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Adjoint Analysis of Seismic Wave Equation and its Applications in Full Waveform Inversion

The adjoint-state method provides a rigorous framework for analyzing sensitivity and gradient information in inverse problems constrained by partial differential equations. In this talk, we present an adjoint analysis of the seismic wave equation from a mathematical perspective. Starting with the continuous formulation of the acoustic (and elastic) wave equation, we derive the corresponding adjoint system and establish key identities linking perturbations in the model parameters to variations in the data misfit functional. This framework clarifies the structure of the gradient and Hessian operators that underpin full waveform inversion (FWI). We also discuss the role of regularization and the theoretical connections between adjoint analysis and PDE-constrained optimization. The presentation aims to highlight how the adjoint framework unifies sensitivity analysis and optimization theory in the context of seismic imaging.

Finally, if time allows, I will present real-world applications of FWI in hydrocarbon exploration, carbon sequestration monitoring, and medical imaging, emphasizing the central role of adjoint-based analysis in advancing both the theory and practice of seismic inversion.