An Integrated Interval Neural Network for Uncertainty Modeling in Inhomogeneous Materials

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Abstract. Engineering fields rely heavily on the Finite Element Method (FEM) as a modeling tool in deterministic systems where no uncertainty is introduced. The effects of uncertainty are of growing concern in the analysis and design of engineering structures and need to be studied to improve the predictability of mathematical models. Recently, in addition to others, Interval Finite Element Method (IFEM) has been introduced to account for uncertainties by incorporating interval arithmetic into the conventional FEM formulation, in which all uncertain parameters are defined as intervals. Nonetheless, in combination with complexity of structures and inhomogeneous materials, the computational and experimental cost remains an inevitable issue in such simulations.

This work aims at integrating Artificial Neural Networks (ANN) and IFEM techniques to establish a flexible and efficient approach for modeling uncertainties in general inhomogeneous structures, in which an Interval Neural Network (INN) is employed as a substitution for the conventional constitutive material model to establish a homogenized representation of structures regardless of material complexity. In this approach, at first, the required dataset is generated by creating and running a set of IFEM simulations. The INN will then be trained to predict the homogenized mechanical behavior of the structure as a function of independent parameters. Afterwards, the trained INN will be integrated in the IFEM procedure to obtain the system's response under uncertainty. The proposed approach is applied to a set of engineering problems to illustrate and verify the capabilities of the methodology.

Keywords: Interval Finite Element Method, Interval Neural Network, Machine Learning, Inhomogeneous Material