Contribution ID: **39** Type: **not specified**

Local Constrained Bayesian Optimization for High-Dimensional Industrial Design

Bayesian optimization (BO) has become a cornerstone methodology for the data-efficient tuning of expensive black-box systems encountered throughout business and industrial practice, ranging from chemical process design and structural engineering to controller calibration and the configuration of large-scale machine learning pipelines. In most of these applications, the objective must be optimized subject to unknown and equally expensive-to-evaluate constraints reflecting safety thresholds, physical feasibility, or budgetary limits. While constrained BO (CBO) addresses this need in low dimensions, its performance degrades sharply as the number of design variables grows, since standard regret bounds scale exponentially with dimension. Existing high-dimensional remedies based on trust regions are prone to premature shrinkage when the descent direction is blocked by tight or complex constraints, a failure mode we observe repeatedly on industrial design tasks.
We propose Local Constrained Bayesian Optimization (LCBO), a framework that extends gradient-based local BO to constrained problems via a quadratic-penalty surrogate. LCBO alternates between rapid local descent and uncertainty-driven exploration. Under mild regularity conditions, we prove that the KKT residual converges at a rate depending only polynomially on the dimension for common kernels, which is a marked improvement over global CBO guarantees. Empirically, on synthetic benchmarks up to 100 dimensions, a 25-bar truss design, a 50-dimensional stepped cantilever beam, and a 102-dimensional MuJoCo control task, LCBO consistently outperforms state-of-the-art CBO baselines in sample efficiency, stability, and final solution quality, demonstrating its promise for real-world industrial optimization under constraints.

Special/ Invited session

Classification

Mainly methodology

Keywords

high dimensional optimization, Bayesian optimization, local search, convergence analysis

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Track Classification: AI: Machine Learning and Predictive Analytics