



復旦大學
FUDAN UNIVERSITY

Applied Math Ph.D. Seminar

Diffusion Models for PDE-Constrained Inverse Problems: Algorithms and Applications to Full Waveform Inversion

Speaker: Chen Min (Shanghai Jiao Tong University)

Time: 2026-10-08, 16:10 to 17:00

Location: Rm 1801, Guanghua East Tower

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Abstract: PDE-constrained inverse problems arise throughout science and engineering, from medical imaging and fluid dynamics to geophysical exploration. A central example is full waveform inversion (FWI), which recovers subsurface velocity from seismic recordings by solving a severely ill-posed and nonconvex PDE-constrained optimization. Classical regularizers stabilize inversion but often fail to reproduce realistic geological structures, while supervised deep learning methods are efficient but generalize poorly to unseen structures, noise, and changing acquisition geometries. Diffusion models provide powerful data-driven priors by learning the score of Gaussian-corrupted marginals and generating samples via reverse-time SDEs or probability-flow ODEs. They have achieved strong results in image-domain inverse problems, but their use in PDE-governed problems remains challenging: existing diffusion-based algorithms introduce priors in various ways, yet physical constraints and the diffusion sampling process are not naturally consistent, and balancing prior guidance with stable, physics-aware optimization is difficult. This talk reviews PDE inverse problems, diffusion generative models, and diffusion-based inverse-problem algorithms, and then presents two recent works that embed pretrained diffusion priors into FWI. The first uses a decoupled latent-optimization formulation with an auxiliary physical variable, preserving classical smoothed-velocity initialization while letting the diffusion sampler provide a prior-consistent decoded velocity. The second couples a persistent physical state to the diffusion prior through a Gaussian bridge, mutually refining waveform fitting and denoiser-guided reverse sampling while separating wave-equation and denoiser gradients. Both methods are validated on OpenFWI and transferred to larger geological models under clean, noisy, and incomplete acquisitions. The results illustrate how diffusion priors can be made compatible with PDE constraints and provide practical algorithms for FWI and broader PDE-governed inverse problems.