ARTIFICIAL INTELLIGENCE & CYBER SECURITY

BAYESIAN NETWORKS

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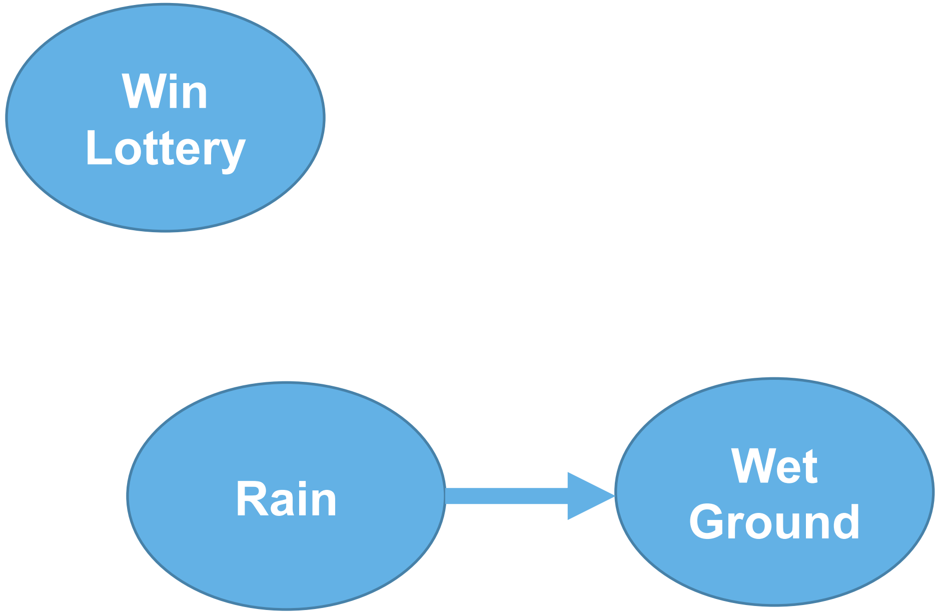
Bayesian examples
Initial example

Joint probability distribution

$$P(L, R, W)$$

Given the graph

$$= P(L)\,P(R)\,P(W \mid R)$$



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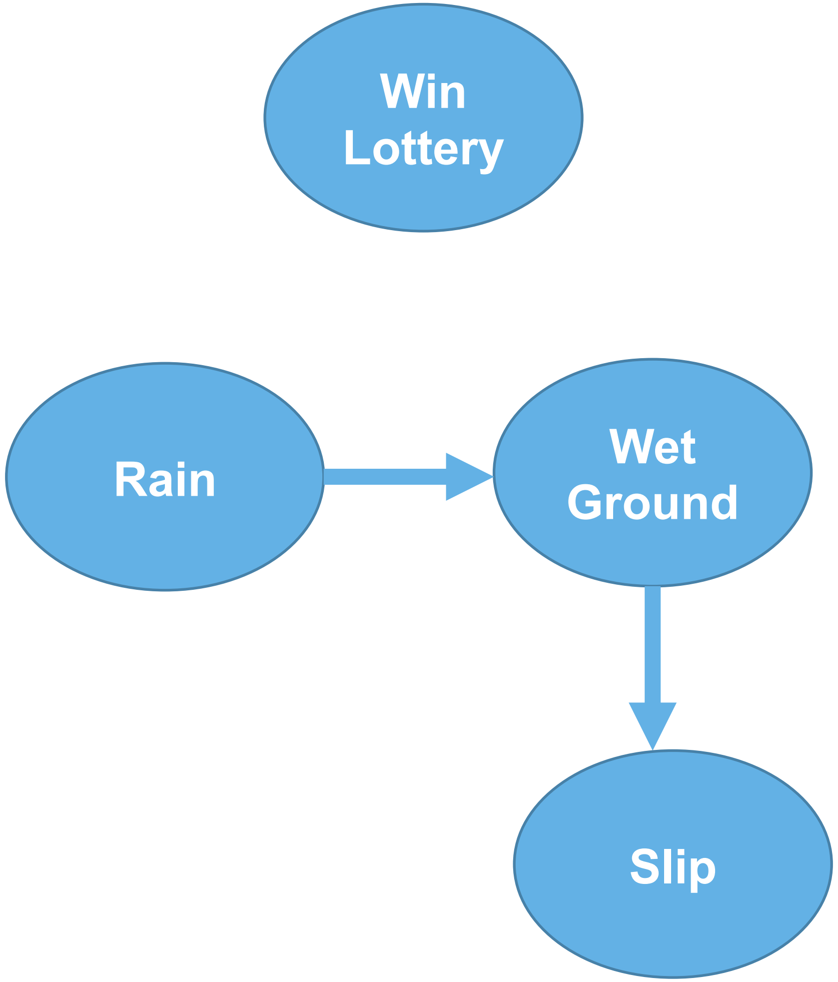

