Laboratory Demonstrations of Optimal Identification and Control for Tip-Tilt Systems

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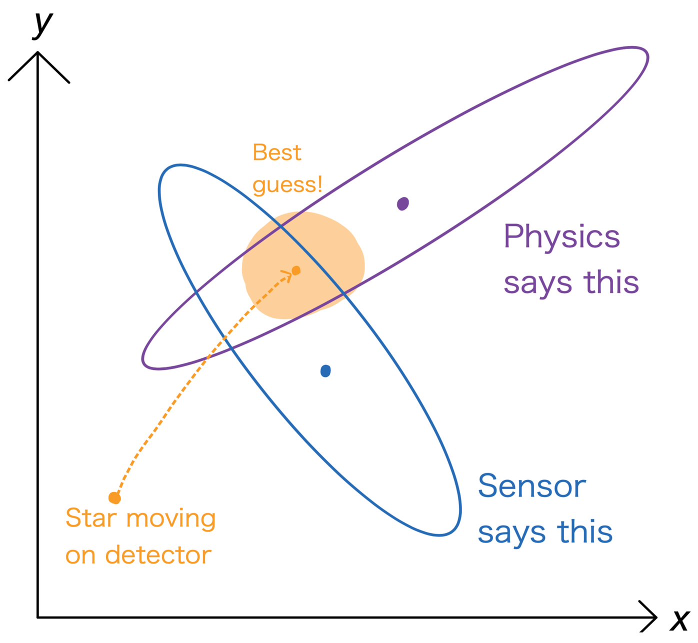
Research Aims

- Demonstrate linear-quadratic-Gaussian (LQG) control in tip/tilt with FAST
- Determine need for DM plant model in controller
- Build infrastructure for control experiments on UCSC SEAL testbed

The general principle of LQG control

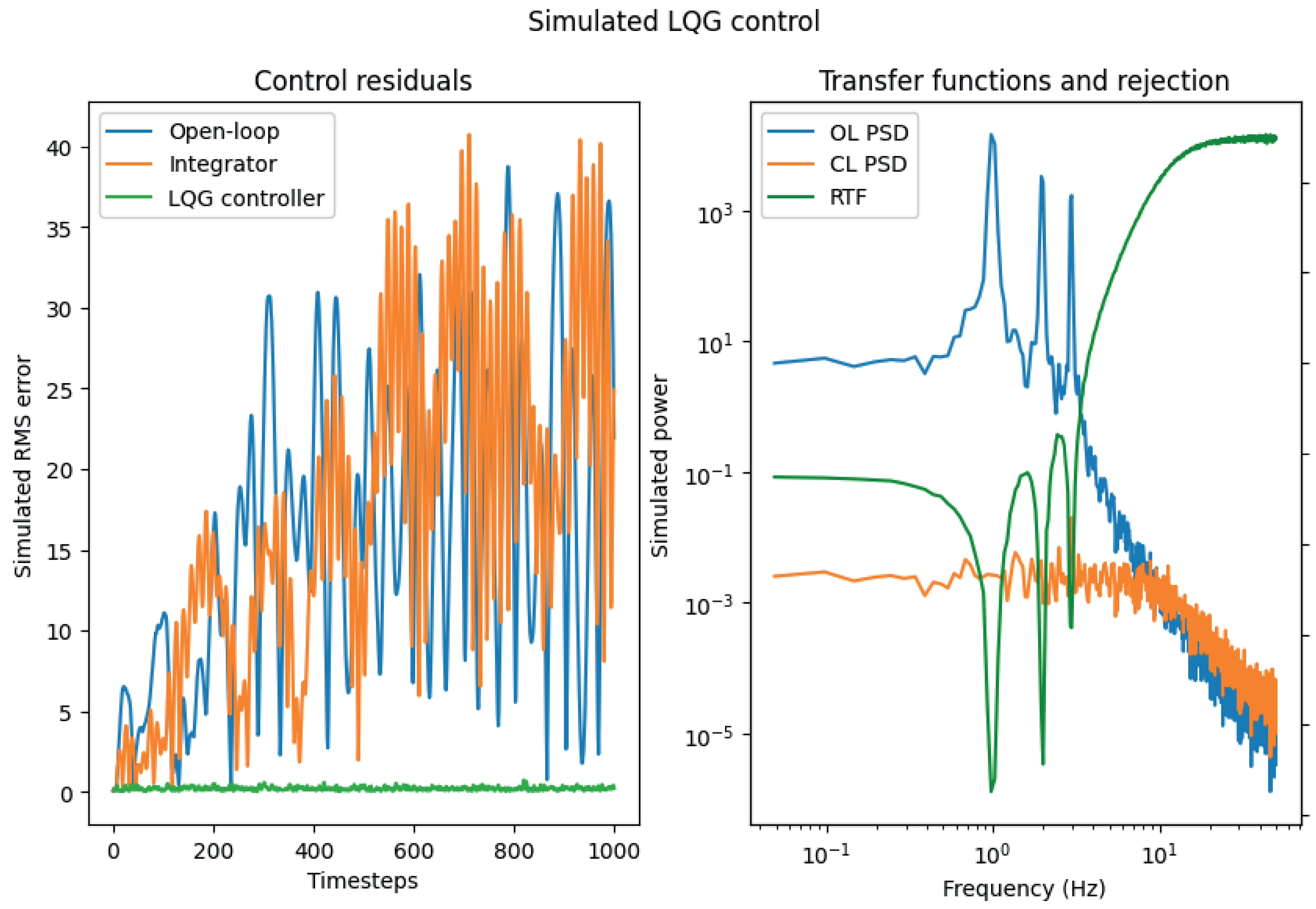
- The star moves around based on physics (atmosphere, vibrations) + random noise
- Sensors give us information, but with different random noise
- Combine them optimally: **Kalman filtering**
- Use this to predict and control the future states: **Linear-Quadratic-Gaussian (LQG) control**



