Gaussianized Design Optimization for Covariate Balance in Randomized Experiments

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Achieving covariate balance in randomized experiments enhances the precision of treatment effect estimation. However, existing methods often require heuristic adjustments based on domain knowledge and are primarily developed for binary treatments.

This paper presents Gaussianized Design Optimization, a novel framework for optimally balancing covariates in experimental design. The core idea is to Gaussianize the treatment assignments: we model treatments as transformations of random variables drawn from a multivariate Gaussian distribution. Under Gaussianization, we derive a measure of covariate balance as a function of covariates and the Gaussian covariance matrix, which effectively assesses the estimation error of the widely used Horvitz-Thompson estimator. This converts the design problem into a nonlinear continuous optimization over Gaussian covariance matrices. Compared to existing methods, our approach offers great flexibility in optimizing covariate balance across a diverse range of designs and covariate types.

Adapting the Burer-Monteiro approach for solving semidefinite programs, we introduce first-order local algorithms for optimizing covariate balance, improving upon several widely used designs. Furthermore, we develop inferential procedures for constructing design-based confidence intervals under Gaussianization and extend the framework to accommodate continuous treatments. Simulations demonstrate the effectiveness of Gaussianization in multiple practical scenarios.

The full version of this paper can be found at https://arxiv.org/abs/2502.16042.

CCS Concepts: • **Applied computing → Operations research**; • **Theory of computation → Theory and algorithms for application domains**.

Additional Key Words and Phrases: Continuous Treatments, Covariate Balance, Mehler's Formula, Optimal Experimental Design

ACM Reference Format:
Wenxuan Guo, Tengyuan Liang, and Panos Toulis. 2025. Gaussianized Design Optimization for Covariate Balance in Randomized Experiments. In *The 26th ACM Conference on Economics and Computation (EC '25), July 7–10, 2025, Stanford, CA, USA.* ACM, New York, NY, USA, 1 page. https://doi.org/10.1145/3736252.3742647

Acknowledgments

TL is supported by the NSF Career Award DMS-2042473 and by the Wallman Society of Fellows at the University of Chicago. PT acknowledges support from NSF award SES-2419009.

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EC '25, Stanford, CA, USA

ACM ISBN 979-8-4007-1943-1/25/07
https://doi.org/10.1145/3736252.3742647