

PROCEEDINGS

An Intelligent Mesh-free Computational Framework with Adaptive Multiscale Modeling for High-Fidelity Wave Simulation in Complex Heterogeneous Media

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ABSTRACT

Accurate wave simulation in complex heterogeneous media remains challenging because strong material contrasts, irregular interfaces, and multiscale structures often require spatially varying computational resolution. This study presents an intelligent mesh-free computational framework with adaptive multiscale modeling for high-fidelity wave simulation in heterogeneous media. The proposed framework combines localized mesh-free approximation with an adaptive resolution strategy, allowing computational resources to be concentrated automatically in regions containing complex structures or rapidly varying wavefields, while smoother regions are represented with a relatively economical discretization. Such a strategy reduces the dependence on globally uniform resolution and improves the flexibility of numerical modeling for media with complicated spatial variations. Numerical experiments involving representative heterogeneous models demonstrate that the proposed framework can accurately reproduce major wave-propagation characteristics, including reflection, transmission, and wavefield interactions across complex interfaces, while maintaining stable numerical performance under adaptive spatial configurations. The results indicate that the proposed approach provides an effective balance between modeling accuracy and computational efficiency, and offers a flexible numerical framework for high-fidelity wave simulation in complex heterogeneous environments.

KEYWORDS

Mesh-free method; Adaptive multiscale modeling; Heterogeneous media; Wave simulation; High-fidelity computation

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