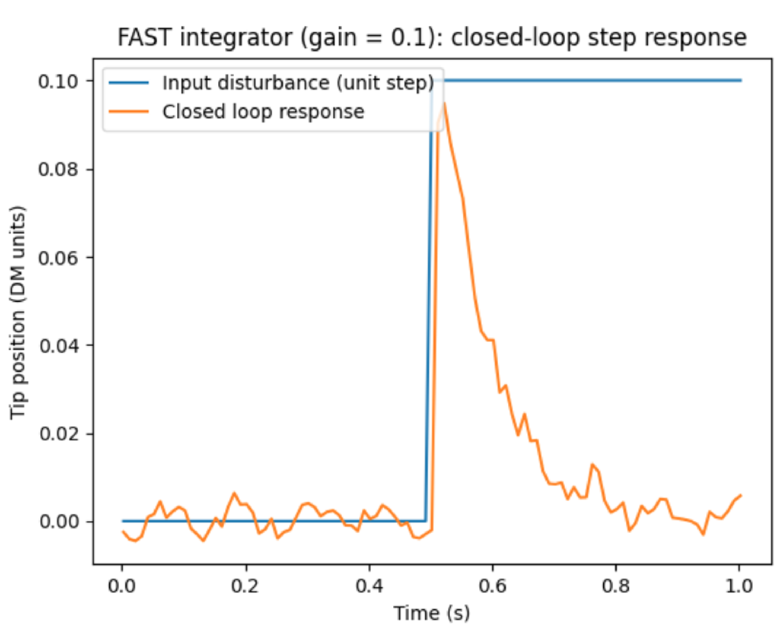
State-space model and simulations

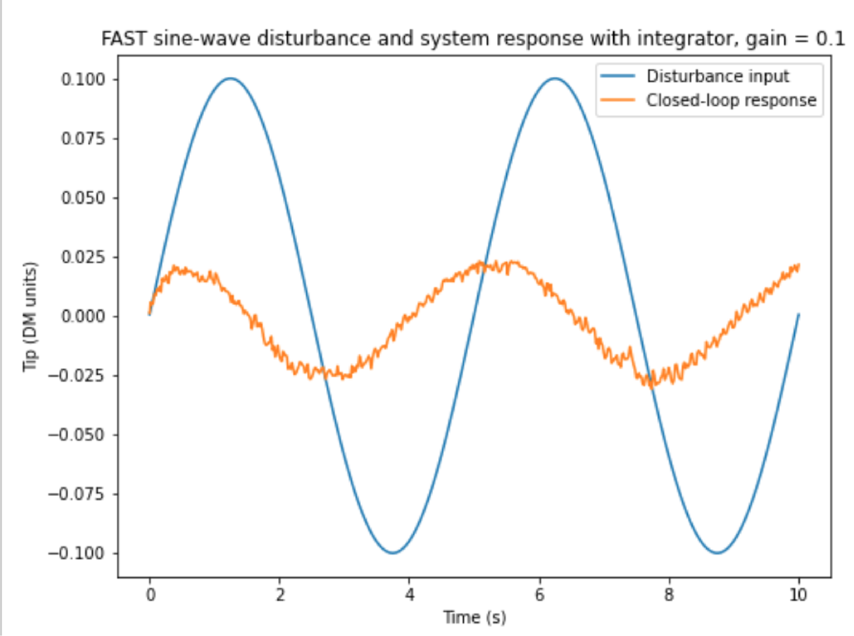
We consider turbulence and vibrations by analyzing the open-loop PSD
- Fit autoregressive model to the linear trend (turbulence)
- Fit autoregressive models to the peaks (vibrations)
- Use sum of models for prediction/correction

