Homework #7: Chapters 16, 18

The following exercises are due on Thursday, May 4 at 1pm. Note that this homework is continued on the reverse side of the paper.

1. *[25 pts.]* Consider a student who has the choice to buy or not buy a textbook for a course. Assume that we have three Boolean random variables: *B* indicating whether the student chooses to buy the book, *M* indicating whether the student has mastered the material in the book, and *P* indicating whether the student passes the course. Since the course has an open-book final, *P* is **not** independent of *B* given *M*. Assume that the following conditional probabilities hold:

   $P(p|b,m) = 0.9$ $\quad$ $P(m|b)=0.9$
   $P(p|b,\neg m) = 0.5$ $\quad$ $P(m|\neg b)=0.7$
   $P(p|\neg b,m) = 0.8$
   $P(p|\neg b,\neg m) = 0.3$

   a) *[10 pts.]* Draw a Bayesian network for the problem. If you have insufficient information to provide a complete Bayesian network, provide as complete of a network as possible.
   b) *[10 pts.]* The student's utility is a function of both buying the book and of passing. A common way to represent utilities that depend on multiple attributes in cases such as this is to use an **additive utility function,** e.g. $U(s)=U_{Buy}(s) + U_{Pass}(s)$. For this student, $U_{Buy}(s) = -100$ if he buys the book and 0 if not, and $U_{Pass}(s) = 2000$ if he passes the course and 0 if he does not. Compute the expected utility of buying the book and of not buying it.
   c) *[5 pts.]* What is the rational thing for the student do?

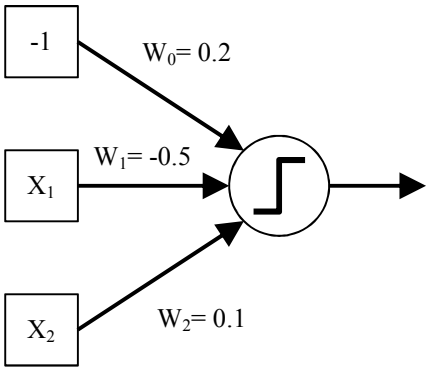
2. *[25 pts. total]* Consider the training set in Table 1 below.

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	2	No	Yes	No
X_7	Gold	2	Yes	No	No
X_8	Gold	4	Yes	Yes	Yes

Table 1. Animal Training Set

   a) *[4 pts.]* Calculate the entropy of the training set.
   b) *[16 pts.]* Calculate the information gain for each of the four attributes: *color*, *legs*, *tail*, and *furs*. **Hint:** $\log_2 x = \ln x / \ln 2 = \log_{10} x / \log_{10} 2$.
   c) *[5 pts.]* Based on your findings in part b), draw a partial decision tree that includes the attribute on which the first test should be performed and its immediate child nodes. You may use a question mark for the attribute of any nodes that cannot be completely classified by the first attribute test.

3. *[25 pts.]* Use the perceptron learning rule (equation 18.7, p. 724; ch18-learning.pptx, slide #6) to teach the perceptron shown below to recognize implications (i.e. $X_1 \Rightarrow X_2$). Assume that a **threshold activation function** is being used and that the threshold function returns 1 when its input is ≥ 0 and returns 0 otherwise. For initial weights, use $W_0 = 0.2$, $W_1 = -0.5$, and $W_2 = 0.1$. For the learning rate, use $\alpha = 0.1$. Use only the examples in the table to the right of the network in your learning process. Stop the training once the weights remain unchanged for one full pass through the examples. The examples must be used in the order given by the table below. Start again with the first example whenever you exhaust all of the examples but have not yet reached the stopping criteria. Show all of the intermediate calculations and values (not just the answer or the updated weights after each example).



Training Set		
X_1	X_2	Out
0	1	1
1	0	0
0	0	1
1	1	1

4. *[10 pts.]* Consider the case of learning to play tennis (or some other sport with which you are familiar). Explain how this process fits into the general learning model from Fig. 2.15 (p. 55), identifying each of the components of the model as appropriate. Is this supervised learning or reinforcement learning?

5. *[15 pts.]* Give an example of a feed-forward neural network that computes the exclusive or (XOR) function of two inputs (you do not need to use a learning algorithm to construct it). Recall that XOR is true exactly when one input is true and the other is false. Assume that 1=true and 0=false for all inputs and outputs. You must mention which activation function you are using.