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 oversimplified and restrictive. 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.
    - Randomised experiments: randomisation 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; counterfactual calculus; other examples.
3. **Design and statistical methods:**
    - Observed confounders: matching, randomisation inference, Rosenbaum's sensitivity analysis; 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.

Pre-requisites

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

Literature

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

Additional support

Lecture notes will be provided. Three examples sheets will be provided and three associated examples classes will be given. There will be a revision class in the Easter Term.