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Causal Inference with Cocycles

Many interventions in causal inference can be represented as transformations of the variables of interest. Abstracting interventions in this way allows us to identify a local symmetry property exhibited by many causal models under interventions. Where present, this symmetry can be characterized by a type of map called a cocycle, an object that is central to dynamical systems theory. We show that such cocycles exist under general conditions and are sufficient to identify interventional distributions and, under suitable assumptions, counterfactual distributions. We use these results to derive cocycle-based estimators for causal estimands and show that they achieve semiparametric efficiency under standard conditions. Since entire families of distributions can share the same cocycle, these estimators can make causal inference robust to mis-specification by sidestepping superfluous modelling assumptions. We demonstrate both robustness and state-of-the-art performance in several simulations, and apply our method to estimate the effects of 401(k) pension plan eligibility on asset accumulation using econometric data.

Based on joint work with Hugh Dance (UCL/Gatsby Unit): https://arxiv.org/abs/2405.13844