8 pts) Consider the following belief network:



1. Compute the joint probablity of $Earthquake$ and $\neg Burglary$.
2. Compute the probability of $Alarm$.