Reduced-Order Wave-Propagation Modeling Using the Eigensystem Realization Algorithm

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Abstract: Modeling of sound propagation in complex environments requires high-performance computing (HPC) to simulate three-dimensional wave fields with realistic fidelity. This is especially true for urban environments, where sound waves are reflected and diffracted by buildings and other structures or objects. As a result, energy from a source typically travels along multiple paths to reach a sensing location, with constructive or destructive phase interference observed in continuous signals. Finite-difference time-domain (FDTD) and other numerical calculations using HPC can predict these wave fields with required fidelity, but the computational investment would have far greater return if a reduced-order model could be produced from the results. Two types of reductions have practical application: a reduction of the three-dimensional model domain to a desired subset of the wave field while maintaining the three-dimensional effects, and a reduction of the dynamic-system order while maintaining a required accuracy.

The objective of this work is to develop reduced-order models using wave-field signals from three-dimensional FDTD computations of a linear-time-invariant urban-acoustic model. The work applies a modification of the Eigensystem Realization Algorithm (ERA), using correlation matrices of system impulse response functions, in order to simultaneously operate on tens of thousands of output signals from the wave field. The results include predicted acoustic wave-field signals from reduced-order models, in comparison with full-model signals, over a large and highly resolved just-above-ground-level domain. In addition, as is common with ERA, the model order and accuracy is selectable by an appropriate singular-value cutoff. We conclude that the method efficiently produces high-fidelity reduced-order HPC models of sound propagation in complex environments.

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