Fast r-adaptivity for multiple queries of heterogeneous stochastic material fields

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ABSTRACT

The Monte Carlo approach in stochastic modeling requires multiple queries to numerical (typically finite element) solutions of similar problems. In the case of random material fields, only the material properties vary between different realizations, often representing perturbations of a simple material description around a reference configuration (typically a uniform material field). The different instances of the Monte Carlo sampling are usually computed with the same finite element mesh, which is designed to provide a reasonable accuracy in the case of the average material field. However, this mesh is not accounting for the actual realization of the stochastic material field and therefore it does not obtain the maximum accuracy that could be achieved with the computational resources employed. The possibility of designing a new mesh from scratch for each Monte Carlo realization is not realistic: the computational cost of redesigning the mesh based on the fluctuating material field is unaffordable when the number of Monte Carlo samples increases. Moreover, the perturbations in the material field are not expected to require a drastically different mesh. Note for instance, that the local mesh refinement resolving the patterns in the solution associated with the geometrical features of the domain are kept constant all along the Monte Carlo process. The strategy proposed in this paper consists in modifying for each realization a mesh designed to be efficient in the reference (unperturbed) case. The mesh is then modified following an r-adaptive scheme at each Monte Carlo realization. The mesh adaption is performed on the basis of simple criteria accounting for the actual (perturbed) material field. Note that the r-adaptive approach suits the needs of the current scope (optimal distribution of the computational resources, having set a priori the number of degrees-of-freedom) but does not allow guaranteeing the final accuracy of the results obtained.