Ghostbusters

Using Bayesian Inference to hunt the invisible

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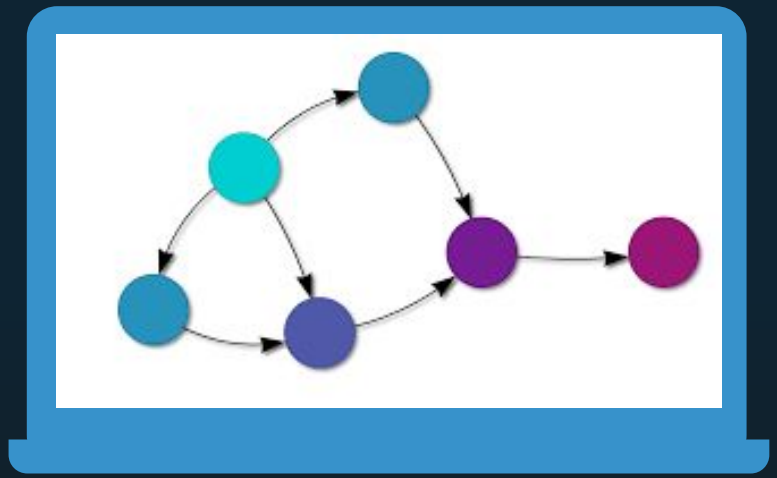
01

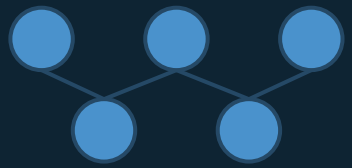
Introduction & Motivation

Bayesian Net



A tool to describe a complex distribution over number of variables using small interactions.

Components



Nodes:Each node represent a variable

Acyclic graph:The graph is directed and representing the relationships between the variables

Each node:Hidden the conditional distributions with parents

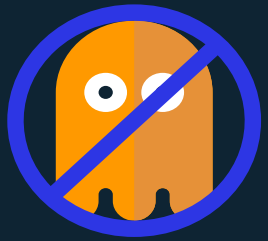
Why Use A Bayes Net?

- One of the key advantages of Bayesian networks is their ability to handle uncertain relationships between variables in a principled way.
- They can capture the inherent uncertainty in many real-world problems and be used to make predictions and decisions under uncertainty, by computing the probabilities of different outcomes given the available evidence.
- The advantage of Bayesian networks is their ability to handle incomplete or missing data. Bayesian networks can handle missing data by using probabilistic inference to estimate the missing values based on the available evidence.
- This is particularly useful in applications such as medical diagnosis, where some symptoms or test results may be missing or inconclusive..

