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Vibration Mitigation in Adaptive Optics of Large Telescopes Using Model Predictive Control

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Summary

Large telescopes such as the Extremely Large Telescope (ELT) will suffer on the influence of structural vibrations to reach the diffraction limited performance. In the ELT a deformable mirror (DM) and tip-tilt mirror (TTM) are in the optical path of the telescope to compensate for the atmospheric turbulences and structural vibrations. Under specific condition as strong atmospheric turbulences and vibrations, the compensation mirrors in large telescopes can reach their stroke limits due to the mechanical dynamics. In this scenario the proportional-integral-derivative (PID) or linear quadratic Gaussian (LQG) control approach cannot reach the optimal performance of the adaptive optics system. Therefore, we propose a model predictive control (MPC) to consider the mirror dynamics and the corresponding actuator constraints in the control law. In a simulation study we analyze the performance in comparison to the PID and LQG control. To show the applicability we tested the optimization algorithms of the MPC on a real time environment. Furthermore, we improve the state estimation of the structural vibrations by using additional accelerometers from the telescope structure in a sensor fusion concept. The sensors are combined in a multi-rate observer. The observer is operated with the fastest sample rate and changes its observer gain dependent on the incoming sensor signal. Therefore, the wavefront sensor can be operated with a slower sample rate for a better signal to noise ratio and the high frequency vibrations can be detected by additional accelerometers, where the optical performance can be increased. In a simulation study we could show that as well the MPC control as the multi-rate observer can improve the performance for astronomical observations.

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