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Ajit Desai, Mohammad Khalil, Chris Pettit, Dominique Poirel, Abhijit Sarkar

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Scalable Domain Decomposition Solvers for Stochastic PDEs in High Performance Computing

Ajit Desai[a], Mohammad Khalil[b], Chris Pettit[c], Dominique Poirel[d], Abhijit Sarkar[a,*]

[a]*Department of Civil and Environmental Engineering, Carleton University, Ottawa, Ontario, Canada*
[b]*Sandia National Laboratories, Livermore, California, United States*
[c]*Department of Aerospace Engineering, United States Naval Academy, Annapolis, Maryland, United States*
[d]*Department of Mechanical and Aerospace Engineering, Royal Military College of Canada, Kingston, Ontario, Canada*

Abstract

Stochastic spectral finite element models of practical engineering systems may involve solutions of linear systems or linearized systems for non-linear problems with billions of unknowns. For stochastic modeling, it is therefore essential to design robust, parallel and scalable algorithms that can efficiently utilize high-performance computing to tackle such large-scale systems. Domain decomposition based iterative solvers can handle such systems. Although these algorithms exhibit excellent scalabilities, significant algorithmic and implementational challenges exist to extend them to solve extreme-scale stochastic systems using emerging computing platforms. Intrusive polynomial chaos expansion based domain decomposition algorithms are extended here to concurrently handle high resolution in both spatial and stochastic domains using an in-house implementation. Sparse iterative solvers with efficient preconditioners are employed to solve the resulting global and subdomain level local systems through multi-level iterative solvers. Parallel sparse matrix-vector operations are used to reduce the floating-point operations and memory requirements. Numerical and parallel scalabilities of these algorithms are presented for the diffusion equation having spatially varying diffusion coefficient modeled by a non-Gaussian stochastic process. Scalability of the solvers with respect to the number of random variables is also investigated.

Keywords:
Schur complement, Parallel preconditioner, Balancing domain decomposition by constraints, Dual-primal finite element tearing and interconnect method, Polynomial chaos expansion, Coarse grid