## Foundations of Artificial Intelligence

Prof. Dr. B. Nebel, Prof. Dr. W. Burgard
B. Frank, A. Karwath, G. Röger
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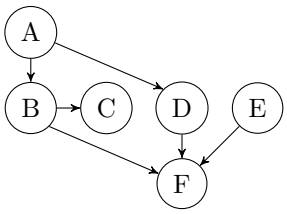
University of Freiburg
Department of Computer Science

# Exercise Sheet 9

**Due: Tuesday, July 7, 2009**

**Exercise 9.1** (Bayesian Networks)

Consider the following Bayesian network:




(a) Rewrite the joint probability distribution $P(A, B, C, D, E, F)$ using the conditional independencies expressed by the network.

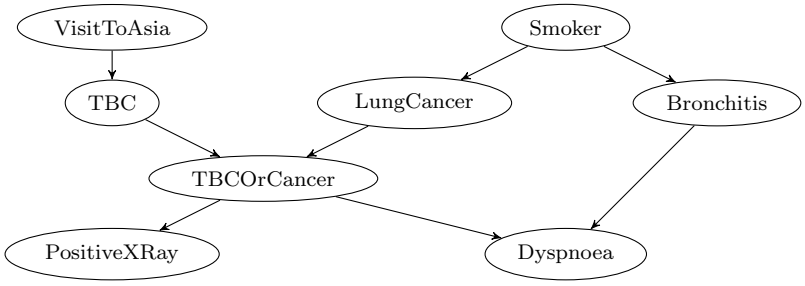
(b) Suppose that all the random variables $A, B, C, D, E, F$ in the Bayesian network can only have two possible values *yes* and *no*. What's the minimum number of probabilities required to fully define the Bayesian network whose structure is given above?

*Hint:* Remember that e.g. $P(E = yes) = 1 - P(E = no)$.

(c) How many probabilities would be required to define the full joint distribution over $A, B, C, D, E, F$ if we could not assume the conditional independencies expressed by the Bayesian network?

**Exercise 9.2** (Bayesian Networks)

Consider the following Bayesian network:




(a) Determine which of the following conditional independence statements follow from the structure of the Bayesian network ($Ind(U, V \mid W)$ denotes that $U$ is conditionally independent of $V$ given $W$, and $Ind(U, V)$ denotes unconditional independence of $U$ and $V$):

(i) $Ind(TBC, VisitToAsia)$

(ii) $Ind(VisitToAsia, Smoker)$

(iii) $Ind(VisitToAsia, PositiveXRay \mid TBCOrCancer)$

(iv) $Ind(VisitToAsia, Dyspnoea \mid TBCOrCancer)$

(v) $Ind(TBC, Smoker \mid PositiveXRay)$

(b) Compute $P(Dyspnoea|Smoker, \neg TBC)$. The relevant entries in the conditional probability tables are given below:

$$
\begin{aligned}
P(LungCancer|Smoker) &= 0.1 \\
P(LungCancer|\neg Smoker) &= 0.01 \\
P(Bronchitis|Smoker) &= 0.2 \\
P(Bronchitis|\neg Smoker) &= 0.1 \\
P(TBCOrCancer|TBC, LungCancer) &= 1 \\
P(TBCOrCancer|TBC, \neg LungCancer) &= 1 \\
P(TBCOrCancer|\neg TBC, LungCancer) &= 1 \\
P(TBCOrCancer|\neg TBC, \neg LungCancer) &= 0 \\
P(Dyspnoea|TBCOrCancer, Bronchitis) &= 0.9 \\
P(Dyspnoea|TBCOrCancer, \neg Bronchitis) &= 0.7 \\
P(Dyspnoea|\neg TBCOrCancer, Bronchitis) &= 0.6 \\
P(Dyspnoea|\neg TBCOrCancer, \neg Bronchitis) &= 0.05
\end{aligned}
$$

**Exercise 9.3** (POP algorithm)

Consider a planning problem with initial state $\{x\}$ and goal $\{y, z\}$ as well as the actions $a_1 = \langle\{x\}, \{\neg x, y\}\rangle$, $a_2 = \langle\{x\}, \{\neg x, z\}\rangle$, and $a_3 = \langle\emptyset, \{x\}\rangle$, where the first components of the tuples always denote the preconditions and the second components denote the effects.
Sketch a complete and consistent plan including all temporal and causal links as it would be computed by the POP algorithm.

The exercise sheets may and should be handed in and be worked on in groups of three (3) students. Please fill the cover sheet[1] and attach it to your solution.

[1] `http://www.informatik.uni-freiburg.de/~ki/teaching/ss09/gki/coverSheet-english.pdf`