# Local Semantics and Markov Blanket

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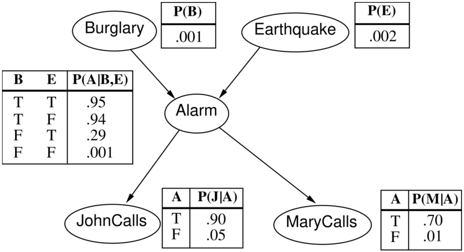
6CCS3AIN

# Global semantics

- We can calculate the full joint distribution as the product of the local conditional distributions:

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



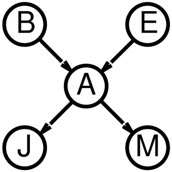

| P(B) |
|---|
| .001 |

| P(E) |
|---|
| .002 |

| B | E | P(A\|B,E) |
|---|---|---|
| T | T | .95 |
| T | F | .94 |
| F | T | .29 |
| F | F | .001 |

| A | P(J\|A) |
|---|---|
| T | .90 |
| F | .05 |

| A | P(M\|A) |
|---|---|
| T | .70 |
| F | .01 |




- Compute: $P(j \wedge m \wedge a \wedge \neg b \wedge \neg e)$

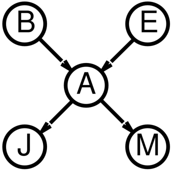
# Global semantics

- We can calculate the full joint distribution as the product of the local conditional distributions:

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

- $P(j \wedge m \wedge a \wedge \neg b \wedge \neg e)$

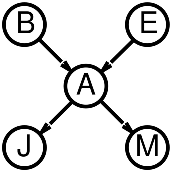
$$\begin{aligned} &= P(j|a)P(m|a)P(a|\neg b, \neg e)P(\neg b)P(\neg e) \\ &= 0.9 \cdot 0.7 \cdot 0.001 \cdot 0.999 \cdot 0.998 \\ &\approx 0.00063 \end{aligned}$$




- Application of the chain rule.

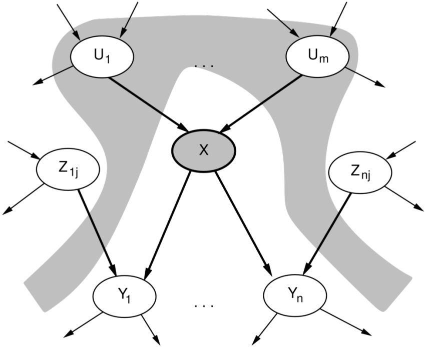
# Compactness

- A CPT for Boolean $X_i$ with $k$ Boolean parents has $2^k$rows for the combinations of parent values
- Each row requires one number $p$ for $X_i = true$ (the number for $X_i = false$ is just $1 - p$)
- If each variable has no more than $k$ parents, the complete network requires $O(n \cdot 2^k)$ numbers
- Grows linearly with $n$, vs. $O(2^n)$ for the full joint distribution
- For burglary net, $1 + 1 + 4 + 2 + 2 = 10$ numbers (vs. $2^5 - 1 = 31$)



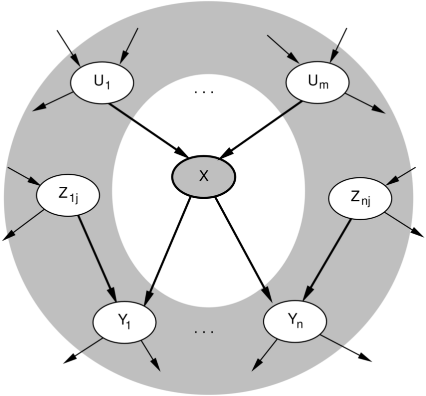
# Local semantics

- A node $X$ is conditionally independent of its non-descendants (e.g., the $Z_{i,j}$s) given its parents (the $U_i$s shown in the gray area).



# Markov blanket

- Each node is conditionally independent of all others given its Markov blanket: parents + children + children's parents




Andrey Markov

# Markov blanket

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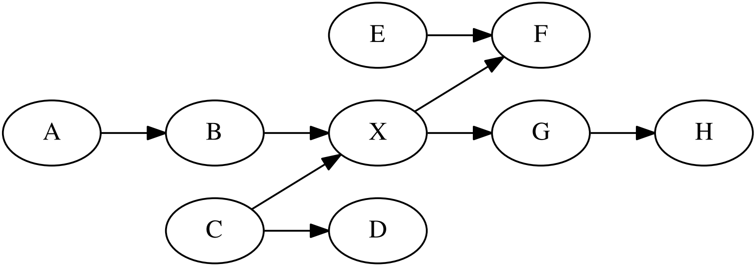
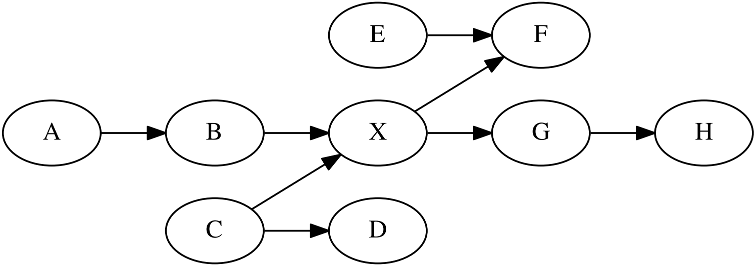



- Markov blanket of $X$?

# Markov blanket

- Each node is conditionally independent of all others given its Markov blanket: parents + children + children's parents




- Markov blanket of $X$?
- Answer: B,C,E,F,G

# Constructing Bayesian networks

- Build Bayesian networks like any other form of knowledge representation.
- First figure out the variables that describe the world.
- Then decide how they are connected.
  Conditional independence.
- Then work out the values in the CPTs.


Kathy Laskey

# Ways of compressing further

- CPT grows exponentially with number of parents
  - Use distributions that are defined compactly
- Deterministic nodes are the simplest case.
- $X = f(Parents(X))$ for some function $f$
  - Boolean functions:

$$NorthAmerican \Leftrightarrow Canadian \vee US \vee Mexican$$

  - Numerical relationships among continuous variables

$$\frac{\partial Level}{\partial t} = \text{inflow + precipitation - outflow - evaporation}$$