UNIVERSITY OF MANITOBA
Midterm

Winter 2011

COMPUTER SCIENCE

Machine Learning

Date: **Friday, 2nd March 2011**
Time: **15:30 - 16:20**
Room: **EITC E2-165, University of Manitoba**

(Time allowed: 50 Minutes)

NOTE: Attempt all questions.
This is a *closed* book examination.
Use of non-programmable calculators is *permitted*.
Use of any other electronic equipment is strictly forbidden.
Show your work to receive full marks.

SURNAME:

FORENAME(S):

STUDENT ID:

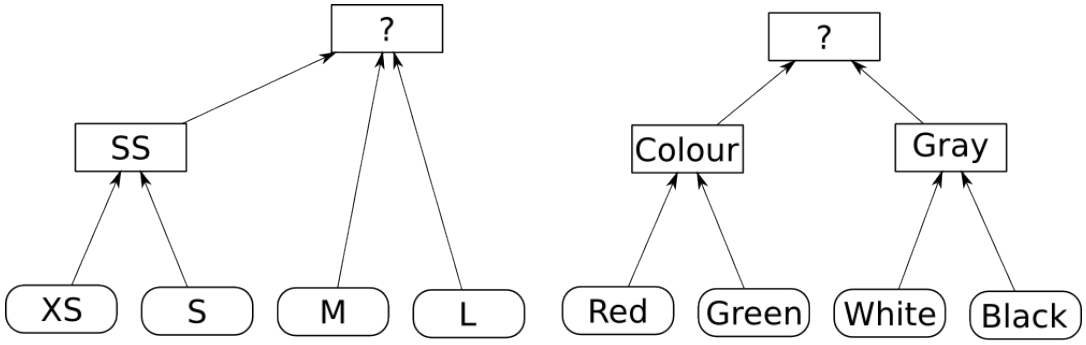
A	B	C	Total
34	33	33	100

Surname: _____

Forename(s): _____

Section A: Candidate Elimination

1. Given below is a conjunctive hypothesis space for a simple domain D.



Show a trace of the execution of the Candidate Elimination algorithm on the domain D given the following training sequence. For each instance, show the resulting S and G sets. I already did the first entry for you.

