Correlation vs. Causation

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Correlation does NOT imply Causation

I used to think correlation implied causation.

Then I took a statistics class. Now I don't.

Sounds like the class helped. Well, maybe.
Reichenbach Principle

• If two events are correlated, it is either because:
  i. there is a causal connection between the two, or
  ii. there is a third event that brings about the correlation.

• Markov Equivalent Classes:
  • $X$ correlated with $Z$.

Distributionally Equivalent
A general mathematical language for causality

• Interventions (actions) vs. observation – the do-operator (Pearl 2000)

\[ p(y \mid do(T = t), X = x) = p(y \mid T = t, X = x) \]

• Causation vs. Correlation

  • Randomized Controlled trials (RCTs) can help identify causal relationships and effects by careful design!

What happens when you can’t intervene – or don’t know what to intervene on, e.g., economics?
Causal Inference and Discovery

• Causal Inference
  • When you can’t intervene, can you identify effects?

• Causal Discovery
  • When you don’t fully understand the system, can you discover causal relationships from observational/partially-observational?
Applications

- Neuroscience: Effective connectivity
- Healthcare: Automated diagnoses
- Fairness: Decision making with sensitive attributes
- Science: Flexibility with experiments
- Artificial Intelligence: A more general understanding of the world
Interested? Here are some starting points.

• Potential Outcomes (Rubin) vs. Graphical (Pearl) Framework

• Potential Outcome
  • Ignorability, Conditioning

• Graphical Framework
  • $do$-calculus
  • Back-door criterion, Blocking
Thanks!

Questions?