Causal Inference (M16)

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From its onset, modern statistics engages in the problem of inferring causality from data. A common mindset is that causal inference is only possible using randomised experiments, but developments in statistics and related fields have shown that this view is too simplistic. We now have a much better understanding of the assumptions and methodologies that enable causal inference from observational, non-experimental data. This course aims to cover some of the most fundamental ideas in causal inference, a vibrant research area where statistical theory meets scientific practice.

1. **Motivations:**
    - Principles of causal inference: motivations; historical perspectives; basic concepts.
    - Randomized experiments: randomization tests, regression adjustment and its asymptotic inference.
    - Path analysis and linear structural equation models (SEMs).
2. **Languages for causality:**
    - Probabilistic directed acyclic graphical (DAG) models: Markov properties, d-separation, structure discovery.
    - Counterfactual causal models: nonparametric SEMs; single-world intervention graphs; g-computation formula.
    - Causal identification: back-door criterion, front-door criterion; potential outcomes calculus; other examples.
3. **Design and statistical methods:**
    - Observed confounders: matching, randomisation inference, Rosenbaum's sensitivity analysis; influence functions and semiparametric inference.
    - Instrumental variables (IV): core IV assumptions; generalised method of moments; principal stratification.
    - Other selected topics: regression discontinuity design; difference in differences and negative control methods; mediation analysis; longitudinal data and time-varying treatments; meta-analysis and evidence synthesis.

Prerequisites

This course assumes familiarity with undergraduate-level probability and statistics.

Literature

1. Hernán M. A. and Robins, J. M. *Causal Inference: What If.* Chapman & Hall, 2020.
2. Imbens, G. W. and Rubin, D. B. *Causal Inference in Statistics, Social, and Biomedical Sciences.* Cambridge University Press, 2015.
3. Lauritzen, S. L. *Graphical Models.* Clarendon Press, 1996.
4. Angrist, J. D. and Pischke, J. S. *Mostly Harmless Econometrics: An Empiricist's Companion.* Princeton University Press, 2008.

Additional support

Lecture notes will be provided. Three examples sheets will be provided and three associated examples classes will be given. A fourth example class will ask the student to read and present an applied research article. There will also be a revision class in the Easter Term.