[20 marks]

```
<S,White>     +  S-Set = <S,White>
                 G-Set = <?,?>
<XS,Red>      -  S-Set = <S,White>
                 G-Set = <S,?> <?,Gray>
<M,Black>     -  S-Set = <S,White>
                 G-Set = <S,?> <?,White>
<L,Red>       -  S-Set = <S,White>
                 G-Set = <S,?> <?,White>
<XS,White>    +  S-Set = <SS,White>
                 G-Set = <?,White>
<M,Green>     -  S-Set = <SS,White>
                 G-Set = <?,White>
<L,White>     +  S-Set = <?,White>
                 G-Set = <?,White>
<M,White>     +  S-Set = <?,White>
                 G-Set = <?,White>
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2. What is the minimum number of examples needed to learn the target concept <SS,Colour> in the domain D.

   Show the minimum training set such that the candidate elimination algorithm will learn the target concept. For each sample in the training set show the classification, the resulting S-set and G-set. One entry of the training set is already given in the answer box below.

   If it is impossible to determine a minimum training set such that the candidate elimination algorithm is able to learn the concept <SS,Gray>, then say so in your answer and explain why.

   [14 marks]

The minimum size of the training set is 4 samples.

Instance	Classification	S/G-set
<XS, Green>	+	S-set: <XS, Green>
		G-set: <?,?>
<S, Red>	+	S-set: <SS,Colour>
		G-set: <?,?>
<L, Red>	-	S-set: <SS, Colour>
		G-set: <SS,?>
<S, White>	-	S-set: <SS,Colour>
		G-set: <SS,Colour>

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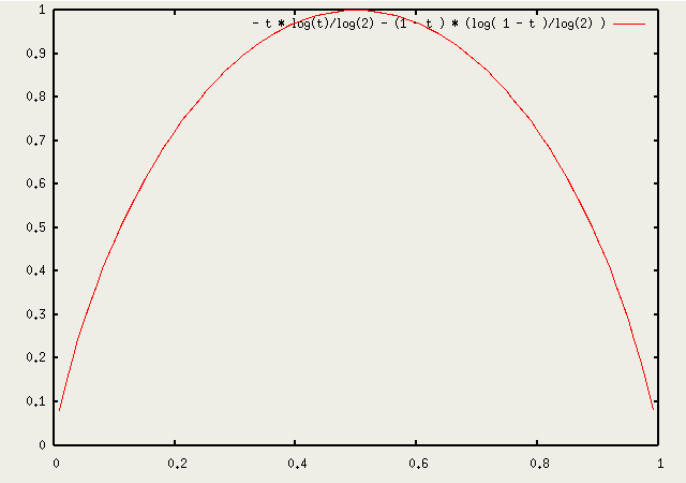
Section B: Decision Trees

The information gain Gain(S,A) of an attribute A for a sample set S is defined as

$$\text{Gain}(S, A) = \text{Entropy}(S) - \sum_{v \in \text{Values}(A)} \frac{\|S_v\|}{\|S\|} \text{Entropy}(S_v)$$

A graph of the entropy function is shown in the figure below. You can use this graph when answering the following questions.



3. Given below is a set of instances from a medical diagnosis domain with two attributes blood pressure (`Blood`) and height (`Height`)).

   Given the set of instances shown below, calculate the information gain for the attributes Blood and Height is trying to predict if a patient has a disease (`Disease`).

Instance	Blood	Height	Disease
x1	Normal	Normal	Yes
x2	High	Tall	Yes
x3	Normal	Small	Yes
x4	Normal	Tall	No
x5	High	Normal	No
x6	Low	Tall	No
x7	Low	Normal	No
x8	High	Small	Yes
x9	Low	Small	Yes

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[20 marks]

Information Gain(Blood) = 0.07

Information Gain(Height) = 0.37

```
All: ent(4,5) = 0.99
Attribute Blood:0.
All: 0.99 -
Blood = Normal: 3/10 * 0.91
Blood = High: 3/10 * 0.91
Blood = Low: 3/10 * 0.91
= 0.97 - 0.91 = 0.07

