Surrogate-Assisted Global Sensitivity Analysis of Multilevel Block Preconditioners for Coupled Multiphysics Systems

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Finite element discretizations of coupled multiphysics problems yield large, sparse, block-structured linear systems. Solving these systems can account for a substantial share of the computational cost. Multilevel block preconditioners are one approach to solving such systems, but their performance depends on many parameters. Despite their potential influence on time-to-solution, these parameters are frequently selected based on experience or investigated only through limited parameter studies.

In this contribution, we investigate variance-based global sensitivity analysis as a systematic tool for identifying performance-critical solver parameters. Focusing on algebraic multigrid and block preconditioning, we treat solver parameters as uncertain inputs and time-to-solution as the quantity of interest. Sobol indices quantify the global influence of individual parameters and their interactions.

Since direct Monte Carlo estimation can involve many solver evaluations, we train a Gaussian process regression model on data obtained from solver runs and use it as a surrogate model to estimate the sensitivity indices inexpensively. Experiments on representative coupled multiphysics problems indicate that a subset of parameters has a dominant influence on solver performance, while others may be candidates for fixed default values.

References:

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