ALBERT-LUDWIGS-
UNIVERSITÄT FREIBURG

Advanced AI Techniques

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Overall Course Outline

I. Learning Bayesian Networks

II. Probabilistic Approaches to Natural Language Understanding

III. Probabilistic Approaches in Robotics (MDPs and POMDPs)

VI. Game-Theoretic Approaches to Multi-Agent Systems

Each of these topics will be covered in roughly four weeks.

1. Bayesian Networks – Introduction / Repetition

structure: The graph structure encodes the factors of a JPD:

- nodes represent variables,
- edges represent "direct dependencies".

parameters: Specified by a conditional probability table (CPT) attached to each node quantify direction / strength of dependencies:

$$p(x|\,\mathrm{fanin}(x))$$

$$p(x_1,\ldots,x_n) = \prod_{i=1}^{n} p_i(x_i \mid \mathrm{fanin}(x_i))$$

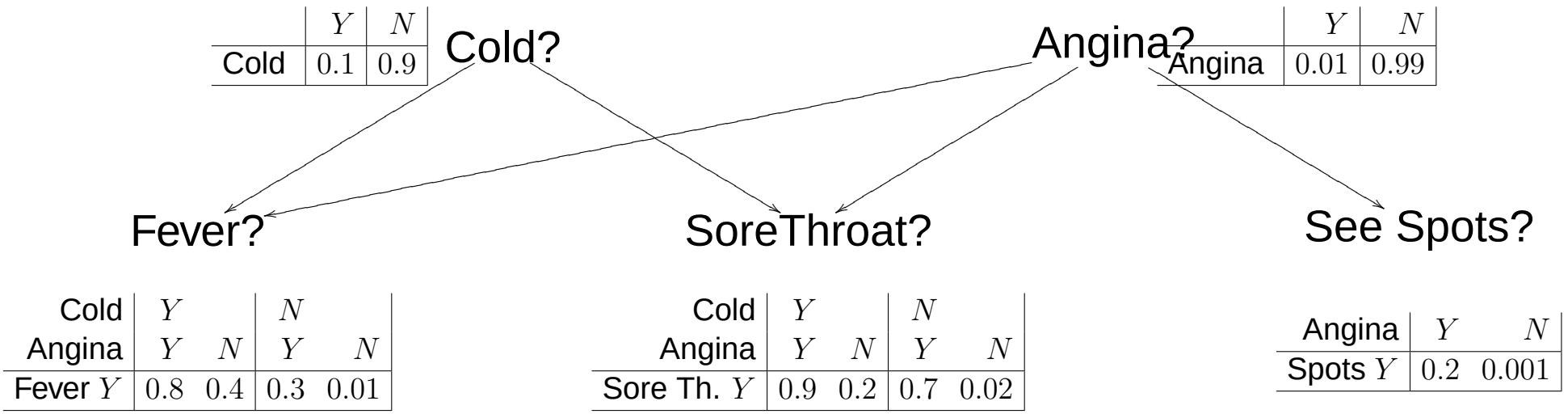

Figure 1: Example Bayesian Network.

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2. Learning Parameters

If we know

- which variables may influence which others (the structure),
- but not the exact quantities (the parameters),
- and we have data,

we can estimate the parameters from data.

Case	Cold	Angina	Fever	Sore Throat	See Spots
1	Y	N	Y	N	N
2	N	Y	Y	N	Y
3	Y	N	N	Y	N
4	Y	Y	N	N	N
5	N	N	Y	Y	Y
6	N	Y	Y	Y	N
7	Y	Y	N	N	Y
⋮	⋮	⋮	⋮	⋮	⋮

