Lab 3 Report

Jacob Molin, Victor Lindquist
jacmo699@student.liu.se, vicli268@student.liu.se

October 1, 2020

1 Part II

5.

a) - $P(Meltdown) = 0.02578$.
- If there is icy weather $P(Meltdown|IcyWeather) = 0.03472$.

b) - $P(Meltdown|PumpFailureWarning, WaterLeakWarning) = 0.14535$.
- $P(Meltdown|PumpFailure, WaterLeak) = 0.2$
- The difference is that the first scenario only considers the risk of a meltdown given that the warning systems triggered. The second scenario considers the risk of a meltdown when there are actual failures, even if the warning systems triggered or not.

c) Because they might not appear in the observations since they happen so rarely. Also, some stochastic variables might be very irregular, for instance if they are dependent on other stochastic variables. Water leak, for instance, can be difficult to estimate, because icy weather isn't always the cause.

d) - The alternatives for the domain could be different temparature scales, like Farenheit, Celsius or Kelvin.
- $P(WaterLeak|Temperature)$ will be the same in all alternative domains given that the probability of a certain $Temperature$ corresponds to the domain for that variable. Example: $P(Temperature = 0Celsius) = P(Temperature = 32Farenheit) = P(Temperature = 273.15Kelvin)$

6.

a) It represents the likelihood of a node being true depending on different scenarios of it's parents.

b) - A joint probability distribution is the probability distrubution of multiple variables.
- Using the chain rule in the calculation below we have abbreviated the variables as:

M: *Meltdown*
WLW: *WaterLeakWarning*
PFW: *PumpFailureWarning*
WL: *WaterLeak*
PF: *PumpFailure*
IW: *IcyWeather*

$P(\neg M, \neg WLW, \neg PFW, \neg WL, \neg PF, \neg IW)$
$= P(\neg M|\neg WLW, \neg PFW, \neg WL, \neg PF, \neg IW) \cdot P(\neg WLW|\neg PFW, \neg WL, \neg PF, \neg IW) \cdot P(\neg PFW|\neg WL, \neg PF, \neg IW) \cdot$
$P(\neg WL|\neg PF, \neg IW) \cdot P(\neg PF|\neg IW) \cdot P(\neg IW)$
$= 0.999 \cdot 0.95 \cdot 0.95 \cdot 0.90 \cdot 0.90 \cdot 0.95$
≈ 0.69

- Yes, this is the "normal" state for the nuclear plant to be in.

c) - $P(Meltdown|PumpFailure, WaterLeak) = 0.2$
- No, because *Meltdown* only depends on if there is a *PumpFailure* and/or a *WaterLeak*.

d)

$$P(X|e) = \alpha \cdot \sum_y P(X, e, y)$$

Where $X = \{Meltdown\}$, $E = \{WaterLeak, PumpFailureWarning, WaterLeakWarning, IcyWeather\}$, $e = \{\neg waterleak, \neg pumpfailurewarning, \neg waterleakwarning, \neg icyweather\}$ and $Y = \{PumpFailure\}$.

This gives:

$\mathbf{P(X \mid e)} = \alpha \cdot \Big(P(m, \neg wl, \neg pfw, \neg wlw, \neg iw, \neg pf) + P(m, \neg wl, \neg pfw, \neg wlw, \neg iw, pf)\Big)$
$= \alpha \cdot \Bigg(\Big(P(m|\neg pfw, \neg wlw, \neg pf, \neg wl, \neg iw) \cdot P(\neg pfw|\neg wlw, \neg pf, \neg wl, \neg iw) \cdot P(\neg wlw|\neg pf, \neg wl, \neg iw)$
$\cdot P(\neg pf|\neg wl, \neg iw) \cdot P(\neg wl|\neg iw) \cdot P(\neg iw)\Big) + \Big(P(m|\neg pfw, \neg wlw, pf, \neg wl, \neg iw) \cdot P(\neg pfw|\neg wlw, pf, \neg wl, \neg iw)$
$\cdot P(\neg wlw|pf, \neg wl, \neg iw) \cdot P(pf|\neg wl, \neg iw) \cdot P(\neg wl|\neg iw) \cdot P(\neg iw)\Big)\Bigg)$
$= \alpha \cdot 0.00191$

and

$\mathbf{P(\neg X \mid e)} = \alpha \cdot \Big(P(\neg m, \neg wl, \neg pfw, \neg wlw, \neg iw, \neg pf) + P(\neg m, \neg wl, \neg pfw, \neg wlw, \neg iw, pf)\Big)$
$= \alpha \cdot \Bigg(\Big(P(\neg m|\neg pfw, \neg wlw, \neg pf, \neg wl, \neg iw) \cdot P(\neg pfw|\neg wlw, \neg pf, \neg wl, \neg iw) \cdot P(\neg wlw|\neg pf, \neg wl, \neg iw)$
$\cdot P(\neg pf|\neg wl, \neg iw) \cdot P(\neg wl|\neg iw) \cdot P(\neg iw)\Big) + \Big(P(\neg m|\neg pfw, \neg wlw, pf, \neg wl, \neg iw) \cdot P(\neg pfw|\neg wlw, pf, \neg wl, \neg iw)$
$\cdot P(\neg wlw|pf, \neg wl, \neg iw) \cdot P(pf|\neg wl, \neg iw) \cdot P(\neg wl|\neg iw) \cdot P(\neg iw)\Big)\Bigg)$
$= \alpha \cdot 0.70068$

Which together yields:

$\alpha = \frac{1}{P(X|e)+P(\neg X|e)} = \frac{1}{0.00191+0.70068} = \frac{1}{0.70259}$
$\implies P(X|e) = \alpha \cdot 0.00191 = \frac{0.00191}{0.70259} \approx \mathbf{0.0027}$

2 Part III

2.

a) The owner's chance of survival changed from $P(Survives) = 0.99001$ to $P(Survives|\neg Radio) = 0.98116$ since with the observation of the radio not working there is a possibility that the battery is not working.

b) The owner's chances of survival increases with $0.99505 - 0.99001 = 0.00504$ or approximately 0.5%.

c) Yes. This means that the time and space complexity increases with the complexity of the structure of the Bayesian Network. The alternatives are approximate inference methods, such as variational message passing, which trade computation time for accuracy.

3 Part IV

3.

a) Yes. If a better pump is installed, which has fewer failures, there would be less warnings, which leads to Mr. H.S. not having to act as often.

b) Creating an OR-gate with *PumpFailureWarning* and *WaterLeakWarning* represents the disjunction in the network. *Mr. H.S survives* yields a lower rate of survival than the owner's, since Mr. H.S. only responds to the plant's warnings. $P(Mr.H.Ssurvives = T) = 0.98281$.

c) That a person consistently will act in a certain way with a certain probablitiy, when the person really just might act irrational all of a sudden.

d) You could add a node which contains information about icy weather in previous days. This will affect the node *IcyWeather*, which represents today's likelihood of icy weather.