CMPT 310
Artificial Intelligence Survey

Simon Fraser University
Spring 2018

Instructor: Oliver Schulte

Assignment 4: Chapters 13, 14, 20. Probabilistic Reasoning and Learning

Instructions: The university policy on academic dishonesty and plagiarism (cheating) will be taken very seriously in this course. *Everything submitted should be your own writing or coding.* You must not let other students copy your work. On your assignment, put down your **name**, the number of the assignment and the number of the course. Spelling and grammar count.

Group Work: Discussions of the assignment is okay, for example to understand the concepts involved. If you work in a group, put down the name of all members of your group. There should be no group submissions. Each group member should write up their own solution to show their own understanding.

For the due date please see our course management server https://courses.cs.sfu.ca. The time when you upload your assignment is the official time stamp. If your assignment is late because you did not figure this out soon enough, you will lose marks according to the syllabus policy.

Terminology: The questions are not self-explanatory. Even ordinary English words (e.g., "rationality") may not have their ordinary meaning in an AI context. Part of your task is to learn the AI terminology required to understand the questions. You will likely not understand the questions if you have not studied the course material.

Getting Help. Check the syllabus for communication policy. You have the textbook, the lecture notes, the discussion forum, and you can ask us in office hours or class sessions. We do not provide individual email support.

Handing in the Assignment. Please use the submission system on courses.cs.sfu.ca.

You should post

- a pdf document that contains your written answers, as well as the screenshots and diagrams required.
- A Bayesian network in executable file format (.xml or .bif), for the power station problem.

Probabilistic Reasoning With Bayesian Networks
(Chapter 13 and 14) 60 points total.

Go to www.aispace.org and start the "belief and decision network" tool. Load the sample file "File/Load Sample Problem/Simple Diagnostic Example". We will use this to test some of the basic probability laws. The AIspace tool can do many of these calculations for you, but the purpose of the exercise is to learn the principles behind the calculations. You can use the tool to check your answers, but *you should compute them yourself using the probability calculus together with the conditional probabilities from the Bayesian network.* If you have difficult running the tool in the browser, try downloading the jar file.

Joint Probabilities. (25 points)
Compute the following joint probabilities *up to 6 significant digits.*

1. Use the product formula of Bayes nets and the conditional probability parameters specified by AIspace to compute the probability that: all nodes are false.
2. Use the product formula of Bayes nets and the conditional probability parameters specified by Aispace to compute the probability that: all nodes are false except for Sore Throat, and that Sore Throat is true.
3. Show how can you use these two joint probabilities to compute the probability that: all nodes other than Sore Throat are false. (Where the value of Sore Throat is unspecified.)
4. Verify the product rule:
   P(all nodes are false) =
   P(Sore Throat = false| all other nodes are false) x P(all other nodes are false).
   You may get the first conditional probability by executing a query with the tool.
5. Compute the probability that Sore Throat is true and that Fever is true. (Hint: If you use the right formula, you only need 4 conditional probabilities.)

You can enter the computed probabilities in the table below.

Probability to be Computed	Your Result
P(all nodes false)	
P(Sore Throat = True, all other nodes false)	
P(all nodes other than Sore Throat false)	
P(all nodes are false) = P(Sore Throat = false| all other nodes are false) x P(all other nodes are false).	
P(Sore Throat = true, Fever = True)	

Bayes' Theorem. 15 points

1. (5 points) Use the AIspace tool to compute P(Influenza = False|Wheezing = True).
2. (10 points) Show how you can compute the answer using Bayes' theorem. You may use the tool to find the probabilities that are required for applying Bayes' theorem. Verify that your calculation and the tool give the same answer up to round-off.

Independence. 20 points

"If no evidence is observed, Influenza and Smoking are probabilistically independent."

1. (10 points) Prove this statement from the numerical semantics, i.e. show that the values of Influenza and Smokes are independent for all possibilities. You may use queries in the tool to do this.
2. (10 points) Prove this from the topological semantics, i.e. using the Markov condition that given values for its parents, a variable is probabilistically independent of all its nondescendants.

Knowledge Representation With Bayesian Networks
30 points total

In a power station, an alarm senses when a temperature gauge exceeds a given threshold. The gauge measures the temperature of the core. Using the AIspace tool, draw a Bayesian network that represents the following information about the plant. You may consider editing your Bayes net in a text editor to facilitate copying of similar entries.

1. (5 points) Create a Bayes net with the following variables (=nodes) and domains. Each domain represents a range of possible locations.

