Closed-Loop Until Further Notice: Comparing Predictive Control Methods in Closed-Loop

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Abstract

For future extremely large telescopes, error in adaptive optics systems at small angular separations will be dominated by the lag time of the correction, which can be anywhere from _˜1-5 milliseconds; the natural solution is to apply a predictive correction to catch up with the system delay. Predictive control provides exemplary results in simulation (on the order of 5-10x improvement in RMS error), but shows only modest improvement on-sky (less than 2x in RMS error). This performance limitation is likely impacted by pseudo open-loop (POL) reconstruction, which requires assumptions about the response of the deformable mirror and accuracy of the wavefront measurements that are difficult to verify in practice. In this work, we remove the need for POL reconstruction by considering two closed-loop methods for predictive control: data-driven prediction using a reformulated empirical orthogonal functions (EOF) and the physically-motivated predictive Fourier control (PFC). We extend the EOF method to run in closed-loop, and verify its performance in this new framework. We examine the performance of both methods in simulation under varying turbulence profiles, including simulated single and multi-layer turbulence, and apply them to on-sky telemetry.

Keywords: wavefront control, predictive control, empirical orthogonal functions, linear quadratic gaussian control, telemetry

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