02

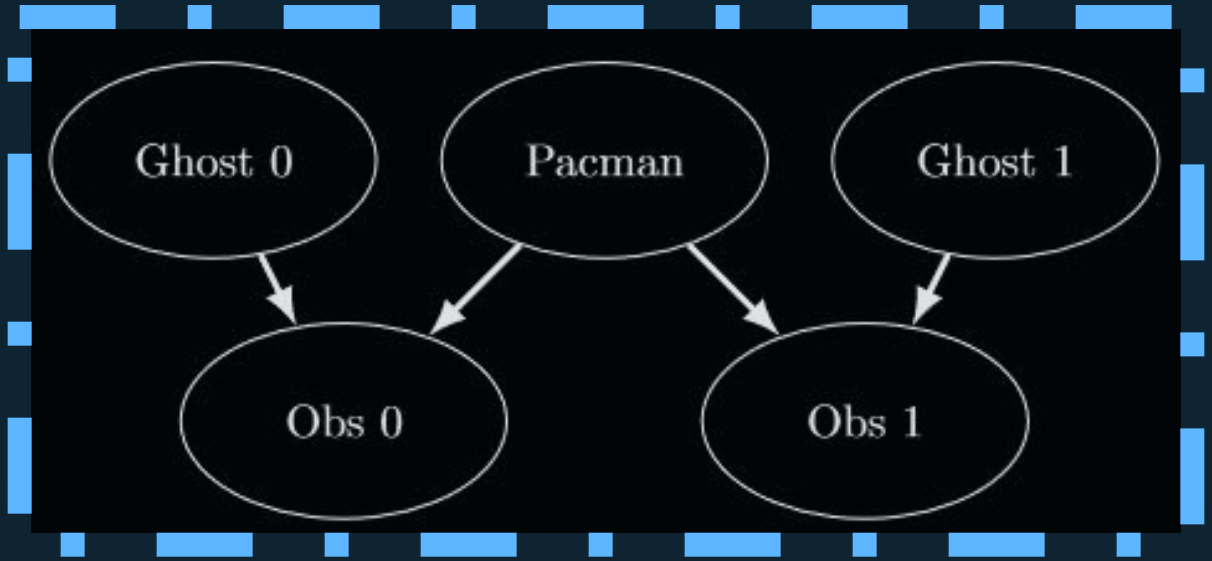
Problem Definition

Problem Definition



Pacman is faced with the task of tracking and capturing frightened but invisible ghosts. To aid him in this pursuit, Pacman has been equipped with a sensor that gives him a noisy readings of the Manhattan distance to each individual ghost. The game's is terminated when Pacman successfully eats all the ghosts.

The main objective is to develop inference algorithms for accurately tracking the ghosts using Bayes Nets by apply exact and approximate inference techniques.


Ghost 0
Pacman
Ghost 1
Obs 0
Obs 1

03 Example

Bayes' Net

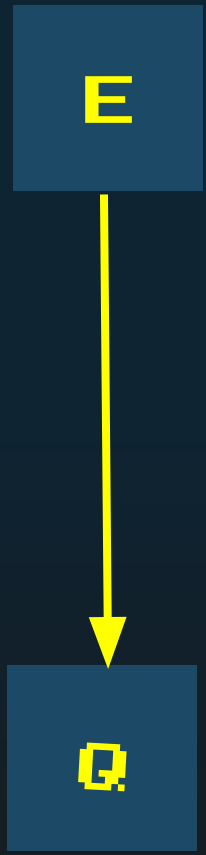
definition

Bayes' net is a for describing complex joint distribution over a large number of variables where that large distribution is built in small pieces in form of conditional distribution

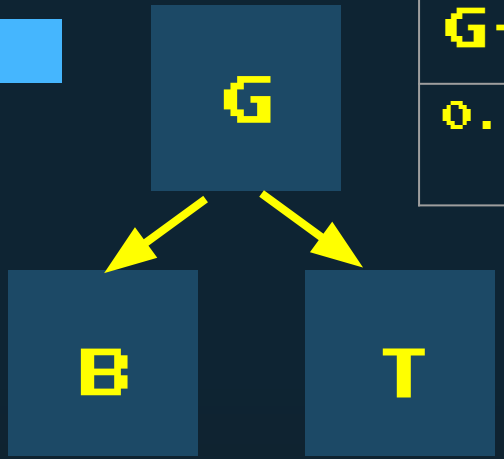
Graph

Nodes: refers to random variables

Arrows: conditional independence (correlation not causation)



$$P(Q,E)=P(Q|E)P(E)$$



G+	G−
0.5	0.5

	B+	B−
G+	0.4	0.6
G−	0.8	0.2

	T+	T−
G+	0.8	0.2
G−	0.4	0.6

$$P(T,P,G)$$

$$=P(G)P(T|G)P(B|G,T)$$

$$=P(G)P(T|G)P(B|G)$$

04 Pseudocode

Outputs: a distribution over X
Inputs: X, the query variable
e, observed values for some set of variables E
bn, a Bayes net
Variables: factors, a matrix with a dimension for each variable, where Factor[VAL1][VAL2][...] is (proportional to) a probability such as P(VAR1=VAL1, VAR2=VAL2, ...)

```
function ELIMINATION-ASK(X, e, bn)
    factors ← [for each variable v in bn.VARS, the CPT for v given e]
    for each var in bn.vars if var is not in e and var is not X do
        relevant-factors ← [all factors that contain var]
        factors.remove(relevant-factors)
        factors.append(SUM-OUT(var, POINTWISE-PRODUCT(relevant-factors)))
return NORMALIZE(POINTWISE-PRODUCT(factors))
```

