Introduction to Bayesian networks

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Contents

- What is a Bayesian network?
- Model building
- Algorithms for inferences
- Software tools

What is a Bayesian network?

Definition (Jensen and Nielsen (2007))

A Bayesian network consists of the following:

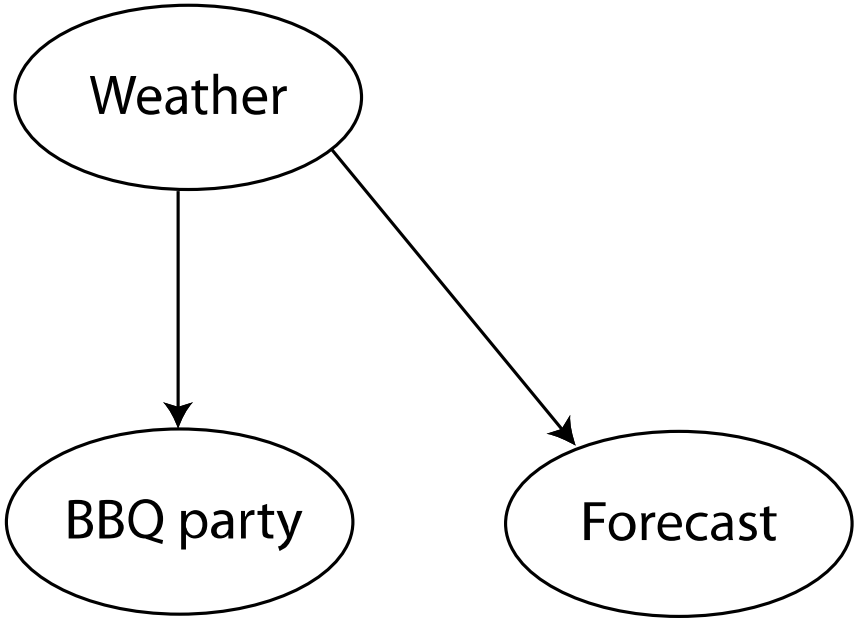
- A set of variables and a set of directed edges between variables.
- The variables together with the directed edges form an acyclic directed graph (DAG).
- Each variable has a finite set of mutually exclusive states.
- To each variable, there is a conditional probability table attached.

Jensen, F.V. and Nielsen, T.D. (2007) Bayesian Networks and Decision Graphs second edition, Springer.

Remark

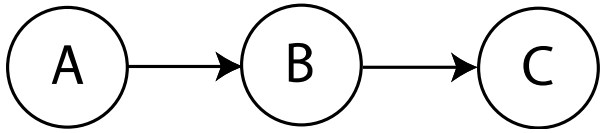
The third and fourth properties may be extended properly so that a network allows for considering continuous variables.

Example of a Bayesian network

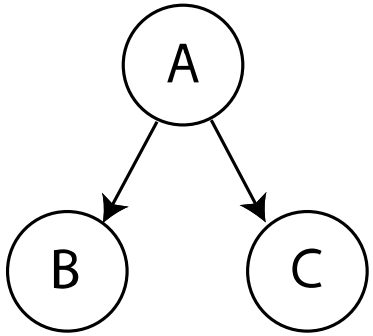


Types of connections

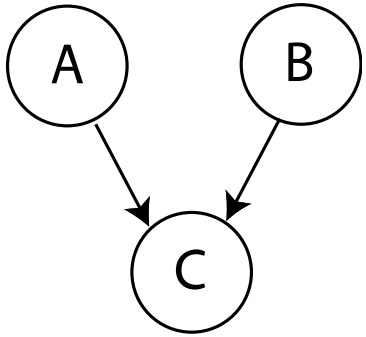
- Serial connection



- Diverging connection



- Converging connection



Any connections in Bayesian networks belong to one of the three types.

