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Weakly intrusive methods for uncertainty quantification and parameterized matrix problems

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A recurring debate exists amongst practitioners of uncertainty quantification over whether black-box techniques are sufficient for meaningful uncertainty quantification or whether existing solvers should be modified to apply so-called intrusive methods. In the context of spectral methods, advocates of intrusive methodologies favor techniques such as Galerkin for their flexibility and smaller number of unknowns, while non-intrusive proponents prefer collocation and pseudo-spectral methods because they require only existing solvers and exhibit comparable asymptotic convergence rates. In this talk, we propose a middle ground: a weakly intrusive paradigm. From a parameterized matrix perspective, a weakly intrusive method needs a matrix-vector product at a point in the parameter space. Methods in this paradigm are easy to implement and promote software reuse and algorithmic design. We show how the spectral Galerkin technique fits into the weakly intrusive framework in a method dubbed Galerkin with Numerical Integration (G-NI). This method depends crucially on a factorization of the Galerkin matrix. This factorization also yields bounds on the eigenvalues and suggests preconditioning strategies including the popular mean based preconditioner.