Distributed Stochastic Finite Element on a Desktop Grid

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Abstract: FEM is a very important tool for various applications in a wide range of engineering fields. Lately, thanks to the improvements in computer hardware and parallel algorithms, FEM models have become quite large and complex. In such situations, due to the lack of information, one needs to handle uncertainty in the objects subjected to analysis, in the conditions the analysis is performed, or in the applied mathematical models.

When variables involved in FEM possess stochastic terms, Stochastic FEM can be used to solve the problem. In Perturbation SFEM which is one of SFEM, one needs to solve at least as many linear systems $Ax = b$ as the number of stochastic terms. If each element has a stochastic term in its material properties, the number of systems will equal the number of elements. Thus, SFEM has been considered to be unpractical for large-scale problems. These systems have the same coefficient matrix A and different right-hand sides.

For problems involving a number of linear systems with the same coefficient matrix A, the seed method has been developed. In this method, the Krylov subspace generated from the seed system is reused considering the orthogonal projections in subsequent systems. This method can be applied to SFEM and reduce the computational cost of CG iterations in the calculations of the perturbation terms. On the other hand, because the aforementioned linear systems can be solved asynchronously and in a distributed manner, SFEM is very suitable to a distributed environment.

We applied the seed method to SFEM and implemented it to fit a distributed environment. In this implementation, 180% speedup is obtained in a test case on a single PC. In order to set certain parameters in the computation, the relation between the convergence history and seed efficiency has been investigated. From an implementation point of view, we built our desktop grid environment utilizing Berkeley Open Infrastructure for Network Computing and Amazon Elastic Computing Cloud. This helps dealing with peak requirements in cases where not enough computational resources are available to satisfy the demand.

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