d-separation

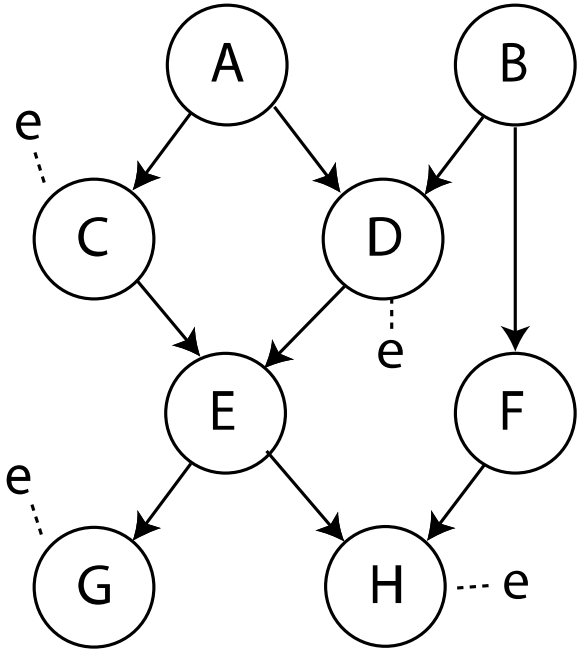
Definition (Jensen and Nielsen (2007))

Two distinct variables A and B in a network are d-separated if for all paths between A and B, there is an intermediate variable V (distinct from A and B) such that

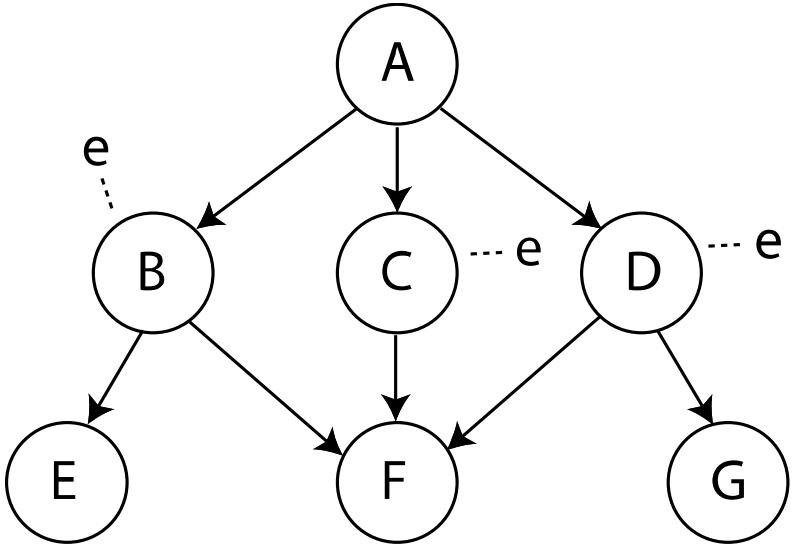
- either the connection is serial or diverging and V is instantiated or
- the connection is converging, and neither V nor any of V's descendants have received evidence.

→ concerns conditional independency.

Questions



E is d-separated to which?



F is d-separated to which?

Fig. 2.11. in Jensen and Nielsen (2007).

