# Bayesian Networks
# Part III

Ullrika Sahlin, Centre of Environmental and Climate Research
Lund University, Sweden
Ullrika.Sahlin@cec.lu.se
http://www.cec.lu.se/ullrika-sahlin

# Can a BBN have continous nodes?

- Yes!
- Efficient algorithms for solving BBNs exists for nodes that have discrete or Gaussian distributions.
- It is possible to discretize any continuous distribution.

# The bnlearn package can build

- Discrete Bayesian networks
- Gaussian Bayesian networks
- Hybrid Bayesian networks which has the following constraints:

  - Discrete nodes can only have discrete parents
  - A continuous node with a continuous parent is specified as a Gaussian network
  - A continuous node with a discrete parent look up its mean and standard error from a table

  http://www.bnlearn.com/examples/custom/

# Is there a difference between BBN and BHM?

- BBN is a simplified quantitative (probabilistic) model since
  - BBNs are usually discrete networks
  - BBNs do not usually consider uncertainty in parameters, only uncertainty in state variables
- Bayesian modelling (BHM) does not differentiate between parameters and state variables, and parameters can be uncertain as well.
- BBN is a special case of a BHM
- Question: Is there a problem not considering uncertainty in parameters?
- Question: Is there a difference in how the parameters are informed in BHM and BBN?

# Things that we discussed

- When you start an assessment you need to think what type of model you need for your problem. It could be a BN or not.
- If you use a BN – you can code this in what way your want, write the whole code from scratch, use an existing software. Never let the software limit what you want to do.
- Softwares are userfriendly and good to show to enduser what the model is and what it is doing. It is not necessary to show all parts of the model, e.g. the submodels to get the parameters.

- When is the model ready? – never, modelling is an iterative process
- Model validation
- Extrapolation from the domain of a model
- Use common sense

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# Things that we discussed

- Parameters in a BN can be assinged by other models (e.g. process models, or statistical models, relative frequences, etc) and both principles from classical statistics and Bayesian data analysis/calibration are possible to use.
- I.e. a BN in itself is a probabilistic causal network and there is no requirement of parameters to be assigned using Bayesian principles.
- A BN treat parameters, i.e. the (conditional) probabilities, as without uncertainty.
- Bayesian principles to learn parameters can be made by temporaily treating parameters as uncertain, use the current parameters as priors, apply Bayes rule to update and then take the posterior mean (or similar) for the parameters as the new parameter values. This process is not seen when running a BN in a software like netica, hugin or genie.

# Things that we discussed

- Forward simulation means propagating uncertainty in the direction of the edges.
- Backward simulation is made when we apply Bayes rule (inverse modelling) to make predictions in the opposite direction of the edges.
- There are several algorithms to perform backward simulation, ranging from pure calculations, sampling from the posterior using MCMC, MH, ABC, etc.
- People understand forward and backward simulation – no need to mention any details of how it is made.

# Things that we discussed

- The recommendation in probabilistic risk assessment is to separate between aleatory (inherent randomness, non-reducable) uncertainty and ignorance (lack of knowledge on something) for example using 2 dimensional MC forward simulation.
- In my view, the probability in a BN should represent either aleatory or ignorance, but not both. In many applications, this distinction is not clear – perhaps because it is obvious to the user what is done.
- Another option is to add intervals on the parameters. One name for this is a credal network. There are plenty of theoretical results on forward and backward simulation of credal networks.

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# Name competition

- Probabilistic causal network (clearly in the top)
- Bayesian Belief Network
- Bayesian Network
- Influence Diagram (requires decision and utility nodes)
- Uncertainty Network (bad suggestion)