Additional terms to model delay due to hardware



Results with Integrator Control





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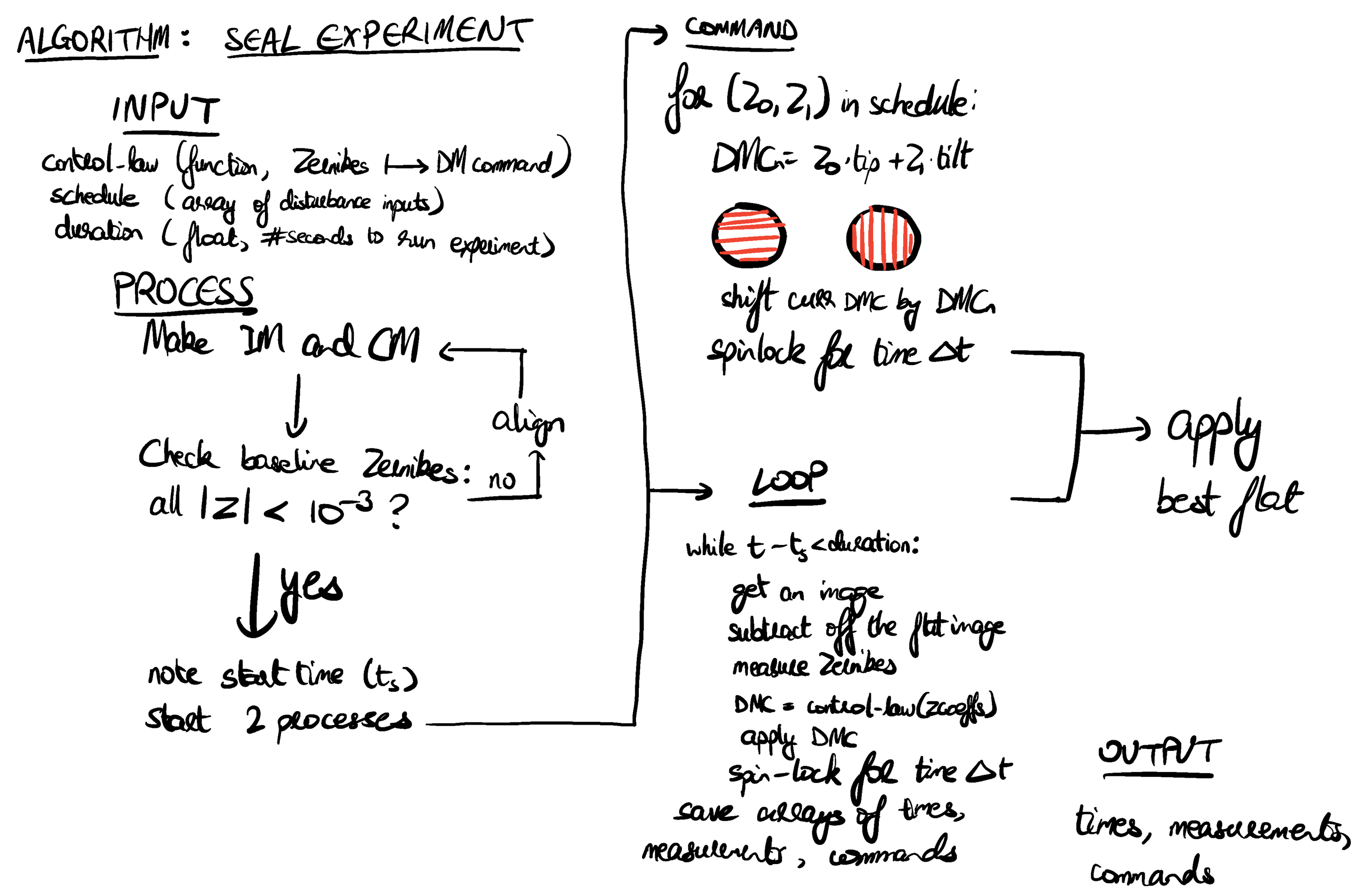
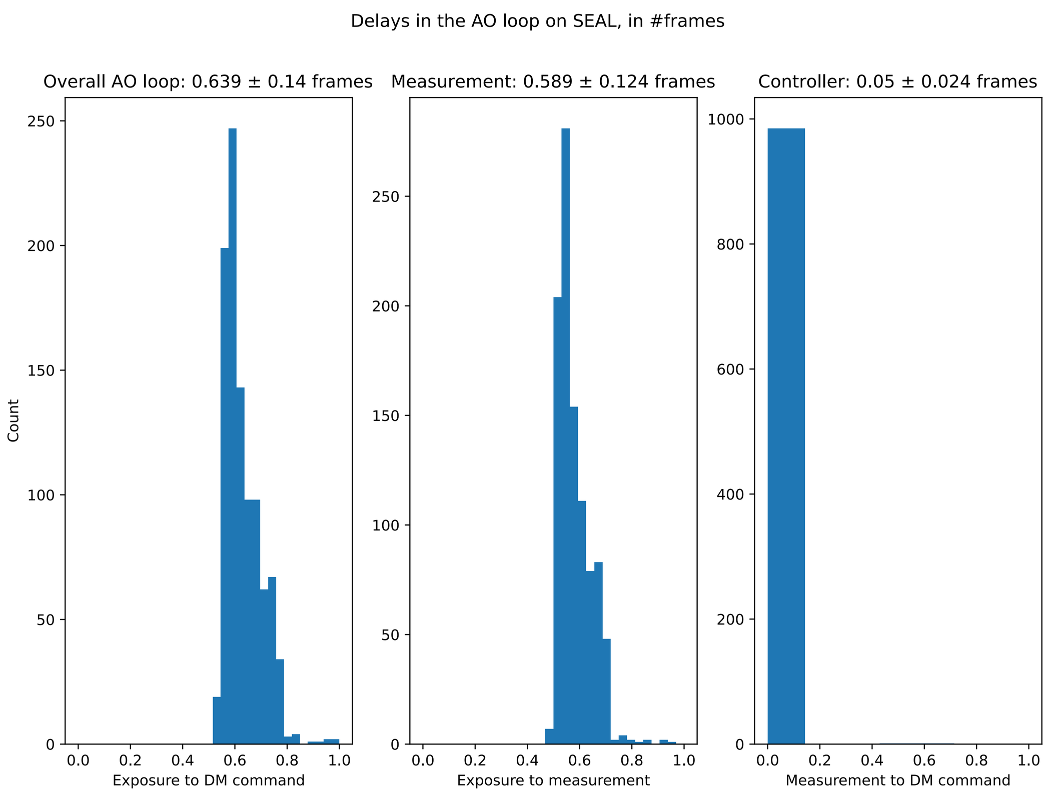
Experimental Procedure

