Tasks for part II

5a) 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?

If no observations have been done the monitoring shows 0.02578 in probability for a meltdown. If the weather has the added observation “Icy weather=true” the risk for a meltdown increases to 0.03472

5b) Suppose that both warning sensors indicate failure. What is the risk of a melt-down 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 answer must be expressed in conditional probabilities)

- PumpFailureWarning=True; WaterLeakWarning=True
  The risk for meltdown is 0.14535
- PumpFailure=True; WaterLeak=True;
  Risk for meltdown is 0.20000
- The difference is 0.05465

5c) 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 probabilites in the model of the plant do you think are difficult or impossible to estimate?

- The more rare or volatile a state is, the harder it is to get accurate statistics for it, or in other words, the more observations the smaller the standard deviation becomes.
- IceWeather: Reasonably predictable considering the level of accuracy in weather prognosis. (This is by itself a great accomplishment, but due to a lot of research in the subject of weather science we take fairly accurate predictions for granted)
- Water Leak/Pump failers: This would be fairly difficulty to predict. Stress tests outside the system might aid in assessing the probabilities, but it might be generally difficult to decide anything with any certainty when the unit is added to the system.
- PumpFailureWarning/WaterLeakWarning: The accuracy of these two should be fairly easy to predict, as repeated stress tests and simulated failures on the equipment they are connected to could easily be repeated.
- Meltdown: This must be considered as a difficult state to predict. The repeatability is very low, and this system is very dependent on a lot of other systems, thus adding to the complexity and in turn affecting the predictability negatively.

5d) 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?

Icy Weather most likely affects the water-leaks by water reaching a specific temperature, thus making the water freeze. If we assume that icy weather doesn’t always indicate that water is frozen, while water being frozen would always indicate icy weather, the change from icy weather temperature would make reduce the probability of water leaks occurring; the result would be this:

Icy Weather	P(WaterLeak=T)	P(WaterLeak=F)
T	Increases	Decreases
F	Decreases	Increases

6a) What does a probability table in a Bayesian network represent?

It tells how the probability for the given nodes possible states considering the different probabilities for its parents' states.

6b) 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?

0.9*0.95*0.95*0.9*0.95*0.999=0.687…
~69% chance makes it a pretty common state.

6c) 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 risk will be 20%, the value of IcyWeather will not affect the value as the bad thing that can happen cause of IcyWeather already have happened.

6d) 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.

$$P(M|\neg WL) = P(M|PF,\neg WL) * P(PF) + P(M|\neg PF,\neg WL) * P(\neg PF)$$
$$= 0.15 * P(PF) + 0.001 * P(\neg PF) \quad (1)$$

$$P(PF|\neg PFW) = P(\neg PFW|PF) * P(PF) * \alpha = 0.1 * 0.1 * \alpha = 0.01\alpha \quad (2)$$

$$P(\neg PF|\neg PFW) = P(\neg PFW|\neg PF) * P(\neg PF) * \alpha = 0.95 * 0.9 * \alpha = 0.855\alpha \quad (3)$$

$$(2) + (3): 1 = P(PF|\neg PFW) + P(\neg PF|\neg PFW) = 0.01\alpha + 0.855\alpha = 0.865\alpha \quad (4)$$

$$(4): 0.865 * \alpha = 1 \rightarrow \alpha = \frac{1}{0.865} \quad (5)$$

$$(5), (2)\ and\ (3)\ inserted\ in\ (1): P(M|\neg WL) = 0.15 * \frac{0.01}{0.865} + 0.001 * \frac{0.855}{0.865} = 0.00272$$

Part III: Extending a network

The owner of the nuclear plant is quite selfish and wants to optimize profit of the plant at the expense of safety, yet he is very worried about his future survival in case a problem with the plant arises. Instead of increasing the safety of the plant which is costly, he decides to analyse his chances of escaping from the plant in case of a melt-down. As an apprentice to the owner, the owner wants you to investigate the properties of his escape vehicle (his car). Your model of the car is the same as in exercise 14.7, figure 14.21 (p. 560) in the course book with the extension of the "*IcyWeather*" variable, which of course is the same as we already have in our model of the plant. After a year of observations and subjective assumptions you come up with the following conditional and prior probabilities:

- **P(battery | icyWeather) = 0.8**
- **P(battery | ¬icyWeather) = 0.95**
- **P(radio | battery) = 0.95**

- **P(ignition | battery) = 0.95**
- **P(gas) = 0.95**
- **P(starts | gas ∧ ignition) = 0.95**
- **P(moves | starts) = 0.95**
- **P(survives | moves ∧ melt-down) = 0.8**
- **P(survives | moves ∧ ¬melt-down) = P(survives | ¬moves ∧ ¬melt-down) = 1.0**
- **P(survives | ¬moves ∧ melt-down) = 0.0**

Fill in the rest of the probabilities by using common sense reasoning about the domain.

