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Non-Statistical Uncertainty Quantification Analysis with Parallel CAE Solvers, ADVENTURE

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Uncertainty quantification (UQ) is a computational field to evaluate probabilistic effects of uncertainty in input parameters of a system such as geometry, physical properties, and boundary conditions, on the response of the system.

One of the most common and widely used methods for UQ is the Monte Carlo (MC) method. The MC method evaluates probability distributions of system response by generating random numbers, i.e. samples, that follow specific probability distributions of input parameters with uncertainty. The most attractive feature of the MC method is to enable to use an independent deterministic simulator as a black box, while the method suffers from slow convergence and increasing computational cost.

On the other hand, non-statistical methods expand input and output random fields of a system into a function in a probability space, respectively. They have high computational efficiency with maintaining accuracy.

Among a variety of UQ methods [1], we choose a method to integrate the Non-Intrusive Polynomial Chaos (NIPC) method [2], which is one of non-statistical methods, with two kinds of opensource parallel CAE solvers, i.e. ADVENTURE_Themal, a heat conduction solver, and ADVENTURE_Fullwave, an electro-magnetic wave solver [3]. The ADVENTURE solvers have been tuned for a variety of latest HPC environments including the Supercomputer Fugaku.

We evaluate computational complexity of the proposed method theoretically as well as numerically, and identify bottleneck processes for larger scale of problems in HPC environments. Finally we demonstrate practical performances of the proposed method by solving some practical problems such as thermal conduction and electromagnetic wave problems.

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