Connecting Philosophy with Actual Science

**Philosophy**: Interventionist Theory of Causation

**Actual Science**: Statistical Causal Inference

**Directed Acyclic Graph (DAG)**: a bunch of variables connected by arrows

* Directed: temporal direction embedded in arrows
* Acyclic: no closed loops
* Graph: represents causal structure

Smoking

Lung Cancer

Yellow Fingers

|  |  |
| --- | --- |
| **Completeness of DAGs** | **Incompleteness of DAGs** |
| * All common causes are present
* All arrows are drawn
 | * Not all mediators are present
* Not all causes are present
 |

**Scheines (1997, p.186)**: “Prior to any interpretation, a DAG is a completely abstract mathematical object.”

**Causal Interpretation of DAGs**

* What does “Smoking -> Yellow Fingers” *mean*?
* Manipulating/intervening on smoking changes whether yellow fingers
* If smoke, then yellow fingers
* If no smoke, then no yellow fingers

These are all very good…but how do we get to DAGs and causal inference from statistics and probabilities?

**Conditional Independence**

* “**X ⫫ Y | Z**” means “X and Y are probabilistically independent, conditional on Z”

P(X n Y|Z) = P(X|Z) \* P(Y|Z)

**Unconditional/Marginal Independence**

* **“X ⫫ Y**” means “X and Y are probabilistically independent”

P(X|Y) = P(X) \* P(Y)

**Causal Markov Condition (CMC)**: X is independent of all variables (except X’s effects), conditional on X’s direct causes.

* Yellow Fingers and Lung Cancer are independent, conditional on Smoking.
* CMC can be understood as a sufficient condition for causation (Hausman and Woodward, 1999, p.523): If X and Y are *dependent*, conditional on X’s direct causes, then Y is an effect of X—i.e., X causes Y.

**Why CMC**

* Causal inference in controlled experiments assumes CMC
* CMC is compatible with philosophical theories of probabilistic causation
* Influential methods in social science, Structural Equation Modelling (SEM) assumes CMC

**Faithfulness**: Ignore cases where X causes Y, but X and Y are independent, conditional on X’s direct causes.

Smoking

Exercise

Health

* Smoking causes poor Health, but they can be independent, conditional on Smoking’s direct causes.
* Faithfulness can be understood as a necessary condition for causation (Hausman and Woodward, 1999, p.523): If X causes Y, then X and Y are dependent, conditional on X’s direct causes.

**Why Faithfulness**

* Embraced by working scientists
* No Miracles: Independencies are explained by causal structure rather than chance

**Causal Sufficiency**: All common causes of the variables were *measured*.

**From Independencies to Causal Inference**

CMC, Faithfulness, and Causal Sufficiency all serve to narrow down the set of DAGs that are compatible with the observed data (independencies).

**Independencies**:

X1 ⫫ X2

**DAGs**:

Assuming CMC

X2

X1

 ? ? ? ? ? ? ? ?

X3

“Even if we assume that all the Causally Markov graphs that might have produced data with these independencies involve only X1, X2, and X3, then there are still nine such graphs. Their only shared feature is that each has some direct connection between X1 and X3 and between X2 and X3” (Scheines, 1997, p.194).

* How does CMC—which talks about conditional independencies—give us DAGs based on unconditional independencies?
* What are the other 8 DAGs?

Assuming CMC and Faithfulness

X3

X1

X2

* How does Faithfulness eliminate the 8 DAGs?

Assuming Causal Sufficiency

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* The above already implicitly assumes Causal Sufficiency: “involve *only* X1, X2, and X3”.
* Without Causal Sufficiency, there are many possible (infinite?) DAGs.

**Gems and Coals**

 Aspires to be as clear and simple as possible. The goal is explanation.

 Assumes a fair bit of background knowledge of the reader. As a result, the paper skips explanations here and there.

 Introduces d-separation but refuses to explain it fully…

**References**

Hausman, D. M., & Woodward, J. (1999). Independence, Invariance and the Causal Markov Condition. The British Journal for the Philosophy of Science, 50(4), 521–583. <http://www.jstor.org/stable/40072257>

Scheines, R. (1997). "An Introduction to Causal Inference," in V. R. McKim and S. P. Turner, eds., *Causality in Crisis?* University of Notre Dame Press.