Deep Interval Neural Network in Computational Mechanics

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Abstract

The analysis and design of complex engineering systems is exposed to a great number of uncertainties in the inputs of the systems' models. Not modeling this uncertainty properly can lead to inaccurate and even disastrous expectations of the system's performance. In the context of computational mechanics, a system analysis under uncertainty is commonly performed using the stochastic finite element method (SFEM) or the interval finite element method (IFEM). The SFEM integrates random field theory with the conventional FE method to model the spatiotemporal-varying uncertainty in the system inputs and propagate the uncertainty through the FE model. Despite its widespread adoption, random field theory is inadequate for cases where there is not enough data to select a probability distribution. As an alternative, the IFEM integrated with newly proposed *interval fields* are an alternative to random fields when we do not possess enough knowledge about the probability distributions of system inputs.

Previously, we presented an interval field method which can model the spatiotemporal variation of an IFEM input variable through a real-valued interval neural network using indirect observations (Betancourt et al. (2018)). For this work, we build on the previous paper by adding the capability to process the interval uncertainty in the domain through a novel deep interval neural network (DINN), developed by the authors, to obtain interval predictions of the input IFEM variable. Thus, with the DINN we predict the spatial and/or temporal variation of an unknown IFEM interval input $\mathbf{Y}$ (e.g. material properties) that cannot be directly measured, based on other interval observations $\mathbf{X}$ (i.e. sensor measurements). Finally, the predictions of the DINN must be mapped onto the FE mesh of the IFEM.

A numerical experiment is conducted using a dataset of concrete mix measurements with interval uncertainty to predict concrete strength. We demonstrate that our method achieves good results compared to ground truth values of the material properties. In addition, the presented method can be used in multiple scales, engineering materials, and data types.

References

D. Betancourt, R. Muhanna, and R. Mullen, in *Proceedings of the 8th international workshop on reliable engineering computing* (University of Liverpool, 2018), vol. 8.