CS 486/686: Introduction to Artificial Intelligence

Causality

Plan for Today

- Example using HMMs
- Introduction to Causality

HMM Example

- Imagine we are trying to figure out what the weather was sometime in the past. However, we have lost the temperature data. But we do have a copy of Kate's diary where she recorded how many ice cream cones she ate each day! What can we infer about the weather?

HMM Example

- States = {H, C}
- Observations {1 ice cream, 2 ice creams, 3 ice creams}
- Prior: P(H)=0.8, P(C)=0.2
- Dynamics: P(H|H)=0.6, P(H|C)=0.5
- Observation Model:

	H	C
1 Ice Cream	0.2	0.5
2 Ice Creams	0.4	0.4
3 Ice Creams	0.4	0.1

Introduction to Causality

- Causality is the study of how things influence each other (causes lead to effects)

- Causal dependence: X causes Y if and only if changes to X lead to changes in Y
  - Example: Diseases cause symptoms, but symptoms do not cause diseases

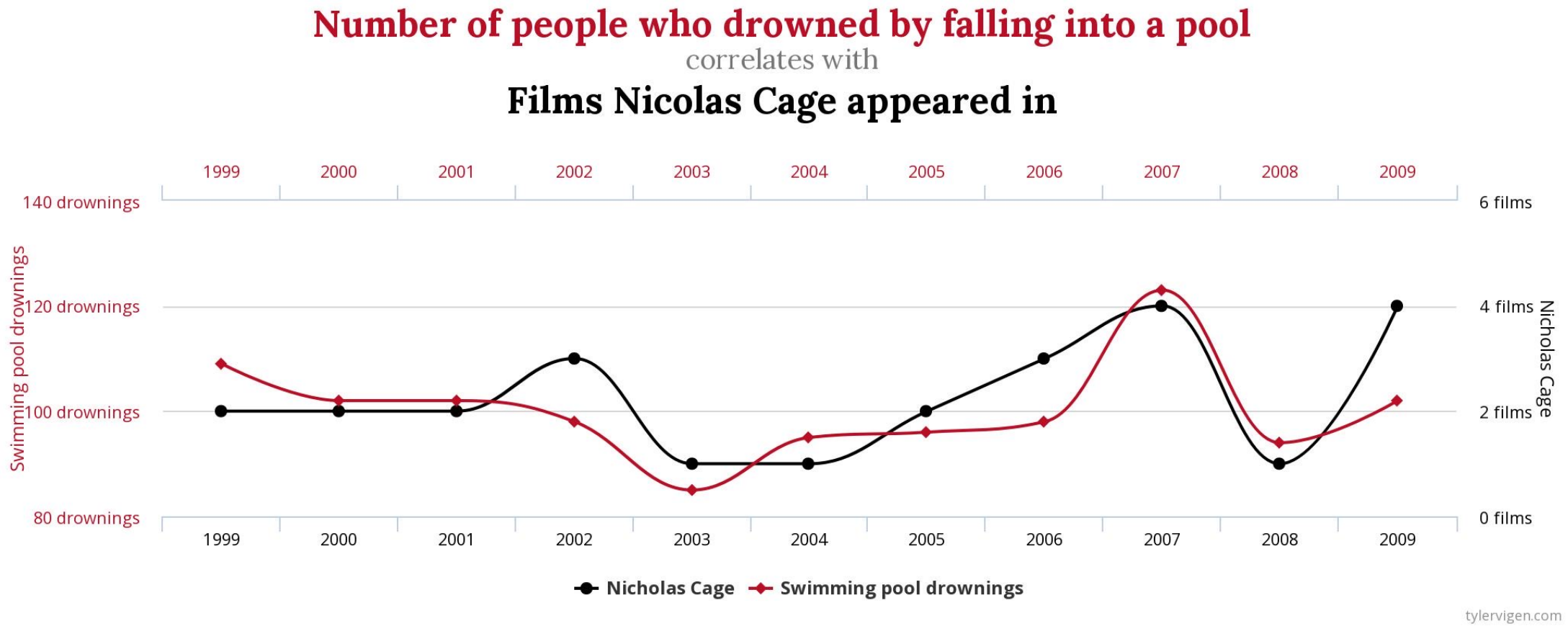
Causality and Correlation (not the same thing!)

