Enhancing Acoustic Wave Propagation Prediction with Symmetry-Informed Model

Hee-Sun Choi[1], Byoungil Jeon[2], Yonggyun Yu[2], Hogeon Seo[2]

[1]Applied Artificial Intelligence Section , Korea Atomic Energy Research Institute (KAERI), Republic of Korea, [1]Applied Artificial Intelligence Section , Korea Atomic Energy Research Institute (KAERI) , Republic of Korea

We propose a symmetry-informed surrogate model utilizing a fully-connected neural network to estimate the propagation of acoustic waves across arbitrary locations, times, and wave excitation widths. This model serves as an implicit representation of acoustic wave propagation. To enhance predictive performance, we introduce a residual based on an inherent physical feature: the symmetry characteristic in acoustics. The proposed model achieves the R-squared value exceeding 98%, and its inference is approximately 215 times faster compared to results obtained through FEM simulations using COMSOL Multiphysics. Primarily, three key benefits accompany the suggested residual: no specific model architecture is required, no labeled data or reference solutions are necessary, and the generalization ability is improved across all input dimensions. This study incorporates numerical investigations to validate the superior generalization ability of models trained with the symmetry constraint. We also explore the influence of regularization rates, sampling methods, and additional hyperparameters introduced by the proposed residual. The symmetry-informed surrogate model demonstrates potential feasibility for real-time wave propagation prediction in a practical application: defect visualization through ultrasonic imaging techniques. The results affirm that the capability of surrogate models for generalized implicit representation can be heightened by incorporating physics-informed training residuals, making it an innovative tool for defect identification through optimization methodologies or reinforcement learning that demand fast and reliable wave propagation prediction.