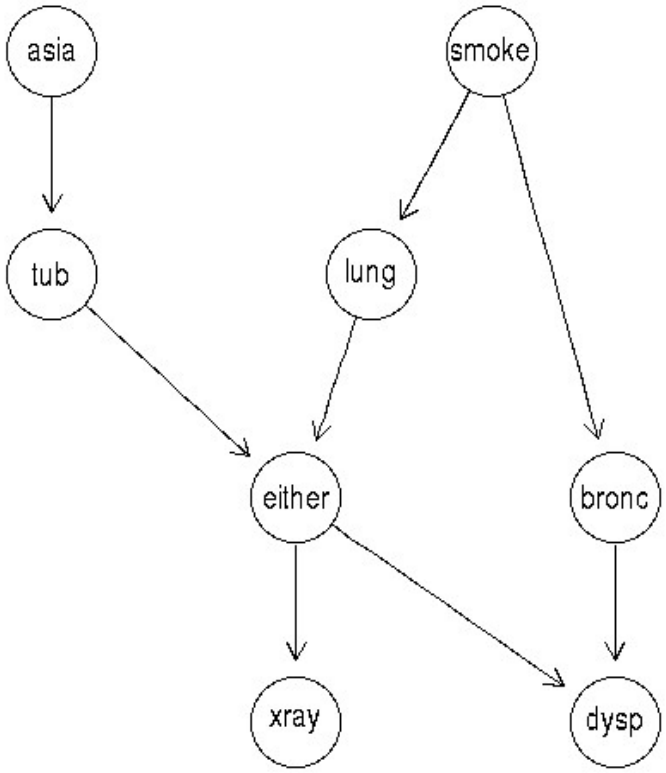
CSE455/555 - Intro to Pattern Recognition
Problem Set 3: Exact Inference with Probabilistic Graphical Models

Due Date: Sunday, April 10, 2022 11:59PM

In this problem set, you will make exact inferences about probabilistic graphical models using the state-of-the-art graphical model packages in your most comfortable programming languages, and understand those exact algorithms. You can find tutorials in python (Building Probabilistic Graphical Models with Python) R (Graphical Models and Bayesian Networks with R) from Course Documents → Reading Materials on UBLearns The function calls in different packages are different, but the point here is that we make graphical model our actionable machine learning tool in this course.
You will work with the chest clinic graphical model below. The data you are going to use is in the following tables. The R code used to generate the data is also provided.



```
> library(gRain)
> yn <- c("yes","no")
> a <- cptable(~asia, values=c(1,99), levels=yn)
> t.a <- cptable(~tub | asia, values=c(5,95,1,99), levels=yn)
> s <- cptable(~smoke, values=c(5,5), levels=yn)
> l.s <- cptable(~lung | smoke, values=c(1,9,1,99), levels=yn)
> b.s <- cptable(~bronc | smoke, values=c(6,4,3,7), levels=yn)
> e.lt <- cptable(~either | lung:tub,values=c(1,0,1,0,1,0,0,1),
   levels=yn)
> x.e <- cptable(~xray | either, values=c(98,2,5,95), levels=yn)
> d.be<-cptable(~dysp|bronc:either, values=c(9,1,7,3,8,2,1,9),
   levels=yn)
> cpt.list <- compileCPT(list(a, t.a, s, l.s, b.s, e.lt, x.e, d.be))
> cpt.list$asia asia
yes    no
0.01 0.99
> cpt.list$tub asia
tub   yes   no yes
0.05 0.01 no 0.95
0.99
> cpt.list$smoke
smoke
yes no
0.5 0.5
> cpt.list$lung smoke
lung yes   no yes
  0.1 0.01 no 0.9
  0.99
> cpt.list$bronc smoke
bronc  yes  no
  yes  0.6 0.3
  no   0.4 0.7
> ftable(cpt.list$either,row.vars = 1)
       lung yes no tub yes
       no yes no
either
yes   1 1   1 0
no    0 0   0 1
> cpt.list$xray either
xray  yes   no yes
  0.98 0.05 no
  0.02 0.95
```

asia	
yes	no
0.01	0.99

	asia	
tub	yes	no
yes	0.05	0.01
no	0.95	0.99

smoke	
yes	no
0.5	0.5

	smoke	
lung	yes	no
yes	0.1	0.01
no	0.9	0.99

	smoke	
bronc	yes	no
yes	0.6	0.3
no	0.4	0.7

	lung	yes		no	
	tub	yes	no	yes	no
either					
yes		1	1	1	0
no		0	0	0	1

	either	
xray	yes	no
yes	0.98	0.05
no	0.02	0.95

1 Task-1

(a) Draw the moral graph, triangulated graph and the junction tree.
Please read the related parts in the tutorials and draw graphs using your choice of language. This is a coding task and your code will be graded. DO NOT draw graphs by hand and upload images.
(b) Explain why the "running intersection property" is satisfied in your junction tree.

2 Task-2

(a) Describe how the different terms on the right hand side of $p(V) = p(a)p(t|a)p(s)p(l|s)p(b|s)p(e|t,l)p(d|e,b)p(x|e)$ are distributed among the different junction tree clusters.
(b) Write out the messages using these terms and verify that the message passing algorithmindeed gives the cluster marginals.
(c) Use message-passing algorithm to find the joint probability of "tub=yes, lung=yes,bronc=yes", given evidence that "asia=yes, xray=yes".
This is also a coding task, use your choice of language and refer to the tutorials.

3 Task-3[Optional]

Find the joint probability with MCMC.

4 Submission

Submit your solutions as a single ipynb file through UBlearn. You can use Google Colab: https://colab.research.google.com/notebooks/intro.ipynb https://towardsdatascience.com/getting-started-with-google-colab-f2fff97f594c. The ipynb file should include your code, execution results, any explanations and answers to the questions. Use text cells to answer questions and add explanations.

Markdown guide for text cells:
https://colab.research.google.com/notebooks/markdown_guide.ipynb#scrollTo=Lhfnlq1Surtk
https://colab.research.google.com/notebooks/basic_features_overview.ipynb#scrollTo=4hfV37gxpP_c
You can also add math to text cells using LaTeX. Just place the statement within a pair of $ signs. Please typeset your mathematics. Do not upload pictures of handwriting math formulas. Math typesetting help: https://www.codecogs.com/latex/eqneditor.php

6 Rubric

Total: 10 points + 2 bonus points

Task-1:
5 points: 4 points part(a), 1 points part(b).
Task-2:
5 points: 1 points part(a), 3 points part(b), 1 point part(c).
Task-3:
2 bonus points.

8 Acknowledgement

9 Academic Integrity

Academic integrity is a fundamental university value. Any violation will be reported to the University and will result in penalties in grades.
Do not share your answers with other students. This is an individual assignment. You are not allowed to work in groups. Working in groups and submitting similar answers is considered a violation of academic integrity.
Do not plagiarize someone else's words, ideas, or data you find online. Always cite your sources.