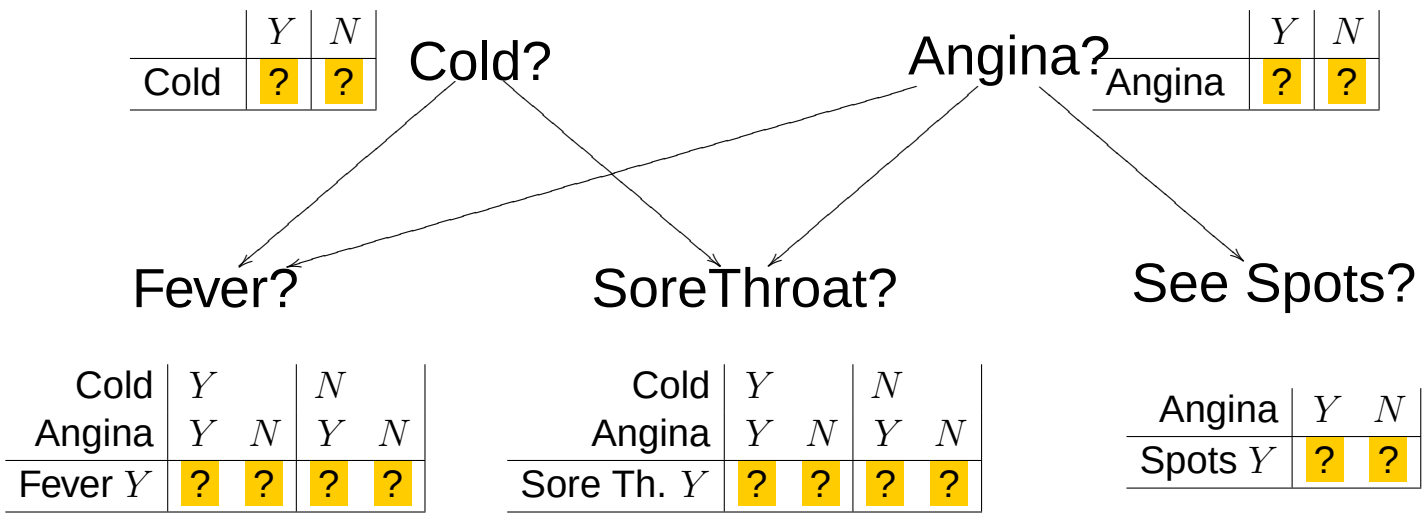

Figure 2: Bayesian network structure with unknown parameters.

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we can estimate the parameters from data.

Case	Cold	Angina	Fever	Sore Throat	See Spots
1	Y	N	Y	N	N
2	?	Y	Y	N	Y
3	Y	N	?	Y	N
4	Y	Y	N	N	N
5	N	N	Y	Y	?
6	N	Y	Y	Y	N
7	Y	Y	N	N	Y
⋮	⋮	⋮	⋮	⋮	⋮

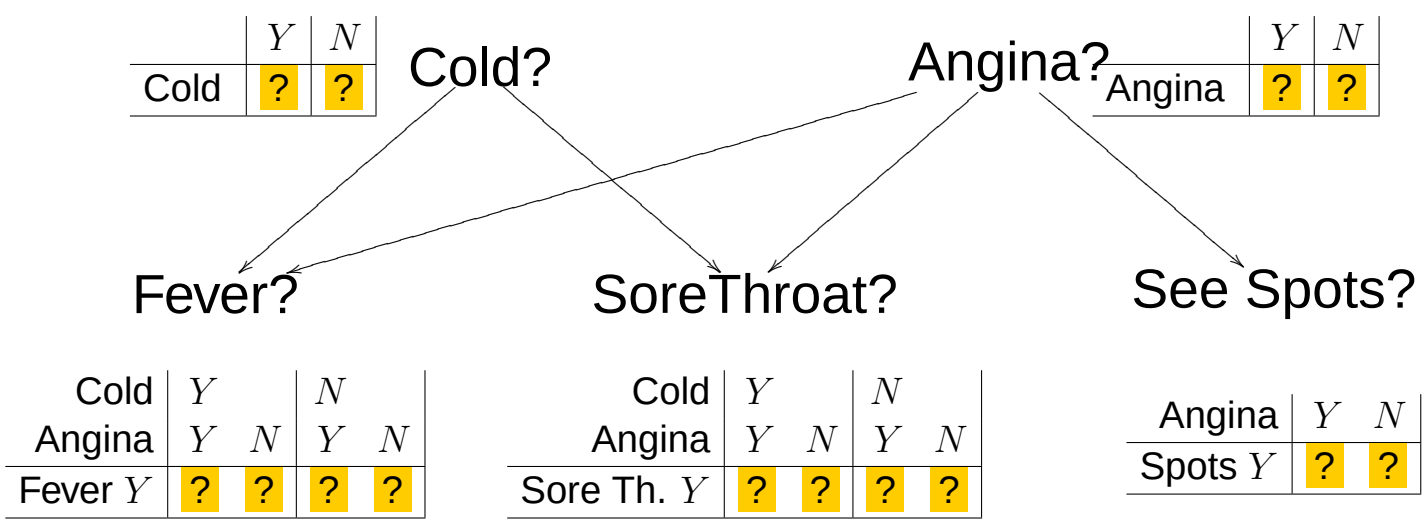

Figure 2: Bayesian network structure with unknown parameters.

3. Learning Structure

Learning structure requires

- the specification of a model selection criterion as well as
- a search procedure over a subspace of possible graph structures.

