Artificial Intelligence

Bayesian Networks

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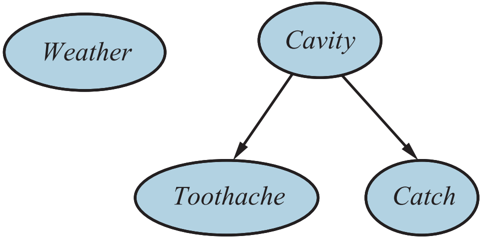
Representation of Uncertain Knowledge

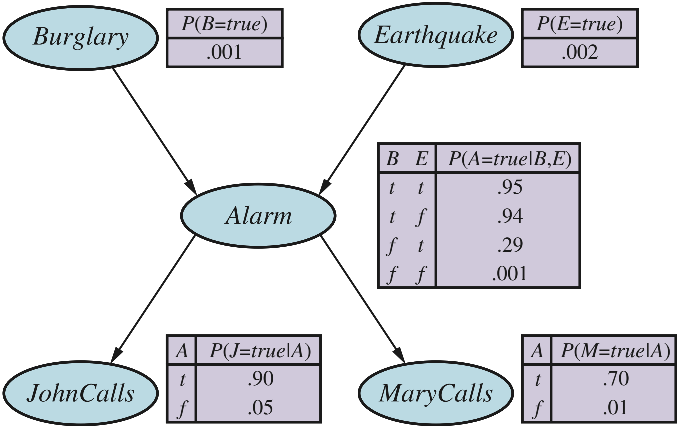
AIMA

Bayesian Network Topology



Conditional Probability Tables

The *syntax* of a Bayes net consists of a directed acyclic graph (DAG) with some local probability information attached to each node.



P(B=true)
.001

P(E=true)
.002

B	E	P(A=true|B,E)
t	t	.95
t	f	.94
f	t	.29
f	f	.001

A	P(J=true|A)
t	.90
f	.05

A	P(M=true|A)
t	.70
f	.01

Semantics of Bayesian Networks

The *semantics* defines how the syntax – a DAG with local probabilities – corresponds to a joint distribution over the variables of the network.

A Bayes net contains:

- n variables, $X_1, \ldots, X_n$, and
- (implicit) joint distributions $Pr(X_1 = x_1 \wedge \cdots \wedge X_n = x_n)$, or $Pr(x_1, \ldots, x_n)$.

Each entry in the joint distribution is defined by:

$$Pr(x_1, \ldots, x_n) = \prod_{i=1}^{n} \theta(x_i | parents(X_i))$$

where $parents(X_i)$ denotes the values of $Parents(X_i)$ that appear in $x_1, dots, x_n$. So each entry in the joint distribution is the rpoduct of appropirate elements of the local CPTs in the Bayes net.

Constructing Bayesian Networks

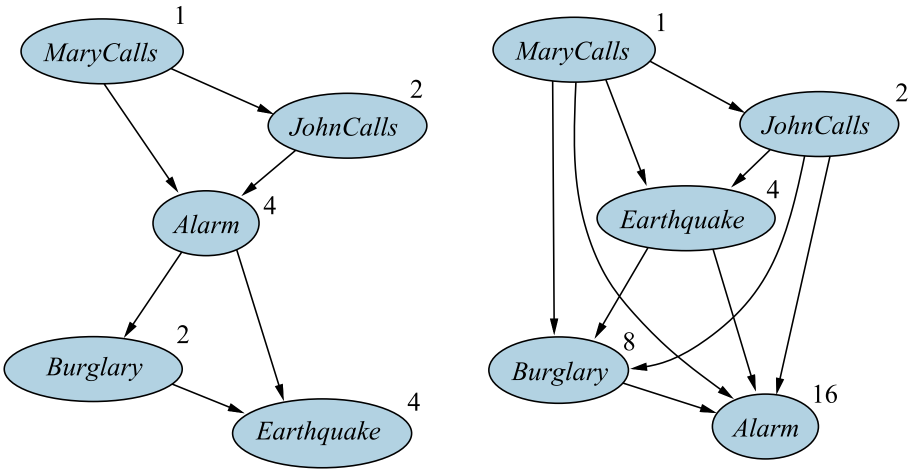
First, meet conditions:

TODO: conditions

1. Nodes: First determine the set of variables that are required to model the domain. Now order them, $\{X_1, \ldots, X_n\}$. Any order will work, but the resulting network will be more compact if the variables are ordered such that causes precede effects.
2. Links: For $i = 1$ to n do:

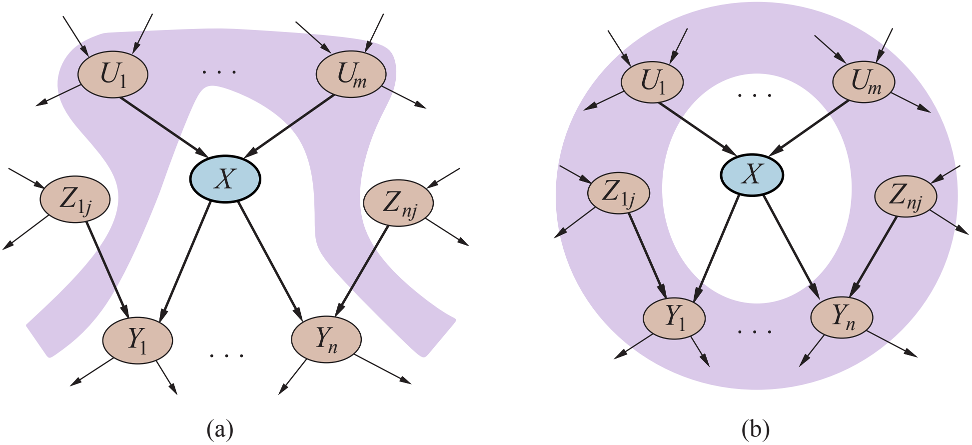
- Choose a minimal set of parents for X_i from $X_1, \ldots, X_{i-1}$, such that Equation (13.3) is satisfied.
- For each parent insert a link from the parent to X_i.
- CPTs: Write down the conditional probability table, $P(X_i | Parents(X_i))$.