$P(L, R, W, S)$

$= P(L)\,P(R)\,P(W \mid R)\,P(S \mid W)$

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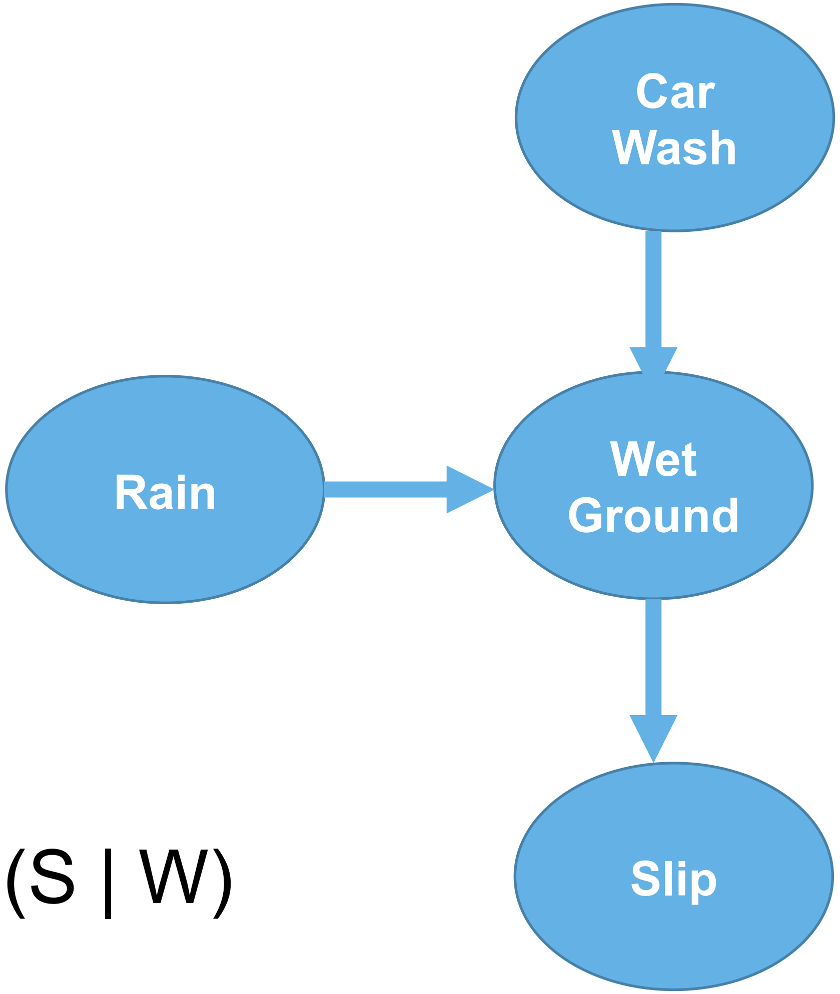

P(R, W, S, C)

= P(R) P(C) P(W | R,C) P(S | W)

P(X | Parents (X))

