Lab 3 - Report

Part - 2

5. Use the applet and the loaded Bayesian Network to answer the following questions

A. 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?

Answer:

The risk of meltdown if no observations have happened = P(meltdown) = 0.02578
The risk of meltdown if there is icy weather is = P(meltdown | icy weather = True) = 0.03472

B. 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|…).

Answer:

The risk of meltdown given both warning sensors indicate failure = P(meltdown | PumpWarningFailure, WaterLeakWarning) = 0.00273
The risk of failure in case of WaterLeak and PumpFailure = P(meltdown | waterleak, pumpfailure) = 0.2

C. 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?

Answer:

As conditional probabilities for the stochastic variables are estimated through experimentation and observation, the inability to conduct experiments for a specific condition and the limited availability of existing data are problematic in getting accurate numbers. I think the conditional probablity for a meltdown occurring in case of pump failure or a meltdown occurring due to water leaks are very difficult to find because of very limited historic data and also the inability to experiment because of the risk of actually causing a meltdown.

D. 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?

Answer:

I think that the domain for this variable will change to a continuous distribution from a minimum temperature to a maximum temperature.
Continuous probability distributions can be handled in two way

1. Discretisation - dividing up values into possible set of interval for which probability distributions can be found
2. To define the continuous variable using one of the standard probability density functions

6. To guide your understanding of how Bayesian networks work we provide a few theory questions below that should be answered using the lecture slides and/or book. When asked to calculate something manually **show your calculations**.

Clarification: You can read relevant conditional probabilities out of the tables in the applet ("View Probability Table"). This is just from the domain XML file you loaded above and not something the applet has calculated.

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

Answer:

A probability table in a bayesian network specifies the probability of variables of a node in a bayesian network.

B. 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?

Answer:

Joint probability distributions are probability distributions that assign values to a combination of variable/value pairs.

P(Meltdown=F, PumpFailureWarning=F, PumpFailure=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F)

= P(IcyWeather=F) * P(WaterLeak=F|IcyWeather=F) * P(WaterLeakWaring=F|WaterLeak=F) * P(PumpFailure=F) * P (PumpFailureWarning=F|PumpFailure=F) * P(Meltdown=F| PumpFailure=F,WaterLeak=F)

= 0.95 * 0.9 * 0.95 * 0.9 * 0.95 * 0.999 = 0.693779

C. 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!

Answer:

The risk of failure in case of WaterLeak and PumpFailure = P(meltdown | waterleak, pumpfailure) = 0.2
Knowing the state of any other variables will not matter as the nodes WaterLeak and PumpFailure have effects on Meltdown.

D. 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.

Answer

Calculating for Meltdown = T

P(Meltdown = T|PumpFailureWarning=F WaterLeakWaring=F, WaterLeak=F, IcyWeather=F)

= α * P(Meltdown = T , PumpFailureWarning=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F, PumpFailure=F) + P(Meltdown, PumpFailureWarning=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F, PumpFailure=T)

= α * P(IcyWeather=F) * P(WaterLeak=F|IcyWeather=F) * P(WaterLeakWaring=F|WaterLeak=F) * P(PumpFailure=F) * P (PumpFailureWarning=F|PumpFailure=F) * P(Meltdown=T| PumpFailure=F,WaterLeak=F) **+** P(IcyWeather=F) * P(WaterLeak=F| IcyWeather=F) * P(WaterLeakWaring=F|WaterLeak=F) * P(PumpFailure=T) * P (PumpFailureWarning=F|PumpFailure=T) * P(Meltdown=T|PumpFailure=T,WaterLeak=F)

= α * (0.95*0.9*0.95*0.9*0.95*0.001 + 0.95*0.9*0.95*0.1*0.1*0.15)

= α *(0.00069447375 + 0.001218375)

= α * 0.00191284875

Now calculating for Meltdown = F

P(Meltdown = F|PumpFailureWarning=F WaterLeakWaring=F, WaterLeak=F, IcyWeather=F)

= α * P(Meltdown = F , PumpFailureWarning=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F, PumpFailure=F) + P(Meltdown= F, PumpFailureWarning=F, WaterLeakWaring=F, WaterLeak=F, IcyWeather=F, PumpFailure=T)

= α * P(IcyWeather=F) * P(WaterLeak=F|IcyWeather=F) * P(WaterLeakWaring=F|WaterLeak=F) * P(PumpFailure=F) * P (PumpFailureWarning=F|PumpFailure=F) * P(Meltdown=F| PumpFailure=F,WaterLeak=F) **+** P(IcyWeather=F) * P(WaterLeak=F| IcyWeather=F) * P(WaterLeakWaring=F|WaterLeak=F) * P(PumpFailure=T) * P (PumpFailureWarning=F|PumpFailure=T) * P(Meltdown=F|PumpFailure=T,WaterLeak=F)

= α *(0.85 * 0.1 * 0.1 * 0.95 * 0.9 * 0.95 + 0.999 * 0.95 * 0.9 * 0.95 * 0.9 * 0.95)

= α * (0.006904125 + 0.730293975)

= α * 0.7371981

Now adding P(Meltdown = T |..) and P(Meltdown = F | ..) should give 1

Hence,

α * 0.00191284875 + α * 0.7371981 = 1

α = 1 / 0.73911094875

α = 1.35297684561

Hence the P(Meltdown = T|PumpFailureWarning=F WaterLeakWaring=F, WaterLeak=F, IcyWeather=F) = α * 0.00191284875 = 0.00258804006

PART - 3

Answer the following questions:

A. 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?

Answer:
P(survival | radio = false) = 0.10265

B. 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?

Answer:
Before introduction of the bicycle P(survival) = 0.99001
After Introduction of the bicycle P(survival) = 0.99505

So the probability of survival increases after introduction of the bicycle

C. 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?

Answer:
Complixity of exact infernence in Bayesian Networks depend on the structure of the network. Usually in networks that include propositional logic complexity of exact inference is NP-Hard.
An alternative for exact inference in Bayesian Networks is Approximate Inference

Part 4:

Answer the following questions using your model:

A. 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?

Answer:
P(meltdown) with Mr H.S = 0.02448
P(meltdown) without Mr H.S and existing pump failure probability =0.02578
P(meltdown) without Mr H.S and reducing pump failure probability by 10%(using better pump) = 0.01283
Hence it is better to invest in a better pump

B. 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?

Answer:

This disjunction can be solved by adding a new node *Emergency_warning* that is related to both *PumpFailureWarning* and *WaterLeakWarning.* The probability table of *Emergency_warning* can be designed such that it will be true if any one of the warning are true

P(Survival | Emergency_warning = T, Moves = T, H.S_SolvesEmergency=F) = 0.193393

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

Answer:

We had to make assumptions like the probability that a person was sleeping and had knowledge to fix an error which is really difficult to estimate and find out.

D. 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.

Answer:

This could be described using a transitional model in which specifies the probability distribution of the latest state variables given the previous values.