Assignment 4: EM and Decision Making Under Uncertainty

CS486/686 – Spring 2013

Out: July 12, 2013
Due: July 30, 2013 12pm noon

Be sure to include your name and student number with your assignment.

1. **[60 pts]** Expectation Maximization

   Olertawo is a university town in New Zealand in which there is a strange medical condition called *Dunetts Syndrome*. *Dunetts Syndrome* comes in two forms: mild and severe (as well as not being there at all). It is known that about half the population of Olertawo have *Dunetts*, and that about half of those with *Dunetts* have it in severe form. *Dunetts Syndrome* has three observable symptoms, *Sloepnea*, *Forienndditis*, and *Degar spots*, all of which may be present if the patient has *Dunetts*, but with varying frequencies. In particular, it is well known that *Forienndditis* is present much more often when the condition is in its mild form (it is not as common in severe cases), whereas *Degar spots* are present much more often when the condition is in its severe form (and not as common in the mild cases). *Sloepnea* is present in either form of *Dunetts Syndrome*. However, about 10% of the population have a gene (called *TRIMONO-HT/S*) that makes it so they hardly ever show symptom *Sloepnea* (whether they have *Dunetts Syndrome* or not), but does not affect the other two symptoms. Symptoms *Sloepnea*, *Forienndditis*, and *Degar spots* are sometimes present (but much less often) even if the person does not have *Dunetts Syndrome*.

   (a) construct a Bayesian network (BN) for the domain explained above. Assign priors to each CPT based on the prior information given above. You don't need to be precise - just make educated guesses as to what the CPTs may be.

   (b) you are given a dataset from 2000 patients, giving the existence of the three symptoms *Sloepnea*, *Forienndditis* and *Degar spots*, and whether they have gene *TRIMONO-HT/S* or not. About 20% of the data also has a record of wether the patient actually had *Dunetts Syndrome* or not. Using the Expectation Maximization (EM) algorithm, learn the CPTs for your BN. Run EM until the likelihood of the complete data (the sum of all your "weights" over *Dunetts Syndrome*) only changes by 0.01 or less. Start EM from your prior model, but add a small amount δ of random white noise to each parameter. Do this by adding a different randomly generated number $r \in [0, \delta]$ to each probability in each CPT, and then renormalising. Repeat the EM learning for a range of settings of δ from ~ 0 to $4.$, and do 20 trials for each setting with different randomizations at the start of each trial (but not at the start of each EM iteration). Use at least 20 values of δ evenly spread in $[0, 4)$. The idea is to evaluate the sensitivity of EM to the initial guess. As δ gets bigger, your initial CPTs will become more and more random, and you should get increasing numbers of trials with low accuracy. If your initial guess is not very good, you may even find that adding a small amount of noise helps.

   (c) To validate your learned model, you are given 100 test instances in which it is known whether the patient had *Dunetts Syndrome*. Make a prediction of whether *Dunetts Syndrome* is present for each example in the test set based on your learned model using EM and compare with the actual values of *Dunetts Syndrome*.

   The datasets are available on the course webpage. `trainData.txt` is a file of 2000 training examples with five columns. The first three give the presence/absence of each symptom (in order *Sloepnea*,*Forienndditis*,*Degar spots*,*TRIMONO-HT/S* with 0 indicating the symptom is not present, and 1 indicating it is). The fourth column gives the presence/abscence of gene *TRIMONO-HT/S* (with 0 indicating the gene is not present, and 1 indicating it is). The fifth column is -1 if there is no record of *Dunetts Syndrome*, and $0, 1, 2$ if *Dunetts Syndrome* is recorded as being not present, mild or severe, respectively. `testData.txt` is the 100 examples for testing, has an additional column giving the severity of *Dunetts Syndrome*(the last column: 0=none, 1=mild, 2=severe).

What to hand in:

- A drawing of your Bayesian network showing all CPTs
- A printout of your code for doing EM on this model.
- A graph showing the prediction accuracy, for each value of δ, giving mean accuracy and standard deviation (error bars) over the 20 trials.

2. **[40 pts]** Decision Networks

In this question, you will construct a decision network for deciding whether to study for a course. Suppose that there are two types of courses: *hard* and *easy*, and that you can either *study* or *party*. If you *study*, then you pass an easy course with probability 0.9, and you pass a hard course with probability 0.6. If, on the other hand, you *party*, then you pass an easy course with probability 0.6 and a hard course with probability 0.35. All courses are either *pass* or *fail* (only two possible grades). You can assume you will know the difficulty of a course before making decisions, so you don't need a distribution over the difficulty.

(a) First, you need to elicit your own preferences (your own trade-off for studying versus passing). Assume the best possible situation is one in which you get to *party*, and you *pass*, and the worst possible situation is one in which you *study*, but *fail*. Formulate a standard gamble to elicit the utility of all four possible outcomes $o \in \{study, party\} \times \{pass, fail\}$, and assign each a utility in the range $[0, 1]$. A *standard gamble* means to assign the best outcome a value of 1, the worst outcome a value of 0, and then evaluate the two remaining outcomes, o, by selecting a number p at which you are indifferent between getting o with certainty and getting the best outcome with probability p and the worst outcome with probability $1 - p$.

(b) Draw a decision network for this problem, clearly labeling the decision node, the chance nodes, and the utility node, and showing the conditional probability table (CPT) clearly.

(c) Given the decision network and your elicited utility function, compute the value of studying or partying for both hard and easy courses. Based on this value, what policy should you follow?

(d) Some really good courses have four assignments, a midterm, and a final exam. These six assessments follow each other sequentially as assignment 1, assignment 2, midterm, assignment 3, assignment 4, final. Assume that marks for each assessment are allocated immediately upon hand-in, so that the decision to study or party for the next assessment can be based on the grade of the previous ones. Draw the decision network for this sequential decision making problem.

What to hand in:

- A description of your standard gamble, and a table showing your utility function for the four possible outcomes $o \in \{study, party\} \times \{pass, fail\}$.
- A drawing of your decision network, and your CPTs.
- The value for studying and partying for both types of courses, and the policy you should follow for both types of courses.
- The decision network for the sequential version of the problem

[20 pts] OPTIONAL BONUS QUESTION: Use your preferences and probabilities from Question 2, compute a policy of action for CS486. This will be a sequence of 6 study/party decisions interleaved with 6 pass/fail grades, arranged in a decision tree. That is, the nodes of the decision tree will be the study/party decisions, while the edges will be labeled with pass/fail. You can assume that:

- this is a *hard* course,
- the relative weights of the assignments are as for the real course (so 10% for each assignment, 20% for the midterm, and 40% for the final),
- your preferences elicited in Question 2 can be used as a utility for passing the entire course,
- passing each individual assessment is only valuable to you as a means of passing the entire course,
- each assignment or exam is either given 0 or 100 (fail or pass),
- you don't have to pass the final to pass the course,
- the CPTS for pass/fail are the same for all assessments, and are as given above.

You can relax any of these assumptions, but indicate clearly which ones you are relaxing.
HINT: it is possible to formulate this as a Markov decision process (MDP) with a horizon of 6.

What to hand in for BONUS question:

- Your decision tree for the policy for the complete CS486 course, along with your calculations showing how you arrived at this. Be as clear as possible, and clearly state any assumptions you had to make along the way.
- NOTE: part marks will not be allocated for the bonus question, so only complete solutions will be considered.