The limits of predictive control under frozen flow turbulence and slope-based wavefront sensing

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Abstract

Time-delay error, or AO servo-lag error, is a significant error source in adaptive optics systems. This error arises from the overall latency between sensing the wavefront and applications of the correction. Predictive control algorithms can reduce the time-delay error, providing significant performance gains, especially for instruments dedicated to direct exoplanet imaging.
However, the predictive controller's performance gain depends on multiple factors, such as the type of wavefront sensor, the measurement noise level, the AO system's geometry (aliasing, actuator spacing), and the atmospheric conditions (e.g., seeing, wind speed). This work studies the theoretical limits of predictive control under different imaging conditions through spatio-temporal Gaussian process models.
Further, we study the optimal design of predictive filters. We use the optimal experimental design (OED) methods to answer questions like "how long WFS data history a linear predictive filter should consider in different conditions, at given AO system geometry?"

Keywords: Gaussian process, optimal experimental design, predictive control

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