Synergistic Use of CUF and Machine Learning for Structural Mechanics Problems

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Abstract. This paper presents recent advances in using refined structural theories and machine learning (ML) techniques to tackle structural mechanics problems with high numerical efficiency. The proposed approach exploits the Carrera Unified Formulation (CUF) [1] to obtain refined structural theories, governing equations, and various machine learning techniques to build surrogate models and improve numerical efficiency.

Various applications and numerical cases show the advantages stemming from the synergistic use of CUF and ML. First, the proper choice of the structural theory for a given problem is considered as in [2, 3]. CUF generates training data for Neural Networks (NN), considering higher-order polynomial expansions of the displacement field and problem features, e.g., thickness, material properties, and boundary conditions as inputs. The trained network provides the accuracy of a given structural theory for a given structural problem. For instance, the proposed approach can estimate the accuracy of a third-order shear deformation theory to compute the first natural frequencies of a cross-ply shell without requiring a finite element analysis. Through the Node-Dependent Kinematics (NDK) approach [4], NN can also indicate the spatial distribution of the theories, i.e., the best distribution of structural theories over a set of finite element nodes, to minimize the computational overhead without affecting the accuracy.

The second set of results concerns using CUF and ML for other applications, e.g., optimizing VAT composites. CUF generates accurate static and dynamic responses of VAT structures used to build surrogate models. The latter are then used to span the design space and find optimal configurations.

Lastly, recent advances in coupling CUF and Physics-Informed Neural Networks (PINN) are presented. Examples are solutions of strong-form equations using higher-order structural theories for various cases.

References

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