- A joint distribution P(X,Y) captures correlations between X and Y but does not capture whether a causal relation exists between X and Y, nor the direction of the causal relation if one does exist

- A conditional distribution P(X|Y) does not necessarily indicate X causes Y

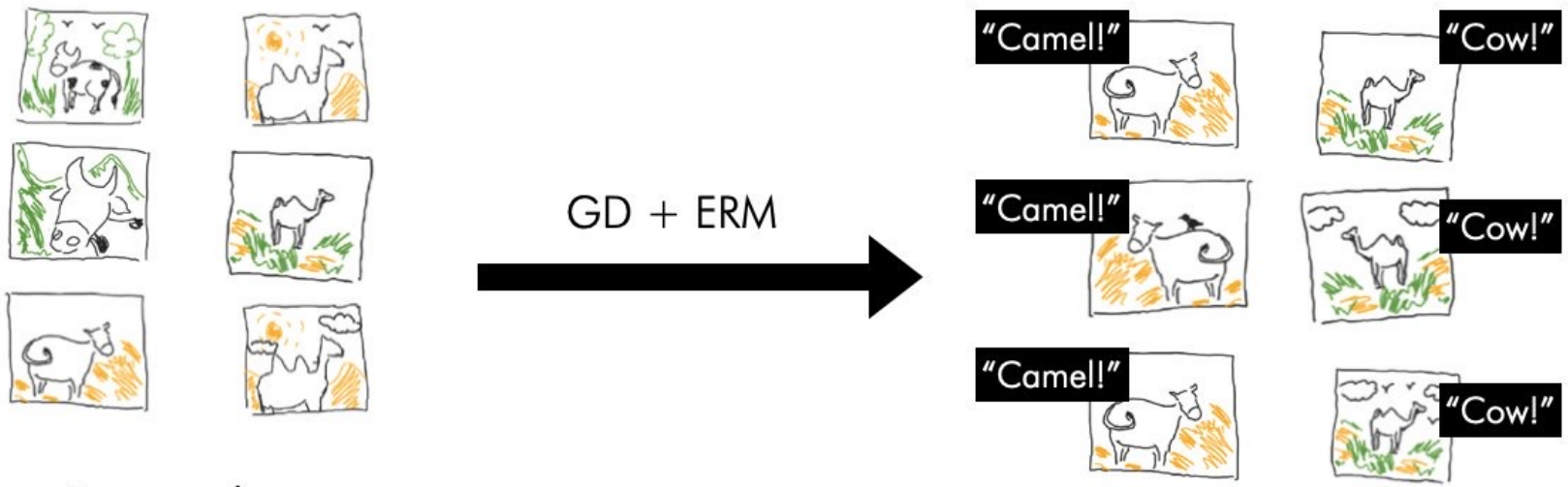
$$P(X|Y) = \frac{P(Y|X)P(X)}{P(Y)}$$

Spurious Correlations



https://www.tylervigen.com/spurious-correlations

Spurious Correlations



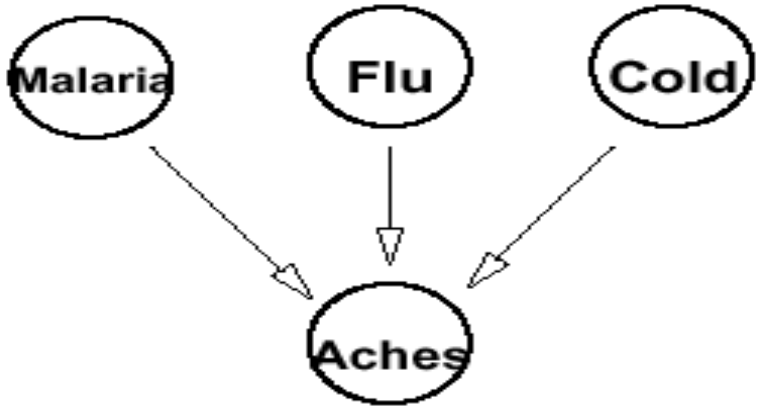
Training domain
Cows: 90% green background
Camels: 90% yellow background

