EECS 391 Introduction to Artificial Intelligence
Fall 2019, Programming Assignment 2 ("P2")

Due: Fri Nov 15 before midnight. **Total Points:** 100 + 20 extra credit

In this assignment, you will implement Bayesian networks in python with the `pgmpy` package. You will first need to have a working python installation on your system and then install the `pgmpy` package. Follow the installation instructions on `pgmpy.org`.

This assignment only requires basic knowledge about python. To familarize yourself with both the package and python, first work through the "Bayesian Networks" tutorial in the documentation:

`github.com/pgmpy/pgmpy_notebook/blob/master/notebooks/2. Bayesian Networks.ipynb`

Note that the tutorial is written in a jupyter notebook, but this is not requried or necessary to complete the assignment. You can write the code using your normal editor and run it to produce text output, which is all we will need.

Write-up: Your write-up should answer the questions like in the written assignments. When relevant, include the source code in the write-up if it is sufficiently short (say half a page or less), otherwise refer to the file.

Exercise 1. Noisy Fuel Guage (from Bishop)

Consider a model of a noisy electric fuel gauge in an old and unreliable car. The state of the guage G indicates the fuel level F. The gauge is electric, so it depends on the fuel level F and the state of the battery B. For simplicity, assume the states are binary with 0 and 1 representing empty and full respectively for G and F or dead and charged for B.

a) Define this Bayes net using the `pgmpy` toolbox. Use the following probabilities: 10 P.

$$p(B=1) = 0.8 \tag{1}$$
$$p(F=1) = 0.9 \tag{2}$$

$$p(G=1|B=0,F=0) = 0.1 \tag{3}$$
$$p(G=1|B=1,F=0) = 0.1 \tag{4}$$
$$p(G=1|B=0,F=1) = 0.2 \tag{5}$$
$$p(G=1|B=1,F=1) = 0.9 \tag{6}$$

b) Derive the mathmatical expression for the probability that the fuel tank is empty given that the fuel guage reads empty. Be sure to express this in terms of probabilities that are defined for the model. 10 P.

c) Use the toolbox to calculate the numerical value of this expression from the model you defined above. 10 P.

d) Show how our beliefs about the state of the fuel tank change when 1) we haven't made any observations yet; 2) we see that the fuel guage reads empty; and 3) we test the battery and find that it is dead. For each case, write the probabilistic expression and derive the numerical value using the toolbox. 15 P.

e) Explain why our belief (i.e. the probability) that the fuel tank is empty goes *down* when learn that the battery is dead. 5 P.

f) Explain what our belief about the fuel tank be if we had *only* observed the dead battery. 5 P.

Exercise 2. Wet Grass (from Pearl/Barber)

Now we will do an only slightly more complicated model that also illustrates the concept of "explaining away." Tracey leaves her house one morning and sees that the grass is wet. She wonders: Was it due to an overnight rain? Or that last night she forgot to turn off her sprinkler?

a) Show graphical model of the Bayes net that models this scenario. Use the following variables: R = it rained last night; S = the sprinkler was left on; and G = the grass is wet. 5 P.

b) Write out the probability tables for this model assuming that: there is a 20% chance of overnight rain; a 10% chance that she left the sprinkler on; rain always makes the grass wet and if it doesn't rain, the grass isn't wet, but the sprinkler fails 5% of the time. 5 P.

c) Define this model using the toolbox. 5 P.

d) Calculate the probabilities for Tracey's original queries using the toolbox (you do not have to provide the mathematical derivation). 5 P.

e) Now suppose that Tracey observes her neighbor, Jack, also has wet grass. Augment your model to incorporate this new information. Use the variable J to represent the state of Jack's grass. Assume that the rain always makes Jack's grass wet, but if it didn't rain, his grass has a 15% chance of being wet for some other reason. Write the graph for the Bayes net model, the probability tables, and the updated code using the toolbox. 10 P.

f) Derive the probabilistic expression and numeric value for the probability that the sprinkler was left on given that Tracey sees that both her grass and Jack's are wet. 10 P.

g) Explain why this new observation *lowers* the Tracey's belief she left the sprinkler on. 5 P.

Exercise 3. (Extra credit) Design your own Bayesian network.

Implement a belief network of your own choosing or design. It should use discrete variables (which could be binary) and be more complex that the examples above. Use the model to illustrate deductive inference problems.

The grading is necessarily subjective, but here is a rubric:

- Was the scenario you are trying to model clearly described? +5 P.
- Were the variables and states well-chosen and clearly explained? +5 P.
- How well did the examples to illustrate the model? +5 P.
- Did the model go beyond or is distinct from what was already convered in the questions above? For example: larger numbers of nodes with more complex interactions; more variable states; or using simplifying assumptions for conditional probabilities like noisy-OR. +5 P.