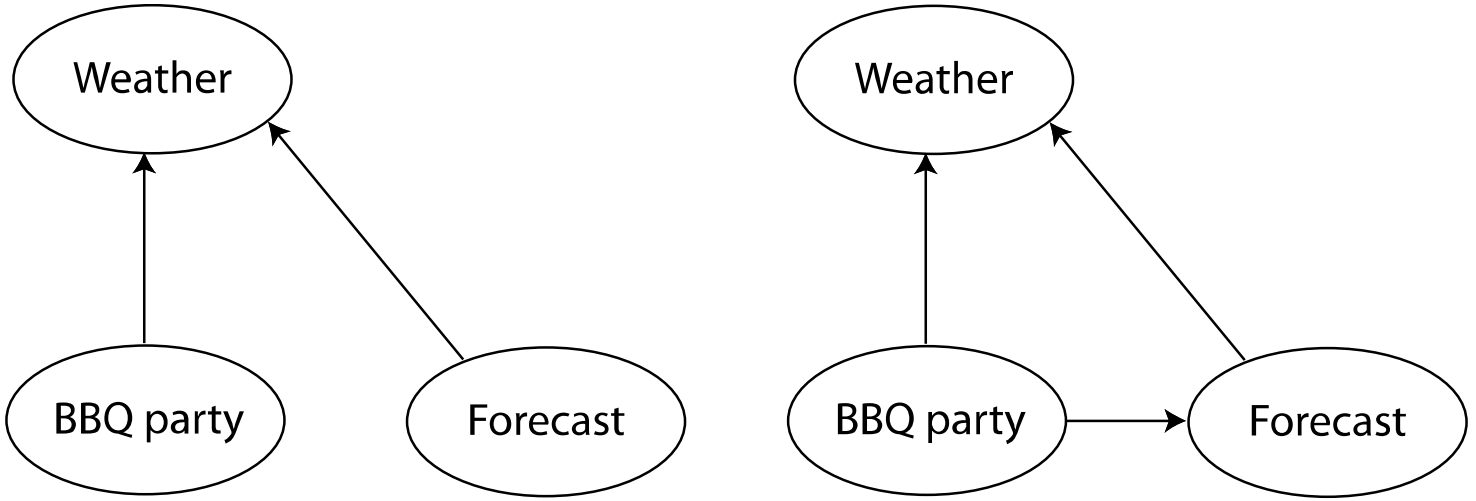
Causal relation in Bayesian networks

Direct arrows in accordance with causal relations!

Why?

Causal relation in Bayesian networks

Because it leads to a minimal representation of the problem in consideration.



The network on the left is not appropriate, because BBQ party and Forecast are independent.

Chain rule for Bayesian networks

Joint probability representation as a product of conditional probabilities.

$$P(U) = \prod_i P(A_i \mid pa(A_i))$$

where

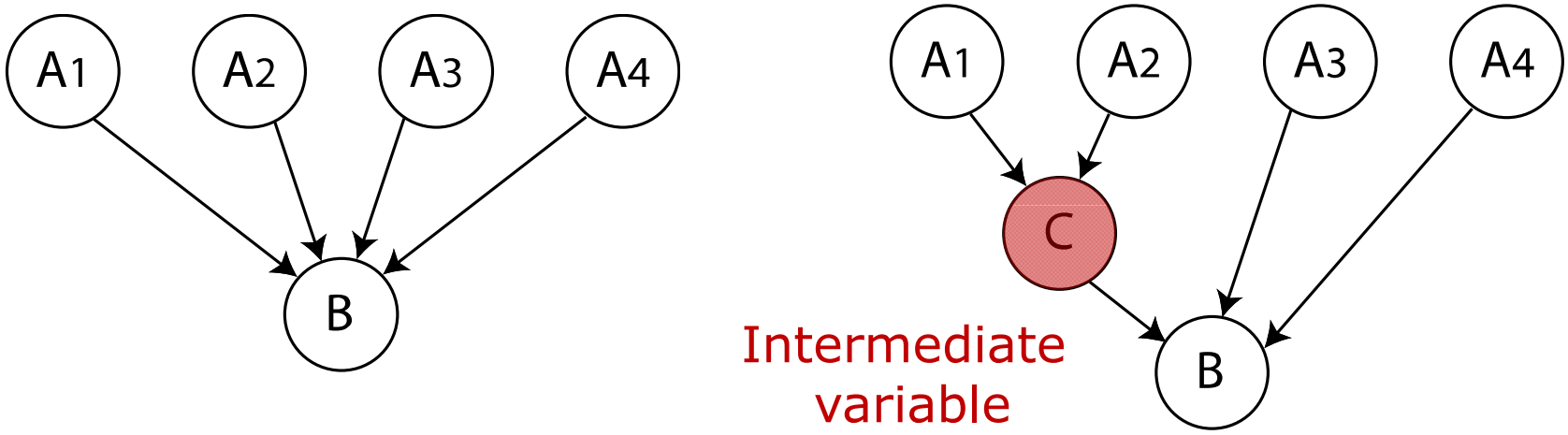
$U = \{A_1, A_2, ..., A_n\}$ is the states of all the variables,

A_i represents the state of i^{th} variable,

$pa(A_i)$ represents the states of the parents of i^{th} variable.

