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Report Lab3 TDDC17

Task for Part II:

***1.** What is the risk of melt-down in the power plant during a day if no observations have been made? What if there is icy weather?*

The risk of melt-down in the power plant is 0.02578. If there is icy weather, the risk increases to 0.03472.

***2.** Suppose that both warning sensors indicate failure. What is the risk of a meltdown in that case? Compare this result with the risk of a melt-down when there is an actual pump failure and water leak. What is the difference? The answers must be expressed as conditional probabilities of the observed variables, P(Meltdown|...).*

The risk in the case that both warning sensors indicate failure is 0.14535.
If there is an actual pump failure and water leak, then the risk will be 0.20000.
The main difference is that the risk increases if we know that there is an actual pump failure and water leak.

$$P(meltdown \mid wlWarning \wedge pfWarning) = \frac{P(meltdown \wedge (wlWarning \wedge pfWarning))}{P(wlWarning \wedge pfWarning)} = 0.14535$$

$$P(meltdown \mid pumpFailure \wedge waterLeak) = \frac{P(meltdown \wedge (pumpFailure \wedge waterLeak))}{P(pumpFailure \wedge waterLeak)} = 0.2$$

***3.** The conditional probabilities for the stochastic variables are often estimated by repeated experiments or observations. Why is it sometimes very difficult to get accurate numbers for these? What conditional probabilities in the model of the plant do you think are difficult or impossible to estimate?*

Few number of observations are bad observations. Meltdown is difficult to estimate because it is depended on more variables.

***4.** Assume that the "IcyWeather" variable is changed to a more accurate "Temperature" variable instead (don't change your model). What are the different alternatives for the domain of this variable? What will happen with the probability distribution of P(WaterLeak | Temperature) in each alternative?*

Different alternative for the domain of this variable can be weather, season, climate and time of the day.
Due to the fact that the distribution density function for the temperature depends on

many variables (thus a varying probability distribution) the probability distribution of P(wateLeak | Temperature) will vary(?).

5. What does a probability table in a Bayesian network represent?

The (conditional) probability of an outcome depending on other adjacent probabilities in a directed graph.

6. What is a joint probability distribution? Using the chain rule on the structure of the Bayesian network to rewrite the joint distribution as a product of P(child|parent) expressions, calculate manually the particular entry in the joint distribution of P(Meltdown=F, PumpFailureWarning=F, PumpFailure=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F). Is this a common state for the nuclear plant to be in?
A joint probability distribution is a table of probability between multiple variables.

$$P(Meltdown = F,\ PumpFailureWarning = F,\ PumpFailure = F,\ WaterLeakWaring = F,\ WaterLeak = F,\ IcyWeather = F) =$$
$$P(-meltdown \mid -pumpFailure,\ -waterLeak)\,P(-plWarning \mid -pumpFailure)\,P(-wlWaraning \mid -waterLeak)$$
$$P(-waterLeak \mid -icyWeather)\,P(-pumpFailure)\,P(-icyWeather) = 0.999 * 0.95 * 0.95 * 0.9 * 0.9 * 0.95531 = 0.69766$$

This is the most probable state, soooo yes(?).

7. What is the probability of a meltdown if you know that there is both a water leak and a pump failure? Would knowing the state of any other variable matter? Explain your reasoning!

The probability: $P(meltdown \mid pumpFailure,\ waterLeak) = 0.2$

Knowing the other states (icyWeather, pumpFailureWarning and waterLeakWarning) would NOT matter.

8. Calculate manually the probability of a meltdown when you happen to know that PumpFailureWarning=F, WaterLeak=F, WaterLeakWarning=F and IcyWeather=F but you are not really sure about a pump failure.

We denote pumpFailureWarning as PFW, waterLeak as WL, waterLeakWarning as WLW, pumpFailure as PF and IcyWeather as IW.

We first study the probability for Meltdown = true:

$$P(Meltdown = T,\ PumpFailureWarning = F,\ WaterLeakWaring = F,\ WaterLeak = F,\ IcyWeather = F) =$$
$$\alpha P(M,\ -PFW,\ -WL,\ -WLW,\ -IW) =$$
$$\alpha \sum_{PF} P(M \mid PF,\ -WL)\,P(PF)\,P(-PFW \mid PF)\,P(-WLW \mid -WL)\,P(-WL \mid -IW)\,P(-IW) =$$
$$\alpha\, P(-WLW \mid -WL)\,P(-WL \mid -IW)\,P(-IW) \sum_{PF} P(PF)\,P(M \mid PF,\ -WL)\,P(-PFW \mid PF) =$$
$$\alpha\, 0.95 * 0.9 * 0.95\,((0.1 * 0.15 * 0.1) + (0.9 * 0.001 * 0.95)) = \alpha * 0.81225 * 0.002355 = \alpha * 0.00191284875$$

We then study the probability for Meltdown = false:

$$P(Meltdown = F,\ PumpFailureWarning = F,\ WaterLeakWaring = F,\ WaterLeak = F,\ IcyWeather = F) =$$
$$\alpha P(-M,\ -PFW,\ -WL,\ -WLW,\ -IW) =$$
$$\alpha \sum_{PF} P(-M \mid PF,\ -WLW)\ P(PF)\,P(-PFW \mid PF)\,P(WLW \mid -WL)\,P(-WL \mid -IW)\,P(-IW) =$$