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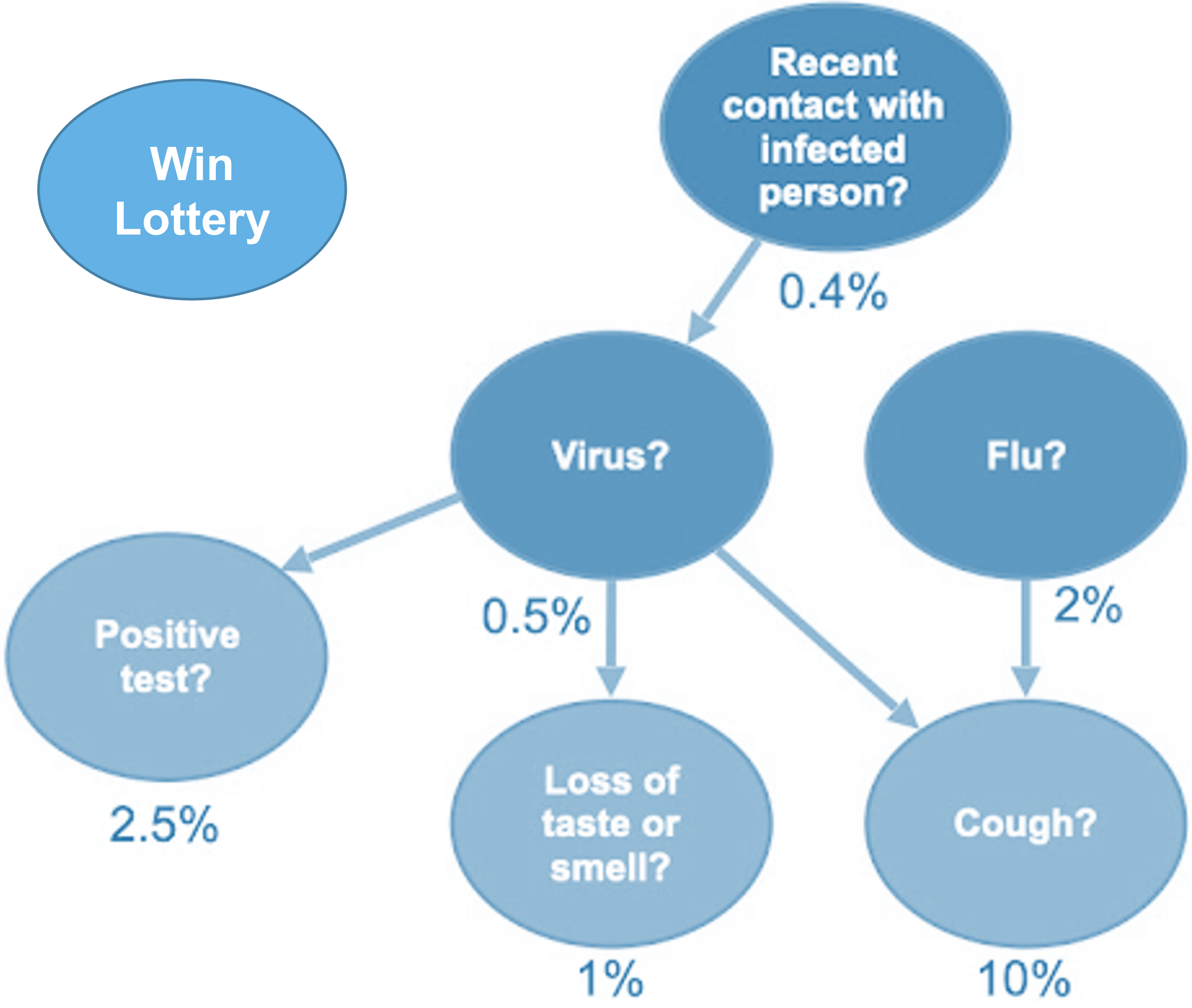
Initial example



http://www.cs4fn.org/smarthealth/bayesiannetworkvirus.php

Bayesian Networks

A simple, graphical notation for conditional independence assertions and hence for compact specification of full joint probability distributions

Syntax: a mathematical graph

- Nodes: random variables
- Edges forming a directed, acyclic graph indicating \direct in
- A conditional distribution for each node given its parents

$$P(X_i \mid Parents(X_i))$$

In the simplest case (categorical variables), conditional distributions are Conditional Probability Tables (CPT) giving the distribution over Xi for every combination of parent values

Bayesian Networks

From a Bayesian network, we can derive:

- Direct influence between variables
- Indirect influence between variables
- Conditional independence between variables (given other variables)
- Marginal independence between variables

In addition, they allow us to reason *efficiently* about the probability distributions over latent (unobserved) variables

- Joint distribution of all variables

$$p(x_1, x_2, \ldots, x_n) = \prod_{i=1}^{n} P(x_i | \mathrm{Parents}(x_i))$$

- By marginalisation, the conditional distributions

Example: Eplaining away

Assume that:

- Earthquakes and Burglaries are independent events
- Both burglaries and earthquakes can trigger your house alarm
- Your alarm automatically calls your phone.

Your alarm calls you.

- What happens to the belief that a burgler broke into your house? Increases
- What about your expectation that there was an earthquake Also Increases

Then you hear that there was an earthquake in your area. What happens to the probability that your house was burglarised?

a It does not change
b It increases further
c It decreases

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Motivation

Modelling direct relationships is crucial

- Reduces the number of parameters in the model
- Simplifies reasoning

Relationships between variables remain complex, and critical: we have many unknowns which are all (indirectly) dependent on each other

If we obtain evidence about some of these variables, how does that affect our belief about the other variables?

BN

Bayesian Networks for

reasoning under uncertainty,
modelling large joint probabilities,
and reasoning with such networks.

Next:

Some examples

The concept of independence in BN