→ A compact representation of joint probability

Divorcing - a useful technique



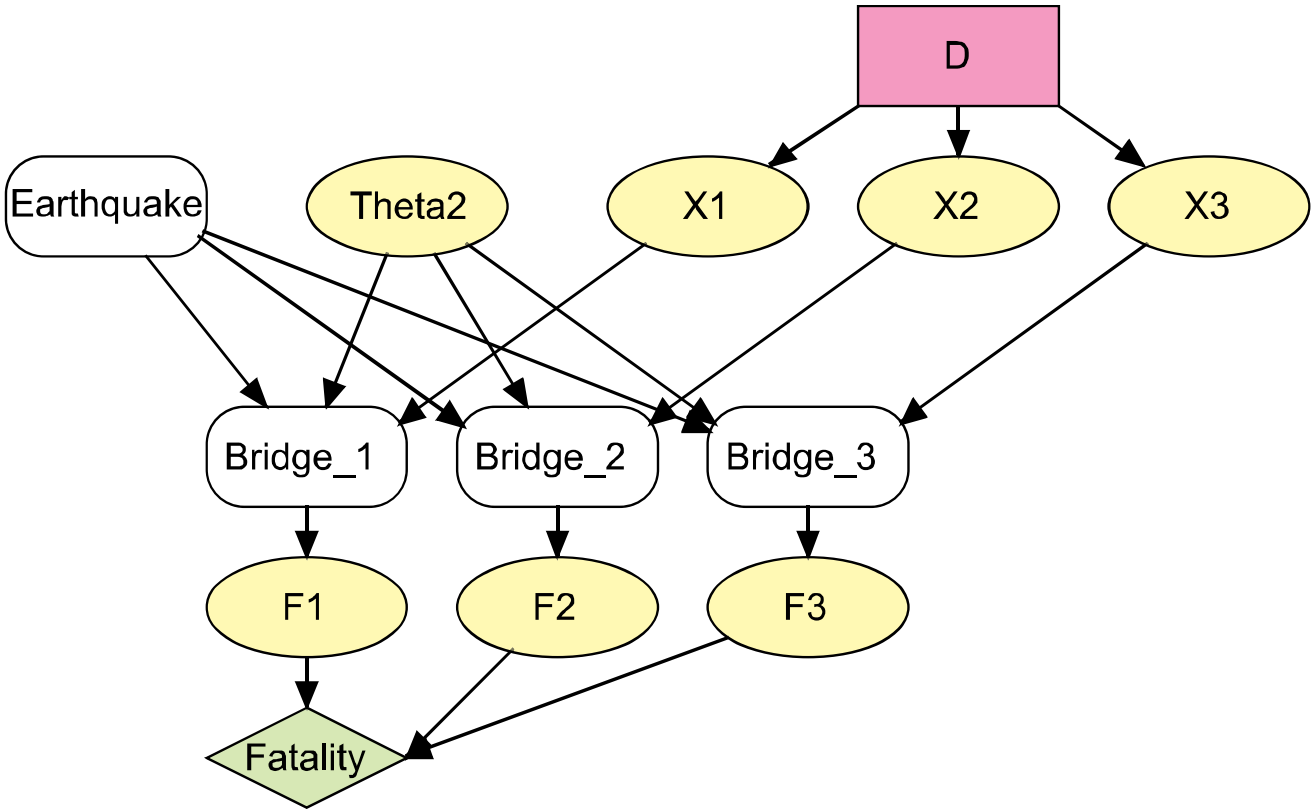
→ Size of the conditional probability tables is reduced.

Fig. 3.26. in Jensen and Nielsen (2007).

