Natural Language Models and Interfaces

BSc Artificial Intelligence

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Institute for Logic, Language, and Computation

2019 — PGMs

Quick intro to PGMs

Check the lecture notes on PGMs

Tabular representation

Suppose A, B, and C are binary rvs

1. How do we represent $P_{A,B,C}$ (without making assumptions)?

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Joint assignments			Probability values
A	B	C	$P_{A,B,C}$
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0	0	1	$P_{A,B,C}(0,0,1)$
0	1	0	$P_{A,B,C}(0,1,0)$
1	0	0	$P_{A,B,C}(1,0,0)$
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Table: Tabular joint distribution over 3 binary rvs

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2. How many probability values does it take in general for n variables with t outcomes each? n^t

Directed graphical models or Bayesian networks

A directed acyclic graph (DAG)

- nodes represent rvs
- edges represent direct influence
- a set of conditional independence statements
  - an rv is conditionally independent of its **non-descendants** given its **parents**

Conditional independence in BNs

Consider A, B, and C, due to chain rule we can write

$$P_{A,B,C}(a, b, c) = P_A(a)P_{B|A}(b|a)P_{C|AB}(c|a, b) \tag{1}$$

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But if we are given a particular set of assumptions

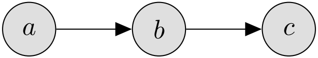

Figure: Examples of BN

then we can simplify it

$$\begin{aligned} P_{A,B,C}(a,b,c) &= P_A(a)P_{B|A}(b|a)P_{C|AB}(c|a,b) \quad (2)\\ &= P_A(a)P_{B|A}(b|a)P_{C|B}(c|b) \quad (3)\end{aligned}$$

C is independent of non-descendants $\{A\}$ given its parents $\{B\}$

Chain rule for Bayesian networks

Chain rule (in general)

$$P_{X_1,\ldots,X_n}(x_1,\ldots,x_n) = \prod_{i=1}^{n} P_{X|X_{<i}}(x_i|x_{<i}) \tag{4}$$

Chain rule for Bayesian networks

$$P_{X_1,\ldots,X_n}(x_1,\ldots,x_n) = \prod_{i=1}^{n} P_{X|\mathsf{Pa}_X}(x|\mathsf{pa}_x) \tag{5}$$

where

- Pa_X set of rvs parents of X
- pa_X assignments of parents of X

Representing BNs

Each variable (given its parents) gets a tabular CPD

Thus for

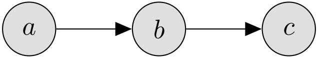

Figure: Examples of BN

A	P_A
0	$P_A(0)$
1	$P_A(1)$

A	B	$P_{B\|A}$
0	0	$P_{B\|A}(0\|0)$
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B	C	$P_{C\|B}$
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Representation cost

- from $O(\prod_{i=1}^{n} |\operatorname{supp}(X_i)|)$
- to $O(\sum_{i=1}^{n} |\operatorname{supp}(X_i)| \times |\operatorname{supp}(\mathsf{Pa}_{X_i})|)$

Exercises

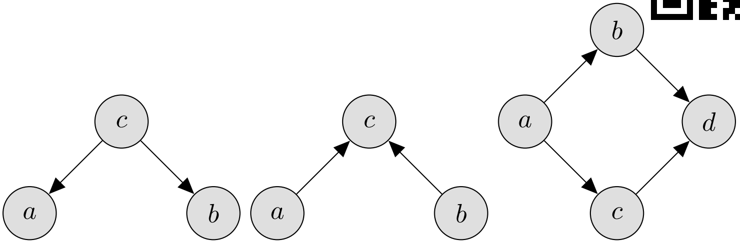

Figure: Write down the factorisation

Quiz

Inferences

So the BN shows us what are the CPDs in the problem

- but what if we want to reason about something that's not a CPD?

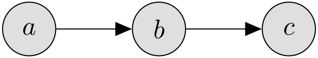

Figure: Examples of BN

Here we have CPDs P_A, $P_{B|A}$, and $P_{C|B}$

- how do we reason about $P_{B|C}$ or $P_{A|B}$?
- or P_B or P_C?
- or $P_{BC|A}$?

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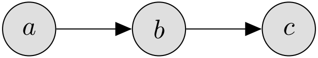

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For whatever combination, we have rules of probability!

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- note that the last sum is the (inferred) marginal $P_B(b)$

Continuation

- we are here

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- now obtain the marginal in the denominator as a function of tabular CPDs

$$\begin{aligned} P_C(c) &= \sum_a \sum_b P_{ABC}(a, b, c) \\ &= \sum_a \sum_b P_A(a) P_{B|A}(b|a) P_{C|B}(c|b) \\ &= \sum_a P_A(a) \sum_b P_{B|A}(b|a) P_{C|B}(c|b) \end{aligned}$$

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Quiz

References I