THE UNIVERSITY OF CHICAGO | DEPARTMENT OF STATISTICS

Master's Thesis Presentation

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"Operator Learning and Bispectrum-Guided Diffusion for Functional Multi-Reference Alignment"

February 18, 2026, at 1:00 PM
Jones 111, 5747 S. Ellis Avenue

Abstract

We consider the functional multi-reference alignment (MRA) problem, where a signal in a function space is recovered from noisy, randomly shifted observations, and develop a coarse-to-fine reconstruction framework that remains effective even in the low signal-to-noise ratio (SNR) regime. The first stage interprets functional MRA as a deconvolution problem and employs a Fourier Neural Operator (FNO) to learn a deconvolution operator from empirical moments of the data to a coarse signal estimate, without explicit shift estimation. The second stage refines this estimate using a score-based diffusion model guided by shift-invariant spectral features. This generative approach integrates low-frequency constraints with computationally efficient bispectrum-based phase information to restore high-frequency details while providing uncertainty quantification. Numerical experiments demonstrate monotone error decay with increasing sample size, systematic improvements over the FNO baseline, and credible intervals that provide reasonable coverage of the true signal.

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