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Optimization under Uncertainty Constrained by Multiscale Phenomena

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Many computational challenges in engineering and science exhibit multiscale and multiphysics phenomena so that large scale optimization and uncertainty quantification are computationally very expensive or completely intractable. Furthermore, uncertainties arising at each scale must be propagated through appropriate mapping mechanisms between scales. In this work, we investigate multiscale formulations to improve on the mapping mechanisms, apply computationally efficient optimization methods to address the significant increase in degrees of freedom, and explore mechanisms to handle uncertainties. We present a computational framework based on multiscale mortar non-overlapping domain decomposition, coupled to Newton-Krylov based optimization and endowed with concepts from stochastic optimization. The multiscale mortar technique provides a convenient and mathematically elegant approach for coupling different numerical methods through physically meaningful interface conditions. Neighboring sub-grids are not required to match along the interfaces. This approach has been used to simulate multiphase flow through porous media, compressible fluid dynamics, multiphysics, computational mechanics, and geomechanics. The large scale optimization strategies we employ are capable of addressing model uncertainties through risk measures, which dictate performance criteria on the handling of the uncertainties in the optimization process. We demonstrate our methodologies on linear elasticity but note that our computational framework is sufficiently general to handle a wide range of applications.