Extensions of Bayesian networks

- Object-oriented Bayesian networks
- Dynamic Bayesian networks

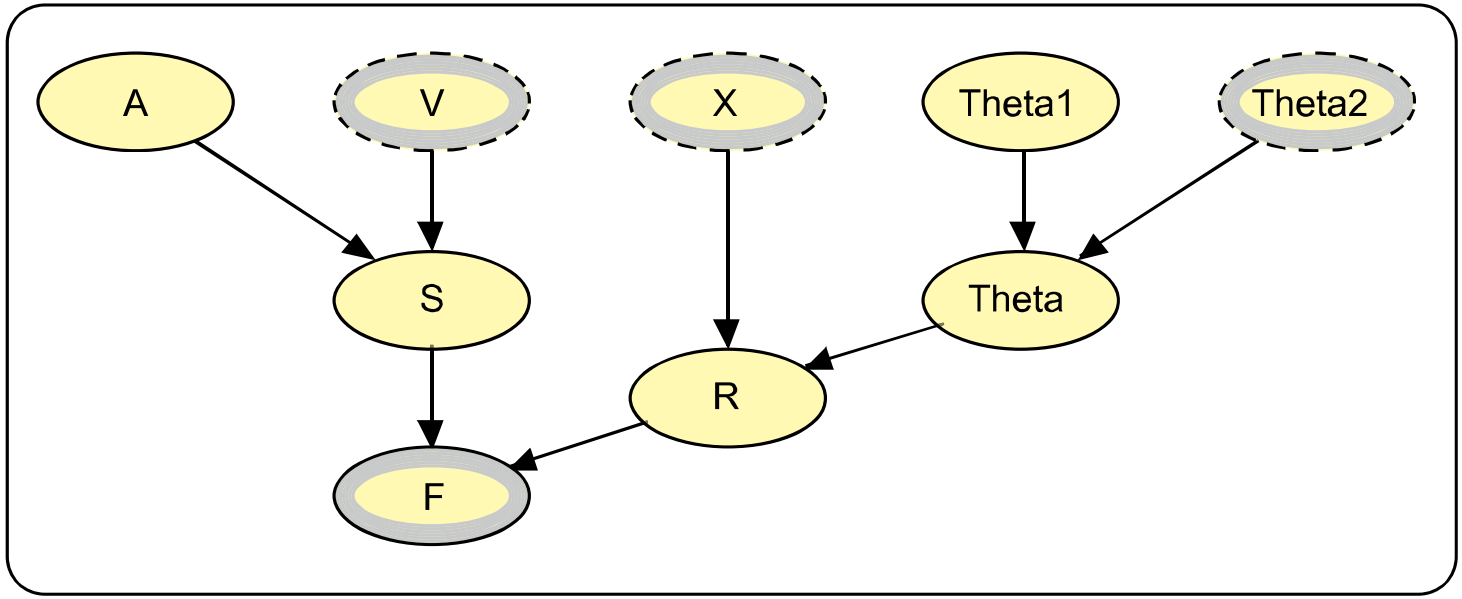
Example of the object-oriented Bayesian networks



