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A Surrogate Model for Rapid Solution of Acoustic Wave Equation Based on the Boundary Element Method and Fourier Neural Operators

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ABSTRACT

A modern approach to control sound is through the development of sound-control materials/structures, which enable a wide range of applications such as noise reduction and non-contact particle manipulation. Designing these sound-controlling metamaterials requires accurate and efficient simulation methods for solving the unbounded acoustic wave equation with changing domain and frequencies. To facilitate the design optimization, surrogate models that are significantly more efficient than full-scale simulations are highly desirable. In this work, we present our recent work on the development of such surrogate models based on the concept of Fourier neural operators (FNO). FNO was originally developed to learn the mapping from a parametric space to the solution space for a family of partial differential equations within a finite domain [1]. However, for unbounded problems with changing domains, directly applying FNO is not feasible. Therefore, we propose to a method that combines the boundary element method (BEM) with FNO. The acoustic BEM offers advantages such as boundary discretization only and is particularly suitable for solving wave propagation problems in infinite domains. In our approach, we use FNO to construct a surrogate model that maps the boundary Euclidean space, representing the geometry of the sound-controlling structure, to the corresponding boundary solution space. Once the boundary values are known, the boundary integral equation is then applied to calculate the acoustic pressure at desired points within the infinite domain. To validate the performance of the BEM-FNO approach, we conducted simulation experiments on a set of 2D benchmark problems with various structures, including ellipses, Helmholtz resonators, and acoustic diffusers. We compared the performance of our approach with conventional BEM approaches and surrogate models based on convolutional neural networks. The results demonstrated that the proposed BEM-FNO approach can accurately and effectively solve the acoustic wave equation with varied structures and frequencies.

KEYWORDS

Surrogate model; acoustic wave equation; boundary element method; fourier neural operators

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References

1. Li, Z. Y., Kovachki, N., Azizzadenesheli, K., et al. (2020). *Fourier neural operator for parametric partial differential equations. arXiv preprint arXiv, 2010.* 08895.