Task for part III

1. **Model the car with the applet tool and integrate it with the model of the plant.**

Assumptions

- If the battery doesn't work, the radio won't work
- If the battery doesn't work, the ignition won't work.
- If either ignition or gas fails, the car won't start
- Vad är "domains"?
- If car doesn't start, it won't move

2. **Answer the following questions:**
    - **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?**

"Survive" is monitored"

Chance of survival	
Before	0,99001
After	0,98116
Change	-0,00885

- **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?

"Survive" is monitored"

Chance of survival	
Before	0,99001
After	0,99505
Change	+0,00504

- **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 complexity is exponential in terms of the simulated systems tree-width.

The alternative to exact inference is approximate inference, this includes sthochastic simulation, Markov chain and Monte carlo methods, genetic algorithms, neural networks, simulated annealing, mean field theory

Part IV: More extensions

Scenario

After your excellent analysis of the plant's Bayesian Network and the creation of the model of the owner's car, he realizes that he is still in great danger. He comes to the conclusion that he needs to hire someone who is in charge of the plant's safety. After some job interviews he decides that a Mr H.S. is the most suitable person for the job because he practically works for free. But Mr H.S. has some less appealing properties:

- **He sleeps a lot during work which means that he can not react that rapidly to warning signals and so on.**
- **He is very incompetent. Even if he is awake it doesn't mean that he knows what to do in case of an emergency.**

You volunteer for the task of modeling Mr H.S.'s behavior with the help of the "Bayes Applet" tool.

Task for part IV

1. **Using your own modeling creativity, create a model of Mr H.S. with the Applet tool. The requirements of the model are the following:**
    - **It must be integrated with the model of the nuclear plant and must depend on the "WaterLeakWarning" and "PumpFailureWarning" stochastic variables.**
    - **It must contain at least four stochastic variables.**
    - **It should match fairly well with the informal description of Mr H.S.'s properties given in the scenario description.**

Four new variables introduced

Variable	Probability
Sleeps	0.4
Notices warning	If not asleep: +0.4 per alarm that beeps
	If asleep: +0.2 per alarm that beeps
Remembers what a warning mean	0.8
Able to act	If both remembers and hears: 0.6
	Otherwise: 0
Meltdown	If not able to act: no chance
	If able to act and 0 fail: 0
	If able to act and 1 fail: -0,09
	If able to act and 2 fail: -0.05

2. **Answer the following questions using your model:**
    - **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?**

	Risk of meltdown	Diff from H.S.
With Mr. H.S	0,02322	0
With orignal pump	0,02578	-0,00256
Neverfailing pump	0,01140	0,01182
With 0.0822 fail pump	0,02322	0

As the table indicates, any pump with a better performance than 0.0822 failure-rate will outperform Mr. H.S. Therefore it's completely possible to replace him.

- **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 too 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? (notice that this question involves a disjunction which can not be answered by querying the network directly)

To answer this question the last model, with the probabilities for Mr H.S. and both car and bike are used. To simulate the fact that Mr H.S. doesn't have a bike, we simply make the observation that the bike in the model doesn't work. Furthermore, due to Mr H.S. will to flee rather than facing the problem he is set to unable to act" and he is also set as if he doesn't notice the warning, thus negating any positive effects his presence might have had should he not have fled.

To calculate the disjunction we first add one node, whose probability is true if both or either of the warnings chime, and that is false if, and only if, neither of the warnings are chiming. This means that the probability of survival can be simulated by setting the "one or both alarms node" to TRUE.

The resulting probability is: 0.96610

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

One of the biggest assumptions would be rational behavior. There are many factors in a person that would, by most standards, be considered irrational. Another big assumption would be that not all probabilities can be determined; if accounting for every factor, weather, mood, sickness, bloodsugar, sleep… and so on, the network would be too huge to be feasible. As for minor behavior studies, the network might still provide fairly accurate results.

- **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.**

A model like the one illustrated below would be able to make an assumption for the third day based on two previous days.