05

Algorithm Analysis

Analysis

Complexity

Depends on the structure of the network or how tree-like it looks

Time complexity

Time complexity depends on the structure and size of Bayesian networks.

Variable elimination

Denoted by the size of largest factor constructed during the operation of the algorithm.
Order of elimination of variables

Polytrees

Undirected path between any two nodes in network.

Variable elimination

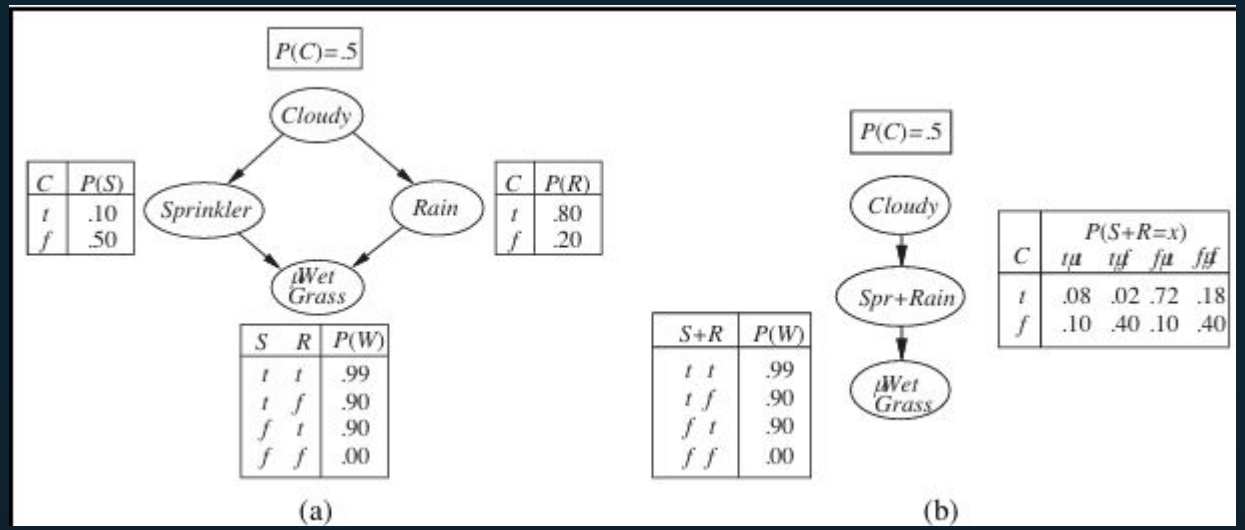
the size is defined as the number of CPT entries.

if the number of parents of each node is bounded by a constant, then the complexity will also be linear in the number of nodes.

Multiply connected

can have exponential time and space complexity in the worst case, even when the number of parents per node is bounded between any two nodes in network.

Network



(a) A multiply connected network with conditional probability tables.
(b) A clustered equivalent of the multiply connected network

Effective method

greedy one:

Eliminate whichever variable minimizes the size of the next factor to be constructed.

Let us consider one more query: $\mathbf{P}(JohnCalls \mid Burglary = true)$. As usual, the first step is to write out the nested summation:

$$\mathbf{P}(J \mid b) = \alpha\, P(b) \sum P(e) \sum P(a \mid b, e) \mathbf{P}(J \mid a) \sum P(m \mid a)\ .$$


THANK YOU!