Hyper-reduction by statistically corrected clustering

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Abstract

The efficiency of projection-based reduced order models hinges on numerically robust and accurate hyper-reduction methods. Recently, statistically compatible hyper-reduction has been introduced as one possible pathway to construct integration points for the reduced-order model (1). For example, second-order statistical compatibility means that the average strain (i.e. the 1st statistical moment) of the full field representation (based on the modes) is exactly met by the reduced integration points and, in addition, the second moment is also exactly preserved. This idea is taken from more analytical homogenization methods, in particular developed by Pedro Ponte-Castaneda (e.g., 2). The recent approach (1) shows good results with small numbers of integration points, often in the order of 10-20, as long as the degree of nonlinearity of field fluctuations is moderate. However, it suffers from a major limitation, namely that the maximum number of reduced integration points is limited. Up to now, it was thus impossible to increase the number of integration points for highly nonlinear problems, where a higher amount would be necessary to reach a good accuracy. In this work, this limitation is overcome by combining the method with a kmeans-based clustering procedure in a generalized strain space, such that the number of integration points can be further increased and convergence to the FEM-solution is achieved even in strongly nonlinear cases.
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(2) Ponte Castañeda, P., 2015. Fully optimized second-order variational estimates for the macroscopic response and field statistics in viscoplastic crystalline composites. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *471*(2184), p.20150665.

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