Announcements

- Assignment 6 due next Monday

"The mind is a neural computer, fitted by natural selection with combinatorial algorithms for causal and probabilistic reasoning about plants, animals, objects, and people. It is driven by goal states that served biological fitness in ancestral environments, such as food, sex, safety, parenthood, friendship, status and knowledge."

...

"In a universe with any regularities at all, decisions informed about the past are better than decisions made at random. That has always been true, and we would expect organisms, especially informavores such as humans, to have evolved acute intuitions about probability. The founders of probability, like the founders of logic, assumed they were just formalizing common sense."

Steven Pinker, How the Mind Works, 1997, pp. 524, 343.

Review

- Probability is defined in terms of measures over possible worlds
- The probability of a proposition is the measure of the set of worlds in which the proposition is true.
- Conditioning on evidence: make the worlds incompatible with the evidence have measure 0 and multiply the others by a constant, to get a measure.
- A belief network is a representation of conditional independence:

  in a total ordering of the variables, each variable is independent of its predecessors given it's parents

Learning Objectives

At the end of the class you should be able to:

- identify conditional independence
- build a belief network for a domain
- predict the inferences for a belief network
- explain the predictions of a causal model
- simulate the operations of variable elimination

Example: fire alarm belief network

Variables:

- Fire: there is a fire in the building
- Tampering: someone has been tampering with the fire alarm
- Smoke: what appears to be smoke is coming from an upstairs window
- Alarm: the fire alarm goes off
- Leaving: people are leaving the building *en masse*.
- Report: a colleague says that people are leaving the building *en masse*. (A noisy sensor for leaving.)

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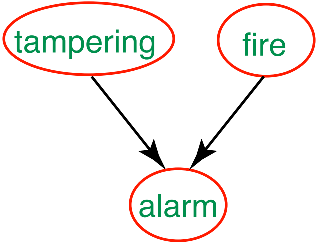
See “Fire Alarm Belief Network” in AIspace.org Belief and Decision Networks App

Components of a belief network

A belief network consists of:

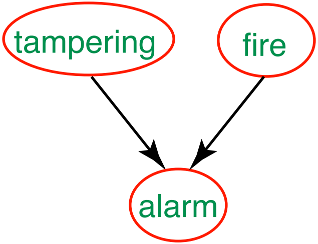
- a directed acyclic graph with nodes labeled with random variables
- a domain for each random variable
- a set of conditional probabilities for each variable given its parents (including prior probabilities for nodes with no parents).

Understanding Independence: Common descendants



- *tampering* and *fire* are

Understanding Independence: Common descendants



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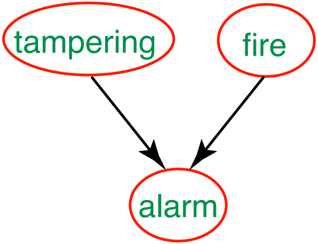

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- *tampering* and *fire* are given *alarm*

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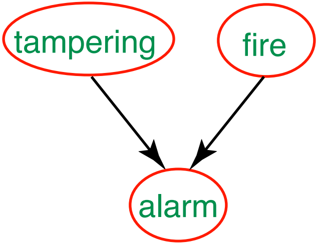

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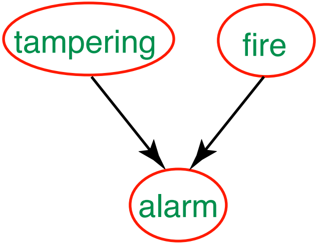

- *tampering* and *fire* are independent
- *tampering* and *fire* are dependent given *alarm*
- Intuitively, *tampering* can explain away *fire*

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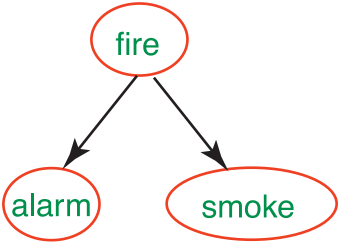

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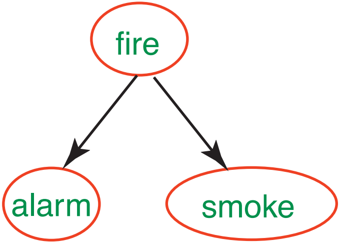

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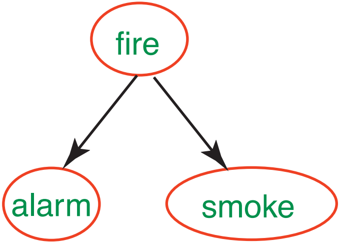

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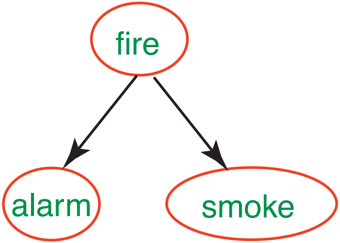

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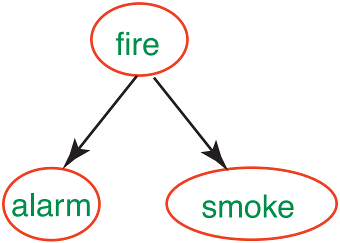
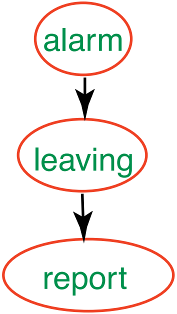


- *alarm* and *smoke* are dependent
- *alarm* and *smoke* are independent given *fire*
- Intuitively, *fire* can explain *alarm* and *smoke*; learning one can affect the other by changing your belief in *fire*.

