Deep Learning Based Causal Inference with Combinatorial A/B Tests on Large-Scale Platforms

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Abstract:

Large-scale online platforms launch hundreds of randomized experiments (a.k.a. A/B tests) every day to iterate their operations and marketing strategies, and the combination of these treatments are typically not exhaustively tested. This triggers an important question of both academic and practical interests: Without observing the outcomes of all treatment combinations, how to estimate the causal effect of any treatment combination and identify the optimal treatment combination? We develop a novel framework combining deep learning and double machine learning to estimate the causal effect of any treatment combination for each user on the platform when observing only a small subset of treatment combinations. Our proposed framework (called debiased deep learning, DeDL) exploits Neyman orthogonality and combines interpretable and flexible structural layers in deep learning. We prove theoretically that this framework yields consistent and asymptotically normal estimators under mild assumptions, thus allowing for identifying the best treatment combination when only observing a few treatment combinations. To check whether our assumptions are satisfied in important empirical contexts, we then collaborate with a large-scale video-sharing platform and implement our framework for three independent experiments. When only observing a subset of treatment combinations, our DeDL approach significantly outperforms other benchmarks to accurately estimate and infer the average treatment effect (ATE) of any treatment combination, and to correctly identify the optimal treatment combination. We further demonstrate with synthetic data that our framework is robust towards model misspecification and variable imbalance.

Key words: Deep Learning; Double Machine Learning; Causal Inference; A/B Tests; Experimentation on Online Platforms

Biography:

Renyu (Philip) Zhang has been an Associate Professor (with tenure) at the Department of Decision Sciences and Managerial Economics, The Chinese University of Hong Kong Business School since September 2022. He is also an economist and Tech Lead at Kwai, one of the world's largest online video-sharing and live-streaming platforms. Philip's recent research focuses on developing data science methodologies (e.g., data-driven optimization, causal inference, and machine learning) to evaluate and optimize the operations strategies in the contexts of online platforms and marketplaces, sharing economy, and social networks, especially their recommendation, advertising, pricing, and matching policies. His research works have appeared in Management Science, Operations Research, and Manufacturing & Service Operations Management, and have been recognized by various research awards of the INFORMS and POMS.

Your attendance is most welcome!

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