Experiments on the Lab for Adaptive Optics SEAL testbed

Before each experiment:
- align optics: grid search across best-flats for contrast ratio
- make interaction/command matrices by applying Zernikes
- check linearity: apply disturbance x, observe y, compare to y = x



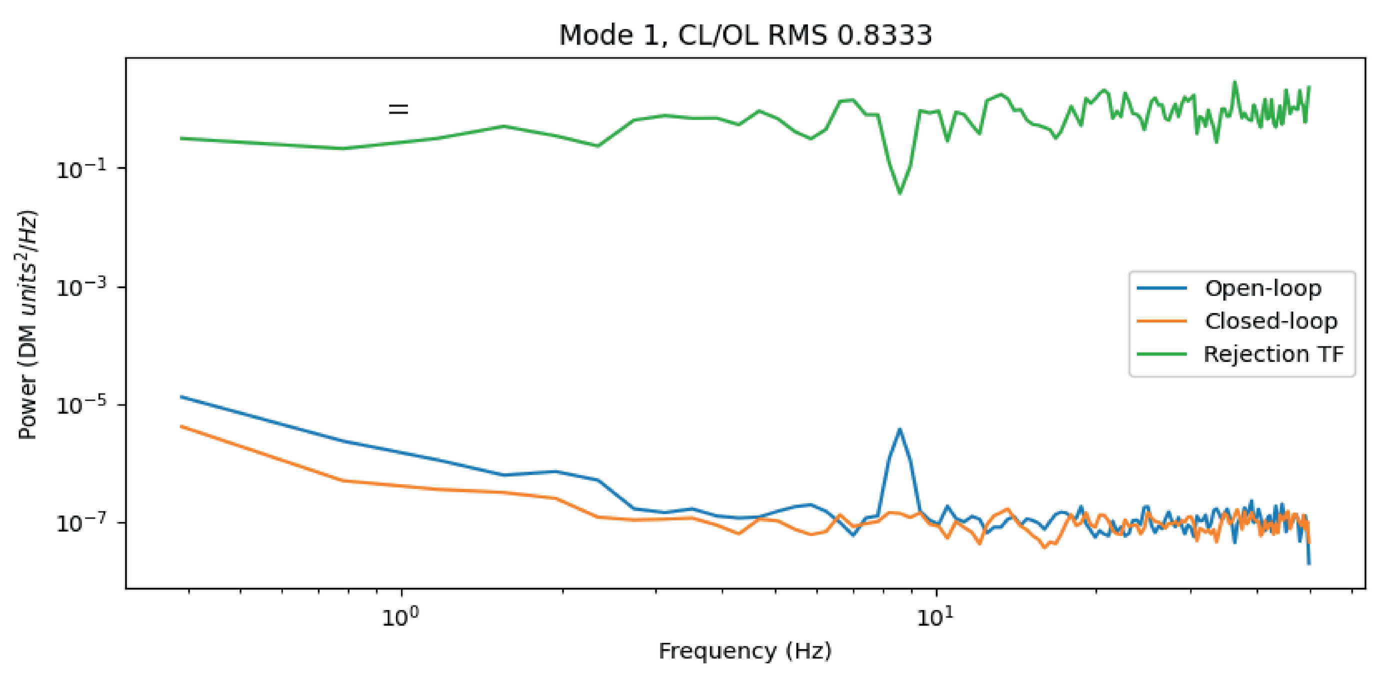
- Custom Python control code supports arbitrary controllers, disturbances, #Zernike modes
- Timing control with multiprocessing + "spin-locks" for a constant frame rate



Results and Future Work

- Showed efficacy of LQG control for AO in simulation
- Developed real-time control infrastructure for SEAL
- Characterized loop response of focal plane WFS AO loop
- Ongoing work to show effectiveness of LQG on bench and add in plant model

Future work: testing more computationally-intensive algorithms in the same framework, removing bottlenecks in the AO loop to increase the rate



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