Case	Cold	Angina	Fever	Sore Throat	See Spots
1	Y	N	Y	N	N
2	N	Y	Y	N	Y
3	Y	N	N	Y	N
4	Y	Y	N	N	N
5	N	N	Y	Y	Y
6	N	Y	Y	Y	N
7	Y	Y	N	N	Y
⋮	⋮	⋮	⋮	⋮	⋮

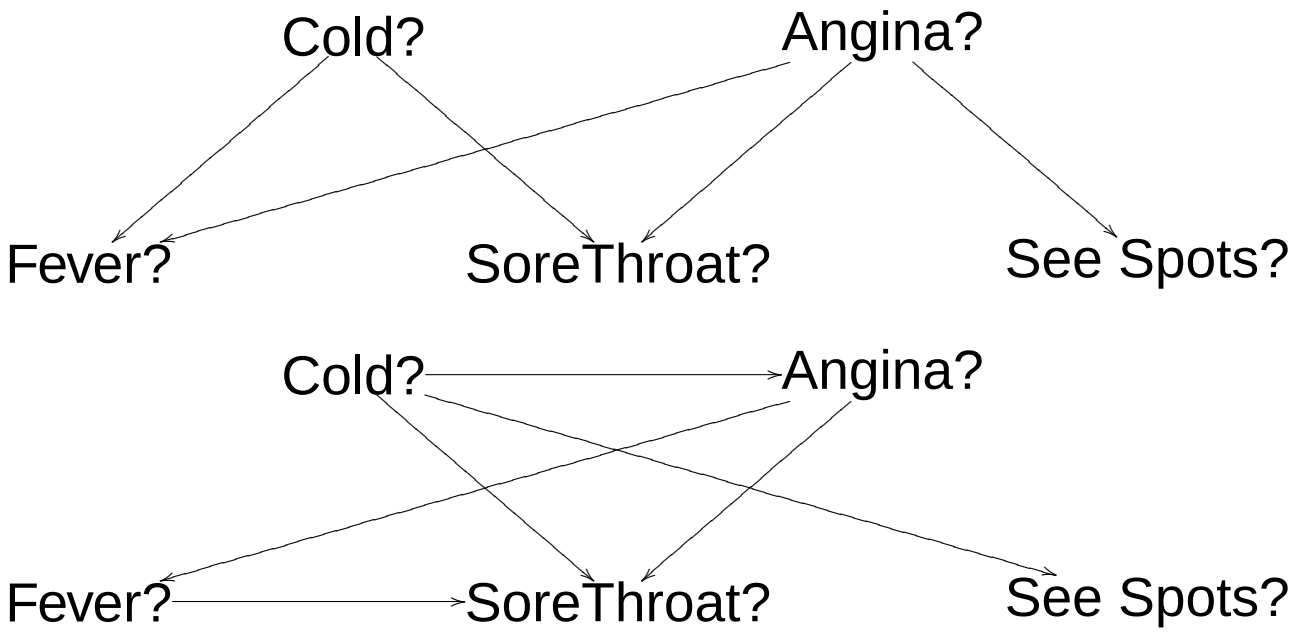

Figure 3: Different bayesian network structures.

Text books

- Richard E. Neapolitan. *Learning Bayesian Networks*. Prentice Hall, 2003
- Finn V. Jensen. *Bayesian networks and decision graphs*. Springer, New York, 2001
- Enrique Castillo, José Manuel Gutiérrez, and Ali S. Hadi. *Expert Systems and Probabilistic Network Models*. Springer, New York, 1997
- Christian Borgelt and Rudolf Kruse. *Graphical Models*. Wiley, New York, 2002

Bayesian Networks Software

open source:

- BNJ (Java, http://bndev.sourceforge.net, W.H. Hsu)
- jBNC (Java, http://jbnc.sourceforge.net, J. Sacha), can be integrated in Weka.
- unbbayes (Java, http://unbbayes.sourceforge.net, B. Domingues et al.)
- PNL (C++, http://www.intel.com/research/mrl/pnl, V. Eruhimov & K.Murphy).

open source, based on commercial software:

- Bayes Net Toolbox (Matlab, http://www.ai.mit.edu/~murphyk/Software/BNT/bnt.html, K. Murphy), based on Matlab.

commercial software:

- Hugin (http://www.hugin.com)
- WinBugs (http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/contents.shtml, D. Spiegelhalter).

. . . and there are many others (see http://www.ai.mit.edu/~murphyk/Bayes/bnsoft.html).

Exercises and tutorials

- There will be exercise sheets
- Exercises will be corrected.
- Tutorials by Alexander Scivos (AI Group Bernhard Nebel)

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References

[BK02] Christian Borgelt and Rudolf Kruse. *Graphical Models*. Wiley, New York, 2002.

[CGH97] Enrique Castillo, José Manuel Gutiérrez, and Ali S. Hadi. *Expert Systems and Probabilistic Network Models*. Springer, New York, 1997.

[Jen01] Finn V. Jensen. *Bayesian networks and decision graphs*. Springer, New York, 2001.

[Nea03] Richard E. Neapolitan. *Learning Bayesian Networks*. Prentice Hall, 2003.