Understanding Independence: Chain



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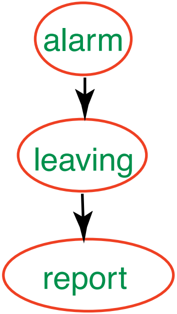

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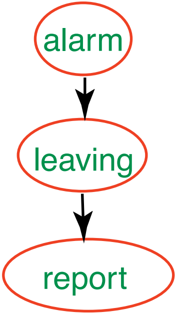

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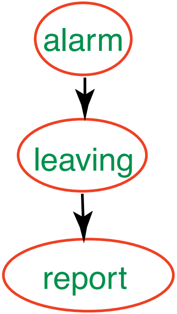

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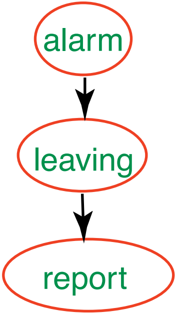

- *alarm* and *report* are dependent
- *alarm* and *report* are independent given *leaving*
- Intuitively, the only way that the *alarm* affects *report* is by affecting *leaving*.

Belief network summary

- A belief network is a directed acyclic graph (DAG) where nodes are random variables.
- The parents of a node n are those variables on which n directly depends.
- A belief network is automatically acyclic by construction.
- A belief network is a graphical representation of dependence and independence:
  - A variable is independent of its non-descendants given its parents.

Constructing belief networks

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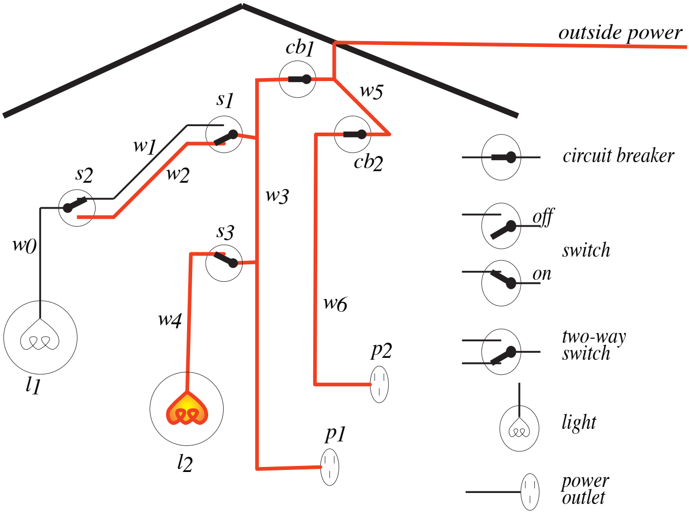
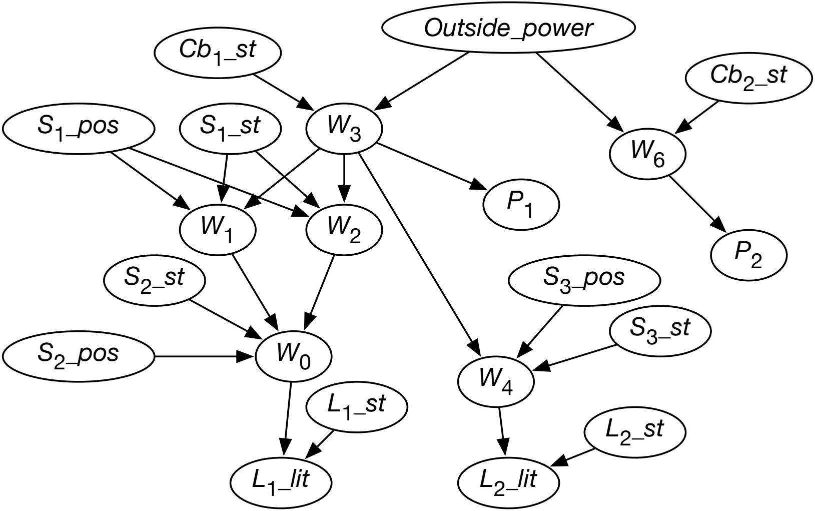
- What is the relationship between them? This should be expressed in terms of a directed graph, representing how each variable is generated from its predecessors.
- How does the value of each variable depend on its parents? This is expressed in terms of the conditional probabilities.

Task Domain: Electrical Environment



Example belief network



Example belief network (continued)

The belief network also specifies:

- The domain of the variables:
  $W_0, \ldots, W_6$ have domain $\{live, dead\}$
  S_1_pos, S_2_pos, and S_3_pos have domain $\{up, down\}$
  S_1_st has $\{ok, upside\_down, short, intermittent, broken\}$.

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- Conditional probabilities, including:
  $P(W_1 = live \mid s_1\_pos = up \land S_1\_st = ok \land W_3 = live)$
  $P(W_1 = live \mid s_1\_pos = up \land S_1\_st = ok \land W_3 = dead)$
  $P(S_1\_pos = up)$
  $P(S_1\_st = upside\_down)$