Variable	Domain	Meaning
A	{T,F}	alarm sounds
FA	{T,F}	alarm is faulty
FG	{T,F}	gauge is faulty
G	{Normal, High}	gauge reading
T	{Normal, High}	core temperature

2. Draw edges between the nodes and specify conditional probability tables to represent the following information.

   a. (6 points) The alarm works correctly unless it is faulty. If it is faulty, it never sounds.

   b. (6 points) If the gauge is not faulty, there is a 90% chance that it gives the correct temperature. If the gauge is faulty, there is a 10% chance that it gives the correct temperature.

   c. (10 points) Suppose the alarm and gauge are working correctly and the alarm sounds. Using calculus probability, and the various conditional probabilities in the network, calculate the probability that under these circumstances, the temperature of the core is high. You can make the following assumptions. (i) The temperature is normal 70% of the time, high 30% of the time. (ii) The gauge is faulty 10% of the time, not faulty 90% of the time.

   d. (3 points) Use the AIspace query tool to confirm your answer from c.

What to Submit for this question: Everything specified in the problem, including answers and brief explanations. In addition: A loadable .xml or .bif file for your Bayesian network in part 1. A screenshot of your Bayesian network, screenshots of your CP-tables, and a screenshot of your query and the answer from AIspace.

Chapter 20. Bayesian Network Parameter Learning
27 points total.

Consider the Bayes Net from Figure 1. This Bayes net says that the value of Will Wait can be predicted from the values of Pat (Patron) and Hun (Hungry). Let **D** denote the subset of the data from Figure 1 comprising only the three columns Hun, Pat, Will Wait. So **D** is the 12x3 matrix shown below.

Table 1. Dataset for this problem.

Hun	Pat	Will Wait
T	Some	F
T	Full	F
F	Some	T
T	Full	T
F	Full	F
T	Some	T
F	None	F
T	Some	T
F	Full	F
T	Full	F
F	None	F
T	Full	T

1. (17 points) Based on the *Maximum Likelihood method*, fill in the conditional probabilities for the Bayes net structure in the table below. Some of the conditional probabilities may be undefined.

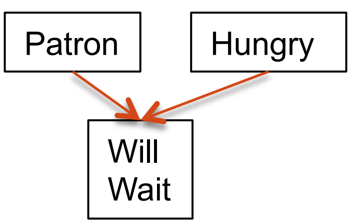

Figure 1

Sample Answers, not the solution

Hun	P(Hun)
T	0.5
F	0.5

Pat	P(Pat)
Some	0.3
Full	0.3
None	0.3

Hun	Pat	Will Wait	P(WW|Pat,Hun)
T	Some	T	0.5
T	Some	F	0.5
F	Some	T	0.4
F	Some	F	0.6
F	Full	T	0.2
F	Full	F	0.8
T	Full	T	0.1
T	Full	F	0.9
F	None	T	0.3
F	None	F	0.7
T	None	T	0.4
T	None	F	0.6

Your Solution

Table 2. Probability Table for Hungry. Your Answer

Hun	P(Hun)
T	
F	

Table 3. Probability Table for Patron. Your Answer.

Pat	P(Pat)
Some	
Full	
None	

Table 4. Conditional Probability Table for Will Wait. Your Answer.

Hun	Pat	Will Wait	P(WW|P,H)
T	Some	T	
T	Some	F	
F	Some	T	
F	Some	F	
F	Full	T	
F	Full	F	
T	Full	T	
T	Full	F	
F	None	T	
F	None	F	
T	None	T	
T	None	F	

2. (10 points) Assuming that the conditional probabilities are estimated using the maximum likelihood method from question 1, what is the data likelihood of the data set **D** given the Bayesian network from Figure 1? To compute this, consider only the three variables Hun, Pat, Will Wait (see examples in lecture notes). Fill in the table below (with joint probabilities). Some of the joint probabilities may be undefined, these should be omitted from the data likelihood.

Table 5. Dataset + joint probabilities. Sample Answer, not the solution.

Hun	Pat	Will Wait	P(WW,Pat,Hun)
T	Some	F	0.075
T	Full	F	0.075
F	Some	T	0.075
T	Full	T	0.075
F	Full	F	0.075
T	Some	T	0.075
F	None	F	0.075
T	Some	T	0.075
F	Full	F	0.075
T	Full	F	0.075
F	None	F	0.075
T	Full	T	0.075

The likelihood of the dataset **D** is approximately $3.16*10^{-14}$.

Table 6. Dataset + joint probabilities. Your Answer.

Hun	Pat	Will Wait	P(WW,Pat,Hun)
T	Some	F	
T	Full	F	
F	Some	T	
T	Full	T	
F	Full	F	
T	Some	T	
F	None	F	
T	Some	T	
F	Full	F	
T	Full	F	
F	None	F	
T	Full	T	

The likelihood of the dataset **D** is approximately ….