DOI: doi.org/10.47363/JAICC/ICMLAIDS2026/2026(5)17

Temporal Alignment and Covariate Matching for Robust Synthetic Controls

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Abstract

Synthetic control estimation under varying data regimes requires distinct strategies for counterfactual alignment. When direct controls are available, KD-tree–based nearest-neighbor search combined with entropy balancing enforces pre-treatment covariate similarity, enabling difference-in-differences weighting for robust causal inference. In contrast, absence of controls necessitates dynamic trajectory matching: Dynamic Time Warping identifies series with aligned temporal patterns, while Bayesian Structural Time Series synthesizes these into latent counterfactual paths via state-space modeling. This framework addresses imbalance, temporal misalignment, and structural uncertainty inherent in observational causal analysis.