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Phase prediction under Taylor hypothesis using zonal models in LQG AO control

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Summary

The upcoming AO systems for VLTs and ELTs will feature a huge number of WFS measurements and DM actuators, and the design of high-performance controllers is a real challenge. In this context, the distributed Kalman filter (DKF) has been proposed as a massively parallelizable observer for LQG wide-field AO control. It is based on a turbulence model that has to be defined both in a zonal basis (spatially sampled phase points) and in the spatial Fourier domain.

To evaluate an upper bound control performance, we need to define a turbulence model as close as possible to that of the simulated system, and extendable to a DKF formulation.

A multilayer turbulence model defined in a zonal basis with known wind directions and Cn2 profile is the natural candidate. The corresponding minimum variance controller, a Linear Quadratic Gaussian (LQG) regulator, will thus feature a Kalman filter build from this model. However, a turbulence model based on the frozen flow assumption has to face, in each layer and at each iteration, the appearance of a crescent of zeros when layers are estimated on the pupil support and then shifted according to the wind direction. These edge effects induce a performance degradation, that we propose to quantify in a single-conjugated AO configuration. We then propose different solutions to counteract these effects, based on the estimation of phase points outside the telescope pupil. At last, we compare this zonal-based LQG regulator with the standard integral action controller and with an LQG regulator based on an auto-regressive model of order two (boiling turbulence model) defined in a Zernike basis, an approach that was used on sky on the CANARY pathfinder.

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