Algorithm design for mixed-integer black-box optimization problems with uncertainty

Thomaser, A.M.

Summary

This thesis investigates the design of optimization algorithms for solving complex and computationally expensive optimization problems from various domains. As an example of a real-world optimization problem, the task of designing parameters for vehicle dynamics control systems is considered. The increasing competition in the automotive industry requires the tailored, swift development of technologically sophisticated vehicles. Therefore, the computationally expensive state-of-the-art simulation technologies are combined with optimization algorithms.

The thesis focuses on one central question: How can an optimization algorithm be effectively and efficiently designed to solve computationally expensive real-world problems? This central question leads to a number of further research questions that cover the design process from the mathematical definition of the objective function of real-world problems to the complicated issues of quantifying uncertainty in optimization.

An important practical contribution of this thesis is the creation of a dataset that represents real-world optimization problem instances from the field of vehicle dynamics. This dataset reduces the computational effort associated with complex simulations and enables efficient benchmarking of algorithms. This facilitates the development of advanced optimization algorithms for specific challenges in the automotive industry in a computationally efficient and methodologically robust framework.

A central aspect of the research is the development of a meta-optimization framework for tuning the parameters of the Covariance Matrix Adaptation Evolution Strategy (CMA-ES). The proposed method involves the generation of surrogate optimization problems that mirror the complexity of the original optimization problem landscapes. Then, the generated surrogate optimization problems are used as tuning references for the meta-optimization. The experiments conducted demonstrate the potential of the approach for broad application to various optimization problems.

Furthermore, the effects of discretization on the performance of optimization algorithms are discussed. A CMA-ES variant able of handling discrete variables is investigated across different discretization levels and problem dimensions. Recommendations for adjusting the parameters are provided to improve performance.

In addition, a dynamic allocation method is developed to dynamically assign evaluations to individuals within a population. This method quantifies the uncertainty in the selection of the top individuals. Combining this method with CMA-ES significantly reduces the number of evaluations required. This improves computational efficiency in uncertain optimization environments.

Finally, the potential for applying the meta-optimization framework to different problem classes and industries is discussed. Moreover, further efficiency improvements are achievable, for example, by minimizing the computational effort associated with evaluations and feature computations as well as developing a database to leverage information from previous optimizations. In addition, the extension to multi-objective optimization is a promising area for future research.