

DERIVATIVE-FREE OPTIMIZATION FOR MIXED-VARIABLE ENGINEERING DESIGN

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Abstract

Many engineering design problems involve decision variables of different types, including continuous, discrete, and categorical components, together with objective functions obtained from complex simulations where derivative information is unavailable. These characteristics pose significant challenges for optimization algorithms, particularly in terms of robustness, scalability, and the handling of heterogeneous variable domains.

This work addresses derivative-free optimization methods for mixed-variable problems, with a focus on approaches that rely solely on function evaluations while maintaining theoretical convergence guarantees. The discussion is centered on direct search methodologies and their extensions to multiobjective and simulation-based settings.

Particular attention is given to algorithmic strategies that improve robustness with respect to problem scaling and variable heterogeneity. A framework is considered in which the optimization process is performed in a normalized search space, while objective function evaluations are carried out in the original physical domain. This separation allows the underlying algorithms to operate independently of the physical scales of the variables, leading to improved numerical behavior across a wide range of problem classes.

The treatment of discrete and categorical variables is also discussed, emphasizing deterministic mechanisms that avoid reliance on stochastic perturbations and preserve reproducibility. These strategies enable the consistent handling of mixed-variable structures without introducing additional algorithmic complexity.

The proposed ideas are illustrated on representative benchmark and engineering design problems, highlighting their potential for improving robustness and efficiency in simulation-based optimization.

Overall, this work contributes to the development of reliable and scalable derivative-free optimization methodologies for mixed-variable engineering design, providing a flexible framework applicable to a broad class of problems.