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Nelder-Mead Parametric Optimization of Elastic Metamaterials with Artificial Neural Network Surrogate Model

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Abstract : Some of the most fundamental challenges of elastic metamaterials (EMMs) optimization can be attributed to the high consumption of computational power resulted from finite element analysis (FEA) simulations that render the optimization process inefficient. Furthermore, due to the inherent mesh dependence of FEA, minuscule geometry features, which often emerge during the later stages of optimization, induce very fine elements, resulting in enormously high time consumption, particularly when repetitive solutions are needed for computing the objective function. In this study, a surrogate modelling algorithm is developed to reduce computational time in structural optimization of EMMs. The surrogate model is constructed based on a multilayer feedforward artificial neural network (ANN) architecture, trained with prepopulated eigenfrequency data prepopulated from FEA simulation and optimized through regime selection with genetic algorithm (GA) to improve its accuracy in predicting the location and width of the primary elastic band gap. With the optimized ANN surrogate at the core, a Nelder-Mead (NM) algorithm is established and its performance inspected in comparison to the FEA solution. The ANNNM model shows remarkable accuracy in predicting the band gap width and a reduction of time consumption by 47%.

Keywords : artificial neural network, machine learning, mechanical metamaterials, Nelder-Mead optimization
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