All: 0.99 -
Height = Normal: 3/10*0.91
Height = Tall: 3/10*0.91
Height = Small: 3/10*0
= 0.37
```

4. Given is the following rule base, where all conclusions relate to the plant output.

Number	Water	Flow	Pump		Plant output
R1	Normal	High	Off	→	Normal
R2	Cold	Normal	On	→	Low
R3	Hot	Low	On	→	Normal
R4	Normal	Low	Off	→	Low
R5	Cold	High	Off	→	Low
R6	Hot	Low	Off	→	Normal

Show the decision tree **with the minimum number of nodes** that is equivalent to this rule base.

[13 marks]

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Section C: Neural Nets

5. Given below is an artificial neural network (ANN) with three input nodes (X1,X2,X3), two hidden nodes, and one output node.

   The network uses simple threshold nodes (i.e., the node will output 1.0 if the sum of the weighted inputs is greater than or equal to the threshold, 0 otherwise).

   You are trying to learn the boolean target function f_1.

   Show a set of weights and thresholds for all nodes that implement the function f_1. If it is impossible to represent the function f_1 with the given neural network, then state this in your answer and explain why.

   [20 marks]

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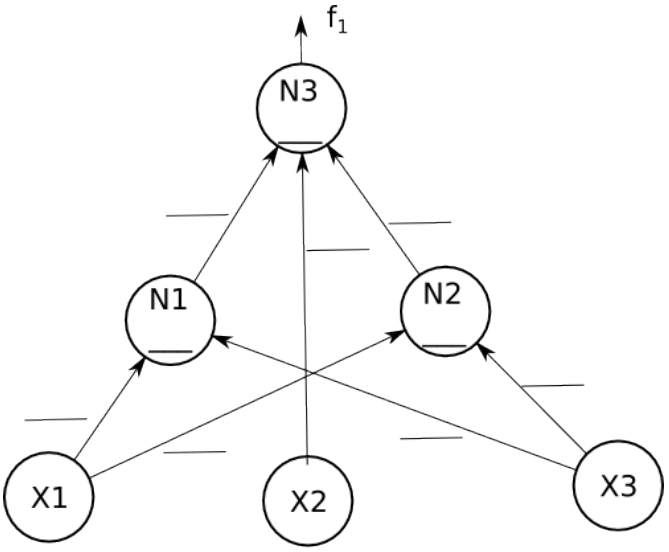

x_1	x_2	x_3	f_1
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	0

N1=0.1,N2=0.1,N3=0.1
X2-¿N3=+1.0,X1-¿N1=+1.0,N1-¿N3=-1.0
0 all other weights

6. Given below is a neural network with three nodes $N1$,$N2$, and $N3$, as well as two inputs $X1$ and $X2$. The network uses threshold neurons, that is a neuron will generate an output of 1, if the sum of the weighted inputs is greater than or equal to the threshold, 0 otherwise.

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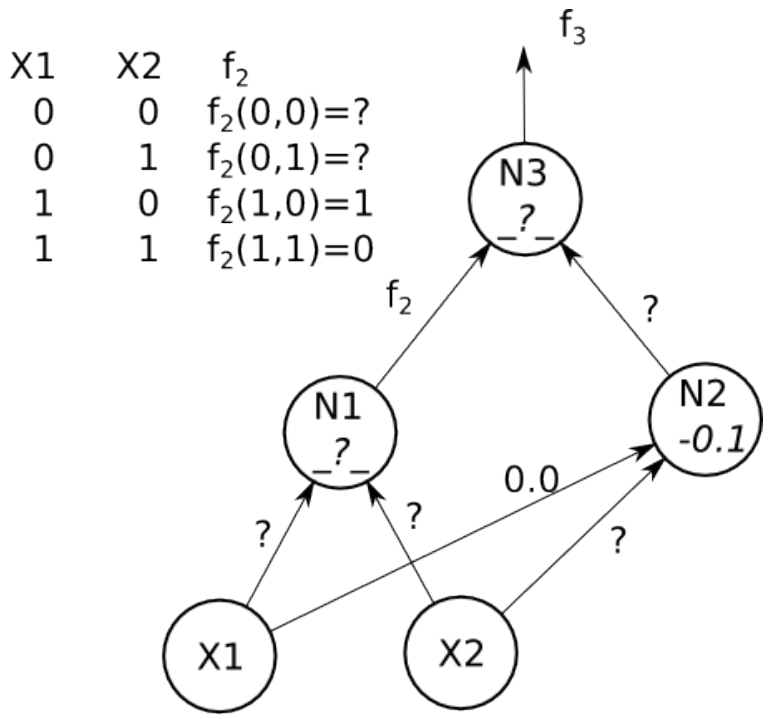

The only other available information about the network is:

- the function f_2 (i.e., the output of node $N2$) is $f_2(0,0)$ =?,$f_2(0,1)$ =?,$f_2(1,0) = 1$, and $f_2(1,1) = 0$.
- the weight of the link $X1$ to $N2$ is 0.0
- the threshold of node $N2$ is -0.1

Answer the following questions either with either

- **true** if the statement is definitely true,
- **false** if the statement is definitely false,
- **unknown** if there is not enough information given in the question to determine the truthfulness of the statement.

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[13 marks]

The weight from $X1$ to $N1$ must be positive: Unknown

The weight from $X2$ to $N1$ must be positive: False

At least one combination of inputs $X1$ and $X2$ will result in $f_3 = 1$: Unknown

If $f_2(1, 0) = f_3(1, 0)$, then the weight from $N1$ to $N3$ is larger than the weight from $N2$ to $N3$:True

If $f_2 = f_3$, then the weight from $X2$ to $N2$ must be 0: False

If $f_2 = f_3$, then the weight from $N2$ to $N3$ must be 0: False

The weigth from $N1$ to $N3$ must be positive: Unknown

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Additional work pages