Commentary

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Problems of Nonlinear Programming (NLP) and Robust Design Optimization Problems

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Description

In Robust Optimization (RO) problems, a common method for dealing with data uncertainty is robust counterpart reformulation. The robust counterpart formulation is difficult to derive from the duality theory, especially for complex uncertainty sets. A novel approach for RO problems is presented in this article to lessen the reliance on robust counterparts. The proposed method can find robust solutions without formulating robust counterparts thanks to the feasible space projection. To project the high-dimensional feasible space on the low-dimensional space of the objective function and uncertainty parameters, the RO model can be reformulated as a semi-algebraic system using a modified cylindrical algebraic decomposition method. System parameters are involved in the majority of practical optimal design or control issues. Due to the measurement and estimation errors in the actual problems, these parameters may be uncertain. The optimization problems may have suboptimal or even impossible solutions if the uncertainties are not taken into account. In order to deal with optimization with uncertainty, Robust Optimization (RO) is such an important technique that has been utilized in numerous real-world industries.

Optimization Strategies Used To Deal With Uncertainties

The four general categories of uncertainty are as follows: based on the various sources, model-inherent, process-inherent, external, and discrete. The optimization strategies used to deal with uncertainties can be roughly divided into two groups: Reactive optimization prefers real-time optimization based on simulation or reoptimization after uncertain events have occurred, while preventive optimization takes into account uncertainties in the initial mathematical model. The user must specify the type of the uncertain data set in advance in the traditional RO solving scheme, and then robust reformulation techniques are used to construct the corresponding robust counterpart optimization problem. This robust counterpart model can be solved to find the best possible solution for any realization of the data uncertainty in the set. By taking into account straightforward data perturbations, the robust counterpart optimization problem was first presented. By reformulating the first direct programming model, the vigorous arrangement can be acquired to vaccinate every single imaginable irritation. However, because it guarantees feasibility against all potential realizations in the uncertainty set, it is the most conservative approach. Other robust counterpart methods were further developed by some researchers to lessen the conservatism. Based on the assumption of the ellipsoidal uncertain set, proposed a conic quadratic formulation of the robust counterpart. Later, they came up with an adaptable, robust solution for linear programming problems with variable parameters. Because it makes decisions that are more adaptable than those that can be adjusted based on the realized portion of the data, the adjustable RO method is less conservative than the traditional RO method. An RO strategy employing second-order cone programming to minimize the worst-case residual was proposed for the least-squares problems with uncertain parameters. Then, RO was extended to include problems with uncertain semidefinite programming. proposed a polyhedral and interval uncertainty set whose conservativeness can be controlled by introducing a budget parameter. Investigated conic optimization issues based on RO and utilized it to address inventory control issues. proposed a robust method for general Nonlinear Programming (NLP) optimization. Conic representable sets provide the framework for the uncertainty sets.

A novel approach to addressing RO issues

After selecting the uncertainty sets for each uncertainty parameter, the initial RO model can be rewritten as a semi-algebraic system by substituting an auxiliary variable for the objective function. After that, a reworked CAD technique is used to project the high-dimensional feasible space onto the low-dimensional objective function and uncertain parameter space, which is represented by a union of a number of disjointed cells. Finally, since each cell's lower profile can be expressed analytically, the final robust solution can be obtained by performing a max-max decision criterion and solving the maximization problem for each lower profile. The effectiveness of the proposed RO method is demonstrated by the case studies' outcomes. The robust counterpart formulations are not required for the proposed method, which is based on the projection and decomposition of the feasible space. In addition, the proposed RO method can deal with mixed integer, nonlinear, and linear problems with polynomial constraints thanks to the CAD method's symbolic operation capacity. The deduced analytical expressions show the relationship between the objective function and the uncertain parameters, which can be used to determine the value of the objective function in each scenario within the uncertainty set. However, it should be noted that the proposed method is currently more applicable to relatively small or medium-scaled RO problems due to the CAD technique's heavy computational burden. The proposed method in this work will have more potential applications as more effective CAD-type algorithms are developed.