CS472 Foundations in Artificial Intelligence
Fall 1999
Assignment 5 (100 pts total)

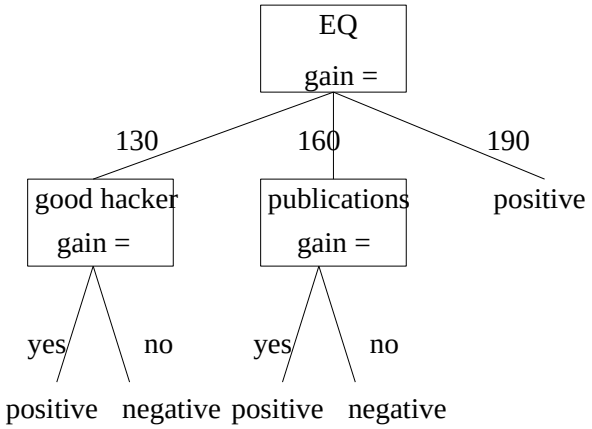
Due (technically) Friday, December 3 at the beginning of class.
Note announcement in class.

Solutions must be typed, although equations, graphs, tables, etc., can be drawn in by hand.

1. **Decision Tree Learning — (25 pts. total)** We are trying to learn the concept of "graduate student". Consider the following set of training examples:

Class	EQ	good hacker?	has publications	hobby
positive	190	yes	no	sci-fi
positive	130	yes	no	music
positive	130	yes	yes	tennis
positive	190	no	yes	tennis
positive	160	yes	yes	tennis
positive	130	yes	yes	music
positive	160	no	yes	music
positive	190	no	no	music
positive	190	yes	yes	sci-fi
negative	160	yes	no	sci-fi
negative	160	no	no	sci-fi
negative	130	no	yes	tennis
negative	160	yes	no	music
negative	130	no	no	music

Applying decision tree learning to this training data produced the following decision tree:



(a) **(10 pts.)** Compute the information gain values.

(b) **(10 pts.)** Classify the examples below, where ? represents a missing value. Justify your answers. (Distinguish between just using the decision tree, and using the decision tree with the training data.)

Class	EQ	good hacker?	has publications	hobby
	190	?	no	sci-fi
	130	?	no	music
	130	yes	yes	?
	160	no	?	tennis

(c) **(5 pts.)** Given the training examples above, can the concept be learned by a *decision list?* If yes, show the decision list, otherwise say why not.

2. **Perceptrons and Neural Nets — (35 pts. total)**

(a) **(5 pts.)** Draw a step-thresholded perceptron that computes the Boolean implication function $a \Rightarrow b$.

(b) **(10 pts.)** Modify the neural network in Figure 1 which computes aXORb, so it computes the Boolean equivalence, $a \equiv b$. You **cannot change the current topological connections**, but you can change the weights and thresholds. *Hint: think about the relationship between XOR and equivalence.*

(c) **(10 pts.)** Show that any propositional Boolean formula representable as the conjunction of literals can be represented by a one-layer perceptron.

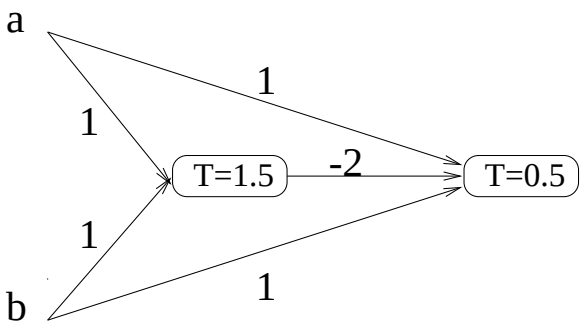


Figure 1.

(d) **(10 pts.)** Can any propositional Boolean formula be represented by a thresholded two-layer neural network? If so, sketch how. (Again, let the propositional letters be your inputs; the network output should give 1 iff the truth assignment given by the input is a satisfying assignment of the Boolean formula.)

3. **(20 pts)** Computational Learning Theory. Show that k-CNF (k literals per clause, k fixed) formulas are PAC learnable. Hint: start algorithm with the conjunction of all possible clauses of length k.

4. **(10 pts.)** Find the smallest decision tree that can be used to represent the concept

$$[p_1(x) \wedge p_2(x)] \vee [p_3(x) \wedge p_4(x) \wedge p_5(x)]$$

Why is this decision tree larger than the expression itself?

5. (**10 pts.**) Consider a neural net with step threshold functions.

- Suppose that you multiply all weights and thresholds by a constant. Will the behavior change? Explain.
- Suppose that you add a constant to all weights and thresholds. Will the behavior change? Explain.