Effects of Node Ordering



(a) (b)

Conditional Independence Relations

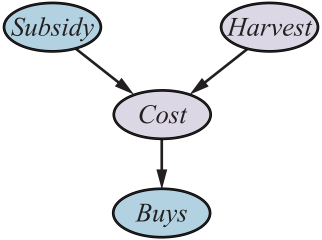


CPTs Under Noisy-or Model

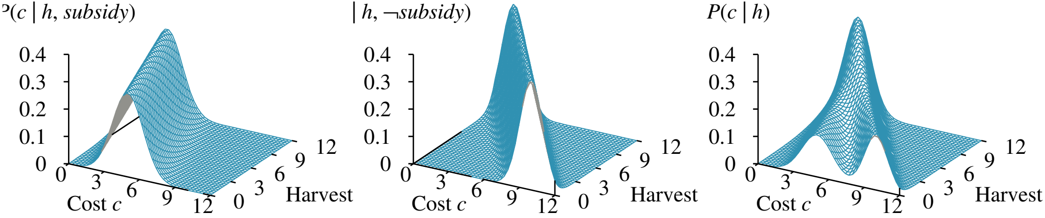
$Cold$	Flu	$Malaria$	$P(fever \mid \cdot)$	$P(\neg fever \mid \cdot)$
f	f	f	0.0	1.0
f	f	t	0.9	**0.1**
f	t	f	0.8	**0.2**
f	t	t	0.98	$0.02 = 0.2 \times 0.1$
t	f	f	0.4	**0.6**
t	f	t	0.94	$0.06 = 0.6 \times 0.1$
t	t	f	0.88	$0.12 = 0.6 \times 0.2$
t	t	t	0.988	$0.012 = 0.6 \times 0.2 \times 0.1$

Bybrid Bayesian Networks

Bayesian Networks with Discrete and Continuous Variables



Linear-Gaussian Conditional Distributions



(a) (b) (c)

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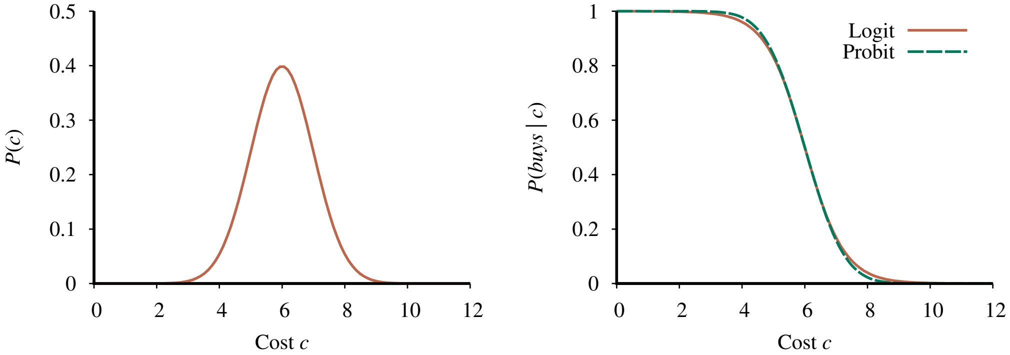
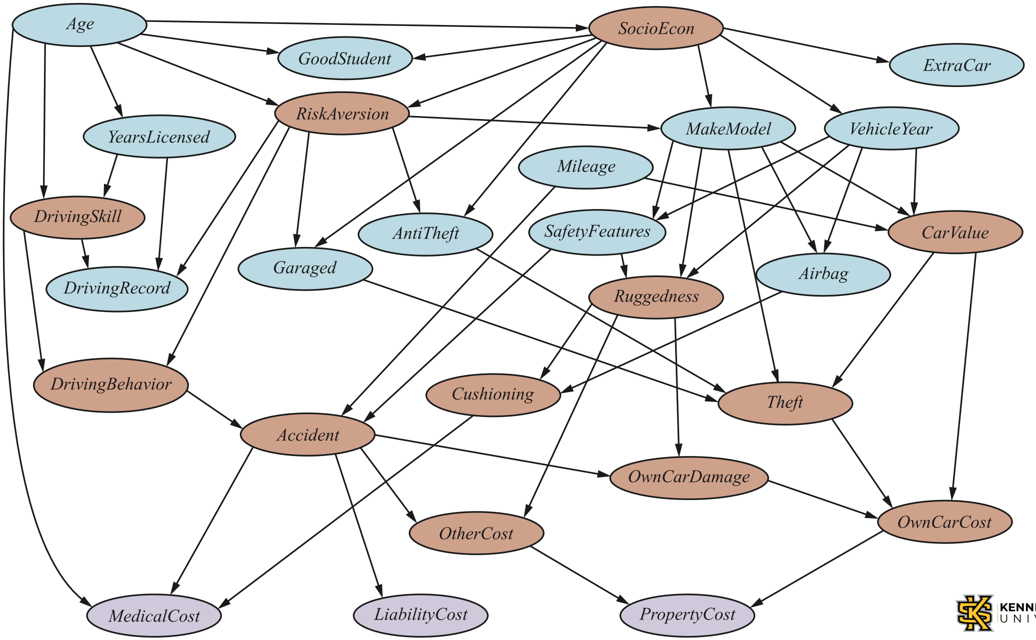
Soft Thresholding for Continuous Parents



(a) (b)

Case Study: Car Insurance



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