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$\alpha P(-WLW \mid -WL)\, P(-WL \mid -IW)\, P(-IW) \sum_{PF} P(PF)\, P(-M \mid PF,\ -WL)\ P(-PFW \mid PF)\ =$
$\alpha\, 0.95\ *\ 0.9\ *\ 0.95\,(\,(0.9\ *\ 0.85\ *\ 0.95)\ +\ (0.1\ *\ 0.999\ *\ 0.95)\,) = \alpha\ * 0.81225\ *\ 0.821655 = \alpha\ *\ 0.667389927375$

To get the probabilities we normalize with respect to α:

1 = α * (0.00191284875 + 0.66738927375) => α = 1.494093573564

We get the probabilities:

=> {true, false} = α * {0.011233721952, 0.695289671297} ≈ {0.00286, 0.99714}

Task for Part III:

1. During the lunch break, the owner tries to show off for his employees by demonstrating the many features of his car stereo. To everyone's disappointment, it doesn't work. How did the owner's chances of surviving the day change after this observation?

If the radio is broken his chances of surviving changes to 0.99132 from 0.9952.
if the battery of the car died his new chances of surviving the day is 0.98969, compared to 0.9952.

2. *The owner buys a new bicycle that he brings to work every day. The bicycle has the following properties:*

> *P(bicycle_works) = 0.9*
> *P(survives | ¬moves ∧ melt-down ∧ bicycle_works) = 0.6*
> *P(survives | moves ∧ melt-down ∧ bicycle_works) = 0.9*

How does the bicycle change the owner's chances of survival?

It gives the owner a higher probability of surviving if the car does not move.
When the owner buys a bicycle his chances of surviving the day decreases from 0.9952 to 0.99457.
If the car does not work his chances of surviving the day decreases from 0.98969 to 0.98814.

This is wierd...

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***3.** It is possible to model any function in propositional logic with Bayesian Networks. What does this fact say about the complexity of exact inference in Bayesian Networks? What alternatives are there to exact inference?*

The time and space complexity of exact inference in multiply connected networks are exponential in the worst case. Alternatives to exact inference can be clustering algorithms(join tree) which reduces the time complexity to O(n). It replaces two boolean nodes in a network into one “mega node”.

Task for Part IV:

***1.** The owner had an idea that instead of employing a safety person, to replace the pump with a better one. Is it possible, in your model, to compensate for the lack of Mr H.S.'s expertise with a better pump?*

Yes. A better pump will result in fewer pump failures and therefore fewer pump failure warnings. The probability of Mr H.S required actions decreases.

***2.** Mr H.S. fell asleep on one of the plant's couches. When he wakes up he hears someone scream: "There is one or more warning signals beeping in your control room!". Mr H.S. realizes that he does not have time to fix the error before it is to late (we can assume that he wasn't in the control room at all). What is the chance of survival for Mr H.S. if he has a car with the same properties as the owner?*

Given the initial conditions we conclude that ‘One or More’ alarms are going off and therefore Mr H.S does not stay; he runs to his car. This results in a survival change to 0.96531.

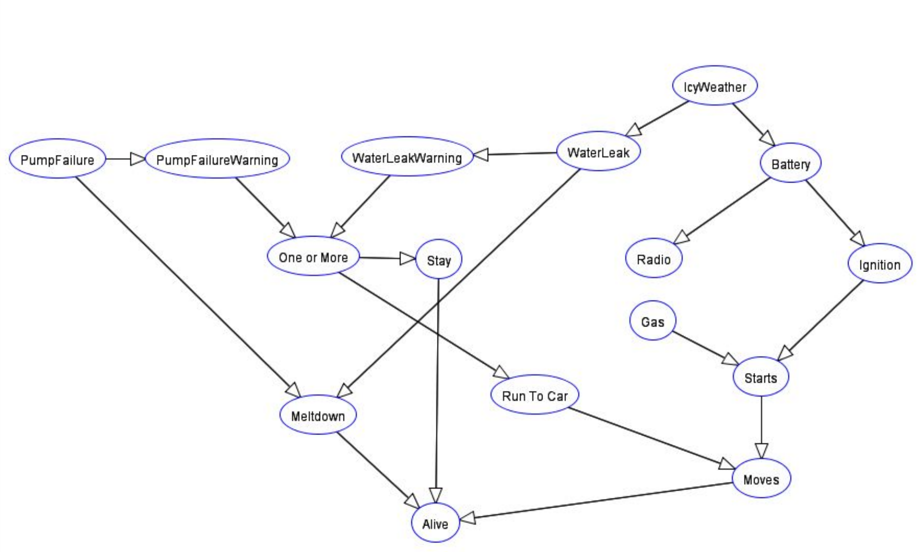

Fig. 1: Our extended network given the initial conditions.

3. *What unrealistic assumptions do you make when creating a Bayesian Network model of a person?*

Unrealistic assumptions when creating a Bayesian Network model of a person can be divided into general situations and specific situations. Unrealistic assumptions about a person's health and attributes.

4. *Describe how you would model a more dynamic world where for example the "IcyWeather" is more likely to be true the next day if it was true the day before. You only have to consider a limited sequence of days.*

Create a node that checks the weather of the day before and calculate the probability for the next day. Also environmental factors such as climate can affect the model to be more dynamic.