STUDENT NAME: _____
STUDENT ID: _____

McGill University
Faculty of Science
School of Computer Science
Final exam

COMP-424A
Artificial Intelligence I

December 8, 2004
2:00-5:00

Examiner: Prof. Doina Precup

Associate Examiner: Prof. Joelle Pineau

This examination is closed-book, closed-notes.
There are 15 pages, including the title page.

Start by writing down your name. Answer the questions directly on the question booklet. Additional pages are provided if necessary. Do not forget to write your name on the additional pages too!

Read the whole exam before starting to work on it.

There are 9 questions, all of which require written answers. Values for each question are shown in parenthesis. As usual, partial credit will be given for incomplete or partially correct answers.

Good luck!

1. [10 points] **Search algorithms**

   (a) [3 points] Suppose you have an admissible heuristic h. Is h^2 admissible? Is $\sqrt{h}$ admissible? Would using any of these alternatives be better or worse than using h in the A^* algorithm?

   (b) [1 point] Suppose you were using a genetic algorithm and you have the following two individual, represented as strings of integers:

   1324421 and 2751421

   Show the result of performing crossover between the 3rd and 4th digit.

   (c) [2 points] Which of the following statements, contrasting genetic algorithms and simulated annealing, are true?

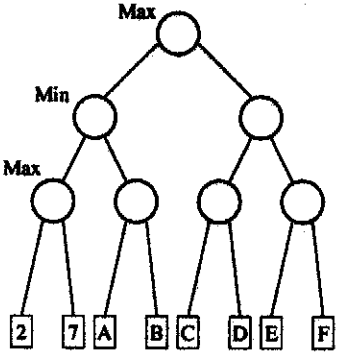
   i. Genetic algorithms are used for minimization problems while simulated annealing is used for maximization problems

   ii. Genetic algorithms maintain several possible solutions, whereas simulated annealing works with one solution.

   iii. Genetic algorithms maintain one solution, whereas simulated annealing maintains several possible solutions.

   iv. Simulated annealing is guaranteed to produce the best solution, while genetic algorithms do not have such a guarantee.

(d) [2 points]
Consider the game tree in the figure below.



Give a value of node A for which node B can be pruned. Give a value of node A for which node B cannot be pruned.

(e) [2 points]
For the same tree, assuming that A=B=7, give values for C and D such that the subtree containing E and F is pruned.

2. [10 points] **Machine learning**

(a) [2 points] Which of the following can learn the OR function (circle all that apply):

i. linear perceptron
ii. a single sigmoid neuron
iii. a network of sigmoid neurons with one hidden layer
iv. none of the above

(b) [2 points] Which of the following can learn the XOR function (circle all that apply):

i. linear perceptron
ii. a single sigmoid neuron
iii. a network of sigmoid neurons with one hidden layer
iv. none of the above

(c) [3 points] You are starting a new company and you want to study the competition first. In particular, you have gathered data about the discounts that they offer to students. Having taken AI, you know a few learning algorithms that can help you analyze the data. You run a few of them and get the following accuracy results:

Algorithm	Training data	Test data
NeuroChamp	70%	70%
TopRegress	65%	75%
Brainy	90%	65%%

Which learner would you prefer for predicting future data, and why?

(d) [3 points] Suppose that you want to train a neuron of the form:

$$f(x) = w_0 + \log(w_1 x + w_2)$$

Give update rules for w_0, w_1 and w_2, assuming you do incremental gradient descent using mean-squared error as an error function.

3. [15 points] **Bayes nets**

The Starfleet academy has decided to create a class of android students. 90% of these androids study hard for their exams. Out of the androids who study hard for an exam, 80% get an A. Out of the androids who do not study, only half get an A. Androids who study hard have a 75% probability of depleting their battery in less that a day. Androids who do not study hard have a longer battery life: only 10% of them deplete their batteries within the next day.

(a) [7 points] Draw a Bayes net describing the problem statement above.

(b) [3 points] You notice that your android has depleted its battery in less than a day. What is the probability that it will get an A on the exam it had yesterday?

(c) [5 points] Your friend does not believe that androids are much good at studying. He says he is willing to pay you \$10 if your android gets an A in the class. Recharging the battery costs \$5 Suppose that you could program your android to study or not to study at will (this is not very ethical, but it is technically feasible). What is the best course of action for you?

