Data driven reduced order modeling for first order hyperbolic systems with application to waveform inversion

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Abstract

Waveform inversion seeks to estimate an inaccessible heterogeneous medium by using sensors to probe the medium with signals and measure the generated waves. It is an inverse problem for a hyperbolic system of equations, with the sensor excitation modeled as a forcing term and the heterogeneous medium described by unknown, variable coefficients. The traditional formulation of the inverse problem, called full waveform inversion (FWI), estimates the unknown coefficients via nonlinear least squares data fitting. For typical band limited and high frequency data, the data fitting objective function has spurious local minima near and far from the true coefficients. This is why FWI implemented with gradient based optimization can fail, even for good initial guesses. We propose a different approach to waveform inversion: First, use the data to "learn" a good algebraic model, called a reduced order model (ROM), of how the waves propagate in the unknown medium. Second, use the ROM to obtain a good approximation of the wave field inside the medium. Third, use this approximation to solve the inverse problem. I will give a derivation of such a ROM for a general first order hyperbolic system satisfied by all linear waves in lossless media (sound, electromagnetic or elastic). I will describe the properties of the ROM and will use it to solve the inverse problem for sound waves.
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