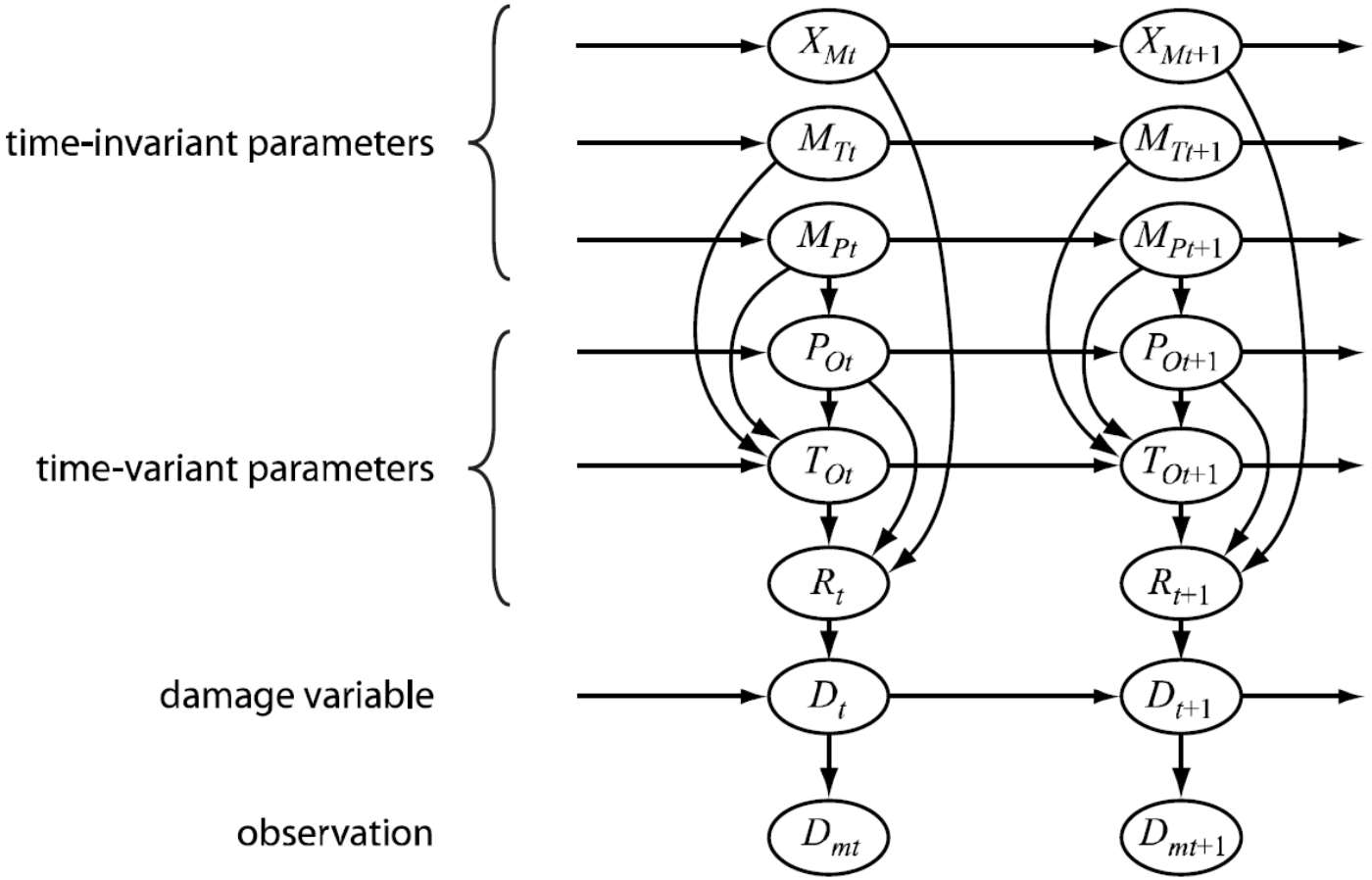
Nishijima K., Maes M.A., Goyet J., Faber M.H.. Constrained optimization of component reliabilities in complex systems. Structural Safety 2009; 31 168-78.

Example of the object-oriented Bayesian networks

Bridge_1 Bridge_2 Bridge_3



Example of dynamic Bayesian networks



Straub, D. (2009) An efficient computational framework for probabilistic deterioration modeling and reliability updating, ICOSSAR2009, Osaka, Japan.

Some algorithms for inferences

Exact inferences ⟵

- Junction tree propagation

Implementation into Bayesian networks by means of
- Discretization
- Mixture of truncated exponentials (MTE) etc.

Approximate inferences

- Loopy belief updating
- Variational approximations

Stochastic inferences

- Likelihood weighting
- Gibbs sampling
- Metropolis-Hasting sampling
- Slice sampling

See Langseth et al. (2009) and Jensen and Nielsen (2007).

Langeth, H., Nielsen, T.D., Rumi, R. and Salmeron, A. (2009) Inference in hybrid Bayesian networks, Reliability Engineering and System Safety, 94, pp. 1499-1509.

Software for Graphical models/Bayesian networks

More than 50 software tools are available as of August 2009:
see http://people.cs.ubc.ca/~murphyk/Software/bnsoft.html

Among others

- Hugin (http://www.hugin.com/)
- GeNIe (http://genie.sis.pitt.edu/)
- Winbugs (http://www.mrc-bsu.cam.ac.uk/bugs/)

Demonstration of the use of software tools

- Hugin
- GeNIe
- Winbugs

Administration

- Please send me your the file for your presentation by one day before the presentation.
- Duration of the presentation is about 45-60 minutes.
- Presented materials are uploaded, if not disagreed.

- Self-introduction including your interests/applications of Bayesian networks.