4. [10 points] **Logic**

   (a) [6 points] Translate the following sentences in first-order logic:

      i. All citizens of Fredonia speak the same language.

      ii. The Fredonese language has two dialects

      iii. Each citizen of Fredonia speaks exactly one of the two dialects

   (b) [4 points]
   Translate the knowledge base above into conjunctive normal form (using Skolem constants and functions as appropriate)

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   (b) [4 points]
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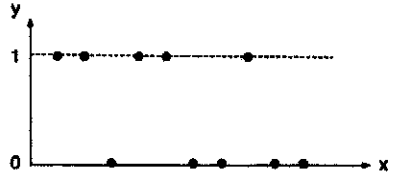
5. [5 points] **Cross-validation**

Consider the training set below, consisting of 10 data points. Each data point has a label of 0 or 1. A majority classifier is defined to output the class label that is in the majority in the training set, regardless of the input. If there is a tie in the training set, then always output class label 1.



You perform leave-one-out cross-validation on this data set.

(a) What is the average training error (reported it as a ratio) ?

(b) What is the average test error (reported as a ratio)?

6. [15 points] **Naive Bayes**

Data the android is about to play in a concert on the Enterprise and he wants to use a naive Bayes classifier to predict whether he will impress Captain Picard. He believes that the outcome depends on whether Picard has been reading Shakespeare or not for the three days before the concert. For the previous five concerts, Data has observed Picard and noted on which days he read Shakespeare. His observations look like this:

D1	D2	D3	LikedConcert
1	1	0	yes
0	0	1	no
1	1	1	yes
1	0	1	no
0	0	0	no

(a) [5 points] Show the Naive Bayes model that Data obtains, using maximum likelihood, from these instances.

(b) [5 points] If Picard reads Shakespeare only on day 1, how likely is he to enjoy Data's concert? What if he reads Shakespeare on days 1 and 3?

(c) [5 points] Suppose that Data records one more instance, having D2=D3=1, but being away on a mission, he was unable to record the value of D1. Can he use this data along with the other examples that he has? If your answer is yes, explain how. If your answer is no, explain why not..

7. [10 points] **Planning**

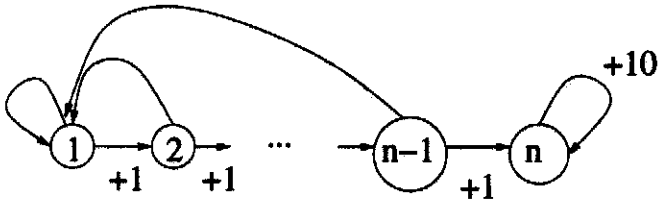
In order to get an A on his AI exam, Shakey the robot has to be awake and to show up in the exam room. In order to get to the exam room from his dorm, Shakey has to have his battery fully charged. On the morning of the exam, Shakey is initially asleep in his dorm. After he wakes up, his battery is always empty at first. Shakey has three actions at its disposal: $WakeUp(S)$, $Recharge(S)$ and $Go(S, Dorm, Exam)$.

(a) [6 points] Describe each of the three actions in terms of preconditions and postconditions (add effects and delete effects)

(b) [4 points] Construct the planning graph for this problem until a solution is found. Show the mutually exclusive actions and mutually exclusive propositions at each level. Extract the solution out of the graph.

8. [15 points] **Markov Decision Processes**

Consider the n-state MDP in the figure below. In state n there is just one action that collects a reward of +10, and terminates the episode. In all the other states there are two actions: float, which moves deterministically one step to the right, and reset, which deterministically goes back to state 1. There is a reward of +1 for a float and 0 for reset. The discount factor is $\gamma = \frac{1}{2}$.



(a) [2 points] What is the optimal policy?

(b) [2 points] What is the optimal value of state n, $V^*(n)$?

(c) [5 points] Compute the optimal value function, $V^*(k)$ for all $k = 1, \ldots n-1$.

(d) [3 points] Suppose you are doing value iteration to figure out these values. You start with all value estimates equal to 0. Show all the non-zero values after 1 and 2 iterations respectively.

(e) [3 points] Suppose that instead of knowing the model of the MDP, you decided to always float and observed the following trajectories:

- n-1, float, +1, n, float, +10.
- n-2, float, +1, n-1, float, +1, n, float, +10.

What would be the Monte Carlo estimate for all states, based on this data? What would be the certainnty equivalence estimate?

9. [10 points] **Applying AI methods**

You have been hired by a large retail company who is having trouble managing its inventory. The company provides 100 kinds of products, and for each product there are two or three suppliers. For each supplier, the company keeps track of their price, of whether they deliver on time or if not, how late they are on each order, and on how many broken products they get in each order. The company also knows at what prices it is able to sell each product, and how fast they can sell it. The company has past data about all the orders it placed or got in the last 5 years. The company also has limited space to store its stock of products. You are required to develop a software package which would decide as well as possible what kinds of products to keep in stock, and what orders to place in order to get them.

Choose **one AI technique** to solve this task. Explain in detail how it would be implemented, what are the pros and the cons.