Test domain
Cows: 0% green background
Camels: 0% yellow background

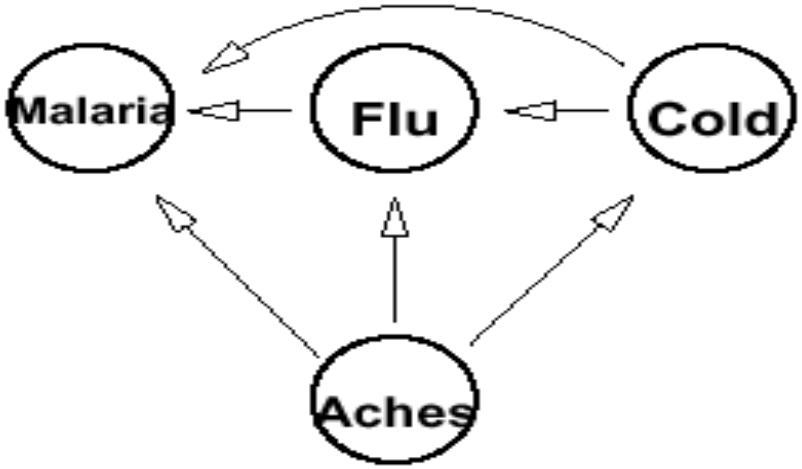
Standard example (Beery et al., '18 Arjovsky et al., '19)

Causal Bayes Net

- Bayes Net where all edges indicate direct causal effects.



Probabilistic Inference
Causal Inference



Probabilistic Inference

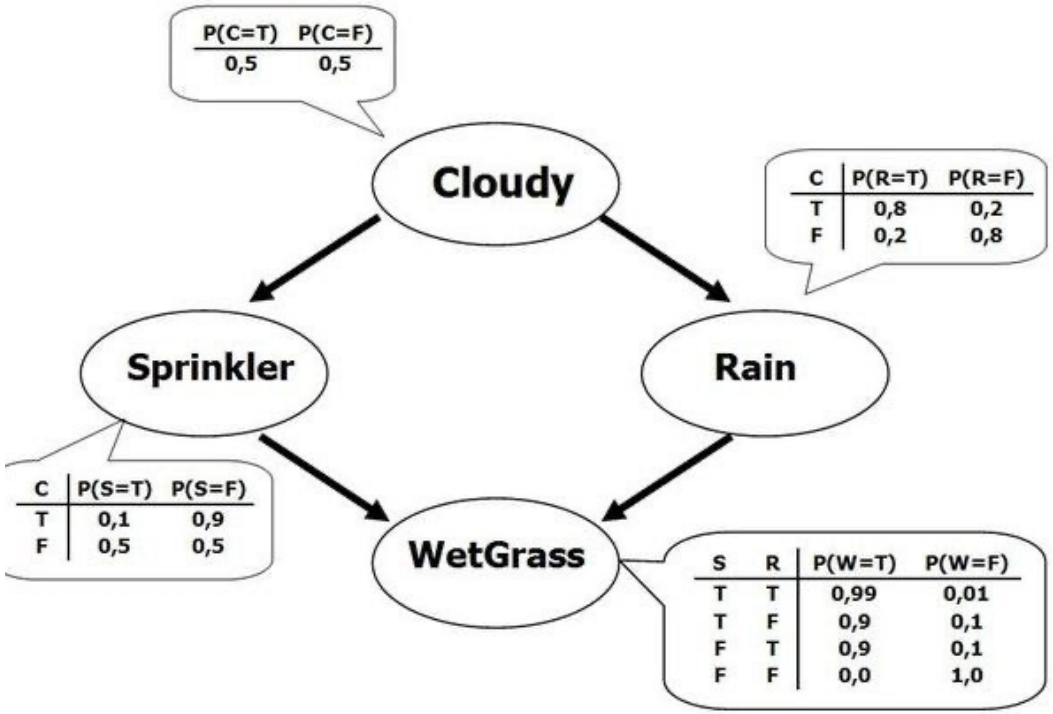
Causal Inference

- Intervention: What is an effect of an action?
  - E.g. what is the effect of a treatment?

Causal networks support intervention queries but non-causal networks do not.

Classic Causal Example

- Observation: What is the likelihood that the grass is wet when the sprinkler is observed to be on?
  - P(WG|S=true)
- Intervention: How does turning on the sprinkler affect the grass?
  - P(WG|**do**(S=true))



Inference with Do Operator

Given a causal graph and query P(X|do(Y=y), Z)

- Remove edges pointing to Y and Parents(Y)
- Perform Variable Elimination on remaining graph
  - Restrict factors to evident Y=y, Z=z
  - Eliminate variables
  - Multiply remaining factors and normalize

What you should know

- Correlation does not imply causation!
- Causal Bayes Nets
  - Probabilistic inference vs causal inference and the do operator