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Deep learning based dimensionality reduction for fracture mechanics

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The computational cost of nonlinear structural analysis can be prohibitive when multiple numerical simulations have to be conducted under various loading conditions or model parameters. To solve this issue, Reduced Order Modeling (ROM) methods have been proposed in the literature. For instance, Principal Components Analysis (PCA) can be used to compute a reduced basis from a database of full-order snapshots [1]. PCA, however, does not reconstruct low dimensional spaces efficiently for highly nonlinear problems, mainly because it is a linear compression method.
More recently, deep learning has also been used for dimensionality reduction [2] of nonlinear high dimensional data. In this work, an original approach based on an autoencoder neural network is developed to construct a nonlinear ROM for a highly nonlinear brittle fracture problem. The problem is modeled and solved using the finite element method with a phase-field model [3]. Different random loading paths are generated and simulated to generate the data set, which is then compressed using the autoencoder as well as PCA. Results both on training and testing (unseen loading paths) data show the superior compression efficiency of the autoencoder. Finally, a complete deep learning framework is proposed to predict crack propagation patterns directly from the loading path.

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