Homework #7: Chapters 18, 19 and 20

The following exercises are due at the beginning of class on Friday, April 27. Note, this homework is continued on the reverse side of the paper.

1. *[30 pts.]* In this problem we'll consider the following training set:

Example	**Color**	**Legs**	**Tail**	**Fur**	**Goal Predicate**
X_1	Brown	4	Yes	Yes	Yes
X_2	Brown	2	No	Yes	No
X_3	Green	4	Yes	No	No
X_4	Brown	0	Yes	No	No
X_5	Black	4	Yes	Yes	Yes
X_6	Black	4	No	Yes	No
X_7	Gold	2	Yes	No	No
X_8	Gold	4	Yes	Yes	Yes

   a. Convert the training set into a set of first-order logic description and classification sentences. Use the predicates *Color(x,c)*, *Legs(x,n)*, *Tail(x,t)* and *Fur(x,f)* in your description sentences and *Q(x)* for your goal predicate. Note, that by using binary predicates for *Tail* and *Fur* we are able to restrict our hypothesis space to include only candidate definitions that are positive conjunctive sentences.

   b. Which of these examples is the candidate definition *Color(x,Brown)* $\wedge$ *Fur(x,Yes)* consistent with? Which examples result in false positives and which ones in false negatives?

   c. Give all the immediate specializations of *Tail(x,Yes)* $\wedge$ *Legs(x,4)* that are consistent with examples X_1 to X_3. Do not consider any other examples. Assume that the hypothesis space only contains hypotheses whose candidate definitions are positive conjunctive sentences (i.e., a set of unnegated atoms separated by and ($\wedge$) symbols). Thus, the immediate specialization of a sentence should differ by only a single conjunct.

   d. Give all the immediate generalizations of *Legs(x,4)* $\wedge$ *Color(x,Gold)* that are consistent with example X_5. Do not consider any other examples. As above, assume that the hypothesis space only contains hypotheses whose candidate definitions are positive conjunctive sentences.

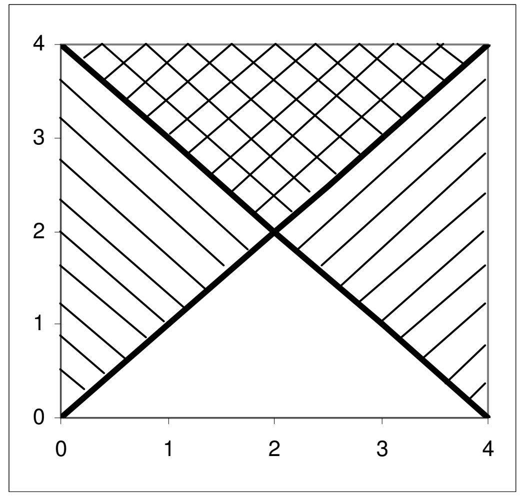
2. *[25 pts.]* Use current best-hypothesis search learning on the training set from problem #1 above. As was demonstrated in class, start with the hypothesis "True" and show your search tree, where each node evaluates the current hypothesis with respect to an example. Assume that the examples are received in the order given and that the hypothesis space only contains hypotheses whose candidate definitions are positive conjunctive sentences. When there is a choice of otherwise equivalent nodes to expand, always choose the one that adds the leftmost remaining condition from the attributes in the table. When a hypothesis is inconsistent with an example, either specialize it or backtrack to the last choice point.

3. *[20 pts.]* For this problem you will construct a series of neural networks, building up to a neural network that can recognize a function that is not linearly separable. All of the neural networks will have two inputs: x and y. Both x and y are real numbers and their values are restricted such that $0 \leq x \leq 4$ and $0 \leq y \leq 4$. Use threshold functions for all nodes in your neural networks and assume that the threshold function returns 1 when its input is ≥ 0 and returns 0 otherwise. Do not use a learning algorithm to develop the neural networks in this problem.

    a. Create a single layer feed-forward neural network (a perceptron) to recognize when the input y is greater than or equal to the input x (i.e. $y \geq x$). This corresponds to the area in the graph above the line from the lower left to upper right.

    b. Create a single layer feed-forward neural network (a perceptron) to recognize when the input y is greater than or equal to 4 minus the input x (i.e. $y \geq 4-x$). This corresponds to the area in the graph above the line from the upper left to lower right.

    c. Create a multilayer feed-forward neural network to recognize when y is $\geq$ both x and 4-x. This corresponds to the double hash marked area in the graph. Obviously, this is not a linearly separable function.



Hints: Approach part c by considering how to combine your answers from parts a and b. Test your neural networks thoroughly to be sure that they perform as expected for various combinations of inputs in the range given (especially near boundaries of the function and input ranges)

4. *[25 pts.]* Consider the following neural network in which the hidden units and output units use a **threshold activation function**. The number of each node is written in bold above it. The t=*x* notation means that a unit has threshold *x* (as opposed to 0). Recall, this is shorthand for an ordinary threshold node which has an additional bias weight of *x* on a fixed input of –1. Given the activation levels written in the boxes for the input units on the left, compute the activation levels (a_3, a_4, a_5, a_6, and a_7) of the remaining nodes in the network. Show you work for each activation level.